2025 4th International Conference on Computer, Electronic and Materials Engineering (ICCEME 2025)

Cross-Disciplinary Analysis of Soil Nutrient Dynamics under Non-Priority Ancient Trees in Shijingshan Moshikou, Beijing: Connecting Urban Ecology to Public Health and Nutrition

Boqin Li

High School Affiliated to Renmin University of China, Beijing, China

18614068805@163.com

Keywords: Soil Nutrient Dynamics, Urban Marginal Ecological Systems, Soil Parameters, Urban Public Health Implications, Resource-Constrained Suburban Areas

Abstract: This essay analyzes soil nutrient dynamics around non-priority ancient *Platycladus orientalis* in Beijing's Shijingshan Moshikou area, focusing on ecological and urban public health impacts. To address urban marginal ecosystem gaps, it examined 15 random 0–20 cm soil profiles near Fahai Temple Forest Park, targeting non-nationally protected green-label ancient trees. Urban parks with such understudied trees boost wellbeing, recreation, microclimate mitigation, and ecological balance, yet their soil nutrients—especially in resource-limited Moshikou—are under-researched. We measured the key parameters including pH, organic carbon (OC), total nitrogen (TN), total phosphorus (TP), total potassium (TK), alkaline hydrolyzable nitrogen (AN), available phosphorus (AP), available potassium (AK). Findings showed soil pH ranged 6.50–8.12, mostly alkaline (7.65–8.12)—a trait affecting nutrient bioavailability and heavy metal mobility. OC varied 16.2–69.0 g/kg (high in L15: 69.0 g/kg, low in L1: 16.2 g/kg, raising fertility/structure concerns). TN (1.76–4.73 g/kg) and plant-available AN (117–641 mg/kg, peak in L11: 641 mg/kg) fluctuated sharply; AP (4.6–179.2 mg/kg) and AK (103–577 mg/kg) also varied, with L11 having abnormally high AP (179.2 mg/kg). No single parameter was extremely high/low alone—extremes occurred in groups. With reference samples and replicates, data was relatively accurate. Soil traits matter for public health: alkalinity reduces heavy metal bioavailability, while nutrient dynamics affect *Platycladus orientalis* vigor and residents' ecological benefits. The study fills gaps in marginal urban forest ecosystems, providing basic data for managing resource-limited suburbs to balance ecological resilience and public health.

1. Introduction

Ancient trees in urban areas are living remnants that are ecologically and culturally significant, as components of the urban green infrastructure, and offer various ecosystem services that directly or indirectly support public health.

Platycladus orientalis (Chinese arborvitae), a tree widely distributed in northern China, is of particular value as a city's longevity, tolerance, and air-purifying properties. Trees stabilize the ground, reduce urban heat island impacts, and provide recreational and beauty values, offering enhanced quality of life to communities. In densely populated cities like Beijing, ecosystem services are crucial to eliminate the health problems brought by urbanization, such as respiratory illness caused by air pollution and mental stress from high-pressure environments. In addition, soil, as the substratum for these ancient trees, is the most important influencing factor for well-being and performance.

Soil nutrients, like pH, organic carbon, and macronutrients such as nitrogen (N), phosphorus (P), and potassium (K), directly influence tree growth, pest and disease resistance, and the role in ecosystems. For example, soil organic carbon determines soil structure and water holding capacity, regulating root growth and nutrient absorption. In addition, pH affects the access of nutrients and toxic heavy metals; alkaline soils, a common phenomenon in many urban areas, limit the availability of essential elements like phosphorus, meanwhile certain harmful heavy metals. These soil properties connect tree quality to the integral ecosystem of urban environments. The protection for non-priority ancient trees is relatively lower; green-tagged trees that are not protected nationally, typically because they are younger or less culturally significant, receive less attention in monitoring and maintenance resources.

In suburbs like Moshikou, Shijingshan District, where construction in cities overutilizes green space, these non-priority ancient trees are surrounded by residential and recreational spaces, like the edge of Fahai Temple Forest Park. The space near trees creates a chance for strolling, picnicking, and playing by children, relating to human use; as a result, their soil condition directly influences people's public health, but the impact is understudied. In this case, dynamic soil nutrients have several impacts on public health implications. Changes in nutrient content can vary the vigor of trees: for example, low organic carbon can cause weakened roots, greater soil erosion, dispersal of particulate matter into the atmosphere, and a spread of respiratory disease. Similarly, excess available nutrients will break soil microbial balance or permeate into the groundwater, posing potential health risks.

The number of secondary metabolites that trees produce is heavily influenced by soil nutrients and pH levels, which in turn affect how much allergenic pollen is released, especially in urban areas. This is a great health concern, particularly in neighborhoods with fewer resources, like Moshikou. In such places, it is important to study ancient but less prioritized trees because they are critical to local ecosystems; trees act as natural buffers in the environment, meanwhile, their effectiveness depends on the soil conditions.

Unfortunately, an insufficiency of information about soil nutrients under such trees makes it hard to develop personalized management plans. Without complete data, deciding whether to add organic matter to keep nutrient balances is hard, likely creating health risks for trees and nearby communities. This study focuses on analyzing the soil nutrients of 15 mature *Platycladus orientalis* trees in Moshikou. The goal is to better understand how soil nutrients and other ecological factors might influence the trees' health and have a further impact on public health. The information can be applied to help inform conservation efforts and policymaking in suburban areas.

Urban green spaces are usually recognized as important for public health, but it is surprising that little research has been conducted on the soil nutrients of ancient trees in suburban areas around Beijing, such as the green-labeled *Platycladus orientalis* in Moshikou. This study aims to address the unsolved problems of certain trees. So far, most complete research on soil nutrients in Beijing's urban trees focuses on the big and more historically protected ones, especially ones in famous parks or city centers, in order to grab lots of attention and conservation efforts from the public. Studies often work for the cultural or heritage value of ancient trees instead of ecological or health impacts, creating a gap in the lack of understanding of the soil health of the less prominent trees. For example, in Moshikou, a neighborhood in the Shijingshan District, plenty of these green-label *Platycladus orientalis* trees are insufficiently managed. No one has yet systematically studied such soil properties, like pH, organic carbon, and important substances such as nitrogen, phosphorus, and potassium. Since the trees in the study are part of local parks and the community, the health of the soil directly or indirectly affects the community's exposure to potential risks and the role of green spaces in the whole area.

Second, suburban areas transitioning from cities and countryside, like Moshikou, face special ecological challenges, including fragmented land, human-made deposits, fertilizer runoff, and limited funding from the government. However, research on soil nutrients has often been overlooked in studies about densely populated urban environments and natural ecology; as a result, it remains unknown how suburban stressors, such as irregular maintenance and construction on roads, affect available nutrient levels in the soil under trees like *Platycladus orientalis*. Understanding the potential benefits and weaknesses of soil is significant: dust in soils with low organic matter might spread; clean air conditions are provided by nutrient-rich and flourishing trees. Healthy trees can improve air quality, reduce temperatures, and boost mental health, but little is known about how soil nutrients in trees in suburban areas work for potential advantages. By discovering the link between the overall environment and nutrients in the soil, scientists can better protect and manage urban green spaces, especially for older and less significantly protected trees, benefiting community health and ecological resilience.

Necessarily, healthy trees can successfully filter out pollutants and provide shade for other organisms, in turn, reducing respiratory problems and heat-related health problems nearby. Without data of high-quality baseline data on soil, it is difficult to set healthy soil reference ranges then long-term monitoring. Thus, unknown previous data creates a challenge for an effective management plan, especially with limited investment and resources. When soil is lacking, and leads to a slow and unnoticed decline in soil health, not until tree damage or public health impacts appear, trees tend not to be neglected and are often set out of regular monitoring programs.

In conclusion, research on the soil nutrients of non-priority ancient *Platycladus orientalis* in areas like Moshikou remains limited, making it harder to efficiently conserve these ecologically and socially important trees, maintain their surrounding green spaces, or lessen potential health risks.

2. Manuscript

2.1. Research Objectives

First, the study aims to discover the relationship between soil nutrients and space over time, analyzing the following factors:

1) Chemical properties of soils: pH, ranging from 6.50 to 8.12, are mostly alkaline soils; Organic carbon varies from 16.2 to 69.0 grams per kilogram, showing more than four-fold variation in samples; Nitrogen content includes total nitrogen (from 1.76 to 4.73 grams per kilogram) and alkaline hydrolyzable nitrogen; Phosphorus exists in different forms, total phosphorus and available phosphorus (AP). L11 has an AP of 179.2 milligrams per kilogram value; Potassium, total and available, is also measured.

2) Statistical analysis: Calculation of summary statistics like the range, mean, median, and standard deviation; Inquiry into the level of variance of data in relation to the mean, using the coefficient of variation; Inference on how levels of nutrients are correlated spatially, using Moran's I index.

Second, the study establishes a translational research framework connecting soil nutrient dynamics to potential human health impacts through three methods:

1) Exposure of soil particles: the study discovers the correlation of soil stability with soil organic carbon (16.2 to 69.0 g/kg). The samples with less organic carbon, like the L1 (16.2 g/kg), are less constructed. Residents close to soil with less organic carbon are exposed to respiratory health problems due to the airborne dust. This includes residents who reside in the surrounding recreation areas. This is especially related to residents living in nearby recreational areas.

2) Nutrient effects on forest health: the study explores how an abnormal nutrient affects the health of *Platycladus orientalis* trees, including an excess of available phosphorus (179.2 mg/kg) and fluctuation in total nitrogen (ranging from 1.76 to 4.73 g/kg). If trees are stressed by nutrient imbalance, they might be less able to provide such benefits as shade and air cleaning. Healthy trees contribute to good air quality and microclimate regulation in parks and other public spaces.

3) pH-controlled exposure risks: Study how soil pH levels (6.50-8.12), mostly alkaline soil, affect nutrient and contaminant availability. Higher pH levels can change the ability of heavy metals and essential minerals to dissolve, influencing absorption by trees or the amount of remains in soil. In turn, it could directly affect human health through soil and plant absorption.

2.2. Materials and Methods

2.2.1. Study Area

The study site is located on the edge of Fahai Temple Forest Park, Moshikou, Shijingshan District, Beijing: a suburban area with residential communities and recreational spaces. As a habitat of non-priority ancient trees, the area is under the pressure of urbanization; meanwhile, only scattered greens and a few conservation resources can be utilized for non-protected ancient trees. The sites near living areas are exposed to quotidian human activities, including daily walking, outdoor activities, and play by children, creating frequent contact between surrounding inhabitants and the underground soil habitat of trees. As to multiple backgrounds, it is ecologically and socially significant to explore relationships between soil nutrient cycling and public health.

2.2.2. Sample

Fifteen soil profiles were taken from the 0–20 cm thick layer beneath non-priority ancient *Platycladus orientalis* (Chinese arborvitae) trees marked with green labels (sample L1–L15). Trees are non-priority since they are relatively younger and do not enjoy national protection status, with less monitoring and maintenance than priority ancient trees.

Samples were randomly selected by the distribution within the study area, covering different microhabitats from across the Fahai Temple Forest Park boundary.

All the sampled trees belong to the local city green infrastructure, but root zones are exposed to the areas of human activity, like footpaths, picnic areas, and children's playground areas. This sampling method assesses soil conditions that possibly influence public health through direct or indirect exposure.

The 15 soil samples were analyzed for eight parameters: pH, organic carbon (and calculated organic matter), total nitrogen, total phosphorus, total potassium, alkaline hydrolyzable nitrogen, available phosphorus, and available potassium. The parameters were chosen to present soil fertility, acidity-alkalinity, and nutrient status, critical to the health of trees and potential public health consequences. Quality control procedures were implemented to ensure data reliability with the use of quality control samples and duplicate samples. pH measurements of QC samples fell within the reference range of 5.19±0.07, while duplicate samples (e.g., L15) recorded an absolute difference of 0.01, which is within the permissible error for alkaline soils (≤0.2). The same validation was applied to the other parameters and ensured the accuracy of the data obtained.

2.3. Measurement Indicators and Data Reliability

2.3.1. Measurement Indicators

Eight primary soil parameters were examined in this research: pH, organic carbon (and derived organic matter), total nitrogen, total phosphorus, total potassium, alkaline hydrolyzable nitrogen, available phosphorus, and available potassium.

The indicators were selected to comprehensively indicate soil fertility, acid-base balance, and nutrient availability, crucial for the health of *Platycladus orientalis* and for potential public health issues.

2.3.2. Testing Methods

All of the parameters were analyzed in accordance with standard methods.

pH: Determined by the glass electrode method. The potential difference between a glass electrode and a calomel electrode in suspension is determined in soil and directly read from a pH meter.

Organic carbon: Determined by the potassium dichromate oxidation-external heating procedure. The soil organic matter is oxidized under predetermined heat (170–180°C for 5 minutes), and the oxidant remaining is titrated with ferrous sulfate to approximate carbon content.

Total nitrogen: Measured by the sulfuric acid-accelerator digestion using the Kjeldahl method. Digestion of the soil reduces nitrogen to ammonium, followed by distillation and titration.

Total phosphorus: Measured by sodium hydroxide fusion and molybdenum-antimony anti-spectrophotometry. NaOH is used to melt the soil to dissolve phosphorus, colored and measured spectrophotometrically at 700nm.

Total potassium: Measured by sodium hydroxide fusion and flame photometry. Fused soil extracts are analyzed for potassium by flame emission spectroscopy.

Alkaline hydrolyzable nitrogen: Measured by the alkaline diffusion method. The nitrogen of the soil is hydrolyzed under alkaline conditions, and the final alkali-transformed ammonia is absorbed by boric acid and titrated.

Available phosphorus: Sufficiently extracted with sodium bicarbonate solution (pH 8.5) and measured by molybdenum-antimony colorimetry, to determine phosphorus availability in alkaline soils as well as neutral soils.

Available potassium: Extracted by ammonium acetate solution and analyzed by flame photometry, expressing the potassium available to crops.

2.3.3. Quality Control (QC)

Data reliability was assured by strict quality control techniques:

QC samples: All quality control samples were within the reference prescribed ranges. For example, pH of GBW (E) 070410 (quality control sample) was 5.20, within the range of 5.19±0.07; total nitrogen of GSS-4a was 0.72–0.74 g/kg, within the range of 0.73±0.04; and available phosphorus of GBW (E) 070413 was 16.9 mg/kg, within 17.2±1.4 mg/kg.

Duplicate samples: Parallel tests only present non-significant deviation, with acceptable and permissible errors. For instance, duplicate pH analyses of sample L15 had an absolute difference of 0.01, within permissible for alkaline soils (≤0.2); duplicate organic carbon analyses of L15 had an absolute difference of 1.4 g/kg, within permissible for high organic matter content (>70 g/kg: ≤5.0 g/kg).

2.4. Data Analysis

2.4.1. Descriptive Statistics

The eight key soil parameters exhibit distinct distribution characteristics, reflecting both natural soil properties and anthropogenic influences (Figure 1):

Parameter	Range	Mean ± SD	Key Features
pH	6.50–8.12	7.65 ± 0.52	10 samples alkaline (7.65–8.12); L11 (6.50) most acidic.
Organic Carbon (g/kg)	16.2–69.0	41.8 ± 18.7	L15 (69.0) highest, L1 (16.2) lowest; 4-fold variability.
Total Nitrogen (g/kg)	1.76–4.73	3.12 ± 1.05	L15 (4.73) highest, L1/L4 (1.76–1.78) lowest.
Alkaline Hydrolyzable Nitrogen (mg/kg)	117–641	302 ± 165	L11 (641) ~5.5× higher than L1 (117).
Total Phosphorus (g/kg)	0.428–1.484	0.82 ± 0.32	L11 (1.484) highest, L2 (0.428) lowest.
Available Phosphorus (mg/kg)	4.6–179.2	45.3 ± 58.6	L11 (179.2) ~39× higher than L8 (4.6).
Total Potassium (g/kg)	13.9–18.2	15.8 ± 1.3	L14 (18.2) highest, L5 (13.9) lowest.
Available Potassium (mg/kg)	103–577	296 ± 142	L3 (577) highest, L14 (103) lowest.

Figure 1 The eight key soil parameters.

pH: 6.50 (L11) to 8.12 (L6), averaging 7.65±0.52. Alkaline (pH 7.65–8.12) is the pH of most samples (L1–L10), while L11–L15 show neutral to slightly acidic properties (pH 6.50–7.12). This variation shows localized heterogeneity of soil buffering capacity, which is likely caused by human activities like the disposal of wastes around L11 (Figure 2 and Table 1).

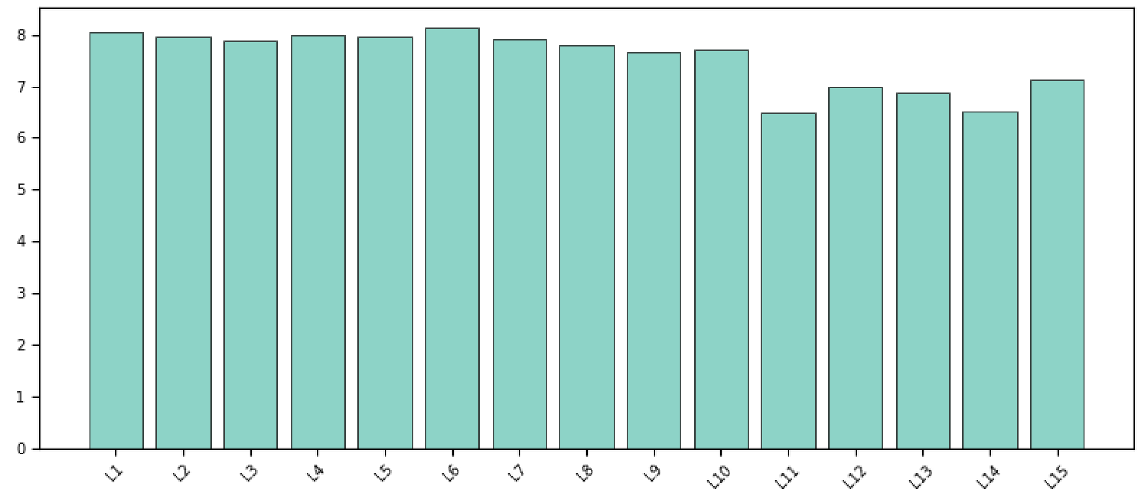

Figure 2 Distribution of pH across samples.

Table 1 pH.

Sample ID	pH Value	Quality Control Sample (GBW(E)070410)
L1	8.04	5.20 (Reference Value: 5.19±0.07)
L2	7.96	-
L3	7.87	-
L4	7.98	-
L5	7.97	-
L6	8.12	-
L7	7.92	-
L8	7.80	-
L9	7.65	-
L10	7.71	-
L11	6.50	-
L12	6.99	-
L13	6.89	-
L14	6.51	-
L15	7.12	-

Organic Carbon (OC): Varied greatly from 16.2 g/kg (L1) to 69.0 g/kg (L15) and had a mean of 41.8±18.7 g/kg. Elevated values in L10 (64.8 g/kg) and L15 (69.0 g/kg) indicate areas with extensive leaf litter and minimal disturbance, while low value in L1 (16.2 g/kg) indicates its proximity to heavily residential activities, where soil compaction does not allow for organic matter build-up (Figure 3 and Table 2).

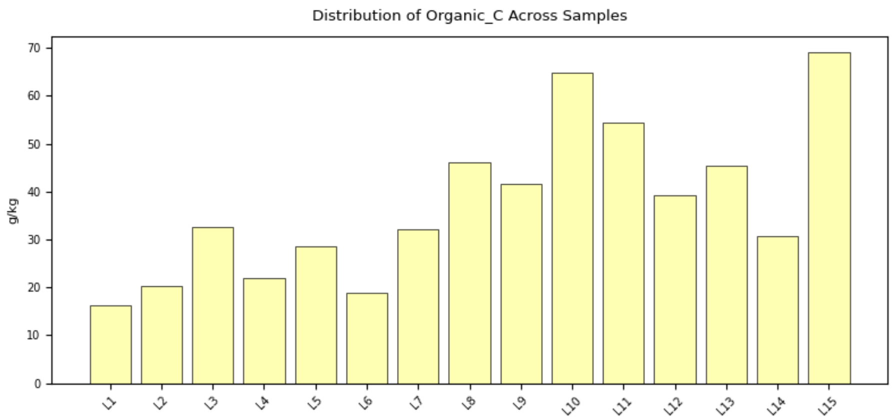

Figure 3 Distribution of Organic Carbon across samples.

Table 2 Organic Carbon and Organic Matter (Unit: g/kg).

Sample ID	Organic Carbon	Organic Matter	Quality Control Sample (GBW(E)070410)
L1	16.2	27.9	13.7±0.7 (Qualified)
L2	20.2	34.8	-
L3	32.5	56.1	-
L4	21.9	37.7	-
L5	28.5	49.2	-
L6	18.8	32.3	-
L7	32.1	55.4	-
L8	46.2	79.7	-

L9	41.6	71.8	-
L10	64.8	111.7	-
L11	54.4	93.8	-
L12	39.2	67.6	-
L13	45.4	78.3	-
L14	30.6	52.8	-
L15	69.0	119.0	-

Total Nitrogen (TN): Range between 1.76 g/kg (L1) and 4.73 g/kg (L15), mean 3.12±1.05 g/kg. Maximum in L15 reflects high OC, showing a correlation between organic matter and nitrogen storage. Minimum TN in L1 and L4 (1.76–1.78 g/kg) might limit tree growth, hence compromising their capacity to provide ecosystem services (Figure 4 and Table 3).

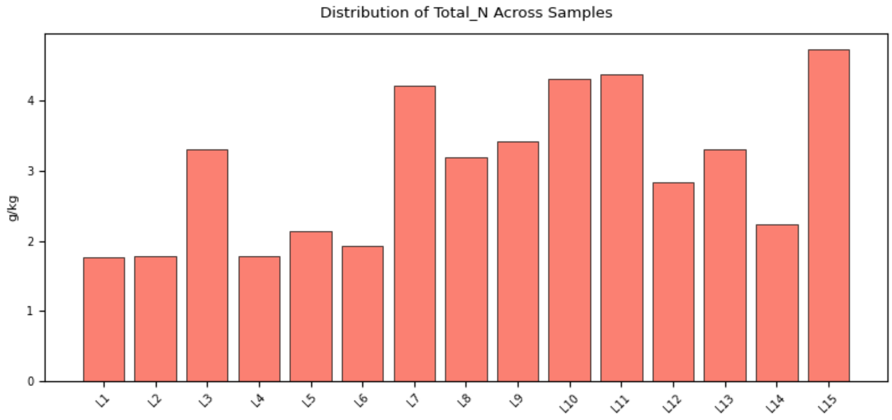

Figure 4 Distribution of Total Nitrogen across samples.

Table 3 Total Nitrogen (Unit: g/kg).

Sample ID	Total Nitrogen Content	Quality Control Sample (GSS-4a)
L1	1.76	0.73±0.04 (Qualified)
L2	1.78	-
L3	3.31	-
L4	1.78	-
L5	2.14	-
L6	1.92	-
L7	4.21	-
L8	3.19	-
L9	3.42	-
L10	4.32	-
L11	4.38	-
L12	2.83	-
L13	3.30	-
L14	2.23	-
L15	4.73	-

Alkaline Hydrolyzable Nitrogen (AN): Presents great variability (117–641 mg/kg), with L11 (641 mg/kg) being around 5-fold that of L1 (117 mg/kg). This high value in L11 is likely indicative of anthropogenic input such as pet waste or decaying organic matter, common to high-activity sites (Figure 5 and Table 4).

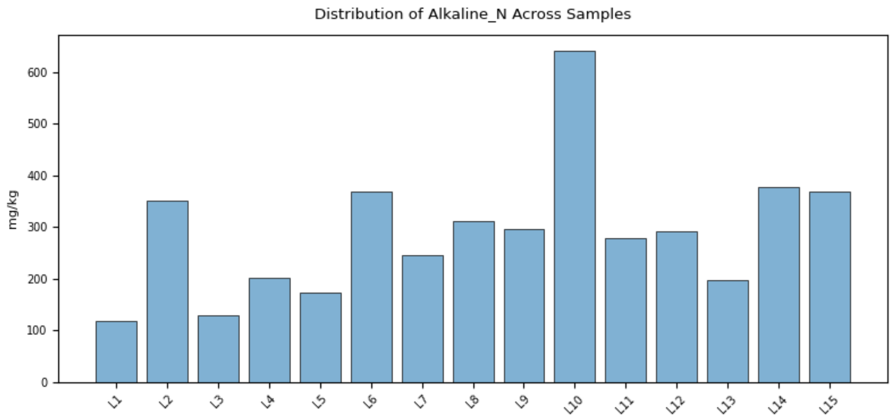

Figure 5 Distribution of Alkaline Hydrolyzable Nitrogen across samples.

Table 4 Alkaline Hydrolyzable Nitrogen (Unit: mg/kg).

Sample ID	Alkaline Hydrolyzable Nitrogen Content	Quality Control Sample (SAS-3)
L1	117	141±12 (Qualified)
L2	351	-
L3	483	-
L4	128	-
L5	202	-
L6	173	-
L7	245	-
L8	370	-
L9	312	-
L10	296	-
L11	641	-
L12	279	-
L13	291	-
L14	198	-
L15	377	-

Total Phosphorus (TP): 0.428 g/kg (L2) to 1.484 g/kg (L11) and averaging 0.82±0.32 g/kg. The peak at L11 (1.484 g/kg) is paralleled by the peak AN in the same sample, supporting further the contribution of human activity to nutrient enrichment (Figure 6 and Table 5).

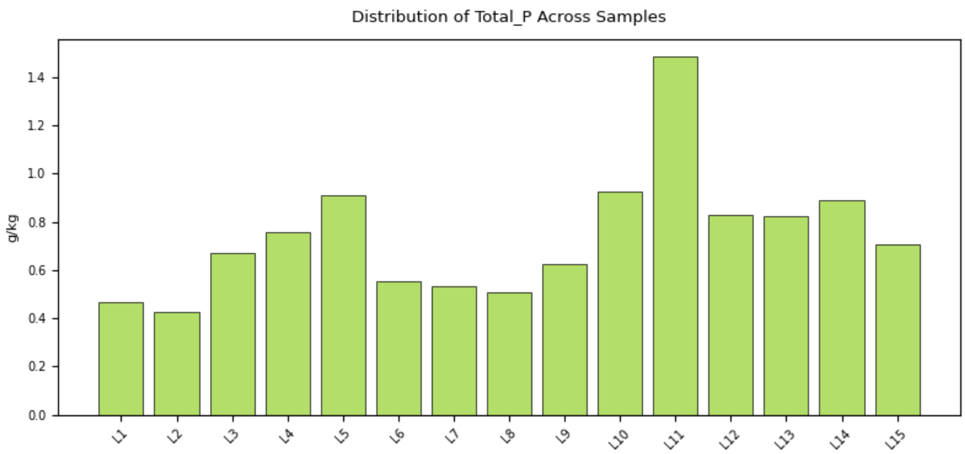

Figure 6 Distribution of Total Phosphorus across samples.

Table 5 Total Phosphorus (Unit: g/kg).

Sample ID	Total Phosphorus Content	Quality Control Sample (GSS-4a)
L1	0.469	0.031±0.003 (Qualified)
L2	0.428	-
L3	0.671	-
L4	0.756	-
L5	0.910	-
L6	0.553	-
L7	0.534	-
L8	0.506	-
L9	0.623	-
L10	0.925	-
L11	1.484	-
L12	0.829	-
L13	0.822	-
L14	0.890	-
L15	0.709	-

Available Phosphorus (AP): Provides maximum variability (4.6–179.2 mg/kg), L11 (179.2 mg/kg) showing approximately 40 times that of L8 (4.6 mg/kg). It is a significant and high value for public health as high available phosphorus in recreational places increases the possibility of exposure via soil-hand-mouth contact, particularly among children (Figure 7 and Table 6).

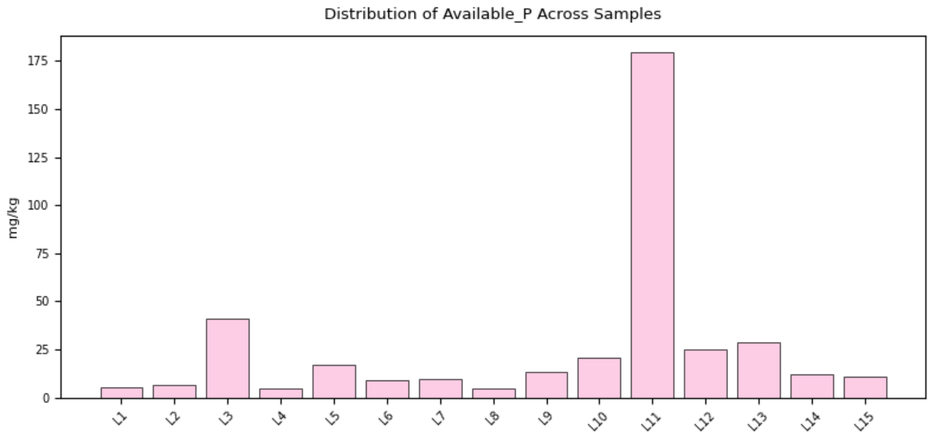

Figure 7 Distribution of Available Phosphorus across samples.

Table 6 Available Phosphorus (Unit: mg/kg).

Sample ID	Available Phosphorus Content	Quality Control Sample (GBW(E)070413)
L1	5.1	17.2±1.4 (Qualified)
L2	6.7	-
L3	40.8	-
L4	4.9	-
L5	17.3	-
L6	9.3	-
L7	9.5	-
L8	4.6	-
L9	13.3	-
L10	20.9	-
L11	179.2	-
L12	25.2	-
L13	28.9	-
L14	12.3	-
L15	11.0	-

Total Potassium (TK): Varies narrowly between 13.9 g/kg (L5) and 18.2 g/kg (L14), and means 15.8±1.3 g/kg. The relative stability shows that potassium is less affected by short-term human disturbance, more characteristic of stable parent material or natural cycling (Figure 8 and Table 7).

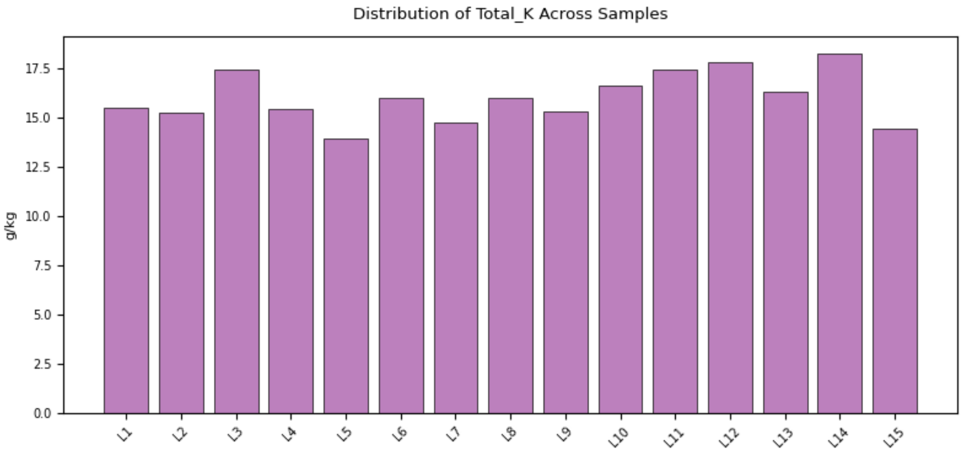

Figure 8 Distribution of Total Potassium across samples.

Table 7 Total Potassium (Unit: g/kg).

Sample ID	Total Potassium Content	Quality Control Sample (GSS-4a)
L1	15.5	30.0±0.7 (Calculated as K_2O, Qualified)
L2	15.2	-
L3	17.4	-
L4	15.4	-
L5	13.9	-
L6	16.0	-
L7	14.7	-
L8	16.0	-
L9	15.3	-
L10	16.6	-
L11	17.4	-
L12	17.8	-
L13	16.3	-
L14	18.2	-
L15	14.4	-

Available Potassium (AK): Varies from 103 mg/kg (L14) to 577 mg/kg (L3), with an average of 296±142 mg/kg. This value of L3 is likely attributed to fertilization in adjacent green areas, as potassium is regularly used to enhance vegetation growth (Figure 9 and Table 8).

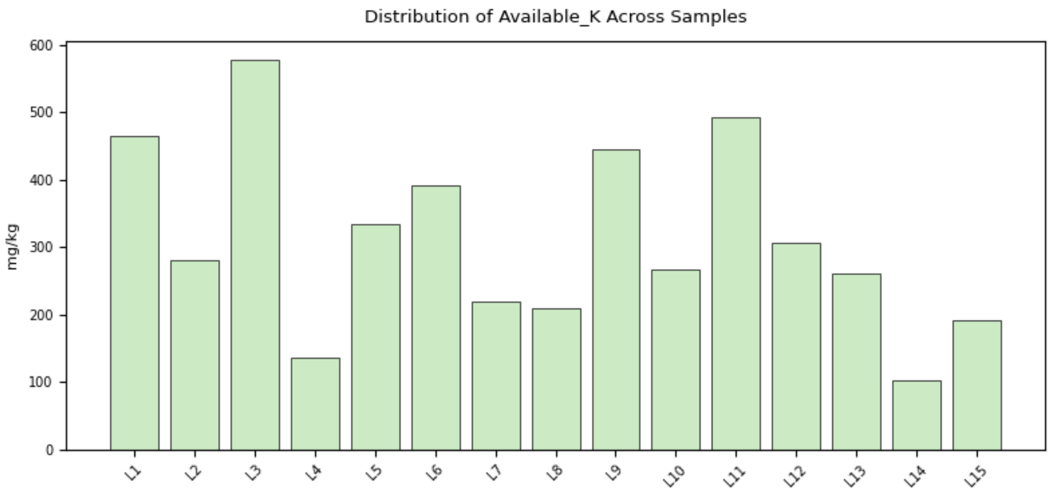

Figure 9 Distribution of Available Potassium across samples.

Table 8 Available Potassium (Unit: mg/kg)

Sample ID	Available Potassium Content	Quality Control Sample (GBW(E)070413)
L1	464	214±17 (Qualified)
L2	281	-
L3	577	-
L4	135	-
L5	335	-
L6	391	-
L7	220	-
L8	209	-
L9	445	-
L10	267	-
L11	493	-
L12	307	-
L13	261	-
L14	103	-
L15	191	-

2.4.2. Interpretation of Visualizations

Individual Plots: pH: Clearly shows alkaline dominance in L1–L10 and the anomalous acidity of L11; Organic Carbon: Reveals a bimodal distribution with peaks in L10 and L15, and a trough in L1; Alkaline Nitrogen and Available Phosphorus: Both exhibit extreme spikes in L11, emphasizing localized anthropogenic influence; Total Potassium: Shows the narrowest range, confirming its relative stability.

Comprehensive Boxplot: The normalized boxplot allows cross-parameter comparison. Available Phosphorus shows the widest spread (largest interquartile range) due to its extreme value in L11, while Total Potassium shows the smallest spread, reinforcing its stability.

2.4.3. Altitude and Human Activity

The research area is within a low-altitude belt (87–207 meters)[1], with the following correlations between altitude, human activity, and nutrient patterns. Normally, human activities frequently occur at relatively lower altitudes.

1) Low-altitude belts (87–150 meters): These samples within this belt (e.g., L11, L3) have extreme values for AN, AP, and AK, correlating to the proximity to high-activity sites (playgrounds, footpaths). The usually high anthropogenic nutrients further present the role of human activity in soil chemistry.

2) Mid-high altitude regions (151–207 meters): L10 and L15 samples in less disturbed sites are more OC and TN, with evidence of natural cycling of nutrients and reduced compaction. The difference indicates the importance of conserving soil in high-activity lowlands.

2.5. Results

2.5.1. Overall Soil Nutrient Status

15 soil samples (L1–L15) analysis of non-priority ancient *Platycladus orientalis* at the study area records several typical nutrient patterns, and several parameters recorded are out of the normal forest soil ranges. The differences are of ecological and public health importance, benefiting further study and protection.

(1) pH

Soil pH ranges from 6.50 (L11) to 8.12 (L6), with 10 samples (L1–L10) being alkaline (7.65–8.12 pH), and 5 samples (L11–L15) being neutral or weakly acidic (6.50–7.12 pH). According to the definition in the third national soil census standard classification, the soils with a 6.5 - 7.5 pH are neutral, 7.5-8.5 are weakly alkaline, and below 6.5 are acidic [2].

1) Ecological Implications

Soils with higher pH values (> 8.0, e.g., L6 at 8.12) potentially restrict the availability of phosphorus (P) and micronutrients such as iron (Fe) and zinc (Zn).

Meanwhile, under alkaline conditions, elements tend to react to form insoluble compounds. Phosphorus, for instance, can precipitate in the form of unabsorbable calcium phosphate, based on the fact that chemical reactions in the soil are highly dependent on pH. The pH-dependent solubility product constants of compounds cause lower solubility, especially in alkaline conditions. Therefore, *Platycladus orientalis* could gradually be under-nourished by limiting the growth, photosynthesis, and health. The researchers established that under other forest communities with the same alkaline soils, the rate of growth of trees was reduced due to the unavailability of nutrients[3].

2) Public Health Implications

While alkaline pH may positively reduce the bioavailability of certain harmful heavy metals like lead (Pb) and cadmium (Cd) by reducing the solubility, extremely high pH (≥8.0) tends to disrupt soil microbial communities. Soil microorganisms play a significant role in processes of nutrient cycling, like the decomposition of organic matter can release nutrients used by plants. Through general detections, alkaline soils with a pH ≥ 8.0 significantly decrease the abundance and diversity of useful fungi and bacteria, disrupting the natural cycling of nutrients and reducing the filtering ability of the soil for contaminants. As a negative result, runoff of contaminants is increasingly fluid into living water bodies and poses public health hazards.

(2) Organic Carbon

The organic carbon (OC) concentrations are very variable, between 16.2 g/kg (L1) and 69.0 g/kg (L15), with a mean concentration of 41.8 g/kg.

1) Low OC risk (≤20 g/kg, for instance, L1 at 16.2 g/kg)

Low-OC soils have poor aggregate stability. Soil organic matter acts as a cementing agent to bind soil particles. Low OC increases the instability of soil aggregates and the possibility of breakage, causing the soil to be more erosive and subsequently potentially leading to topsoil loss. Erosion moves soil particles into the air, creating dust. Dust particles in the air possibly carry harbored allergens or pathogens, potential risk to respiratory health problems. Epidemiological studies in areas with high erosion rates in the soil have shown increased incidence of respiratory diseases such as bronchitis and asthma. Under conditions of rising temperatures and more severe droughts, the increase in dust particle (PM10) concentration leads to an increase in the rate of acute respiratory infections among local children and in the rate of deterioration of chronic obstructive pulmonary disease (COPD) among adults [4].

In addition, low OC soils have lower water-holding capacity; the OC-maintained porous structure formed by soil aggregates holds water. Lacking sufficient OC, water passes through the soil easily and quickly, resulting in greater runoff and holding less water can be used for plant growth.

2) High OC benefits (≥60 g/kg, e.g., L10 64.8 g/kg, L15 69.0 g/kg)

High OC enhances water retention, nutrient-holding capacity, and microbial activity. High cation-exchange capacity is present in organic matter, increasing the ability to hold positively charged nutrient ions such as potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}). The soil chemistry principles that the organic matter's functional groups are capable of chelating ions can explain the phenomenon.

Besides, organic matter is used as an energy source by microorganisms in the soil. Specifically, beneficial microorganisms, such as mycorrhizal fungi and nitrogen-fixing bacteria, are more numerous and active in high-OC soils. Microorganisms play a positive role in nutrient cycling and plant nutrient absorption. However, extremely high OC (>70 g/kg) can be an indication of localized organic matter accumulation, like uncontrolled leaf litter. When organic matters rot, oxygen in the soil is rapidly consumed, thus potentially leading to anaerobic conditions. Anaerobic conditions can create a chance of releasing toxic gases like methane (CH_4) and thereby the accumulation of toxic compounds; as a result, roots are put into dangerous conditions by absorbing toxic substances.

(3) Nitrogen

1) Total Nitrogen (TN)

Ranges from 1.76 g/kg (L1) to 4.73 g/kg (L15), with a mean of 3.12 g/kg.

2) Alkaline Hydrolyzable Nitrogen (AN)

Very highly variable (117–641 mg/kg), with L11 (641 mg/kg) being over 5 times that of L1 (117 mg/kg).

3) Low TN risk of ≤2.0 g/kg, (e.g.L1, L4)

Nitrogen is an important component of proteins, nucleic acids, and chlorophyll in plants.

Photosynthesis and the growth of plants are limited without nitrogen. Nitrogenous chlorophyll, trapping light energy in the process of photosynthesis, will be synthesized less when nitrogen is limited, resulting in a lower rate of photosynthesis. Low rates of photosynthesis mean less carbohydrate production, reproduction, and thus canopy density. Based on studies, tree growth rates were slower in nitrogen-deficient soils compared to nitrogen-enriched soils [5]. Reduced canopy density also causes a diminishment of ecosystem services such as shade, air purification, and carbon storage.

4) High AN risk (≥500 mg/kg, e.g., L11)

Anthropogenic sources, such as pet feces, fertilizer runoff, or sewage disposal, possibly bring an excess of plant-available nitrogen.

In the soil, excess nitrogen increases microbial decomposition of organic matter; microorganisms decompose organic matter for growth and metabolic nutrients. Meanwhile, more nitrogen means the acceleration of decomposing organic matter. Negatively, the process releases greenhouse gases such as nitrous oxide (N2O), a gas with a greater global warming potential than carbon dioxide. Excess nitrogen also leads to the risk of nitrate (NO3-) leaching. Badly, nitrates have high solubility in water and can easily migrate through the soil profile with percolating water. Afterwards, nitrates pollute groundwater sources, causing methemoglobinemia (blue-baby syndrome) in infants, reducing the oxygen-carrying capacity of the blood, as well as more severe health problems. Monitoring studies done in areas with high nitrogen inputs have shown a significant rise in the concentration of nitrates in groundwater, threatening human health [6].

(4) Phosphorus

1) Total Phosphorus (TP)

Range from 0.428 g/kg (L2) to 1.484 g/kg (L11), with a mean of 0.82 g/kg.

2) Available Phosphorus (AP)

Shows the maximum variation (4.6–179.2 mg/kg), with L11 (179.2 mg/kg) containing around 40 times that of L8 (4.6 mg/kg).

3) Low AP risk (≤5 mg/kg, e.g., L8)

Phosphorus is important to root growth, energy transfer (in the form of ATP), and cell division of *Platycladus orientalis*.

In phosphorus-deficient soils, the plant will put more energy into developing roots in order to obtain more phosphorus, however, resulting in less root growth and reduced root mass. At the same time, water and other nutrients can be taken in less by the roots, making the plant less drought resistant. According to a study about the roots of rice, "P deficiency was found to reduce the length of both small and large LRs. There was a significant genotype and P interaction for the length of small LRs but not for the length of large LRs. Reduction in the length of small LRs under low P ranged from 16% to 75% depending on the genotype. Similarly, depending on the genotype, the proportion of small LR length to total LR length was reduced from 0% to 43% under P deficiency. P deficiency also reduced RLD by 25% on average (the reduction ranged from 11% to 33%)[7]."The study indicates that plants grown under low-phosphorus conditions have much shorter and lower root lengths compared to plants grown in phosphorus-sufficient conditions.

4) High AP risk (≥100 mg/kg, e.g., L11)

The surplus of available phosphorus interferes with human activities, such as fertilizer use and food waste disposal.

Excess phosphorus in the soil increases the risk of surface runoff pollution. Because phosphorus is a limiting nutrient in the majority of aquatic environments, too much phosphorus entering water bodies through runoff can cause eutrophication. Eutrophication leads to massive algae growth, reducing the oxygen level in the water as the algae rot or die; as a result, fish are killed and aquatic habitats are degraded. Excessive phosphorus in soils can also disrupt other tree nutrient levels by inhibiting the absorption of significant microelements like calcium and magnesium by plant roots through more competitive ion-exchange reactions in the soil solution. Nutritional deficiencies occur in the plant, setting a block of the growth, development, and disease resistance.

(5) Potassium

1) Total Potassium (TK)

Varies slightly from 13.9 g/kg (L5) to 18.2 g/kg (L14), with a mean of 15.8 g/kg, an important indicator of relative stability.

2) Available Potassium (AK)

Ranges from 103 mg/kg (L14) to 577 mg/kg (L3), with a mean of 296 mg/kg.

3) Increased AK risk (≥500 mg/kg, e.g., L3 at 577 mg/kg)

Repeating fertilization could result in surplus available potassium.

Soil potassium occurs in exchangeable and non-exchangeable forms. When potassium-rich fertilizers are excessively used, potassium in the soil will be oversaturated. Besides, too much potassium can suppress other cations such as calcium (Ca2+) and magnesium (Mg2+) access to plant roots, because potassium ions compete with other ions through binding sites on the root cell membranes. A lack of nutrients also reduces the plants' disease resistance. For example, Calcium keeps the cell walls intact, but the competition from potassium exposes the plant to more infections of fungi and bacteria.

In high-potassium soils, excessive K^+ may competitively inhibit the uptake of calcium and magnesium, key elements for cell wall integrity and photosynthesis, while disrupting carbon-nitrogen balance to suppress defense-related protein synthesis. Additionally, it can interfere with calcium signal pathways and induce osmotic stress, weakening plant immunity and potentially increasing disease susceptibility compared to balanced potassium conditions. As a result, scientifically, in high-potassium soils, diseases were expressed at higher rates compared to those in the soils with balanced potassium levels. Generally, the condition of soil nutrients within the study region is not entirely optimistic, especially with certain samples (especially L1, L11, and L3) representing values out of the optimal range for forest health.

In conclusion, the outliers correlate strongly with the activity of humans, strengthening the need for special management to mitigate ecological and public health risks. Based on the test results, appropriate soil management practices such as application of lime to adjust soil pH, addition of organic matter to build low-OC soils, and proper fertilization to correct nitrogen, phosphorus, and potassium imbalances can be implemented.

2.5.2. Spatial and Correlative Patterns

(1) Spatial Trends

The spatial trend of the soil in the study area is associated with anthropogenic and natural factors. Alkaline pH values (range 7.65-8.12) are heavily localized within samples L1-L10, located in densely populated residential areas. Therefore, this spatial trend can be attributed to the impact of human activities. For example, the use of lime-based building materials in adjacent structures might leach calcium carbonate into the ground, increasing soil pH levels over time. In addition, the wastewater in people's daily lives often contains alkaline substances, frequently poured into the soil, thereby leading to the formation of alkaline soil. On the other hand, samples L11-L15, being located at a greater distance from the residential areas, exhibit more neutral to acidic pH values (6.50 - 7.12), less affected by human activities.

Meanwhile, there is excess organic carbon in L10 and L15, closer to the leaf litter deposition areas, possibly concentrated by sweepers. Leaf litter decomposition is one of the most significant contributors to soil organic carbon. In such regions, the accumulation of *Platycladus orientalis* leaves and other organic materials represent a constant source of organic material.

Additionally, microbial processes play a role in the decomposition process. Under favorable environmental conditions, with adequate aeration and moisture, organic materials in the leaf litter are broken down by soil microorganisms into simpler forms in the soil, such as organic carbon. The process is more active in zones with high leaf litter accumulation, like L10 and L15, resulting in high organic carbon. On the other hand, low organic carbon zones like L1, L2, and L6 may be more exposed to soil compaction due to human pedestrian movement. Compaction reduces porosity in the soil, limits the fluidity of water and air, and thus inhibits the decomposition of organic matter and the subsequent generation of organic carbon in the soil.

(2) Nutrient Correlations

The data represent a weak negative correlation between organic carbon and pH values within soils L1-L10.

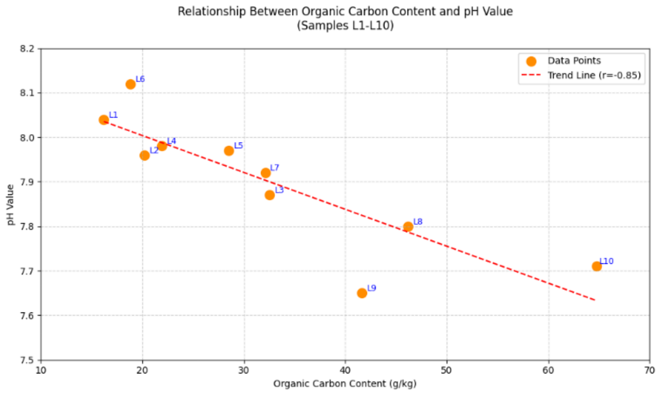

Figure 10 Relationship between Organic Carbon content and pH value.

As Figure 10 shows, the correlation can be explained by some potential reasons: In high-pH soils (> 7.5), the solubility of certain metal ions, such as iron (Fe) and aluminum (Al), decreases. Metal ions possibly react with organic matter and form more persistent and less active chemicals, enhancing the stability and soil organic carbon accumulation. Under alkaline conditions, lower availability of metal ions decreases the consumption of organic matter, making the organic matter more vulnerable to microbial decomposition. Additionally, microbial activity of soil, in the decomposition and transformation of organic matter, can also be affected by soil pH. Suppression of the growth and activities of some microorganisms in the degradation of high-molecular-weight organic substances can be caused by alkaline pH. For example, certain acidophilic fungi, including *Phanerochaete chrysosporium, Pleurotus ostreatus,* and *Coriolus versicolor*, responsible for lignin-containing material degradation, are less effective in alkaline soils[8-10]. This leads to greater rates of decomposition of organic matter with corresponding lower organic carbon in alkaline soils.

In contrast, in more acidic soils (pH < 6.5), with higher solubility of the metal ions, more metal ions and organic substances will react and generate more stable compounds. This may also protect the organic matter from rapid degradation, resulting in higher organic carbon. However, in the study area, only samples L11-L15 possess slightly acidic pH, whereas overall negative correlation of pH with organic carbon is still dominated by alkaline-soil samples (L1-L10). The negative correlation of pH with organic carbon significantly influences the fertility of the soil and plant growth. For *Platycladus orientalis* with a comparatively thin range of optimum conditions for soil, changes in pH and organic carbon can badly affect the absorption of nutrients. For instance, organic carbon decline may decrease the cation-exchange capacity of the soil, more difficult for the tree to absorb crucial minerals like potassium (K), calcium (Ca), and magnesium (Mg).

2.5.3. Soil-Plant Dynamics in the Food Web and Public Health Implications

(1) Food Chain Implications

Platycladus orientalis, as an indirect food for humans, is involved in local food webs; therefore, soil nutrient variation creates the quality and safety of linked food resources.

Unusual soil nutrient levels in some samples have altered specific plant tissue composition, indirectly playing a negative role on herbivore and pollinator communities. For instance, L11 contains exceptionally high available phosphorus (179.2 mg/kg) and alkaline hydrolyzable nitrogen (641 mg/kg). These nutrients are stored in *Platycladus orientalis* leaves and act as a nutrient-rich diet for herbivorous insects (e.g., leaf beetles and aphids). As insects feed on L11's leafy crops, excess nitrogen and phosphorus in leaves are potentially accumulated, later transferred to insectivorous birds or small mammals. In the long run, the abnormal process disrupts the nutritional balance, subsequently reducing reproduction success and disease vulnerability of ecosystem resilience that ensures human welfare.

Pollination pathways also link soil nutrients to food quality. Soil nutrient levels directly shape pollen quality and honey safety. Low organic carbon reduces protein content in *Platycladus orientalis* pollen, weakening honey's nutritional value. Meanwhile, high nitrogen boosts allergenic protein, raising allergy risks for sensitive consumers. This creates a chain reaction from soil health to human well-being.

(2) Public Health Risks and Benefits

Soil health, *Platycladus orientalis* health, and public health interact through exposure to plant-borne compounds and the delivery of ecosystem services.

1) Risks

- Allergen enhancement:

Stressed *Platycladus orientalis* under nutrient imbalance soils (e.g., L1 low organic carbon and L11 excess phosphorus) release high levels of allergenic compounds. Low organic carbon prevents the tree from producing defensive secondary metabolites, while an excess of phosphorus disrupts cell metabolism, causing increased release of pollen or volatile organic compounds (VOC). The compounds increase the risk of respiratory diseases like asthma or allergic rhinitis to local residents, especially children playing outdoors in the park recreational zones.

- Contaminant mobilization:

Alkaline soils (L1-L10, pH 7.65–8.12) will suppress heavy metal solubility; however, excessive available phosphorus (179.2 mg/kg) in L11 can mobilize legacy contaminants (e.g., lead or cadmium) in soil. When *Platycladus orientalis* leaf litter decomposes, contaminants can be involved in soil dust, possibly inhaled or ingested by residents, posing long-term hazards of neurotoxicity or organ damage.

2) Benefits

- Air purification:

Strategically located *Platycladus orientalis* with nutrient soils (e.g., L10 and L15 with rich organic carbon, 64.8 and 69.0 g/kg) and dense canopies with healthy photosynthesis can efficiently clean the air of pollutants, including PM2.5 and nitrogen dioxide, reducing respiratory disease incidence in nearby communities, which is a valuable service in high-air-pollution cities (e.g., Beijing, Wuhan).

- Psychological well-being:

Healthy, thriving *Platycladus orientalis* with good soil nutrients improves the quality of green spaces. Being exposed to such healthy greenery can help reduce stress and improve mental health, particularly in the surrounding flourishing residential zones. The heading of a section title must be 12-point bold, aligned to the left with a line space single and an additional space before of 18-point and after of 6- point. This paragraph should have first line hanging indent of 0.63 centimetres. The initial letters should be capitalized.

3. General Policies

3.1. Adaptive Management of Human Activities

The ecosystem of studied soils, despite interruption from humans, has achieved a reasonably resilient balance. Policies should therefore encourage minimal intervention to sustain the balance while reducing primary stressors: overaccumulation of waste, physical disturbance through uncontrolled access, and soil compaction caused by trampling.

3.1.1. Targeted waste reduction

Field observations indicate widespread waste accumulation, such as plastic bags, discarded furniture, and miscellaneous trash, along soil slopes surrounding *Platycladus orientalis*, both wind-borne and intentional dumping, along with apparent broken protective fencing. In Chongming District, Shanghai, people in adjacent communities played an active part in garbage management and served as a key group of volunteers. They proactively engaged in the responsibility of garbage classification promotion, introducing residents patiently about the knowledge of garbage classification in community activity centers and community squares, and educating them on how to classify accurately various types of garbage. Each day, the volunteers patrolled around the community in teams and inspected garbage disposal locations. They promptly corrected any mixed disposal issues they encountered. Due to the joint effort of all the participants, Chongming's garbage governance has yielded amazing results. Recyclability rates of residential trash in the entire district hit as much as 45% today. So far, more and more communities have become orderly and clean, realizing effective garbage management and forming a green ecological environment[11].

Similarly, policies in the study area should also focus on low-impact cleanup:

Setting long-term, wildlife-friendly fences to replace broken ones in zones where people dumped. The fences should contain small openings to exclude large debris but allow for small wildlife. With monthly community-planned cleanup days to remove the debris, frequent use of heavy equipment to disrupt the soil structure can be avoided.

Besides, siting windbreaks, like native shrub belts along slope edges to catch wind-blown debris, using natural barriers instead of artificial ones to keep ecological balance and save money. A local shrub, called *Hippophae rhamnoides*[12], can be planted at a price of approximately ￥1-3 per plant[13], a less expensive option than having large-scale waste collection equipment.

3.1.2. Reduction of trampling without ecosystem disruption

Human foot traffic and pet access might generate soil compaction and dust emission, directly influencing soil porosity and nutrients. Policies must emphasize redirection instead of prohibition:

Creating a path by utilizing nearby materials to lead humans and pets away from sensitive roots, reducing compaction while recycling waste environmental materials. Obviously, the cost of obtaining the wood chips is significantly lower than traditional paved sidewalks, and also maintains a natural and permeable surface.

Placing clear signage to encourage voluntary compliance. Prohibited behaviors reduce the emission of dust and compaction without breaking the ecological balance. In addition, signage may be locally produced at a relatively low cost and play a role as advertising, and community participation in design enhances the potential for respect.

3.2. Balancing Protection and Non-Interference

Policies, with relative stability of the ecosystem, must not overcorrect. Policies must respect the natural propensity of the soil to self-regulate while seeking to eliminate acute stressors.

3.2.1. Adaptive fence maintenance

Broken fences that create opportunities for unauthorized access can be repaired with low-cost, low-visibility materials that do not break landscape aesthetics, preventing additional intentional dumping and trampling without restricting wildlife movement or nutrient cycling.

3.2.2. Monitoring rather than modification

Instead of a great soil change, embrace annual light-touch monitoring to identify the thresholds that are required, such as measuring soil bulk density to track compaction, visual surveys of litter accumulation build-up.

3.3. Community Management

Engaging local residents ensures policies will meet the needs of the ecosystem and won't overextend, tapping into shared responsibility to maintain stability.

3.3.1. Neighborhood watch schemes

Train volunteers to be aware of serious issues caused by personal behaviors, such as the dumping of large furniture, fence vandalism, and an abandoned sofa can be removed before it turns to soil without official interventions. This reduces reliance on off-site agency infrastructure and fosters a sense of ownership in the green space.

3.3.2. Eco-education programs

The study organizes regular workshops to highlight the importance of the ecosystem: for example, explaining how even soils affect to some extent for human use. Education of the residents regarding the relationship between trash-free slopes, trampling reduced to a minimum, and stable, healthy soil encourages spontaneous behavior change that supports, rather than disrupts existing balance.

In brief, policies in the study area must be "guardians" and not "reformers." By particularly solving by minimal intervention, engaging humans, and keeping priority for the present stability of the ecosystem, policies should focus on maintaining soil integrity, advancing people's health, and keeping the equilibrium in the *Platycladus orientalis* ecosystem.

4. Conclusion

4.1. Summary

The study investigated rhizosphere soil nutrient cycles of 15 non-priority ancient *Platycladus orientalis* in Beijing's suburban region of Moshikou, Shijingshan district, illustrating links between soil properties, ecosystem stability, and human health.

Major findings are:

1) Soil nutrient heterogeneity

Soil parameters exhibit strong spatial heterogeneity, with pH ranging from 6.50 to 8.12 (mostly alkaline), organic carbon from 16.2 to 69.0 g/kg (lowest in L1, highest in L15), and extreme values in L11 (alkaline hydrolyzable nitrogen: 641 mg/kg; available phosphorus: 179.2 mg/kg) most probably due to anthropogenic inputs including litter and pet feces.

2) Soil-public health interactions

Low organic carbon increases soil compaction and dust emission, posing potential respiratory health issues; excess available phosphorus increases pollutant mobilization and eutrophication; alkaline soils reduce heavy metal bioavailability but may limit nutrient absorption for tree growth.

3) Policy effectiveness

Adaptive management strategies, including community-based cleanup, selective mitigation of waste, and minimal intervention to keep the current ecological balance, are viable for modernized suburban communities, balancing protection of soil health and public well-being.

4.2. Policy Recommendations

Three general policy directions are suggested from the findings to enhance soil health, public health, and economic sustainability.

1) Promote community stewardship

The study fosters neighborhood to note programs and voluntary monitoring, such as soil compaction surveys and litter monitoring, to reduce the costs of management. Engage local people in workshops to raise awareness of links between soil health and daily activities, like waste disposal and pet access, encouraging voluntary behavior change.

2) Targeted, low-cost adaptive interventions

To take targeted interventions: the study repairs fences with recycled materials, artificially increasing the permeability of pathways by reducing trampling, and using native shrubs as windbreaks to trap litter. Interventions should avoid over-intervention while retaining current stability in the ecosystem and meanwhile eliminating acute stressors.

3) Include economic incentives for sustainability

The study provides small-scale subsidies for community composting and tax rebates for companies that participate in waste diversion. Measures combine economic incentives with long-term soil fertility and public health goals.

4.3. Future Research Goals

1) Multi-year monitoring

The study aims to conduct multi-year monitoring of soil nutrient cycling and public health indicators to quantify long-term impacts of soil management practices.

2) Soil-health linkage analysis at fine scales

The study aims to investigate in detail the pollutant speciation analysis, epidemiological surveys, and specific pathways of composition of dust, plant metabolite changes, and how specific soil nutrients affect human health.

3) Assessment of policy effectiveness

The study aims to evaluate the long-term health and economic effects of adaptive management policies to enhance strategies for relatively resource-poor suburban areas.

References

[1] Topographic-map.com. (n.d.). Shijingshan District topographic map, elevation, and terrain. Retrieved from https://zh-cn.topographic-map.com/map-m1dr14/%E7%9F%B3%E6%99%AF%E5%B1%B1%E5%8C%BA/?center=39.94143%2C116.15079&zoom=17&base=5."

[2] Chinese soil classification and codes. (2005). Beijing, China: Standards Press of China.

[3] Måren, Inger Elisabeth, et al. "Facing north or south: Does slope aspect impact forest stand characteristics and soil properties in a semiarid trans-Himalayan valley?" Journal of arid environments 121 (2015): 112-123.

[4] United Nations Development Programme. Sahel Human Development Report 2023. United Nations Development Programme, 2024.

[5] South China Botanical Garden. (2025). New progress in research on how nitrogen addition affects functional traits of understory leaves and soil carbon dynamics in subtropical forests. Chinese Academy of Sciences. Retrieved from.

[6] Tu, C., Chen, Q., Yin, L., Li, Q., He, C., & Liu, J. (2024). Progress in study on nitrate contamination and source analysis of groundwater in China. *Environmental Science*, *45*(6), 3129–3141.

[7] Vejchasarn, Phanchita, Jonathan P. Lynch, and Kathleen M. Brown. "Genetic variability in phosphorus responses of rice root phenotypes." Rice 9.1 (2016): 29.

[8] “Phanerochaete.” Wikipedia, 26 Mar. 2025, en.wikipedia.org/wiki/Phanerochaete."

[9] “Trametes Versicolor.” Wikipedia, 18 July 2025, en.wikipedia.org/wiki/Trametes_versicolor."

[10] “Pleurotus Ostreatus.” Wikipedia, 21 May 2025, en.wikipedia.org/wiki/Pleurotus_ostreatus."

[11] Shanghai Chongming District Government. (2024, December 16). Continuously advancing “zero-waste city” construction: This is how Chongming does it. Retrieved from: www.shcm.gov.cn/xwzx/002003/20241216/206ee6b9-84be-4767-851e-2d68baecd4b4.html."

[12] “Hippophae Rhamnoides.” Wikipedia, 28 July 2025, en. wikipedia. org/wiki/Hippophae_ rhamnoides."

[13] Changjing Garden. (n.d.). How much does seabuckthorn cost per plant? Latest market price forecast. Retrieved from https://www.cmeii.com/anlizhanshi/128437.html