Sustinere
Journal of Environment and Sustainability
Volume 8 Number 1 (2024) 103-122

Print ISSN: 2549-1245 Online ISSN: 2549-1253
Website: https://sustinerejes.com E-mail: sustinere.jes@uinsaid.ac.id

REVIEW

Determinants of spatial distribution of trees outside forests along urban-rural gradients: A review

Dorcas Wambui Kariuki[2*], Sammy C. Letema[1] and Godwin O. Opinde[1]
1. Dept. of Spatial and Environmental Planning, Kenyatta University, P.O. Box 43844-00100, Nairobi, Kenya
2. Dept. of Environmental Sciences, Muranga University of Technology, P.O. Box 75-10200, Murang'a, Kenya

Article history:
Received 12 February 2024 | Accepted 8 April 2024 | Available online 20 May 2024

Abstract. Urbanization can create uncertainty for biodiversity. Understanding the spatial distribution of trees along urban-rural gradients is crucial for sustainable land management and the conservation of biological diversity. However, limited information is available on the factors influencing the distribution of trees outside forests along urban-rural transition gradients. This paper uses the Preferred Reporting items for Systematic Reviews and Meta-Analyses (PRISMA) to review how distance from urban centers, land use types, socio-economic disparities, and community attitudes and perceptions impact the spatial distribution of trees outside forests along urban-rural gradients. The review indicates that the species composition, diversity, density, and spatial arrangement of trees outside forests vary along the urban-rural gradient. The most commonly cited factors influencing this distribution are respondents' attitudes and perceptions of trees, socio-economic factors, and land use variations. Distance from the urban center was the least cited factor. However, there is significant variation in how different factors impact this distribution from study to study. Therefore, further research is needed to better understand the factors driving changes in the diversity of trees outside forests in various urban-rural contexts and to determine whether variations exist across different settings.

Keywords: Attitudes and perceptions; Land uses; Socio-economic factors; Trees outside forests; Urban-rural gradient

1. Introduction

As cities continue to expand, natural vegetation is often cleared and replaced with human-made structures, leading to loss of biodiversity and species (Sanaei et al., 2020; Singh et al., 2018). Although some studies suggest that tree species richness may be higher in cities than natural forests (Gillespie et al., 2017), the relationship between urbanization and plant diversity has not been adequately explored (M. Wang et al., 2020). Nevertheless, there is growing interest in Trees Outside Forests (TOF), their diversity, distribution, and relationship with urbanization factors (Abdulmalik et al., 2020; Bourne & Conway, 2014; Chauhan & Dogra, 2016; Chukwumaucheya, 2012; Di Cristofaro et al., 2020; Jeong et al., 2023). Therefore, the urban-rural paradigm is a useful model for studying the effects of urbanization on plant communities.

Previous empirical studies, though limited, show varying patterns of change in how TOF are spatially distributed along the urban-rural gradient (Ranta & Viljanen, 2011; Vakhlamova et al.,

*Corresponding author. E-mail: dkariuki@mut.ac.ke
DOI: https://doi.org/10.22515/sustinere.jes.v8i1.385

2014; M. Wang et al., 2020). This pattern can be attributed to various factors. For example, the existence of numerous spatial patterns of plants distribution along an urban-rural transitional gradient in a city can be attributed to the high heterogeneity of urban environments, which provides many habitats for various plant species (M. Wang et al., 2020). Additionally, urban socio-economic activities, diversity, and land use management practices significantly influence how plants are spatially distributed (M. Wang et al., 2020). However, it is challenging to unravel how each factor individually affects the spatial distribution of plants along the urban-rural gradient (Ruas et al., 2022). Therefore, it is crucial to consider multiple factors when studying the influence of urban development on species distribution and diversity (M. Wang et al., 2020).

As countries strive towards sustainability in the management of tree resources and conservation of biological diversity, as outlined in the United Nations Sustainable Development Goal number 15, it is imperative to understand the principal issues associated with the existence of TOF. It is crucial to discern their prospective implications and suggest measures to augment their productivity. To provide a comprehensive and up-to-date review of recent developments associated with TOF, this study reviewed articles addressing factors influencing the distribution of TOF along urban-rural transition gradients. These factors include proximity to the urban core, land use patterns, residents' attitudes and perceptions, and socio-economic status. The paper reviews the variation in spatial distribution of TOF with distance from urban areas, how variation in land use types along urban-rural gradients influences TOF's spatial distribution, how people's perceptions of TOF affect their spatial distribution, and how socioeconomic status influences their spatial distribution. The findings of this paper will be helpful in achieving the United Nations' target to incorporate the significance of ecosystems and biodiversity into national and local planning, development procedures, and poverty alleviation strategies.

2. Material and method

2.1. Review protocol and search

A systematic review of published articles was conducted using keywords to search the following electronic databases: Tandfonline, Science Direct, EBSCOhost, and Google Scholar. Additional relevant articles were obtained by tracing the citations in the reference lists of the included articles. The review followed to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist (Page et al., 2021). Based on the aims of this review, a review protocol documenting the criteria for literature inclusion and exclusion was developed beforehand, as detailed in Table 1.

Table 1: Inclusion and exclusion criteria for the selection of literature

Criteria	Decision
When the predefined search terms occur wholly or as a minimum in the title, abstract, or keywords of the article	Inclusion
The article is published in a peer-reviewed journal	Inclusion
The article is full-length and written in the English language	Inclusion
The article addresses at least one of the determinants of the distribution of TOF or the distribution pattern of TOF.	Inclusion
Articles duplicated in the search results	Excluded
Inaccessible articles	Excluded
Review papers and metadata.	Excluded
Articles that were published before 2010	Excluded

The search was conducted between 25th July 2023 and 15th August 2023. It was restricted to primary studies published in English between January 2010 and June 2023 to focus mainly on the most recent developments in the field. Table 2 summarizes the key search terms and the number of articles obtained from each database. Additionally, 106 articles were identified through tracing of citations.

Table 2: Key search terms used and the number of articles obtained from each database

Database	Search term and search string		Articles obtained	Full-text articles assessed for eligibility
Google Scholar	Search terms – where all is found in the title of the article	Trees Outside Forests	121	24
		Perceptions of Trees Outside Forests	1	1
		Perceptions of urban trees	13	13
		Trees along urban-rural gradient	6	6
		Land uses and trees (diversity)	95	10
		Effects of socio-economic factors on trees outside forests diversity	0	0
		Trees and socio-economic	26	6
Science Direct	Search terms - using article title, abstract, and keywords	Trees Outside Forests	336	19
		Perceptions of Trees Outside Forests	4	0
		Perceptions of urban trees	169	54
		Socioeconomics and trees diversity	63	12
		Trees, urban-rural gradient	55	12
		Effects of land use on trees diversity	237	18
EBSCOhost	Search terms – where all is found either in the article title, abstract, or keywords	Trees Outside Forests	122	9
		Perceptions of Trees Outside Forests	1	1
		Perceptions of urban trees	26	26
		Trees and socio-economic factors	160	10
		Land use type and tree species diversity	20	4
	Search term – where all is found in all text	Trees along urban-rural gradient	10	4
Taylor and Francis	Search terms - using article title, abstract, and keywords	Trees Outside Forests	68	0
		Perceptions of Trees Outside Forests	0	0
		Perceptions of urban trees	2	2
		Socioeconomics and Trees Outside Forests	4	2
		Effects of land use on trees diversity	36	0
	Search term – where all is found anywhere in the article	Trees outside forests diversity along urban-rural gradient	421	4

2.2. Study selection

The selection of relevant articles was based on the sub-themes of the study, and the selection process is summarized in Figure 1. The titles, abstracts, keywords, author names and affiliations, year of publication, and journal titles of selected papers were exported to a Microsoft Excel spreadsheet for data management. The search results were screened depending on the article title, abstract, and keywords. Using the developed protocol (Table 1), articles that met the inclusion criteria were selected for further analysis.

The first step involved reading the titles of the collected articles, discarding those irrelevant to the research topic. In the second step, the abstracts of the remaining papers were reviewed, excluding those whose abstracts did not correspond to the research topic. Step three, eligibility assessment, involved screening the full texts of the included articles. In the fourth step, elevant data from the chosen studies were extracted and synthesized to identify trends and patterns in the distribution of TOF along an urban-rural gradient based on distance from urban areas, land use types, socio-economic status, and people's attitudes and perceptions. The study's findings were summarized under various TOF sub-themes, research gaps analyzed, and suggestions for further research highlighted.

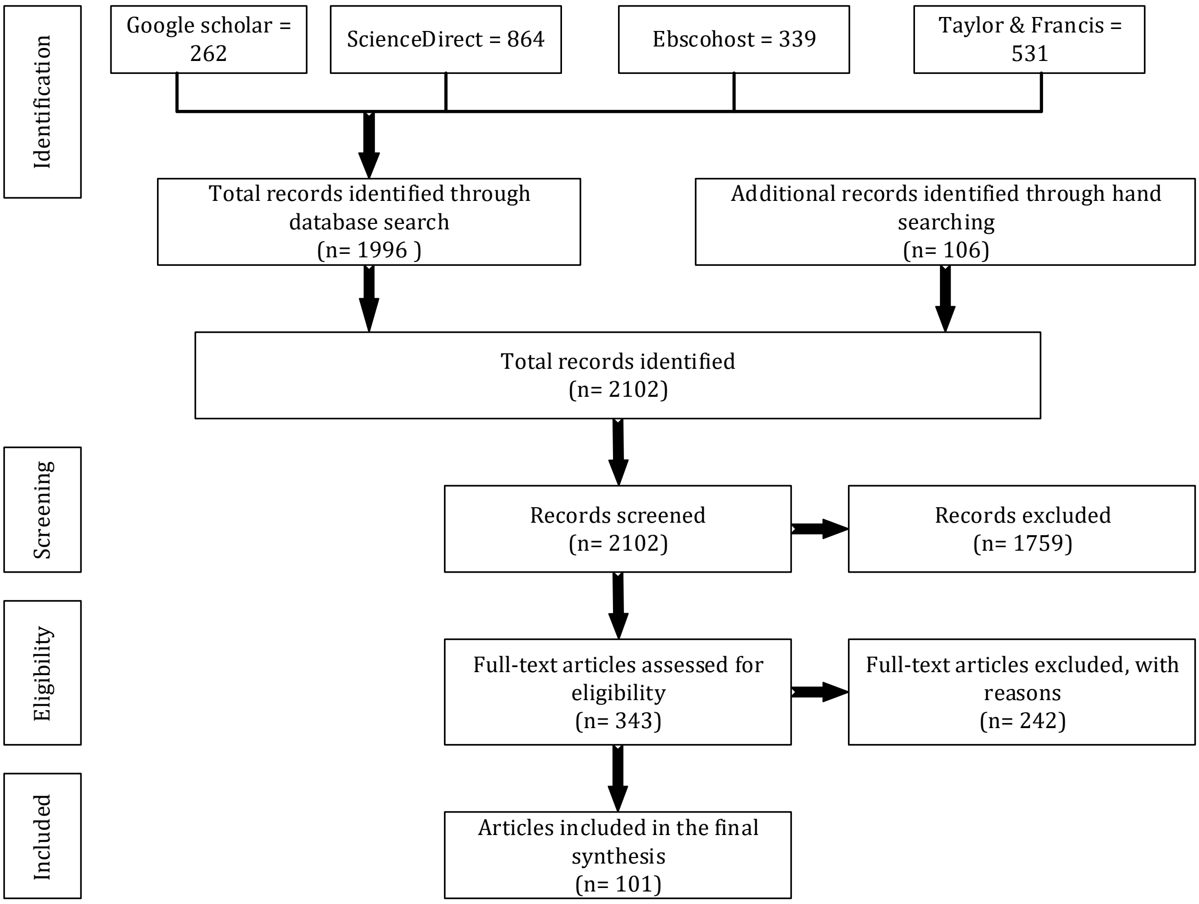

Figure 1. Flow chart of the study selection process

3. Result and discussion

Over the last decade, there has been an increase in the number of studies evaluating the distribution of TOF and their influencing factors (Figure 2). This review identified 101 studies that explain the variation in the distribution of TOF along urban-rural gradients influenced by various determinants.

Twenty-three of these studies were conducted in Asia, 23 in North America, 22 in Europe, 25 in Africa, 6 in Australia, and only 2 in South America. Eighteen studies strictly used the urban-rural gradient to explain the variation in spatial distribution of TOF. The other 83 studies used simple comparison of variations between urban and non-urban areas, or variations within urban, peri-urban, or rural areas.

The most frequently cited factors influencing the species composition and spatial distribution of TOF are the respondents' attitudes and perceptions of trees (66 citations) and socio-economic factors (46 citations), with land use type being the least cited factors (33 citations). Overall, the studies identified various specific factors affecting the spatial distribution of TOF, and the extent and nature of the impact of these factors varied from one study to another depending on the specific contexts in which the studies were carried out.

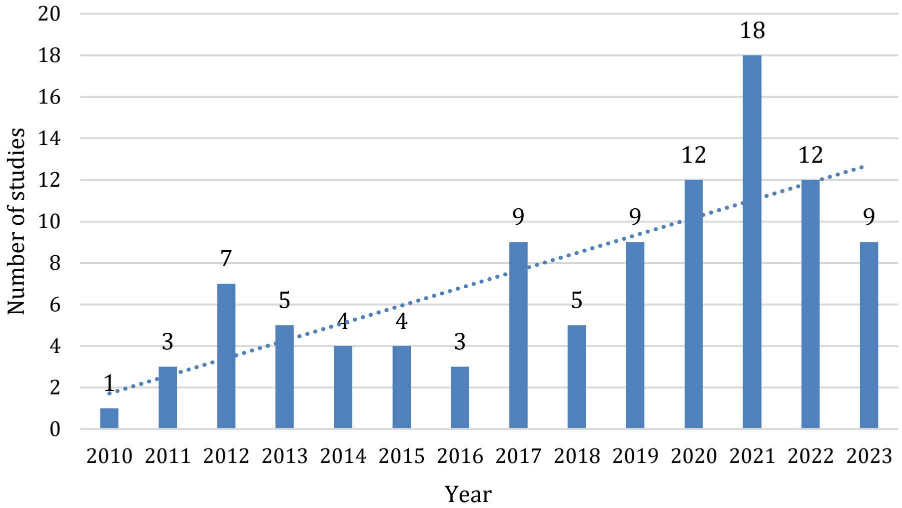

Figure 2. Number of studies relating spatial distribution of TOF and their determinants between January 2010 and June 2023

3.1. Spatial distribution of trees outside forest with distance from urban cores

Studies have shown that the spatial distribution of TOF varies depending on the distance from urban areas (Table 3). Some regions experience a mild negative impact on plant diversity due to proximity to the city center (Panyadee et al., 2012), while others show an increase in plant diversity and density as the distance from urban to rural areas increases for both native and exotic species (Cameron et al., 2015; Nock et al., 2013; Ranta & Viljanen, 2011; Salmoiraghi et al., 2020; Vakhlamova et al., 2014). However, tree species abundance generally decreases in highly urbanized areas (Rija et al., 2014; Schwoertzig et al., 2016).

Native (Bazzato et al., 2021; Jha et al., 2019) and exotic (Bazzato et al., 2021; Jha et al., 2019; Vakhlamova et al., 2014; M. Wang et al., 2020) plant species have higher richness in urban areas than in rural areas. This suggests that increasing the distance from urban to rural areas negatively affects the diversity of both exotic and native species. On the contrary, studies have found that plant diversity is highest in areas of moderate disturbances (Xiao et al., 2023; Yan et al., 2018), which supports the theory of intermediate perturbation, which suggests that areas with moderate disturbances have more plant species diversity than areas with low or high disturbances (Connell, 1978). This is because intense anthropogenic activities from urbanization often lead to loss of plant diversity and species extinction by altering their natural habitat, fragmentation and isolation of plant populations, thereby leading to increased exposure to pollution and other stressors (Alue et al., 2022; R. Pandey & Kumar, 2018; Singh et al., 2018; M. Wang et al., 2020).

Further, the authors also found that the composition of tree species and the distribution of larger and older trees vary among urban, transition, and rural zones. For example, in Bengaluru, ornamental and shade tree species are the most abundant in the urban areas, while timber and multiple-purpose tree species dominate the rural areas (Jha et al., 2019). In contrast, the transition zone features a blend of tree species observed in urban and rural domains (Jha et al., 2019). However, there is no variation in the percentage of native species along the urban-rural gradient, with approximately 35% in urban, transition, and rural landscapes. The decrease in tree species diversity along the gradient is more pronounced with exotic tree species. Therefore, further studies are needed to examine the impact of anthropogenic activities on plant diversity and species extinction, as well as the composition and distribution of tree species in urban, transition, and rural zones.

Table 3: Changes in spatial distribution of trees along urban-rural gradient

Determinant variable	Indicator	Result	Conclusion	Selected references
Increase in the distance from the urban center toward rural areas	Mild negative impact on TOF diversity	Non-significant	Inconsistent results	(D. Pandey et al., 2021; Panyadee et al., 2012; Rija et al., 2014; Schwoertzig et al., 2016; M. Wang et al., 2020)
	Increase in diversity and density for both native and exotic species	Positive		(Cameron et al., 2015; Nock et al., 2013; Ranta & Viljanen, 2011; Salmoiraghi et al., 2020; Vakhlamova et al., 2014).
	Decrease in the diversity of exotic species	Negative		(Bazzato et al., 2021; Jha et al., 2019; Vakhlamova et al., 2014; M. Wang et al., 2020)
	Decrease in the diversity of native species	Negative		(Bazzato et al., 2021; Jha et al., 2019)
	No impact on the diversity of native species	Not significant		(M. Wang et al., 2020)
	Increase and then decrease in species diversity for both native and exotic species.	Positive/ negative		(Xiao et al., 2023; Yan et al., 2018)
	Variation in species composition of TOF	Positive/ negative		(Jha et al., 2019)
	Decrease in the population of larger and older trees	Negative		(Jha et al., 2019; Salmoiraghi et al., 2020; Sikuzani et al., 2019)

3.2. Spatial distribution of trees outside forests in different land use types along urban-rural transition gradients

The distribution of trees in different land-use areas, ranging from highly urbanized to rural environments, is known as the distribution of TOF along an urban-rural gradient (Rossi et al., 2016). This distribution is influenced by both natural and human factors, such as land use changes resulting from urbanization, agricultural expansion, and deforestation (Helen et al., 2019; Jha et al., 2019; Nock et al., 2013). These changes significantly alter the distribution of TOF, impacting the landscape mosaic by increasing or decreasing heterogeneity (Helen et al., 2019; Nock et al., 2013). Therefore, understanding TOF distribution patterns in various land use types is crucial for managing and maintaining urban and rural ecosystems, ultimately improving human well-being.

Tree species composition and diversity levels vary significantly between land use types in rural, urban, and suburban zones (Anglaaere et al., 2011; Bazzato et al., 2021; Bourne & Conway, 2014; Dobbs et al., 2013; Jiang et al., 2022; Thammanu et al., 2021), as shown in Table 4. This variation is more pronounced in some land uses than others (Jiang et al., 2022). For example, trees may be present in areas with extensive agriculture in windbreaks or shelterbelts, which are rows of trees planted to protect crops from wind erosion or provide shade for livestock (Thammanu et al., 2021). However, if not controlled, human management practices like pruning, thinning, and fire suppression negatively impact the density and health of these tree resources, limiting the provision of numerous regulatory ecosystem services (Chambers-Ostler et al., 2023).

Outside of forests, the distribution of trees is often patchy and limited in highly urbanized areas like cities and suburbs, mainly due to the density of buildings and paved surfaces, which restrict the open space available for tree growth (Fahey & Casali, 2017). These areas often have limited diversity and are confined to street trees or small park-like areas (Fahey & Casali, 2017). Similarly, the presence, size, shape, and distribution of urban built-up patches significantly influence the presence and life form of native species, with shrubs and deciduous species being more resistant compared to trees and evergreens (H. Wang et al., 2020). Many species are, therefore, limited to only one type of land use (Bourne & Conway, 2014). Therefore, it is necessary to differentiate between land uses when examining urban trees in future studies.

Table 4. Effects of land use type on spatial distribution of trees outside forests along urban-rural gradients

Determinant variable	Indicator	Result	Conclusion	Selected references
Increased urbanization in cities and suburban areas	Negatively influence the presence and life form of native species	Negative	Inconsistent results	(Anglaaere et al., 2011; Bazzato et al., 2022; Bourne & Conway, 2014; Divakara et al., 2022; Dobbs et al., 2013; Fahey & Casali, 2017; Helen et al., 2019; Jiang et al., 2022; Nitoslawski & Duinker, 2016; Nock et al., 2013; H. Wang et al., 2020)
Residential land uses	Encourages higher tree species richness	Positive		(Kendal et al., 2012; Nitoslawski et al., 2017)
Urban parks land use	Encourages higher species diversity of trees	Positive		(McCoy et al., 2022)
Presence of wider roads in urban areas	Supports a higher tree richness and diversity	Positive		(Bhatti et al., 2022; Shams et al., 2020)
Private land use	Lower tree species diversity	Negative		(Gwedla et al., 2022)
	Encourages a higher native tree species diversity	Positive		(Chambers-Ostler et al., 2023; Nitoslawski & Duinker, 2016)
Public land use	Encourages larger tree canopy	Positive		(Dobbs et al., 2013)
Level of urban planning	Variation in the species composition and performance of trees in planned and unplanned neighborhoods	Positive/ negative		(Puplampu & Boafo, 2021; Sikuzani et al., 2020, 2022)
Variation in landscape pattern	Variation in plant species richness	Positive/ negative		(Li et al., 2023)
Agricultural land use	Encourages higher tree density, and species richness of trees	Positive		(Kalema & Witkowski, 2012)
	Lower tree and general plant species diversity	Negative		(Karp et al., 2012)
Variation in agricultural land use type	Variation in tree diversity and densities	Positive/ negative		(Chameno, 2020; Jara et al., 2017)

The distribution of TOF becomes more diverse as we move away from densely populated areas and into more suburban or ex-urban areas (Divakara et al., 2022; Nock et al., 2013). These areas typically have a broader range of land uses, such as residential, commercial, institutional, and agricultural. Within the sub-urban domain, the variation in land use types changes how trees are established and maintained, the planting practices used, and ownership status, often prompted by the various drivers of tree species composition (Nitoslawski & Duinker, 2016). In rural areas, land use type influences the species composition, density, and species richness of trees (Kalema & Witkowski, 2012). Within these rural domains, the three diversity indices (species composition, density, and species richness) are significantly higher in land under cultivation and charcoal production land uses when compared to land under grazing (Kalema & Witkowski, 2012). This is because, in these rural areas, trees may be present in areas with extensive agriculture, such as windbreaks or shelterbelts, which may allow for an increase in the density of trees and create opportunity for the introduction of non-native species, some of which have proven invasive and may threaten the existence of native species. Therefore, future studies should

- Differentiate between land uses when examining urban-rural trees
- Identify the natural and human factors that influence the distribution of trees, such as land use changes due to urbanization, agricultural expansion, and deforestation
- Examine the variation in the composition of tree species and diversity levels between land use types in urban, suburban, and rural zones
- Investigate the impact of land use type on species composition, density, and species richness of trees in urban, suburban, and rural areas.

3.3. Effects of community attitudes and perceptions on the spatial distribution of trees outside forests

The studies reviewed indicate that the presence and management of trees in urban and rural areas largely depend on the attitudes and perceptions of residents (Danquah, 2023; Di Cristofaro et al., 2020; Jeong et al., 2023; Rašković & Decker, 2015), as shown at Table 5. For instance, most respondents prefer natural landscapes with high levels of tree cover and dislike urban and rural areas with no trees (Di Cristofaro et al., 2020). Trees are also a crucial factor influencing people's willingness to stay or visit urban areas (Di Cristofaro et al., 2020). Consequently, the reasons for planting and removing trees vary depending on the type of tree and the attitudes of the residents, leading to diverse species composition and distribution of trees within a locality (Kirkpatrick et al., 2012). Therefore, to influence residents' decisions on tree ownership and management, local governments, managers, and planners need to address the variation in attitudes by segmenting residents based on their attitudes.

People's perceptions of tree benefits vary depending on their spatial location, and different studies indicate variations in perceptions of trees in rural and urban areas (Dorresteijn et al., 2017; Paniotova-Maczka et al., 2021). These variations can be attributed to spatial differences in cultural, social, technical, and climatic factors (Dorresteijn et al., 2017; Paniotova-Maczka et al., 2021). For instance, people in rural areas tend to prefer provisioning tree benefits, while urban people prefer cultural benefits (Paniotova-Maczka et al., 2021). Conversely, urban residents place more value on provisioning ecosystem services, while rural residents place more value on regulating ecosystem services. Both rural and urban residents value cultural ecosystem services equally (Yang et al., 2019).

In rural areas, people perceive tree benefits based on their ecosystem services (Bhebhe et al., 2023; Chauhan & Dogra, 2016; Chukwumaucheya, 2012; Sibelet et al., 2017). For example, farmers are more inclined towards tree species with large canopies, which increase the potential for providing ecosystem services such as air temperature regulation, erosion control, and wind-

Table 5. Relationship between people's perceptions and spatial distribution of trees outside forests

Determinant variable	Indicator	Result	Conclusion	Selected references
Perceived potential danger or nuisance associated with trees	Variation in tree preference, hence a variation in the species composition, diversity and distribution of TOF	Negative	Negative trend	(Danquah, 2023; Drew-Smythe et al., 2023; Jeong et al., 2023; Paniotova-Maczka et al., 2021; Saldarriaga et al., 2020)
Variation in the level of recognition and attitudes towards tree services and disservices	Variation in tree preference, hence a variation in the species composition, diversity and distribution of TOF	Positive/ negative	Inconsistent results	(Anglaaere et al., 2011; Arabomen et al., 2020; Basu et al., 2022; Bhebhe et al., 2023; Blanco et al., 2020; Chukwumaucheya, 2012; Collins et al., 2019; Deng et al., 2017; Di Cristofaro et al., 2020; Dorresteijn et al., 2017; Drew-Smythe et al., 2023; Fernandes et al., 2018; Gwedla & Shackleton, 2019; Jeong et al., 2023; Kičić et al., 2022; Kloster et al., 2021; Lamichhane & Thapa, 2012; Locke et al., 2015; Malik et al., 2021; Olive et al., 2013; Olivero-Lora et al., 2020; Pati et al., 2022; Rae et al., 2011; Rašković & Decker, 2015; Saldarriaga et al., 2020; Sambou et al., 2017; Smith & Sullivan, 2014; Speak & Salbitano, 2021; Suchocka et al., 2019; Wei et al., 2022)
Positive attitude & perception towards: a. Ecological benefits of trees	Variation in preference for trees with potential for providing the specific ecosystem services, hence a variation in species composition, density, and diversity of TOF	Positive	Generally positive trend	(Basu et al., 2022; Blanco et al., 2020; Collins et al., 2019; Dainese et al., 2017; Kičić et al., 2022; Ng et al., 2015; Saldarriaga et al., 2020; Sebek et al., 2016; Sibelet et al., 2017; Zhang et al., 2020)
b. Provisioning value of trees				(Bhebhe et al., 2023; Chauhan & Dogra, 2016; Chukwumaucheya, 2012; Sibelet et al., 2017)
c. Social and community value of trees				(Arabomen et al., 2020; Deng et al., 2017; Drew-Smythe et al., 2023; Ferreira et al., 2021; Gerstenberg & Hofmann, 2016; Hui & Jim, 2022; Jim et al., 2021; Leets et al., 2022; Pati et al., 2022; Speak & Salbitano, 2021; Wolf et al., 2020)
d. Economic benefits of trees				(Arabomen et al., 2020; Danquah, 2023; Drew-Smythe et al., 2023; Hanisah et al., 2012; Jeong et al., 2023; Malik et al., 2021; Ngabinzeke et al., 2021; Plant et al., 2017; Speak & Salbitano, 2021)
Attitudes towards Size and shape of trees	Positive or negative influence on the diversity, species composition and distribution of TOF	Positive/ negative	Inconsistent results	(Dilley & Wolf, 2013; Drew-Smythe et al., 2023; Etshekape et al., 2018; Gerstenberg & Hofmann, 2016; Ngabinzeke et al., 2021)
Attitude towards the geographic origin of trees, i.e. whether native or exotic	Influence the species choice for TOF	Positive/negative	Variable results	(Almas & Conway, 2018; Kirkpatrick et al., 2012)

breaking (Arabomen et al., 2020; Blanco et al., 2020; Chukwumaucheya, 2012; Danquah, 2023; Ferreira et al., 2021; Hui & Jim, 2022; Isaifan & Baldauf, 2020; Jeong et al., 2023; Jim et al., 2021; Jones et al., 2013; Leets et al., 2022; Malik et al., 2021; Moffat, 2016; Sibelet et al., 2017).

In urban areas, trees are perceived to promote social cohesion, and contribute to general human well-being (Ferreira et al., 2021; Gerstenberg & Hofmann, 2016; Hui & Jim, 2022; Jim et al., 2021; Leets et al., 2022; Wolf et al., 2020). They also offer a wide range of economic benefits (Donovan & Butry, 2011; Gilchrist et al., 2015; Hanisah et al., 2012; Leets et al., 2022; Plant et al., 2017; Rašković & Decker, 2015; Shickman & Rogers, 2020). Additionally, urban trees provide visual and aesthetic benefits, cultural diversity, heritage values, historical and symbolic values, creating a sense of connectedness to past experiences and contributing to people's appreciation for life. This explains why individuals may want to plant and maintain specific tree species (Arabomen et al., 2020; Deng et al., 2017; Drew-Smythe et al., 2023; Pati et al., 2022; Speak et al., 2021). Therefore, future studies should conduct place-based research to understand local perceptions of trees and to provide relevant policy guidelines for tree conservation.

3.4. Relationship between socio-economic status and the spatial distribution of trees outside forests

Socioeconomic factors play a significant role in people's attitudes towards and willingness to establish and maintain trees in both rural and urban settings (Table 6). However, the distribution and density of trees in these areas can vary due to these factors (Blanco et al., 2020; Collins et al., 2019; Danquah et al., 2023; Graça et al., 2018; Hanisah et al., 2012; Koyata et al., 2021; Pistón et al., 2022; Suchocka et al., 2019). Understanding the relationship between socioeconomic aspects and the spatial distribution of trees is crucial for comprehending the dynamics of green infrastructure and its role in the spatial ecology of other species. Nevertheless, there is a lack of adequate literature on the relationship between people's demographic factors (e.g., age, gender, income, and education) and their support for tree protection (Bucheli & Bokelmann, 2017).

Furthermore, different socioeconomic factors can impact tree diversity and distribution outside forests in various contexts and regions (Shams et al., 2020; Su et al., 2022). For example, in Ethiopia, there is a significant positive relationship between land-holding size in farmlands, species abundance, and basal areas, but a negative relationship with species richness (Endale et al., 2017). Similarly, land ownership status significantly influences the characteristics of trees, such as their composition, structure, and overall health (Etshekape et al., 2018; Puplampu & Boafo, 2021; Rae et al., 2011; Sikuzani et al., 2020). For instance, studies have shown that trees on private lands have a specific trunk diameter, are shorter, and have smaller crown areas than those on public lands Chambers-Ostler et al. (2023). However, these trees exhibit higher diversity and better conditions (Chambers-Ostler et al., 2023). Hence, further research on trees outside forests and their relationship with socioeconomic and demographic factors is necessary to understand dense urban morphologies and enable inter-city comparisons (Dobbs et al., 2013; McCoy et al., 2022; Sikuzani et al., 2020).

3.5. Future research

This review has identified several gaps in the literature that need to be addressed to advance the field of urban forestry. Firstly, there is no consensus on the impact of distance from urban centers on the spatial distribution of tree populations in terms of species composition, density, diversity, and arrangement patterns. Future research should investigate this, particularly emphasizing their distribution of trees along urban-rural gradients in both small towns and cities.

Secondly, most studies have focused on assessing tree populations in specific land use types, such as agricultural, urban, or suburban land uses. This has resulted in lack of literature on how tree populations are distributed in different land use types, particularly along the urban-rural gradient. Additionally, more research has been conducted in major cities, leaving a gap in the literature concerning small towns and cities, especially in developing and undeveloped countries.

Table 6. Effects of socio-economic factors on the spatial distribution of trees outside forests

Determinant variable	Indicator	Result	Conclusion	Selected references
Age of residents	Old age encourages a positive attitude towards trees; hence, more trees in the residences of older residents	Positive	Inconsistent results	(Abdulmalik et al., 2020; Arabomen et al., 2021; Collins et al., 2019; Deng et al., 2017; Gwedla et al., 2022; Koyata et al., 2021; Lin et al., 2021; Nawaz et al., 2022; Pistón et al., 2022; Suchocka et al., 2019)
	Old age creates a negative attitude towards trees; hence, less trees in the residences of older residents	Negative		(Danquah et al., 2023; Fernandes et al., 2018; Jeong et al., 2023)
Gender	Gender differences influence people's attitudes, perceptions, and willingness to establish and retain trees.	Positive/negative	Inconsistent results	(Blanco et al., 2020; Collins et al., 2019; Danquah et al., 2023; Deng et al., 2017; Graça et al., 2018; Hanisah et al., 2012; Hui & Jim, 2022; Koyata et al., 2021; Lin et al., 2021; Malik et al., 2021; Nawaz et al., 2022; Pistón et al., 2022; Suchocka et al., 2019)
	Female household headship positively influences the establishment/retention of trees	Positive		(Danquah et al., 2023; Lin et al., 2021; Suchocka et al., 2019)
Level of education	Higher education levels positively influence tree growing and retention of TOF	Positive	Generally positive trend	(Arabomen et al., 2021; Blanco et al., 2020; Chameno, 2020; Etshekape et al., 2018; Fernandes et al., 2018; Graça et al., 2018; Hanisah et al., 2012; Jones et al., 2013; Kendal et al., 2012; Lockwood & Berland, 2019; Suchocka et al., 2019)
	Higher education levels negatively influence TOF growing	Negative		(Almas & Conway, 2018)
Type of dwellings	Better dwellings are associated with high species diversity and densities	Positive	Positive trend	(Abdulmalik et al., 2020; Danquah et al., 2023; Jeong et al., 2023; Saldarriaga et al., 2020)
Ethnicity	Ethnic differences influence people's attitudes and willingness to establish and retain trees.	Positive/negative	Inconsistent results	(Danquah et al., 2023; Lin et al., 2021)
Profession	Professionalism positively influences people's perceptions and willingness to support tree care activities	Positive	Positive trend	(Arabomen et al., 2021; Nawaz et al., 2022)

Table 7. Effects of socio-economic factors on the spatial distribution of trees outside forests (cont'd)

Determinant variable	Indicator	Result	Conclusion	Selected references
Length of time spent in urban areas	The longer time spent in urban areas positively influences people's attitudes and willingness to support tree care activities	Positive	Positive trend	(Arabomen et al., 2021; Nawaz et al., 2022)
Land ownership, tenure and right of use	Land ownership status significantly influences TOF species composition, structure, and overall health	Positive/negative	Inconsistent results	(Chambers-Ostler et al., 2023; Dobbs et al., 2013; Duguma & Hager, 2010; Endale et al., 2017; Etshekape et al., 2018; Hui & Jim, 2022; Kirkpatrick et al., 2012; Legesse & Negash, 2021; Olivero-Lora et al., 2020; Puplampu & Boafo, 2021; Rae et al., 2011; Rossi et al., 2016; Sikuzani et al., 2020)
Location of water source	Proximity to water sources positively influences TOF in terms of species composition, diversity, and density	Positive	Positive trend	(Etshekape et al., 2018; Legesse & Negash, 2021; Olivero-Lora et al., 2020)
Variation in species preference and management practices	Brings about unevenness in the distribution of TOF in terms of species composition, diversity, and density	Positive/ negative	Inconsistent results	(Etshekape et al., 2018; Legesse & Negash, 2021; Olivero-Lora et al., 2020)
Residents' knowledge of ecosystem services	Knowledge of ecosystem services positively influences people's willingness to take part in tree conservation programs	Positive	Positive tendencies Research still scarce	(Arabomen et al., 2020)
Income level	High-income levels positively influence the growth and retention of trees	Positive	Inconsistent results	(Danquah et al., 2023; Hui & Jim, 2022; Lin et al., 2021; Lockwood & Berland, 2019; Malik et al., 2021)
	High income does not positively influence people's inclination towards planting trees, and does not positively influence the richness and abundance of trees	Negative		(Arabomen et al., 2020; Cubino & Retana, 2023; Olive et al., 2013)
Landholding size	Large land sizes encourage TOF species diversity, abundance and basal areas	Positive	Generally Positive tendencies	(Abdulmalik et al., 2020; Chameno, 2020; Duguma & Hager, 2010; Endale et al., 2017; Etshekape et al., 2018; Legesse & Negash, 2021)
	Large land sizes negatively influence species diversity	Negative		(Endale et al., 2017)

Therefore, future research should provide insight into the impact of land use type and land use-related factors on the spatial distribution of tree populations along urban-rural gradients and compare them in large and small towns and cities.

Lastly, understanding people's attitudes and perceptions towards trees, their ecosystem services, and disservices is crucial for making green space management decisions with significant implications for urban and rural sustainability. Hence, future research on people's perceptions of tree populations should be conducted in different localities to provide local policy guidelines. Comparative studies across cities and countries are also needed to help strategic policymaking. Furthermore, future research should assess people's perception of specific tree species rather than just trees in general and examine how these perceptions vary with socioeconomic inequalities.

4. Conclusion

Over the last decade, research on how urbanization factors affect the distribution of TOF has increased. However, there are still many gaps in our understanding of how urban expansion affects the presence, location, and diversity of trees, especially along the urban-rural gradient. Understanding how different drivers influence the composition, diversity, density, and spatial arrangement of TOF species remain a challenge. A review of existing literature found that the spatial distribution of TOF varies significantly along the urban-rural gradient, with a combination of factors independently or collectively explains this variation. These factors include land use type, socio-economic factors, residents' attitudes and perceptions, and proximity to urban centers. Studies conducted in developed and developing countries also show varying trends in biodiversity change along urban-rural gradients and land use categories. Similarly, different urban factors impact TOF distribution differently in both small and large cities, with variations dependent on specific geographical contexts. Therefore, more research is needed in different urban contexts to understand the factors driving changes in TOF diversity and to elucidate whether there are variations in outcomes from urban-rural TOF across other localities.

Acknowledgment

The corresponding author is grateful for the financial support provided by DAAD German Academic Exchange Service through a postgraduate scholarship.

References

Abdulmalik, D., Abubakar, B. Y., Sani, M. A., Mukhtar, R. B., Gupa, M. A., & Bello, A. (2020). Trees Outside Forests (Trees on Farmlands): Assessment of farmers perception in Gaya local government area, Kano state, Nigeria. *East African Scholars Journal of Agriculture and Life Sciences*, 3(11), 371-377. https://doi.org/10.36349/easjals.2020.v03i11.005

Almas, A., & Conway, T. (2018). Resident Attitudes and Actions Toward Native Tree Species: A Case Study of Residents in Four Southern Ontario Municipalities. *Arboriculture & Urban Forestry*, 44(8), 101-115. https://doi.org/10.48044/jauf.2018.009

Alue, B. A., Salleh Hudin, N., Mohamed, F., Mat Said, Z., & Ismail, K. (2022). Plant Diversity along an Urbanization Gradient of a Tropical City. *Diversity*, 14(12), 1024. https://doi.org/10.3390/d14121024

Anglaaere, L., Cobbina, J., Sinclair, F., & Mcdonald, M. A. (2011). The effect of land use systems on tree diversity: Farmer preference and species composition of cocoa-based agroecosystems in Ghana. Agroforestry Systems, 81, 249–265. https://doi.org/10.1007/s10457-010-9366-z

Arabomen, O., Babalola, F., Idumah, F., & Ofordu, C. (2021). Residents' attitudes towards tree care programs in cityscapes. *Revista Produção e Desenvolvimento*, 7. https://doi.org/10.32358/rpd.2021.v7.462

Arabomen, O., Chirwa, P., & Babalola, F. (2020). Understanding Public Willingness to Participate in Local Conservation Initiatives of Urban Trees in Benin City, Nigeria. *Arboriculture & Urban Forestry*, 46, 247–261. https://doi.org/10.48044/jauf.2020.018

Basu, N., Oviedo-Trespalacios, O., King, M., Kamruzzaman, M., & Haque, M. M. (2022). The influence of the built environment on pedestrians' perceptions of attractiveness, safety and security. *Transportation Research Part F: Traffic Psychology and Behaviour*, 87, 203–218.

https://doi.org/10.1016/j.trf.2022.03.006
Bazzato, E., Lallai, E., Caria, M., Schifani, E., Cillo, D., Ancona, C., Alamanni, F., Pantini, P., Maccherini, S., Bacaro, G., & Marignani, M. (2022). Land-use intensification reduces multi-taxa diversity patterns of Small Woodlots Outside Forests in a Mediterranean area. *Agriculture, Ecosystems & Environment*, 340, 108149. https://doi.org/10.1016/j.agee.2022.108149
Bazzato, E., Lallai, E., Serra, E., Melis, M. T., & Marignani, M. (2021). Key role of small woodlots outside forest in a Mediterranean fragmented landscape. *Forest Ecology and Management*, 496, 119389. https://doi.org/10.1016/j.foreco.2021.119389
Bhatti, U., Yu, Z., Yuan, L., Wen, L., Nawaz, S. A., & Kaleri, A. (2022). Evaluating The Impact of Roads On The Diversity Pattern And Density of Trees To Improve The Conservation of Species. *Environmental Science and Pollution Research*. 29, 14780–14790. https://doi.org/10.1007/s11356-021-16627-y
Bhebhe, Q. N., Ngidi, M. S. C., Siwela, M., Ojo, T. O., Hlatshwayo, S. I., & Mabhaudhi, T. (2023). The Contribution of Trees and Green Spaces to Household Food Security in eThekwini Metro, KwaZulu-Natal. *Sustainability*, 15(6), 4855. https://doi.org/10.3390/su15064855
Blanco, J., Sourdril, A., Deconchat, M., Barnaud, C., San Cristobal, M., & Andrieu, E. (2020). How farmers feel about trees: Perceptions of ecosystem services and disservices associated with rural forests in southwestern France. *Ecosystem Services*, 42, 101066. https://doi.org/10.1016/j.ecoser.2020.101066
Bourne, K., & Conway, T. (2014). The influence of land use type and municipal context on urban tree species diversity. *Urban Ecosystems*, 17, 329–348. https://doi.org/10.1007/s11252-013-0317-0
Bucheli, P. V. J., & Bokelmann, W. (2017). Agroforestry systems for biodiversity and ecosystem services: The case of the Sibundoy Valley in the Colombian province of Putumayo. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 13(1), 380–397. https://doi.org/10.1080/21513732.2017.1391879
Cameron, G., Culley, T., Kolbe, S., Miller, A., & Matter, S. (2015). Effects of urbanization on herbaceous forest vegetation: The relative impacts of soil, geography, forest composition, human access, and an invasive shrub. *Urban Ecosystems*, 18. 1051–1069. https://doi.org/10.1007/s11252-015-0472-6
Chambers-Ostler, A., Walker, H., & Doick, K. (2023). The role of the private tree in bringing diversity and resilience to the urban forest. *Urban Forestry & Urban Greening*, 9, 127973. https://doi.org/10.1016/j.ufug.2023.127973
Chameno, G. (2020). Management and the influence of socioeconomic factors on tree species diversity in traditional agroforestry practices in Demba Goffa District, South Ethiopia. *Journal of Horticulture and Forestry*, 12, 13–19. https://doi.org/10.5897/JHF2019.0579
Chauhan, S., & Dogra, As. (2016). Trees Outside Forests In India: Socio-Economic, Environmental and Policy Issues – A.S. Dogra & Sanjeev K. Chauhan. *Forestry Technologies – A Complete Value Chain Approach*. 84-100
Chukwumaucheya, A. P. (2012). Trees outside forests and people wellbeing: A case study of fallow and on-farm trees/shrubs in Orlu agricultural zone of Imo state, Nigeria. *Journal of Sustainable Development in Africa*, 14(1), 217-227.
Collins, C. M. T., Cook-Monie, I., & Raum, S. (2019). What do people know? Ecosystem services, public perception and sustainable management of urban park trees in London, U.K. *Urban Forestry & Urban Greening*, 43, 126362. https://doi.org/10.1016/j.ufug.2019.06.005
Connell, J. H. (1978). Diversity in Tropical Rain Forests and Coral Reefs. *Science*, 199(4335), 1302–1310.
Cubino, J. P., & Retana, J. (2023). Socioeconomics explain tree diversity, abundance, and composition in the compact city of Barcelona, Spain. *Landscape and Urban Planning*, 236, 104778. https://doi.org/10.1016/j.landurbplan.2023.104778
Dainese, M., Montecchiari, S., Sitzia, T., Sigura, M., & Marini, L. (2017). High cover of hedgerows in the landscape supports multiple ecosystem services in Mediterranean cereal fields. *Journal of Applied Ecology*, 54(2), 380–388. https://doi.org/10.1111/1365-2664.12747
Danquah, J. A. (2023). Perceptions of landlords to trees in built-up urban areas in Ghana. Arboricultural Journal, 45(3), 238–253. https://doi.org/10.1080/03071375.2022.2129195
Danquah, J. A., Pappinen, A., & Berninger, F. (2023). Determinants of tree planting and retention behaviour of homeowners in built-up urban areas of Ghana. Trees, Forests and People, 13, 100410. https://doi.org/10.1016/j.tfp.2023.100410
Deng, J., Andrada, R., & Pierskalla, C. (2017). Visitors' and residents' perceptions of urban forests for leisure in Washington D.C. *Urban Forestry & Urban Greening*, 28, 1–11.

https://doi.org/10.1016/j.ufug.2017.09.007
Di Cristofaro, M., Sallustio, L., Sitzia, T., Marchetti, M., & Lasserre, B. (2020). Landscape preference for trees outside forests along an urban–rural–natural gradient. *Forests*, 11(7), 728. https://doi.org/10.3390/f11070728
Dilley, J., & Wolf, K. L. (2013). Homeowner Interactions with Residential Trees in Urban Areas. *Arboriculture and Urban Forestry*, 39, 267–277. https://doi.org/10.48044/jauf.2013.034
Divakara, B., Nikhitha, C., Noelke, N., Tewari, V., & Kleinn, C. (2022). Tree Diversity and Tree Community Composition in Northern Part of Megacity Bengaluru, India. *Sustainability*, 14, 1295. https://doi.org/10.3390/su14031295
Dobbs, C., Kendal, D., & Nitschke, C. (2013). The effects of land tenure and land use on the urban forest structure and composition of Melbourne. *Urban Forestry & Urban Greening*, 12(4), 417–425. https://doi.org/10.1016/j.ufug.2013.06.006
Donovan, G. H., & Butry, D. T. (2011). The effect of urban trees on the rental price of single-family homes in Portland, Oregon. *Urban Forestry & Urban Greening*, 10(3), 163–168. https://doi.org/10.1016/j.ufug.2011.05.007
Dorresteijn, I., Schultner, J., French Collier, N., Hylander, K., Senbeta, F., & Fischer, J. (2017). Disaggregating ecosystem services and disservices in the cultural landscapes of southwestern Ethiopia: A study of rural perceptions. *Landscape Ecology*, 32, 2151–2165. https://doi.org/10.1007/s10980-017-0552-5
Drew-Smythe, J. J., Davila, Y. C., McLean, C. M., Hingee, M. C., Murray, M. L., Webb, J. K., Krix, D. W., & Murray, B. R. (2023). Community perceptions of ecosystem services and disservices linked to urban tree plantings. *Urban Forestry & Urban Greening*, 82, 127870. https://doi.org/10.1016/j.ufug.2023.127870
Duguma, L. A., & Hager, H. (2010). Woody Plants Diversity and Possession, and Their Future Prospects in Small-Scale Tree and Shrub Growing in Agricultural Landscapes in Central Highlands of Ethiopia. *Small-Scale Forestry*, 9(2), 153–174. https://doi.org/10.1007/s11842-009-9108-0
Endale, Y., Derero, A., Argaw, M., & Muthuri, C. (2017). Farmland tree species diversity and spatial distribution pattern in semi-arid East Shewa, Ethiopia. *Forests, Trees and Livelihoods*, 26, 199–214. https://doi.org/10.1080/14728028.2016.1266971
Etshekape, P. G., Atangana, A. R., & Khasa, D. P. (2018). Tree planting in urban and peri-urban of Kinshasa: Survey of factors facilitating agroforestry adoption. *Urban Forestry & Urban Greening*, 30, 12–23. https://doi.org/10.1016/j.ufug.2017.12.015
Fahey, R. T., & Casali, M. (2017). Distribution of forest ecosystems over two centuries in a highly urbanized landscape. *Landscape and Urban Planning*, 164, 13–24. https://doi.org/10.1016/j.landurbplan.2017.03.008
Fernandes, C., Martinho da Silva, I., Teixeira, C., & Costa, L. (2018). Between tree lovers and tree haters. Drivers of public perception regarding street trees and its implications on the urban green infrastructure planning. *Urban Forestry & Urban Greening*, 37, 97-108. https://doi.org/10.1016/j.ufug.2018.03.014
Ferreira, V., Barreira, A. P., Loures, L., Antunes, D., & Panagopoulos, T. (2021). Stakeholders' perceptions of appropriate nature-based solutions in the urban context. *Journal of Environmental Management*, 298, 113502. https://doi.org/10.1016/j.jenvman.2021.113502
Gerstenberg, T., & Hofmann, M. (2016). Perception and preference of trees: A psychological contribution to tree species selection in urban areas. *Urban Forestry & Urban Greening*, 15, 103–111. https://doi.org/10.1016/j.ufug.2015.12.004
Gilchrist, K., Brown, C., & Montarzino, A. (2015). Workplace settings and wellbeing: Greenspace use and views contribute to employee wellbeing at peri-urban business sites. *Landscape and Urban Planning*, 138, 32–40. https://doi.org/10.1016/j.landurbplan.2015.02.004
Gillespie, T., Goede, J., Aguilar, L., Jenerette, D., Fricker, G., Avolio, M., Pincetl, S., Johnston, T., Clarke, L., & Pataki, D. (2017). Predicting tree species richness in urban forests. *Urban Ecosystems*, 20, 839–849. https://doi.org/10.1007/s11252-016-0633-2
Graça, M., Queirós, C., Farinha-Marques, P., & Cunha, M. (2018). Street trees as cultural elements in the city: Understanding how perception affects ecosystem services management in Porto, Portugal. *Urban Forestry & Urban Greening*, 30, 194–205. https://doi.org/10.1016/j.ufug.2018.02.001
Gwedla, N., & Shackleton, C. M. (2019). Perceptions and preferences for urban trees across multiple socio-economic contexts in the Eastern Cape, South Africa. *Landscape and Urban Planning*, 189, 225–234. https://doi.org/10.1016/j.landurbplan.2019.05.001
Gwedla, N., Shackleton, C. M., & Olvitt, L. (2022). Trees stocks in domestic gardens and willingness to

participate in tree planting initiatives in low-cost housing areas of the Eastern Cape, South Africa. *Urban Forestry & Urban Greening*, 68, 127484. https://doi.org/10.1016/j.ufug.2022.127484

Hanisah, M. H. N., Hitchmough, J. D., & Muda, A. (2012). The Perception of Kuala Lumpur Publics' on Tree Retention and Urban Development. *Procedia - Social and Behavioral Sciences*, 49, 215–226. https://doi.org/10.1016/j.sbspro.2012.07.020

Helen, null, Jarzebski, M. P., & Gasparatos, A. (2019). Land use change, carbon stocks and tree species diversity in green spaces of a secondary city in Myanmar, Pyin Oo Lwin. *PloS One*, 14(11), e0225331. https://doi.org/10.1371/journal.pone.0225331

Hui, L. C., & Jim, C. Y. (2022). Urban-greenery demands are affected by perceptions of ecosystem services and disservices, and socio-demographic and environmental-cultural factors. *Land Use Policy*, 120, 106254. https://doi.org/10.1016/j.landusepol.2022.106254

Isaifan, R. J., & Baldauf, R. W. (2020). Estimating Economic and Environmental Benefits of Urban Trees in Desert Regions. Frontiers in Ecology and Evolution, 8. 0016 https://www.frontiersin.org/articles/10.3389/fevo.2020.00016

Jara, T., Hylander, K., & Nemomissa, S. (2017). Tree diversity across different tropical agricultural land use types. *Agriculture, Ecosystems & Environment*, 240, 92–100. https://doi.org/10.1016/j.agee.2017.01.042

Jeong, N.-R., Han, S.-W., & Ko, B. (2023). Understanding Urban Residents' Perceptions of Street Trees to Develop Sustainable Maintenance Guidelines in the Seoul Metropolitan Area, Korea. *Forests*, 14, 837. https://doi.org/10.3390/f14040837

Jha, R. K., Nölke, N., Diwakara, B. N., Tewari, V. P., & Kleinn, C. (2019). Differences in tree species diversity along the rural-urban gradient in Bengaluru, India. *Urban Forestry & Urban Greening*, 46, 126464. https://doi.org/10.1016/j.ufug.2019.126464

Jiang, S., Sonti, N., & Avolio, M. (2022). Tree communities in Baltimore differ by land use type, but change little over time. *Ecosphere*, 13(4), e4054. https://doi.org/10.1002/ecs2.4054

Jim, C. Y., Zhang, H., Hui, L. C., & Parker, J. (2021). Agreement levels of London tree officers towards the benefits and costs of urban forests. *Urban Forestry & Urban Greening*, 65, 127356. https://doi.org/10.1016/j.ufug.2021.127356

Jones, R., Davis, K., & Bradford, J. (2013). The Value of Trees Factors Influencing Homeowner Support for Protecting Local Urban Trees. *Environment and Behavior*, 45, 650–676. https://doi.org/10.1177/0013916512439409

Kalema, V. N., & Witkowski, E. T. F. (2012). Land-use impacts on woody plant density and diversity in an African savanna charcoal production region. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 8(3), 231–247. https://doi.org/10.1080/21513732.2012.681070

Karp, D., Rominger, A., Zook, J., Ranganathan, J., Ehrlich, P., & Daily, G. (2012). Intensive agriculture erodes ?-diversity at large scales. *Ecology Letters*, 15, 963–970. https://doi.org/10.1111/j.1461-0248.2012.01815.x

Kendal, D., Williams, N. S. G., & Williams, K. J. H. (2012). Drivers of diversity and tree cover in gardens, parks and streetscapes in an Australian city. *Urban Forestry & Urban Greening*, 11(3), 257–265. https://doi.org/10.1016/j.ufug.2012.03.005

Kičić, M., Haase, D., Marin, A. M., Vuletić, D., & Ostoić, S. K. (2022). Perceptions of cultural ecosystem services of tree-based green infrastructure: A focus group participatory mapping in Zagreb, Croatia. *Urban Forestry & Urban Greening*, 78, 127767. https://doi.org/10.1016/j.ufug.2022.127767

Kirkpatrick, J., Davison, A., & Daniels, G. (2012). Resident attitudes towards trees influence the planting and removal of different types of trees in eastern Australian cities. Landscape and Urban Planning, 107, 147–158. https://doi.org/10.1016/j.landurbplan.2012.05.015

Kloster, D. P., Morzillo, A. T., Butler, B. J., Worthley, T., & Volin, J. C. (2021). Amenities, disamenities, and decision-making in the residential forest: An application of the means-end chain theory to roadside trees. *Urban Forestry & Urban Greening*, 65, 127348. https://doi.org/10.1016/j.ufug.2021.127348

Koyata, H., Iwachido, Y., Inagaki, K., Sato, Y., Tani, M., Ohno, K., Sadohara, S., & Sasaki, T. (2021). Factors determining on-site perception of ecosystem services and disservices from street trees in a densely urbanized area. *Urban Forestry & Urban Greening*, 58, 126898. https://doi.org/10.1016/j.ufug.2020.126898

Lamichhane, D., & Thapa, H. B. (2012). Participatory urban forestry in Nepal: Gaps and ways forward. *Urban Forestry & Urban Greening*, 11(2), 105–111. https://doi.org/10.1016/j.ufug.2011.07.008

Leets, L., Sprenger, A., Hartman, R. O., Jackson, J. H., Britt, M., Gulley, A., Thomas, J. S., & Wijesinghe, S. (2022).

Promoting tree equity in Washington, D.C. Trees, *Forests and People*, 7, 100209. https://doi.org/10.1016/j.tfp.2022.100209
Legesse, A., & Negash, M. (2021). Species diversity, composition, structure and management in agroforestry systems: The case of Kachabira district, Southern Ethiopia. *Heliyon*, 7(3), e06477. https://doi.org/10.1016/j.heliyon.2021.e06477
Li, X., Li, Y., Zhang, S., Lin, R., Chen, M., & Feng, L. (2023). Driving effects of land use and landscape pattern on different spontaneous plant life forms along urban river corridors in a fast-growing city. *Science of The Total Environment*, 876, 162775. https://doi.org/10.1016/j.scitotenv.2023.162775
Lin, J., Wang, Q., & Li, X. (2021). Socioeconomic and spatial inequalities of street tree abundance, species diversity, and size structure in New York City. *Landscape and Urban Planning*, 206, 103992. https://doi.org/10.1016/j.landurbplan.2020.103992
Locke, D., Roman, L., & Murphy-Dunning, C. (2015). Why Opt-in to a Planting Program? Long-term Residents Value Street Tree Aesthetics. *Arboriculture & Urban Forestry*, 41, 324–333. https://doi.org/10.48044/jauf.2015.028
Lockwood, B., & Berland, A. (2019). Socioeconomic Factors Associated with Increasing Street Tree Density and Diversity in Central Indianapolis. *Cities and the Environment (CATE)*, 12(1), Article 6.
Malik, A., Zubair, M., & Manzoor, S. (2021). Valuing the invaluable: Park visitors' perceived importance and willingness to pay for urban park trees in Pakistan. Ecosphere, 12(1), e03348. https://doi.org/10.1002/ecs2.3348
McCoy, D., Goulet-Scott, B., Meng, W., Atahan, B., Kiros, H., Nishino, M., & Kartesz, J. (2022). Species clustering, climate effects, and introduced species in 5 million city trees across 63 US cities. *eLife*, 11, e77891. https://doi.org/10.7554/eLife.77891
Moffat, A. J. (2016). Communicating the benefits of urban trees: A critical review. *Arboricultural Journal*, 38(2), 64-82 2. https://doi.org/10.1080/03071375.2016.1163111
Nawaz, M., Rasheed, F., & Sabir, M. (2022). Opinion of urban dwellers varies to manage the urban spaces for urban forestry: A case study of Faisalabad city*. Pakistan Journal of Agricultural Sciences*, 58(1), 105-113
Ng, W.-Y., Chau, C.-K., Powell, G., & Leung, T.-M. (2015). Preferences for street configuration and street tree planting in urban Hong Kong. Urban *Forestry & Urban Greening*, 14(1), 30–38. https://doi.org/10.1016/j.ufug.2014.11.002
Ngabinzeke, J., Mokuba, H., Mbuangi, J.-P., Baraka Lucungu, P., Bolaluembe, P.-C., Muhongya, J.-M., Mokuba, K., Lucungu, B., & Kahindo, J.-M. (2021). Perceptions of Residents of the Kinkole Neighborhood on the Role of Trees in the Peri-urban Environment of Kinshasa, Democratic Republic of Congo. *Journal of Plant Sciences*, 9, 46–53. https://doi.org/10.11648/j.jps.20210902.13
Nitoslawski, S., & Duinker, P. (2016). Managing Tree Diversity: A Comparison of Suburban Development in Two Canadian Cities. *Forests*, 7(6), 119. https://doi.org/10.3390/f7060119
Nitoslawski, S., Steenberg, J. W., Duinker, P. N., & Bush, P. G. (2017). Assessing the influence of location attributes on urban forest species composition in suburban neighbourhoods. *Urban Forestry & Urban* Greening, 27, 187–195. https://doi.org/10.1016/j.ufug.2017.08.002
Nock, C., Paquette, A., Follett, M., Nowak, D., & Messier, C. (2013). Effects of Urbanization on Tree Species Functional Diversity in Eastern North America. *Ecosystems*, 16, 1–11. https://doi.org/10.1007/s10021-013-9697-5
Olive, A., Rusch, L., & Ayers, A. (2013). Public Perceptions of the Value of Urban Trees in the River Rouge Watershed. Michigan Academician, 41(3), 310–331. https://doi.org/10.7245/0026-2005-41.3.310
Olivero-Lora, S., Meléndez-Ackerman, E., Santiago, L., Santiago-Bartolomei, R., & García-Montiel, D. (2020). Attitudes toward Residential Trees and Awareness of Tree Services and Disservices in a Tropical City. Sustainability, 12(1), 117. https://doi.org/10.3390/su12010117
Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Systematic Reviews*, 10(1), 89. https://doi.org/10.1186/s13643-021-01626-4
Pandey, D., Yadav, Y., Gautam, J., & Pandey, R. (2021). Assessing Biodiversity and Carbon Estimation of Tree Outsides of Forest in Parwanipur Rural Municipality of Central Nepal. *Open Access Journal of Environmental and Soil Sciences*, 6(2), 763-773. https://doi.org/10.32474/OAJESS.2021.06.000231
Pandey, R., & Kumar, H. (2018). Tree species diversity and composition in urban green spaces of Allahabad

city (U.P). *Plant Archives*, 18, 2687–2692.
Paniotova-Maczka, D., Matczak, P., & Jabkowski, P. (2021). Place Attachment and Views on Tree Management. *Frontiers in Psychology*, 12. 639830. https://doi.org/10.3389/fpsyg.2021.639830
Panyadee, P., Sutjaritjai, N., & Inta, A. (2012). The effects of distance from the urban center on plant diversity and composition in homegardens of Shan communities in Thailand. *Thai Journal of Botany*, 4(1), 83-94.
Pati, P., Kaushik, P., Khan, M., & Khare, P. K. (2022). Biodiversity and Ecosystem Services of Trees Outside Forests: A case study from Dr. Harisingh Gour Vishwavidyalaya, Sagar, central India. Indian Journal of Ecology, 49, 298–305.
Pistón, N., Filho, D. S. E. S., & Dias, A. T. C. (2022). Social inequality deeply affects people's perception of ecosystem services and disservices provided by street trees. *Ecosystem Services*, 58, 101480. https://doi.org/10.1016/j.ecoser.2022.101480
Plant, L., Rambaldi, A., & Sipe, N. (2017). Evaluating Revealed Preferences for Street Tree Cover Targets: A Business Case for Collaborative Investment in Leafier Streetscapes in Brisbane, Australia. *Ecological Economics*, 134, 238–249. https://doi.org/10.1016/j.ecolecon.2016.12.026
Puplampu, D. A., & Boafo, Y. A. (2021). Exploring the impacts of urban expansion on green spaces availability and delivery of ecosystem services in the Accra metropolis. *Environmental Challenges*, 5, 100283. https://doi.org/10.1016/j.envc.2021.100283
Rae, R., Simon, G., & Braden, J. (2011). Public Reactions to New Street Tree Planting. *Cities and the Environment (CATE)*, 3(1), 1-20. https://doi.org/10.15365/cate.31102010
Ranta, P., & Viljanen, V. (2011). Vascular plants along an urban-rural gradient in the city of Tampere, Finland. *Urban Ecosystems*, 14(3), 361–376. https://doi.org/10.1007/s11252-011-0164-9
Rašković, S., & Decker, R. (2015). The influence of trees on the perception of urban squares. Urban Forestry & Urban Greening, 14(2), 237–245. https://doi.org/10.1016/j.ufug.2015.02.003
Rija, A., Said, A., Mwamende, K., Hassan, S., & Madoffe, S. (2014). Urban sprawl and species movement may decimate natural plant diversity in an Afro-tropical city. *Biodiversity and Conservation*, 23. 963–978. https://doi.org/10.1007/s10531-014-0646-1
Rossi, J.-P., Garcia, J., Roques, A., & Rousselet, J. (2016). Trees outside forests in agricultural landscapes: Spatial distribution and impact on habitat connectivity for forest organisms. *Landscape Ecology*. 31, 243–254. https://doi.org/10.1007/s10980-015-0239-8
Ruas, R. de B., Costa, L. M. S., & Bered, F. (2022). Urbanization driving changes in plant species and communities – A global view. *Global Ecology and Conservation*, 38, e02243. https://doi.org/10.1016/j.gecco.2022.e02243
Saldarriaga, N., Shrestha, K., McManus, P., & Bajracharya, A. (2020). Greening Sydney: Attitudes, barriers and opportunities for tree planting. *Australian Geographer*, 51 (4), 1–20. https://doi.org/10.1080/00049182.2020.1813948
Salmoiraghi, A., Cruz, P., Gifford, J., & Mickens, J. (2020). Tree species richness and circumference vary between rural, suburban, and urban environments. *Purchase College Journal of Ecology*, Fall, 2-10
Sambou, A., Sambou, B., & Ræbild, A. (2017). Farmers' contributions to the conservation of tree diversity in the Groundnut Basin, Senegal. *Journal of Forestry Research*, 28, 1083–1096. https://doi.org/10.1007/s11676-017-0374-y
Sanaei, A., Ali, A., Yuan, Z., Shufang, L., Lin, F., Fang, S., Ye, J., Hao, Z., Loreau, M., Bai, E., & Wang, X. (2020). Context-dependency of tree species diversity, trait composition and stand structural attributes regulate temperate forest multifunctionality. Science of The Total Environment, 757, 143724. https://doi.org/10.1016/j.scitotenv.2020.143724
Schwoertzig, E., Poulin, N., Hardion, L., & Trémolières, M. (2016). Plant ecological traits highlight the effects of landscape on riparian plant communities along an urban–rural gradient. *Ecological Indicators*, 61, 568–576. https://doi.org/10.1016/j.ecolind.2015.10.008
Sebek, P., Vodka, S., Bogusch, P., Pech, P., Tropek, R., Weiss, M., Zimova, K., & Cizek, L. (2016). Open-grown trees as key habitats for arthropods in temperate woodlands: The diversity, composition, and conservation value of associated communities. *Forest Ecology and Management*, 380, 172–181. https://doi.org/10.1016/j.foreco.2016.08.052
Shams, Z. I., Shahid, M., Nadeem, Z., Naz, S., Raheel, D., Aftab, D., Fraz, T. R., & Roomi, M. S. (2020). Town socio-economic status and road width determine street tree density and diversity in Karachi, Pakistan. *Urban Forestry & Urban Greening*, 47, 126473. https://doi.org/10.1016/j.ufug.2019.126473
Shickman, K., & Rogers, M. (2020). Capturing the true value of trees, cool roofs, and other urban heat island

mitigation strategies for utilities. *Energy Efficiency*, 13(3), 407–418. https://doi.org/10.1007/s12053-019-09789-9
Sibelet, N., Chamayou, L., Newing, H., & Gutiérrez- Montes, I. (2017). Perceptions of Trees Outside Forests in Cattle Pastures: Land Sharing Within the Central Volcanic Talamanca Biological Corridor, Costa Rica. *Human Ecology*, 45, 499–511. https://doi.org/10.1007/s10745-017-9924-3
Sikuzani, Y., Kouagou, R. S., Maréchal, J., Ilunga, E. I. wa, Malaisse, F., Bogaert, J., & Kankumbi, F. M. (2020). Changes in the Spatial Pattern and Ecological Functionalities of Green Spaces in Lubumbashi (the Democratic Republic of Congo) in Relation With the Degree of Urbanization. Tropical Conservation Science, 11(1). 1-17. https://doi.org/10.1177/1940082918771325
Sikuzani, Y., Malaisse, F., Kaleba, S. C., Mwanke, A. K., Yamba, A. M., Khonde, C. N., Bogaert, J., & Kankumbi, F. M. (2019). Tree diversity and structure on green space of urban and peri-urban zones: The case of Lubumbashi City in the Democratic Republic of Congo. *Urban Forestry & Urban Greening*, 41, 67–74. https://doi.org/10.1016/j.ufug.2019.03.008
Sikuzani, Y., Mpibwe Kalenga, A., Yona Mleci, J., N'Tambwe Nghonda, D., Malaisse, F., & Bogaert, J. (2022). Assessment of Street Tree Diversity, Structure and Protection in Planned and Unplanned Neighborhoods of Lubumbashi City (DR Congo). Sustainability, 14(7), 3830. https://doi.org/10.3390/su14073830
Singh, A. K., Singh, H., & Singh, J. S. (2018). Plant diversity in cities. *Current Science*, 115(3), 428–435.
Smith, H. F., & Sullivan, C. A. (2014). Ecosystem services within agricultural landscapes—Farmers' perceptions. *Ecological Economics*, 98, 72–80. https://doi.org/10.1016/j.ecolecon.2013.12.008
Speak, A., & Salbitano, F. (2021). Thermal comfort and perceptions of the ecosystem services and disservices of urban trees in Florence. *Forests*, 12, 1387. https://doi.org/10.3390/f12101387
Speak, A., Usher, M., Solly, H., & Zerbe, S. (2021). Urban forest: Cultural ecosystem services of urban trees through the lens of Instagram. *Journal of Place Management and Development*, 14(4), 497-513. https://doi.org/10.1108/JPMD-08-2020-0079
Su, K., Ordóñez, C., Regier, K., & Conway, T. M. (2022). Values and beliefs about urban forests from diverse urban contexts and populations in the Greater Toronto area. *Urban Forestry & Urban Greening*, 72, 127589. https://doi.org/10.1016/j.ufug.2022.127589
Suchocka, M., Jankowski, P., & Błaszczyk, M. (2019). Perception of Urban Trees by Polish Tree Professionals vs. Nonprofessionals. *Sustainability*, 11, 211. https://doi.org/10.3390/su11010211
Thammanu, S., Marod, D., Han, H., Bhusal, ·, Asanok, L., Ketdee, P., Gaewsingha, N., Lee, S., & Chung, J. (2021). The influence of environmental factors on species composition and distribution in a community forest in Northern Thailand. *Journal of Forestry Research*, 32, 649–662. https://doi.org/10.1007/s11676-020-01239-y
Vakhlamova, T., Rusterholz, H.-P., Kanibolotskaya, Y., & Baur, B. (2014). Changes in plant diversity along an urban–rural gradient in an expanding city in Kazakhstan, Western Siberia. *Landscape and Urban Planning*, 132, 111–120. https://doi.org/10.1016/j.landurbplan.2014.08.014
Wang, H., Huang, Y., Wang, D., & Chen, H. (2020). Effects of urban built-up patches on native plants in subtropical landscapes with ecological thresholds – A case study of Chongqing city. *Ecological Indicators*, 108, 105751. https://doi.org/10.1016/j.ecolind.2019.105751
Wang, M., Li, J., Kuang, S., He, Y., Chen, G., Huang, Y., Song, C., Anderson, P., & Łowicki, D. (2020). Plant diversity along the urban–rural gradient and its relationship with urbanization degree in Shanghai, China. *Forests*, 11(2), 171. https://doi.org/10.3390/f11020171
Wei, H., Zhang, J., Xu, Z., Hui, T., Guo, P., & Sun, Y. (2022). The association between plant diversity and perceived emotions for visitors in urban forests: A pilot study across 49 parks in China. *Urban Forestry & Urban Greening*, 73, 127613. https://doi.org/10.1016/j.ufug.2022.127613
Wolf, K. L., Lam, S. T., McKeen, J. K., Richardson, G. R. A., van den Bosch, M., & Bardekjian, A. C. (2020). Urban Trees and Human Health: A Scoping Review. *International Journal of Environmental Research and Public Health*, 17(12), 4371. https://doi.org/10.3390/ijerph17124371
Xiao, N., Sun, X., Liu, G., & Li, H. (2023). Assessment of Urban Biodiversity: A Case Study of Beijing City, China. In *Floristic Diversity – Biology and Conservation*. G. Shukla, J. A. Bhat, S. Chakravarty, A. W. Almutairi, & M. Li (eds.); p. Ch. 2). IntechOpen. https://doi.org/10.5772/intechopen.106264
Yan, Z., Teng, M., He, W., Liu, A., Li, Y., & Wang, P. (2018). Impervious surface area is a key predictor for urban plant diversity in a city undergone rapid urbanization. *Science of The Total Environment*, 650(1), 335-342. https://doi.org/10.1016/j.scitotenv.2018.09.025
Yang, S., Zhao, W., Pereira, P., & Liu, Y. (2019). Socio-cultural valuation of rural and urban perception on

ecosystem services and human well-being in Yanhe watershed of China. *Journal of Environmental Management*, 251, 109615. https://doi.org/10.1016/j.jenvman.2019.109615

Zhang, J., Yu, Z., Cheng, Y., Chen, C., Wan, Y., Zhao, B., & Vejre, H. (2020). Evaluating the disparities in urban green space provision in communities with diverse built environments: The case of a rapidly urbanizing Chinese city. *Building and Environment*, 183, 107170. https://doi.org/10.1016/j.buildenv.2020.107170