Highlights

- Urban tree species selection significantly shapes soil microbial activity.
- Eucalyptus increased litter decomposition and substrate-induced respiration.
- Neem and Almond altered key soil nutrient concentrations differently.
- Findings inform conservation-based management of urban green spaces.
- Soil biological indicators support ecosystem-based urban forestry planning.

Influence of Selected Urban Tree Species on Soil Microbial Activity, Litter Decomposition, and Soil Chemical Properties in Akure, Southwestern Nigeria

Zoe Faith Zebedee[1]* and S.A. Adejoro[1]

[1]*Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Ondo State, Nigeria*

*Corresponding Author: Zoe Faith Zebedee — zoezebedee11@outlook.com

Abstract

Urban trees shape belowground ecological processes through litter deposition, root exudation, and interactions with soil microbial communities, yet species-specific effects are rarely incorporated into urban green-space management. This study evaluated the effects of five common urban tree species (Eucalyptus globulus, Azadirachta indica, Thuja occidentalis, Prunus dulcis, and Buddleja globosa) on soil microbial activity, litter decomposition, and soil chemical properties within the Federal University of Technology, Akure, Nigeria, to inform conservation-based approaches to tree selection in tropical urban landscapes. Rhizosphere soil samples were collected beneath each species and analyzed for basal respiration, substrate-induced respiration, litter decomposition, and nine chemical properties, including pH, total nitrogen, phosphorus, potassium, calcium, and magnesium. Eucalyptus recorded the highest litter decomposition and substrate-induced respiration rates, while Neem and Almond most strongly influenced soil nutrient concentrations. These species-specific effects demonstrate that tree selection is a practical lever for regulating nutrient cycling and soil health in urban ecosystems, with direct implications for conservation-oriented urban forestry and sustainable green-space design in tropical cities.

Keywords: *Urban forest conservation, soil respiration, litter decomposition, soil microbial activity, nutrient cycling, rhizosphere ecology*

1. Introduction

Urban forests are a core component of urban ecosystems, providing air quality improvement, carbon sequestration, biodiversity conservation, and climate regulation (Nowak et al., 2014; Tyrväinen et al., 2005). Beyond these visible benefits, urban vegetation shapes belowground biological and chemical processes that govern nutrient cycling and long-term soil health — functions increasingly recognized as central to urban ecosystem conservation and management.

The rhizosphere, the interface between plant roots and soil, hosts complex interactions among roots, microorganisms, and soil fauna that drive nutrient mineralization, organic matter decomposition, and carbon cycling (Philippot et al., 2013). Plant species shape rhizosphere conditions through root exudation, litter production, and nutrient uptake, thereby influencing microbial community composition and soil function (Bardgett, 2005).

Soil microorganisms are major drivers of ecosystem productivity and nutrient cycling (van der Heijden et al., 2008), and soil respiration — both basal and substrate-induced — is a widely used indicator of their metabolic activity (Raich and Schlesinger, 1992; Anderson and Domsch, 1990). Litter decomposition rates likewise vary with species-specific litter quality, nutrient content, and lignin concentration (Cornwell et al., 2008; Swift et al., 1979), directly influencing how quickly nutrients are returned to the soil.

Despite growing recognition of these processes, few studies have examined how common urban tree species affect soil respiration, litter decomposition, and nutrient dynamics within tropical university and city landscapes — information that is directly relevant to evidence-based species selection in urban forest conservation programs. This study therefore investigated the effects of five urban tree species on soil microbial activity, litter decomposition, and soil chemical properties at the Federal University of Technology, Akure, Nigeria, with the aim of informing ecologically grounded urban forestry and green-space conservation planning. The specific objectives were to:

1. Evaluate the influence of selected urban tree species on soil basal respiration.
2. Assess differences in substrate-induced respiration among tree species.
3. Determine the effects of selected urban tree species on litter decomposition.
4. Examine the impacts of urban tree species on soil chemical properties and nutrient dynamics.

2. Materials and Methods

2.1 Study Area

The study was conducted at the Federal University of Technology, Akure (FUTA), Ondo State, southwestern Nigeria, a tropical site with distinct wet and dry seasons and a mixed urban forest cover. Five commonly occurring urban tree species were selected: Eucalyptus globulus (Eucalyptus), Azadirachta indica (Neem), Thuja occidentalis (Thuja), Prunus dulcis (Almond), and Buddleja globosa (Butterfly tree).

2.2 Soil Sampling

Composite rhizosphere soil samples were collected beneath each species using standard sampling procedures, then air-dried, processed, and sieved prior to biological and chemical analysis.

2.3 Determination of Soil Chemical Properties

Soil pH was measured in a soil-water suspension. Total nitrogen, available phosphorus, potassium, sodium, calcium, magnesium, organic carbon, organic matter, and electrical conductivity were determined using standard soil laboratory procedures.

2.4 Determination of Soil Basal Respiration

Basal respiration was determined by the alkali absorption technique: 50 g soil samples were incubated in airtight containers, and CO_2 evolved was absorbed in sodium hydroxide and quantified by titration following precipitation with barium chloride.

2.5 Determination of Substrate-Induced Respiration

Substrate-induced respiration was assessed by adding glucose as a readily available carbon source, with CO_2 evolution measured by the alkali absorption method to estimate microbial response to substrate availability.

2.6 Determination of Leaf Litter Decomposition

Litter decomposition was assessed using litter collected beneath each species and monitored throughout incubation, expressed as CO_2 evolved from decomposing material.

2.7 Statistical Analysis

Data were analyzed by ANOVA, with treatment means separated using Tukey's test at $P \leq 0.05$.

3. Results

3.1 Effects of Urban Tree Species on Soil Basal Respiration

Soil basal respiration varied significantly among species during incubation. On Day 1, Thuja recorded the highest value (22.4 mg CO_2-C kg^{-1}), followed by Almond (20.7 mg CO_2-C kg^{-1}), while Eucalyptus and Butterfly tree were lowest. Differences narrowed as incubation progressed: Eucalyptus recorded the highest respiration on Day 7 (27.5 mg CO_2-C kg^{-1}), and all species converged to similar values by Days 14–21.

Table 1. Effects of urban tree species on soil basal respiration (mg CO_2-C kg^{-1} soil)

Tree species	Day 1	Day 2	Day 3	Day 7	Day 14	Day 21
Eucalyptus	9.7^{c}	14.4^{a}	21.0^{a}	27.5^{a}	23.9^{a}	23.3^{a}
Butterfly	9.8^{c}	12.4^{a}	19.5^{a}	25.2^{ab}	21.8^{a}	22.3^{a}
Neem	16.9^{b}	16.7^{a}	21.0^{a}	21.0^{b}	21.7^{a}	23.2^{a}
Thuja	22.4^{a}	13.2^{a}	21.1^{a}	24.3^{ab}	23.5^{a}	22.0^{a}
Almond	20.7^{a}	16.9^{a}	21.3^{a}	24.4^{ab}	22.7^{a}	23.2^{a}

Values followed by different letters within columns are significantly different at $P \leq 0.05$.

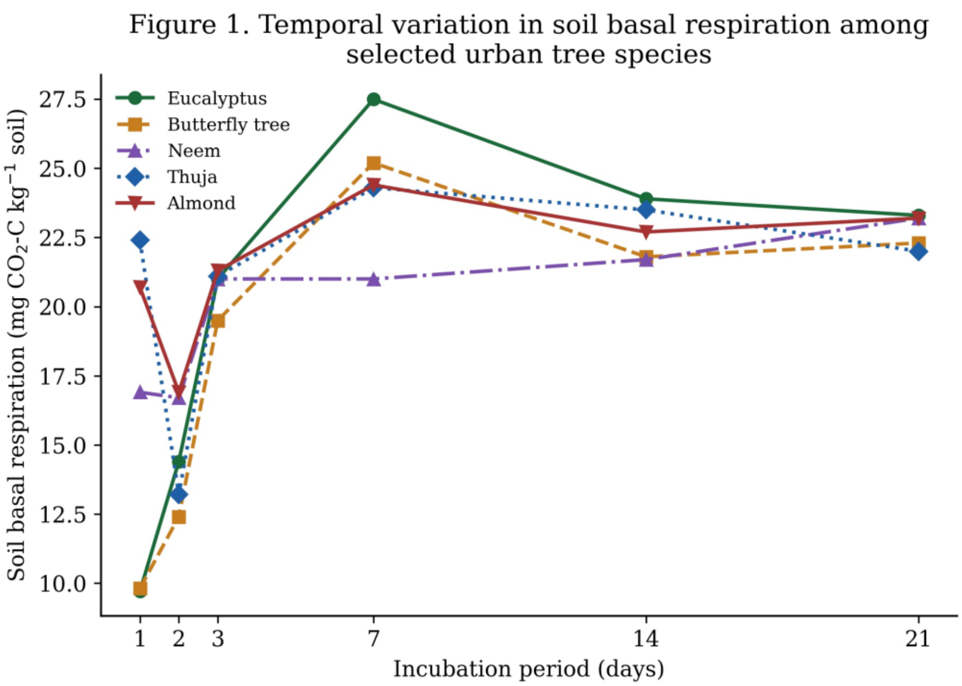

Figure 1. Temporal variation in soil basal respiration among selected urban tree species

3.2 Effects of Urban Tree Species on Substrate-Induced Respiration

Substrate-induced respiration also differed significantly among species. Eucalyptus recorded the highest Day 1 value (19.7 mg CO_2-C kg^{-1}), while Butterfly tree was lowest (7.5 mg CO_2-C kg^{-1}). Values were broadly similar across species between Days 2 and 14, but on Day 21 Eucalyptus rose sharply to 101.3 mg CO_2-C kg^{-1}, far exceeding all other species — indicating a strong microbial response to substrate addition in Eucalyptus rhizosphere soils.

Table 2. Effects of urban tree species on substrate-induced respiration (mg CO_2-C kg^{-1} soil)

Tree species	Day 1	Day 2	Day 3	Day 7	Day 14	Day 21
Eucalyptus	19.7^{a}	21.5^{b}	24.5^{a}	22.8^{a}	24.7^{a}	101.3^{a}

Butterfly	7.5[c]	24.8[a]	23.2[a]	22.6[a]	23.0[a]	24.6[a]
Neem	13.4[b]	26.1[a]	24.3[a]	22.4[a]	23.0[a]	26.9[a]
Thuja	13.0[b]	24.5[a]	24.4[a]	25.2[a]	22.8[a]	24.4[a]
Almond	15.8[b]	21.8[b]	24.5[a]	24.3[a]	23.3[a]	23.6[a]

Values followed by different letters within columns are significantly different at $P \leq 0.05$.

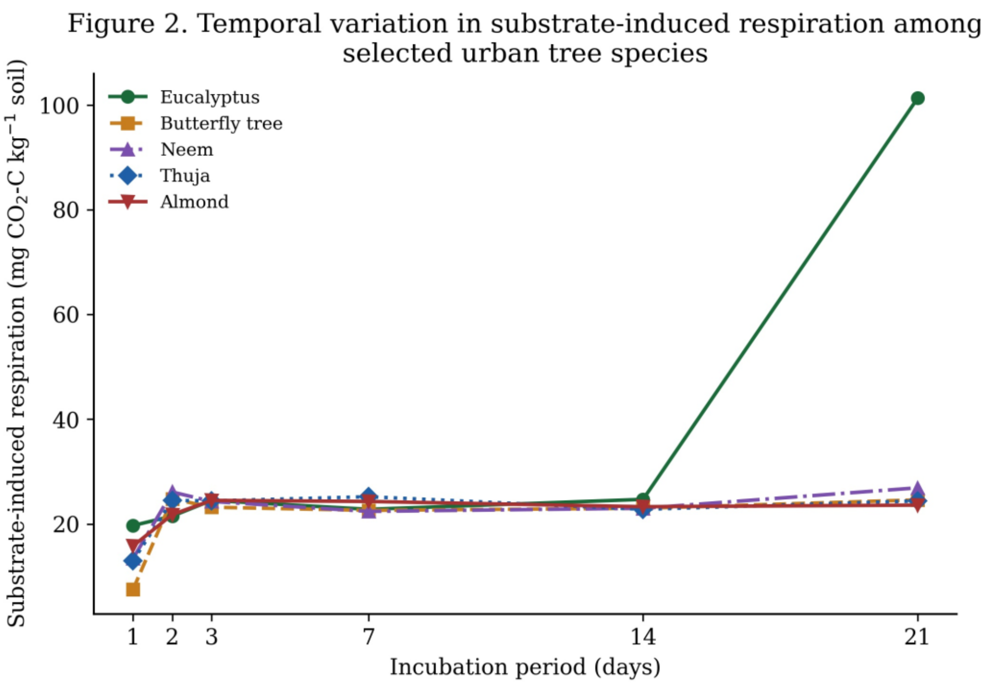

Figure 2. Temporal variation in substrate-induced respiration among selected urban tree species

3.3 Effects of Urban Tree Species on Leaf Litter Decomposition

Litter decomposition varied substantially among species. Eucalyptus consistently recorded the highest values, including the study's overall peak on Day 14 (0.79 mg kg^{-1}); Neem recorded the lowest Day 3 value (0.08 mg kg^{-1}). By Day 21, decomposition ranked Eucalyptus (0.46) > Thuja (0.34) > Butterfly tree (0.26) > Neem (0.18) ≈ Almond (0.178 mg kg^{-1}), reflecting differences in litter quality and susceptibility to microbial breakdown.

Table 3. Effects of urban tree species on leaf litter decomposition (mg kg^{-1})

Tree Species	Day 3	Day 5	Day 6	Day 7	Day 14	Day 21
Eucalyptus	0.36[a]	0.55[a]	0.72[a]	0.49[a]	0.79[a]	0.46[a]
Butterfly	0.21[ab]	0.22[b]	0.32[b]	0.27[ab]	0.39[a]	0.26[a]
Neem	0.08[b]	0.23[a]	0.26[b]	0.18[a]	0.39[a]	0.18[a]
Thuja	0.20[ab]	0.27[ab]	0.27[b]	0.39[ab]	0.31[a]	0.34[a]
Almond	0.13[ab]	0.11[b]	0.20[b]	0.26[a]	0.2799[a]	0.178[a]

Values followed by different letters within columns differ significantly at P ≤ 0.05.

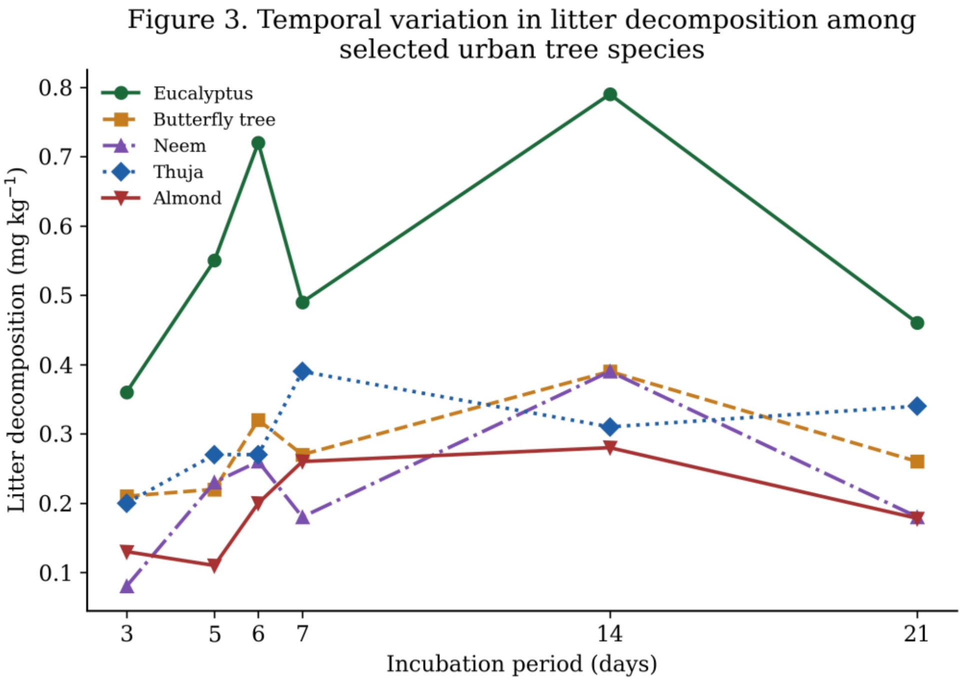

Figure 3. Temporal variation in litter decomposition among selected urban tree species

3.4 Effects of Urban Tree Species on Soil Chemical Properties

Soil chemical properties varied significantly among species. pH ranged from 5.20 (Eucalyptus) to 5.66 (Butterfly tree). Total nitrogen was highest under Almond and Thuja; phosphorus was highest under Neem and Butterfly tree. Potassium was highest under Almond (7.96 mg kg^{-1}); calcium was highest under Neem and Butterfly tree; magnesium was highest under Almond. Organic carbon, organic matter, and electrical conductivity also differed among species, indicating species-specific rhizosphere effects on soil fertility.

Table 4. Effects of urban tree species on soil chemical properties

Species	pH	Total N	P	K	Na	Ca	Mg	OC	OM	EC
Eucalyptus	5.20	0.30^{d}	4.18^{a}	0.25^{a}	0.36^{a}	3.89^{a}	1.53^{d}	1.68^{a}	3.35^{a}	1.57^{b}
Neem	5.37^{a}	1.38^{b}	7.42^{a}	0.36^{c}	0.43^{b}	4.28^{a}	2.40^{cd}	2.05^{a}	3.27^{a}	1.13^{b}
Thuja	5.57^{a}	5.34^{a}	0.37^{c}	4.70^{b}	0.23^{c}	0.40^{d}	4.19^{b}	1.84^{a}	1.60^{b}	2.53^{a}
Butterfly	5.66^{a}	0.81^{c}	7.27^{a}	0.23^{c}	0.40^{b}	4.21^{a}	3.27^{c}	1.82^{a}	2.92^{a}	2.35^{a}
Almond	5.44^{a}	5.37^{a}	0.36^{c}	7.96^{a}	0.67^{a}	0.94^{c}	5.39^{a}	1.84^{a}	1.57^{a}	2.60^{a}

Values followed by different letters within columns differ significantly at P ≤ 0.05.

Note: the significance letter for Eucalyptus pH was not recovered from the original data sheet and should be confirmed by the authors before submission.

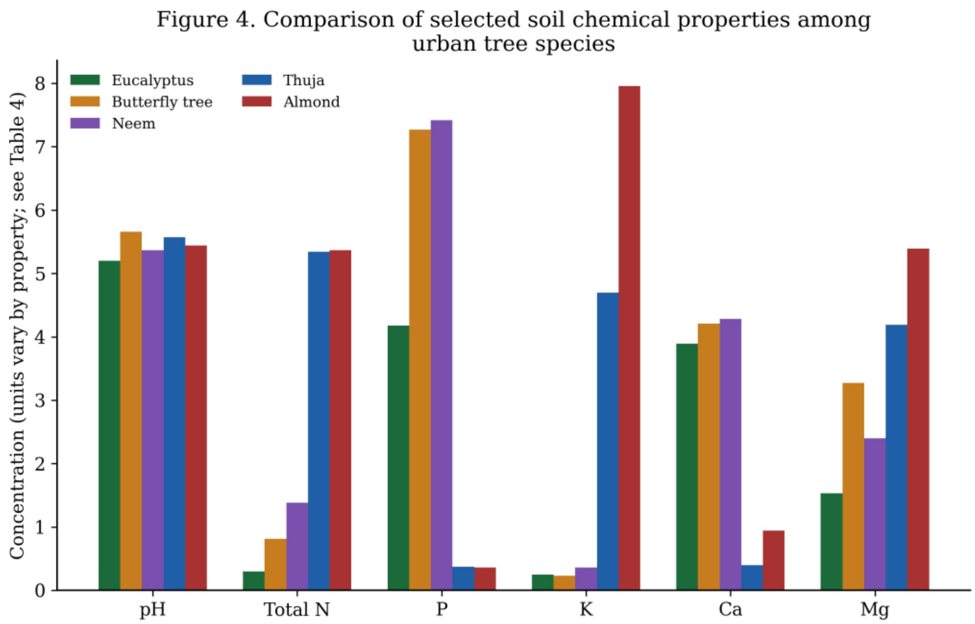

Figure 4. Comparison of selected soil chemical properties among urban tree species

4. Discussion

4.1 Influence of Urban Tree Species on Soil Microbial Activity

Urban tree species significantly influenced soil microbial activity, as reflected in basal and substrate-induced respiration. Soil respiration integrates biological processes tied to decomposition and nutrient cycling (Raich and Schlesinger, 1992), so the differences observed here suggest that tree-specific litter inputs and rhizosphere conditions shaped microbial functioning (Philippot et al., 2013). The pronounced substrate-induced respiration under Eucalyptus, consistent with the eco-physiological quotient framework used to characterize microbial metabolic status (Anderson and Domsch, 1990), points to greater microbial responsiveness in Eucalyptus rhizosphere soils. It is worth noting that laboratory incubation captures heterotrophic microbial activity in the absence of live roots, and thus differs from in situ respiration, which includes an autotrophic root component (Hanson et al., 2000).

4.2 Influence of Urban Tree Species on Litter Decomposition

Litter decomposition varied substantially among species, consistent with evidence that plant species traits are a predominant control on decomposition rates across biomes (Cornwell et al., 2008). Faster decomposition, as seen under Eucalyptus, accelerates nutrient return to soil (Swift et al., 1979), while slower rates under Neem and Almond may favor longer-term organic matter accumulation. Abiotic pathways such as photodegradation can also influence litter mass loss in some ecosystems (Austin and Vivanco, 2006), indicating that microbial activity is not the sole control on decomposition.

4.3 Influence of Urban Tree Species on Soil Chemical Properties

Species-specific effects on pH, nutrient concentrations, organic carbon, and organic matter point to distinct patterns of nutrient uptake, root activity, and litterfall composition. Soil organic matter formation depends on the balance between microbial carbon-use efficiency and stabilization against the mineral matrix (Cotrufo et al., 2013; Six et al., 2002), and represents a continuum of decomposing compounds rather than fixed stable fractions (Lehmann and Kleber, 2015). These properties are central to soil-based carbon sequestration strategies (Lal, 2004a) and to the long-term sustainability of urban green-space soils.

4.4 Conservation and Management Implications for Urban Forestry

These findings carry direct relevance for urban ecosystem conservation. Beyond air quality and climate regulation (Nowak et al., 2014), tree species selection is a practical, low-cost management lever for shaping belowground soil function, nutrient cycling, and long-term soil health in urban green spaces. Because urban forests also deliver recreational, aesthetic, and public-health benefits to city residents (Tyrväinen et al., 2005), integrating soil biological indicators into species-selection decisions supports a more holistic, ecosystem-based approach to urban conservation planning. Species that promote higher microbial activity and faster nutrient cycling, such as Eucalyptus, may be prioritized where rapid soil rehabilitation is needed, while species that favor nutrient retention and organic matter accumulation, such as Neem and Almond, may better serve long-term carbon storage and soil conservation goals (Lal, 2004b).

Overall, these results support incorporating belowground ecological functions into urban forestry and conservation programs, complementing the aboveground criteria — shade, aesthetics, and canopy cover — that currently dominate species-selection decisions in tropical cities.

5. Conclusion

This study found that urban tree species significantly shape soil microbial activity, litter decomposition, and soil chemical properties at the Federal University of Technology, Akure, Nigeria. Eucalyptus generally promoted greater microbial activity and decomposition, while Neem and Almond most strongly influenced soil nutrient concentrations. These species-specific effects underscore those tree selection is a practical, ecosystem-based tool for urban forest conservation and soil health management. Future research should examine microbial community composition, long-term soil carbon dynamics, and how these belowground effects interact with the biodiversity and recreational value of urban green spaces.

Author Contributions

Zoe Faith Zebedee: Conceptualization, field sampling, laboratory analyses, data collection, data interpretation, manuscript drafting, manuscript revision.

S.A. Adejoro: Research supervision, methodology guidance, project administration, manuscript review, and editorial input.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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