***Original Research Article***

**Soil Nutrient Dynamics Under the Haritha Haram Ecosystem in Telangana State, India**

**Abstract**

Soil fertility plays a crucial role in sustaining ecosystem productivity and biodiversity. The “Telangana Ku Haritha Haram” afforestation program, initiated in 2015-16, aims to enhance green cover and improve soil health through large-scale tree planting. This study evaluates changes in soil nutrient dynamics across six Haritha Haram locations in Telangana between May 2023 and April 2024. Soil samples collected at a depth of 0-30 cm were analyzed for macronutrients (Nitrogen (N), Phosphorus (P), Potassium (K), micronutrients (Iron (Fe), Copper (Cu), Manganese (Mn), Zinc (Zn), Boron (B), Molybdenum (Mo), and organic matter components (Humic Acid and Fulvic Acid) using standard analytical methods. A significant increase in available nitrogen (252 to 284 kg ha⁻¹), phosphorus (41.5 to 44.1 kg ha⁻¹), and potassium (385 to 402 kg ha⁻¹) was observed. Micronutrient concentrations also increased. Additionally, humic and fulvic acid contents exhibited a slight increase. These changes are attributed to continuous organic matter accumulation from leaf litter and microbial decomposition, leading to enhanced nutrient availability. The findings highlight the positive impact of afforestation on soil fertility and emphasize the role of organic inputs in sustainable nutrient management within afforested ecosystems.

***Keywords:*** *Fulvic acid, Haritha Haram, humic acid, macronutrients and micronutrients.*

**Introduction**

Soil fertility is a crucial factor influencing plant growth, productivity, and overall ecosystem sustainability. The availability of essential nutrients in soil determines the capacity of an ecosystem to support vegetation and maintain ecological balance. In this regard, assessing the nutrient dynamics in afforested regions such as the Haritha Haram ecosystem provides valuable insights into soil health and fertility status over time.

The Government of Telangana launched the flagship Programme ‘‘Telangana Ku Haritha Haram (Green Garland for Telangana)’’ in 2015-16. It is a large-scale afforestation program aimed at improving green cover, enhancing biodiversity, and promoting sustainable soil management. As vegetation establishes and matures, it contributes significantly to soil nutrient enrichment through the continuous input of organic matter in the form of leaf litter, fallen branches, and decomposed plant material (Nivethadevi et al., 2021). This organic matter undergoes microbial decomposition, releasing essential nutrients into the soil. Understanding the changes in soil nutrient content in such ecosystems is essential for evaluating their role in long-term carbon sequestration and soil fertility enhancement.

Nitrogen (N), phosphorus (P), and potassium (K) are primary macronutrients that play vital roles in plant nutrition. Nitrogen is a key component of chlorophyll, amino acids, and proteins, influencing plant growth and productivity. Phosphorus is involved in energy transfer and root development, while potassium contributes to enzyme activation, water regulation, and stress tolerance in plants. Apart from macronutrients, micronutrients such as iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), boron (B), and molybdenum (Mo) are also essential for various physiological and biochemical processes in plants. Their availability in soil is influenced by organic matter decomposition, microbial activity, and environmental conditions.

Several studies have highlighted the impact of afforestation on soil nutrient dynamics. Continuous organic matter accumulation through leaf litter deposition and microbial decomposition leads to enhanced nutrient availability over time. The decomposition process facilitates the mineralization of organic-bound nutrients, making them available for plant uptake. Seasonal variations, microbial activity, and environmental conditions further influence nutrient cycling processes in such ecosystems. Hence, an investigation was taken to study the nutrient dynamics over a year across the six Haritha Haram locations.

**Material and methods**

A study was conducted to identify the variation in available nutrient content in six different Haritha Haram locations of Telangana state in May 2023 and April 2024. The trees that are planted under Haritha Haram program vary based on the planting model adopted. Different trees such as neem, teak, peepal, banyan, tamarind, eucalyptus, albizia, acacia, sisso, jamun, river tamarind, *Gliricidia* etc. are planted under Haritha Haram programme. Soil samples were collected from five Haritha Haram locations at a depth of 0-30 cm. These collected soil samples were air dried during which stones, visible root fragments and other debris were removed. Each sample was then ground and sieved through both 2 mm sieves for the analysis of various parameters using standard protocols.

The collected soil samples were analyzed for nutrient availability using standard methods. Available nitrogen was determined using the alkaline potassium permanganate method (Subbiah and Asija, 1956), with results expressed in kg ha⁻¹. Available phosphorus content (kg ha⁻¹) was measured following Olsen’s method (Olsen et al., 1954), while available potassium (kg ha⁻¹) was estimated using the flame photometer method (Jackson, 1973). The micronutrients iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn) were extracted using a solution containing 0.005 M Diethylene Triamine Penta Acetic Acid (DTPA), 0.01 M calcium chloride dihydrate, and 0.1 M Triethanolamine (TEA) buffered at pH 7.3 (Lindsay and Norvell, 1978). Available boron and molybdenum were extracted using the AB-DTPA method (Gestring and Soltanpur, 1984) and analyzed through Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). Significant variation in nutrient content in May 2023 and April 2024 was statistically analysed by paired t test.

**Results and Discussion**

**Available Nitrogen**

Between May 2023 and April 2024, there was a significant increase in available nitrogen content in the Haritha Haram locations (Table 1). The mean available nitrogen content across these locations increased from 252 kg ha⁻¹ in May 2023 to 284 kg ha⁻¹ in April 2024. Among the locations, Rajendranagar had recorded the higher levels of available nitrogen content of 280 kg ha⁻¹ in May 2023 and 303 kg ha⁻¹ in April 2024. A slight increase in available nitrogen content was observed in all the locations during this period. The increase in available nitrogen content from May 2023 to April 2024 in Haritha Haram ecosystem might be due to the continuous accumulation of large amounts of organic matter in the form of leaf litter, fallen branches and decaying wood. The decomposition of this organic matter by microbes releases nitrogen into the soil (Assefa *et al*., 2017).

**Available Phosphorus**

Between May 2023 and April 2024, there was a significant increase in available phosphorus content in the Haritha Haram locations (Table 1). The mean available phosphorus content across these locations increased from 41.5 kg ha⁻¹ in May 2023 to 44.1 kg ha⁻¹ in April 2024. Among the locations, Rajendranagar had recorded the higher levels of available phosphorus content of 48.5 kg ha⁻¹ in May 2023 and 50.4 kg ha⁻¹ in April 2024. A slight increase in available phosphorus content was observed in all the locations during this period. The increase in available phosphorus content in Haritha Haram locations could be attributed to the continuous accumulation of organic matter in the form of leaf litter. Additionally, microbial activity and seasonal weather conditions might have influenced phosphorus availability (Yang *et al*., 2019).

**Available Potassium**

Available potassium content was significantly increased from May 2023 and April 2024 in the Haritha Haram locations (Table 1). The mean available potassium content across these locations increased from 385 kg ha⁻¹ in May 2023 to 402 kg ha⁻¹ in April 2024. Rajendranagar recorded the higher available potassium content of 418 kg ha⁻¹ and 433 kg ha⁻¹ in May 2023 and April 2024, respectively. Available potassium content was observed to be increased in all the Haritha Haram locations from May 2023 to April 2024. The increase in available potassium content from May 2023 to April 2024 might be due to the continuous input of organic matter in Haritha Haram ecosystem. The accumulation and decomposition of leaf litter, twigs, and plant residues contribute to the steady release of nutrients, including potassium into the soil. This natural recycling process enhances soil fertility and replenishes potassium reserves over time (Gaisie *et al*., 2016).

**Micronutrients**

Micronutrients like Fe, Cu, Mn, Zn, B and Mo concentrations were found to increase significantly from May 2023 to April 2024 in various Haritha Haram locations (Table 2)

**Available Iron**

Iron content showed an overall increase, with the mean concentration increased from 3.65 ppm in May 2023 to 3.72 ppm in April 2024. The highest Fe concentration was recorded at Rajendranagar (5.68 ppm) in April 2024, compared to 5.62 ppm in May 2023, while the lowest was at Tholkatta (2.75 ppm in April 2024 and 2.64 ppm in May 2023).

**Available Copper**

The mean concentration of copper in the soil increased slightly from an initial average of 2.42 ppm in May 2023 to 2.47 ppm in April 2024. This indicates a consistent increase in copper levels across the locations. The highest Cu concentration was observed at Rajendranagar (2.88 ppm) in April 2024, compared to 2.84 ppm in May 2023, while the lowest was at Tholkatta (1.88 ppm in April 2024 and 1.84 ppm in May 2023).

**Available Manganese**

The mean manganese concentrations showed a significant increase from 7.63 ppm in May 2023 to 7.67 ppm in April 2024. The highest Mn concentration was observed at Rajendranagar (8.95 ppm) in April 2024, compared to 8.88 ppm in May 2023, while the lowest was at Tholkatta (6.45 ppm in April 2024 and 6.40 ppm in May 2023).

**Available Zinc**

Zinc concentration increased significantly from a mean of 1.41 ppm in May 2023 to 1.49 ppm in April 2024. The highest Zn concentration was found at Rajendranagar (1.96 ppm) in April 2024, compared to 1.87 ppm in May 2023, while the lowest was at Tholkatta (0.88 ppm in April 2024 and 0.84 ppm in May 2023).

**Available Boron**

Boron concentration increased significantly, from an average of 0.51 ppm in May 2023 to 0.54 ppm in April 2024. The highest B concentration was observed at Rajendranagar (0.63 ppm) in April 2024, compared to 0.61 ppm in May 2023, while the lowest was at Tholkatta (0.48 ppm in April 2024 and 0.45 ppm in May 2023).

**Available Molybdenum**

A significant increase in molybdenum concentration was observed between May 2023 to April 2024. The mean Mo concentration increased from 0.34 ppm in May 2023 to 0.37 ppm in April 2024. The highest Mo concentration was recorded at Rajendranagar (0.48 ppm in April 2024 and 0.45 ppm in May 2023), while the lowest was at Tholkatta (0.28 ppm in April 2024 and 0.25 ppm in May 2023).

A significant increase in the micronutrient content, including Fe, Cu, Mn, Zn, B and Mo was observed between May 2023 and April 2024 in Haritha Haram ecosystem might be due to a continuous supply of leaf litter, decaying plant material, and microbial activity, leading to increased mineralization and nutrient release into the soil. The decomposition of organic matter likely contributed to the higher availability of micronutrients, particularly Fe, Cu, Mn, Zn, B, and Mo (Dhaliwal *et al*., 2019).

**Humic Acid and Fulvic Acid**

Humic acid and fulvic acid content were significantly increased from May 2023 and April 2024 in the Haritha Haram locations (Table 3). The mean humic acid content across these locations increased from 1.53 g kg-1 in May 2023 to 1.56 g kg-1 in April 2024. Rajendranagar recorded a higher humic acid content of 1.70 and 1.73 g kg-1 in May 2023 and April 2024, respectively. The mean fulvic acid content across these locations increased from 1.07 g kg-1 in May 2023 to 1.09 g kg-1 in April 2024. Rajendranagar had recorded the higher fulvic acid content of 1.13 g kg-1 and 1.15 g kg-1 in May 2023 and April 2024, respectively. Humic acid and fulvic acid content was observed to be increased in all the Haritha Haram locations from May 2023 to April 2024. Humic acid and fulvic acid content was also found to be increased in all of the Haritha Haram ecosystem. The increase in humic and fulvic acid content from May 2023 to April 2024 can be attributed to the continuous input of organic matter through leaf litter deposition and minimal soil disturbance. The slow decomposition of lignin-rich plant residues promotes humus formation, leading to the enrichment of humic and fulvic acids (Bai *et al*., 2020).

**Conclusions**

The study highlights the significant improvements in soil fertility within the Haritha Haram ecosystem due to afforestation efforts. The observed increase in available macronutrients (N, P, K) and micronutrients (Fe, Cu, Mn, Zn, B, Mo) from May 2023 to April 2024 demonstrates the positive impact of continuous organic matter accumulation and microbial decomposition. Among the studied locations, Rajendranagar recorded the highest nutrient concentrations, with available nitrogen increasing from 280 to 303 kg ha⁻¹, phosphorus from 48.5 to 50.4 kg ha⁻¹, and potassium from 418 to 433 kg ha⁻¹. Similarly, Rajendranagar exhibited the highest levels of micronutrients, including Fe (5.68 ppm), Cu (2.88 ppm), Mn (8.95 ppm), Zn (1.96 ppm), B (0.63 ppm), and Mo (0.48 ppm) in April 2024. The increase in humic and fulvic acid content further confirms enhanced organic matter dynamics, contributing to soil health and nutrient availability. These findings emphasize the role of afforestation in sustainable soil management and long-term carbon sequestration. The Haritha Haram initiative has proven to be an effective strategy for improving soil quality, reinforcing the importance of afforestation programs in restoring degraded lands and promoting ecological balance. Future studies should focus on the long-term impacts of afforestation on soil microbial communities and nutrient cycling to optimize afforestation strategies for enhanced sustainability.

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**Table 1. Temporal variation in available nitrogen, available phosphorus and available potassium content of soil in various Haritha Haram locations**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Available Nitrogen**  **(kg ha-1)** | | **Available Phosphorus (kg ha-1)** | | **Available Potassium**  **(kg ha-1)** | |
| **Locations** | **(May 2023)** | **(April 2024)** | **(May 2023)** | **(April 2024)** | **(May 2023)** | **(April 2024)** |
| Rajendranagar | 280 | 303 | 48.5 | 50.4 | 328 | 335 |
| Tholkatta | 224 | 266. | 33.7 | 35.80 | 342 | 356 |
| Basthepur | 266 | 292 | 45.8 | 49.3 | 356 | 373 |
| Peerzadiguda | 253 | 284 | 42.3 | 44.60 | 408 | 418 |
| Malkaram | 238 | 275 | 37.4 | 40.5 | 382 | 395 |
| Mean | 252 | 284 | 41.5 | 44.1 | 363 | 375 |
| **t cal** | **9.13** |  | **8.40** |  | **7.12** |  |
| **t tab** | **2.78** |  | **2.78** |  | **2.78** |  |

**Table 2. Temporal variation in available iron, copper, manganese, zinc, boron and molybdenum content of soil in various Haritha Haram locations**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Available iron (ppm)** | | **Available Copper (ppm)** | | **Available Manganese (ppm)** | |
| **Locations** | **(May 2023)** | **(April 2024)** | **(May 2023)** | **(April 2024)** | **(May 2023)** | **(April 2024)** |
| Rajendranagar | 5.62 | 5.68 | 2.84 | 2.88 | 8.88 | 8.95 |
| Tholkatta | 2.64 | 2.75 | 1.84 | 1.88 | 6.4 | 6.45 |
| Basthepur | 4.36 | 4.41 | 2.64 | 2.69 | 8.67 | 8.73 |
| Peerzadiguda | 2.96 | 2.96 | 2.54 | 2.58 | 7.22 | 7.25 |
| Malkaram | 2.69 | 2.78 | 2.23 | 2.31 | 6.99 | 6.98 |
| Mean | 3.65 | 3.72 | 2.42 | 2.47 | 7.63 | 7.67 |
| **t cal** | **3.30** |  | **6.45** |  | **2.83** |  |
| **t tab** | **2.78** |  | **2.78** |  |  |  |
|  | **Available Zinc (ppm)** | | **Available Boron (ppm)** | | **Available Molybdenum (ppm)** | |
| **Locations** | **(May 2023)** | **(April 2024)** | **(May 2023)** | **(April 2024)** | **(May 2023)** | **(April 2024)** |
| Rajendranagar | 1.87 | 1.96 | 0.61 | 0.63 | 0.45 | 0.48 |
| Tholkatta | 0.84 | 0.88 | 0.45 | 0.48 | 0.25 | 0.28 |
| Basthepur | 1.73 | 1.8 | 0.53 | 0.55 | 0.38 | 0.41 |
| Peerzadiguda | 1.53 | 1.60 | 0.5 | 0.52 | 0.33 | 0.35 |
| Malkaram | 1.07 | 1.23 | 0.48 | 0.5 | 0.30 | 0.32 |
| Mean | 1.41 | 1.49 | 0.51 | 0.54 | 0.34 | 0.37 |
| **t cal** | **4.27** |  | **11.0** |  | **10.6** |  |
| **t tab** | **2.78** |  | **2.78** |  | **2.78** |  |

**Table 3. Temporal variation in humic acid and fulvic acid content of soil in various Haritha Haram locations**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Humic acid (g kg-1)** | | **Fulvic Acid (g kg-1)** | |
| **Locations** | **(May 2023)** | **(April 2024)** | **(May 2023)** | **(April 2024)** |
| Rajendranagar | 1.70 | 1.73 | 1.13 | 1.15 |
| Tholkatta | 1.40 | 1.43 | 1.01 | 1.03 |
| Basthepur | 1.60 | 1.62 | 1.10 | 1.12 |
| Peerzadiguda | 1.50 | 1.53 | 1.07 | 1.09 |
| Malkaram | 1.46 | 1.48 | 1.05 | 1.08 |
| Mean | 1.53 | 1.56 | 1.07 | 1.09 |
| **t cal** | **8.55** |  | **15.8** |  |
| **t tab** | **2.78** |  | **2.78** |  |