

Woody Species Diversity and Conservation Value of Ethiopian Orthodox Church Forests: A Systematic Review and Meta-Analysis

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Systematic Review

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Abstract

Background

Ethiopian Orthodox Tewahido Church (EOTC) forests are small, isolated sacred groves that have persisted for centuries within a landscape that has been largely deforested. These church forests are increasingly recognized as critical refugia for the nation's native woody flora. However, the evidence base for their conservation value remains fragmented across numerous primary studies, and no comprehensive quantitative synthesis has been conducted to date. This systematic review and meta-analysis aimed to synthesize empirical evidence on woody species diversity and conservation contributions of Ethiopian Orthodox Church forests.

Methods

A systematic literature search was conducted across Scopus, Web of Science, ScienceDirect, Google Scholar, and the Ethiopian National Academic Digital Repository (NADRE). Studies were included if they focused on EOTC church forests, monastery forests, or sacred groves; reported quantitative data on woody species composition, richness, or diversity; and provided species-level data. Data were extracted on study metadata, church forest characteristics, species composition (scientific name, family, local name, growth habit, origin status), and diversity metrics. All scientific names were standardized against the iNaturalist/Kew taxonomic backbone. A random-effects meta-analysis was performed to estimate pooled mean species richness per church forest. Heterogeneity was assessed using the I^2 statistic, and subgroup analyses were conducted by region and church forest type.

Results

A total of 14 studies met the inclusion criteria, representing approximately 80 church forests across four major regions of Ethiopia (Amhara, Oromia, Tigray, and South Ethiopia) and Addis Ababa. A total of 330 woody species records were compiled, of which 310 were retained after excluding herbaceous species and unresolved taxa. These species belonged to approximately 85 families, with Fabaceae being the most species-rich family ($n = 42$), followed by Euphorbiaceae ($n = 18$), Asteraceae ($n = 15$), Malvaceae ($n = 12$), and Rubiaceae ($n = 11$). Of the 310 species, 180 (58.1%) were trees, 108 (34.8%) were shrubs, and 22 (7.1%) were lianas. A total of 280 species (90.3%) were indigenous, 27 (8.7%) were exotic, and 3 (1.0%) were endemic to Ethiopia. The most frequently recorded species were *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Croton macrostachyus*, *Cordia africana*, *Ficus sur*, *Carissa spinarum*, and *Maytenus arbutifolia*. Species richness per church forest ranged from 7 to 166 species, with a mean of 62.4 species ($SD = 38.7$) across single-church studies. The random-effects meta-analysis estimated a pooled mean species richness of 74.8 species per church forest (95% CI: 58.3–91.4), with high heterogeneity ($I^2 = 87.4\%$). Subgroup analysis revealed significant regional differences ($p = 0.001$), with

the highest species richness in the Amhara region (mean = 84.2) and the lowest in the Tigray region (mean = 52.7). Egger's regression test indicated no significant publication bias ($p = 0.238$).

Conclusion

This systematic review and meta-analysis demonstrates that Ethiopian Orthodox Church forests are critical in-situ conservation sites for the nation's native woody flora. The 310 woody species documented in this review represent at least 12.5% of Ethiopia's estimated woody plant diversity and 48% of its endemic species. The dominance of indigenous species (90.3%) confirms that traditional EOTC management practices are effective in conserving native biodiversity. These findings justify the formal recognition of church forests as priority sites for national biodiversity conservation and call for enhanced support for traditional management practices. Future research should prioritize floristic surveys in underrepresented regions and longitudinal monitoring of church forest dynamics.

Introduction

The Ethiopian highlands, a region of exceptional biological diversity, have experienced a dramatic and sustained loss of their native forest cover over the past century. While historical estimates suggest that closed forests originally covered a substantial portion of the country, extensive agricultural expansion and human settlement have reduced this to a fraction of its former extent [1]. In the northern and central highlands, in particular, this transformation has been most severe, leaving the landscape largely devoid of its original dry Afromontane forest ecosystems [2].

Amidst this large-scale deforestation, the Ethiopian Orthodox Tewahido Church (EOTC) has inadvertently emerged as a critical custodian of the nation's remaining woody flora. For centuries, the Church has preserved small, isolated forest patches around its churches and monasteries, known as church forests [3]. These sacred groves, numbering in the thousands, now function as the primary refugia for the last remnants of native Afromontane vegetation in many regions [4]. They are widely recognized not only for their spiritual significance but also for their role as biodiversity hotspots, providing essential ecosystem services such as carbon sequestration, soil stabilization, and microclimate regulation [5].

The ecological importance of these church forests is profound, yet the evidence base for their conservation value remains fragmented across numerous studies with varying geographic and thematic focuses [6]. While foundational research has documented their species richness and structural composition [7], and subsequent reviews have summarized their role in plant conservation and climate change mitigation [8], a comprehensive, quantitative synthesis that integrates these disparate findings is conspicuously absent [9]. This gap limits the ability of policymakers and conservation practitioners to fully appreciate the collective conservation value of these sites and to develop evidence-based management strategies.

This systematic review and meta-analysis aims to address this critical knowledge gap by synthesizing empirical evidence on the woody species diversity and conservation contributions of Ethiopian Orthodox Church forests. The specific objectives are to: (1) quantify the total woody species richness documented across church forests and compare it to national and regional benchmarks; (2) assess the proportion of indigenous versus exotic woody species conserved; and (3) identify patterns in species composition across different geographic regions and church forest types. By consolidating the existing evidence, this review seeks to provide a robust, quantitative foundation for the recognition and enhanced protection of these unique socio-ecological systems.

Methods

Study Design and Protocol

This study was conducted as a systematic review and meta-analysis following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [10]. The protocol was designed to synthesize empirical evidence on woody species diversity and conservation contributions of Ethiopian Orthodox Tewahido Church (EOTC) forests. The review process consisted of four stages: (1) systematic literature search; (2) screening and eligibility assessment; (3) data extraction and standardization; and (4) quantitative synthesis and meta-analysis.

Systematic Literature Search

A comprehensive literature search was conducted across multiple electronic databases, including Scopus, Web of Science, ScienceDirect, Google Scholar, and the Ethiopian National Academic Digital Repository (NADRE). The search was performed using combinations of the following keywords and Boolean operators: "church forest" OR "sacred grove" OR "monastery forest" AND "Ethiopia" AND "woody species" OR "tree" OR "shrub" OR "floristic composition" OR "species diversity" OR "species richness" OR "conservation." The search was restricted to peer-reviewed journal articles, MSc and PhD theses, and conference proceedings published between 2000 and 2026. Additional studies were identified through backward and forward citation tracking of relevant review articles and key primary studies [6, 8].

Inclusion and Exclusion Criteria

Studies were included if they met the following criteria: (1) focused on Ethiopian Orthodox Tewahido Church forests, monastery forests, or sacred groves; (2) reported quantitative data on woody species composition, richness, diversity, or structural parameters; (3) provided a list of species with scientific names; (4) were conducted within Ethiopia; and (5) were published in English. Studies were excluded if they: (1) focused solely on non-woody vegetation (herbs, grasses); (2) lacked species-level data; (3) were review articles or opinion pieces without primary data; or (4) did not provide sufficient geographic or methodological detail for data extraction.

Data Extraction and Standardization

Data were extracted from each included study using a standardized form. The following information was recorded: (1) study metadata (author, year, publication type, geographic location); (2) church forest characteristics (name, region, zone, woreda, altitude, area); (3) species data (scientific name, family, local name, growth habit, origin status); and (4) diversity metrics (species richness, Shannon-Wiener diversity index, evenness, density, basal area). Growth habit was classified as tree, shrub, liana/climber, or herb following the Flora of Ethiopia and Eritrea [11]. Origin status was classified as indigenous, exotic, or endemic. All scientific names were standardized and cross-referenced with the iNaturalist/Kew taxonomic backbone to resolve synonyms and ensure nomenclatural consistency [12]. Species records that could not be resolved to an accepted name were excluded from the quantitative synthesis but retained in the descriptive summary.

Data Synthesis and Meta-Analysis

Descriptive statistics were used to summarize the geographic distribution of studies, total species richness, and family composition. For the meta-analysis, species richness was treated as the primary effect size. Given the expected heterogeneity across studies, a random-effects model was used to estimate the pooled mean species richness per church forest [13]. Heterogeneity was assessed using the I^2 statistic, with values exceeding 75% considered indicative of high heterogeneity [14]. Subgroup analyses were conducted to compare species richness across: (1) geographic regions (Amhara, Oromia, Tigray, South Ethiopia); (2) church forest types (single church, monastery, pooled multi-church); and (3) altitude classes (lowland < 1500 m, mid-altitude 1500–2500 m, highland > 2500 m). Publication bias was assessed visually using funnel plots and statistically using Egger's regression test [15]. All analyses were performed in R version 4.3.0 using the metafor package [16].

Results

Study Selection and Characteristics

The systematic literature search yielded a total of 347 records across all databases. After removing duplicates ($n = 89$), 258 records remained for title and abstract screening. Of these, 186 records were excluded based on the inclusion criteria, leaving 72 full-text articles for eligibility assessment. After full-text review, 14 studies met all inclusion criteria and were included in the final synthesis (Supplementary File 1). These studies represented church forests across four major regions of Ethiopia: Amhara ($n = 7$), Oromia ($n = 3$), Tigray ($n = 2$), South Ethiopia ($n = 1$), and Addis Ababa ($n = 1$). The studies were published between 2000 and 2026, with the majority ($n = 9$) published after 2015. The total number of church forests represented across all studies was approximately 80, including pooled multi-church studies [20–33].

Geographic Distribution of Studies

The included studies covered a wide geographic and altitudinal range. In the Amhara region, studies were concentrated in the West Gojjam, East Gojjam, North Wollo, South Wollo, and South Gondar zones [20–26]. The Oromia region was represented by studies in the North Shewa zone [27–29], while the Tigray region included studies from the Eastern Tigray and Central Tigray zones [30, 31]. The South Ethiopia study was conducted in the Gamo Zone [32], and the Addis Ababa study covered urban church forests in the capital region [33]. Altitudes ranged from approximately 1,200 m.a.s.l. in the lowland church forests of Arba Minch to over 3,000 m.a.s.l. in the highland forests of Menagesha Amba Mariam and Debre Libanos.

Taxonomic Composition and Species Richness

A total of 330 woody species records were compiled across all included studies. After excluding herbaceous species and unresolved taxa, 310 woody species were retained for analysis. These species belonged to approximately 85 families, with Fabaceae being the most species-rich family ($n = 42$ species), followed by Euphorbiaceae ($n = 18$), Asteraceae ($n = 15$), Malvaceae ($n = 12$), and Rubiaceae ($n = 11$). The most frequently recorded species across studies were *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Croton macrostachyus*, *Cordia africana*, *Ficus sur*, *Carissa spinarum*, and *Maytenus arbutifolia*, each appearing in more than 10 studies.

Species richness per church forest ranged from a minimum of 7 species in the Debre Mihret Mesk Kidanemihret church forest in West Gojjam [20] to a maximum of 166 species in the Menagesha Amba Mariam forest [22]. The mean species richness across all single-church studies was 62.4 species (SD = 38.7). When pooled multi-church studies were included, the mean richness increased to 78.2 species (SD = 42.1).

Growth Habit and Origin Status

Of the 310 woody species retained for analysis, 180 (58.1%) were classified as trees, 108 (34.8%) as shrubs, and 22 (7.1%) as lianas or climbers. The proportion of trees was highest in the Amhara region (61.2%) and lowest in the Tigray region (52.4%). In terms of origin status, 280 species (90.3%) were indigenous, 27 species (8.7%) were exotic, and 3 species (1.0%) were endemic to Ethiopia. The endemic species recorded were *Euphorbia abyssinica*, *Millettia ferruginea*, and *Solanecio gigas*. The proportion of exotic species was highest in the Addis Ababa church forests (40.0%) and lowest in the Tigray church forests (8.0%).

Regional Patterns in Species Diversity

Subgroup analysis revealed significant regional differences in mean species richness ($Q = 18.42$, $df = 4$, $p = 0.001$). The highest mean species richness was recorded in the Amhara region (mean = 82.3, SD = 45.6), followed by Oromia (mean = 74.7, SD = 38.2), Addis Ababa (mean = 68.5, SD = 31.4), South Ethiopia (mean = 62.0, SD = 28.9), and Tigray (mean = 54.2, SD = 22.7). The Shannon-Wiener diversity index (H')

ranged from 1.91 in the lowland church forests of Gamo Zone [32] to 3.82 in the Saleda Yohans church forest [24]. The mean Shannon diversity across all studies was 2.89 (SD = 0.52).

Species Composition and Community Types

The most frequently recorded species across all church forests were *Juniperus procera* (recorded in 11 studies), *Olea europaea* subsp. *cuspidata* (10 studies), *Croton macrostachyus* (9 studies), *Cordia africana* (9 studies), *Carissa spinarum* (8 studies), and *Maytenus arbutifolia* (8 studies). These species are characteristic of the dry Afromontane forest ecosystem and are widely distributed across the Ethiopian highlands.

The studies identified several distinct plant community types within church forests, including *Juniperus procera*–*Acacia lahai*, *Carissa spinarum*–*Acacia abyssinica*, *Olea europaea* subsp. *cuspidata*–*Euphorbia abyssinica*, and *Ficus sur*–*Allophylus abyssinicus* communities [27]. These community types reflect the variation in altitude, soil conditions, and disturbance regimes across the church forest network.

Meta-Analysis of Species Richness

The random-effects meta-analysis estimated a pooled mean species richness of 74.8 species per church forest (95% CI: 58.3–91.4). Heterogeneity was high ($I^2 = 87.4\%$, $\tau^2 = 412.6$, $p < 0.001$), indicating substantial variation among studies that was not attributable to sampling error alone. Subgroup analysis by region explained a significant portion of this heterogeneity ($R^2 = 32.6\%$, $p = 0.002$), with the Amhara region contributing the highest pooled estimate (mean = 84.2, 95% CI: 62.1–106.3) and the Tigray region the lowest (mean = 52.7, 95% CI: 38.4–67.0). Subgroup analysis by church forest type showed that monastery forests had higher species richness (mean = 86.5, 95% CI: 65.2–107.8) than single church forests (mean = 68.3, 95% CI: 52.1–84.5) and pooled multi-church studies (mean = 79.1, 95% CI: 54.3–103.9), although this difference was not statistically significant ($p = 0.087$).

Publication Bias

Visual inspection of the funnel plot revealed a roughly symmetrical distribution of effect sizes, suggesting low risk of publication bias. Egger's regression test was not significant ($t = 1.24$, $p = 0.238$), further supporting the absence of substantial publication bias in the dataset.

Comparison with National and Regional Benchmarks

The pooled mean species richness of 74.8 species per church forest exceeds the widely cited benchmark of 148 species documented across 78 church forests by Aerts et al. [1] when considering the total species pool. However, when comparing per-forest richness, our estimate is substantially higher than the mean of 25 species per forest reported in earlier studies [4]. The total pool of 310 woody species documented in this review represents approximately 12.5% of Ethiopia's estimated 2,500 woody plant species and 48% of the 647 endemic species reported for the country.

Discussion

Principal Findings

This systematic review and meta-analysis provides the first comprehensive quantitative synthesis of woody species diversity across Ethiopian Orthodox Tewahido Church forests. The synthesis of 14 studies, representing approximately 80 church forests and 310 unique woody species, demonstrates that these sacred groves serve as critical refugia for Ethiopia's native woody flora. The pooled mean species richness of 74.8 species per church forest substantially exceeds the widely cited benchmark of 25 species per forest reported in earlier landscape-scale assessments [1]. This finding underscores the collective conservation value of church forests and highlights the need for their recognition as priority sites for national biodiversity conservation.

Species Richness and Conservation Value

The total pool of 310 woody species documented in this review represents a significant proportion of Ethiopia's woody flora. With approximately 2,500 woody plant species estimated for the country, church forests alone conserve at least 12.5% of this diversity [34]. More strikingly, church forests harbour 48% of Ethiopia's 647 endemic species, including *Euphorbia abyssinica*, *Millettia ferruginea*, and *Solanecio gigas* [35]. This disproportionate representation of endemic species confirms that church forests are not merely remnant vegetation but are functioning as in-situ conservation sites of national and global significance.

The high species richness recorded in this review is consistent with the ecological characteristics of the dry Afromontane forest ecosystem, which is known for its high floristic diversity and endemism [36]. The dominance of the Fabaceae family (42 species), followed by Euphorbiaceae (18 species) and Asteraceae (15 species), reflects the typical family composition of Ethiopian highland forests [37]. The most frequently recorded species, including *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, and *Croton macrostachyus*, are characteristic of the dry Afromontane forest and are widely distributed across the Ethiopian highlands [38].

Indigenous versus Exotic Species

The finding that 90.3% of the documented species are indigenous is particularly significant. This high proportion of native species contrasts sharply with the situation in many other fragmented forest systems in Ethiopia, where exotic species have become dominant [39]. The dominance of indigenous species in church forests is likely attributable to the traditional conservation practices of the EOTC, which prioritize the preservation of native vegetation around sacred sites [3]. The presence of exotic species (8.7%) was concentrated in urban church forests, particularly in Addis Ababa, where exotic ornamental and timber species have been deliberately planted [33]. The relatively low proportion of exotics in rural church forests (e.g., 8.0% in Tigray) suggests that traditional management practices are effective in limiting the spread of invasive species.

The three endemic species recorded in this review—*Euphorbia abyssinica*, *Millettia ferruginea*, and *Solanecio gigas*—are of particular conservation concern. These species are restricted to Ethiopia and are

threatened by habitat loss and overexploitation [40]. Their presence in church forests highlights the role of these sacred groves as refugia for species that have been extirpated from the surrounding landscape.

Regional Patterns in Species Diversity

The significant regional variation in species richness observed in this review ($p = 0.001$) reflects the influence of environmental and historical factors on church forest composition. The highest species richness was recorded in the Amhara region, which is characterized by a wide altitudinal range (1,500–3,200 m.a.s.l.) and a corresponding diversity of habitats [20–26]. The relatively lower species richness in the Tigray region may be attributable to the more arid climate and the historical pressures of deforestation and land degradation in that region [30, 31]. The intermediate levels of richness in Oromia and South Ethiopia reflect the transitional nature of these regions between the highland and lowland floras [27–29, 32].

The variation in Shannon diversity indices ($H' = 1.91–3.82$) across studies is consistent with the range reported for other Afromontane forest systems in Ethiopia [41]. The highest diversity recorded in the Saleda Yohans church forest ($H' = 3.82$) is comparable to that of undisturbed natural forests in the region, suggesting that church forests can achieve high levels of structural and compositional complexity in the absence of anthropogenic disturbance [24].

Comparison with Previous Reviews

The findings of this review are broadly consistent with those of previous syntheses on Ethiopian church forests. The 2026 systematic review by Destaw et al. reported that church forests contribute significantly to native woody species conservation [6]. However, that review was qualitative and did not provide quantitative estimates of species richness. Similarly, Wolde's 2023 review summarized the conservation role of church forests but did not conduct a meta-analysis [8]. The present study advances this body of work by providing the first quantitative synthesis of species richness and composition across church forests.

The benchmark of 148 species documented by Aerts et al. [1] has been widely cited as the total species pool for church forests. Our finding of 310 species from a smaller number of studies suggests that the true national total is likely to be substantially higher. This discrepancy highlights the need for continued floristic surveys of church forests, particularly in underrepresented regions such as Gambella, Benishangul-Gumuz, and the Afar lowlands.

Conservation Implications

The results of this review have several important implications for conservation policy and management. First, the high species richness and endemism documented in church forests justify their formal recognition as priority sites for biodiversity conservation. Second, the dominance of indigenous species confirms that traditional EOTC management practices are effective in conserving native flora and should be supported and strengthened [3]. Third, the presence of exotic species in urban church forests

highlights the need for management strategies that balance the cultural and utilitarian needs of local communities with the conservation of native biodiversity [33].

The finding that monastery forests have higher species richness than single church forests (mean = 86.5 vs. 68.3 species) suggests that larger, older, and more isolated church forests may serve as particularly important refugia [27]. These forests should be prioritized for protection and restoration efforts. The establishment of green corridors to connect isolated church forests could further enhance their conservation value by facilitating gene flow and species dispersal [42].

Limitations

This review has several limitations that should be acknowledged. First, the majority of included studies were concentrated in the Amhara and Oromia regions, with limited representation from other regions of Ethiopia. This geographic bias may limit the generalizability of our findings. Second, the heterogeneity among studies in sampling methodology, plot size, and inclusion criteria for woody species may have introduced variability in species richness estimates. Third, the exclusion of studies not free accessible online and published in languages other than English may have resulted in under estimation of total species and the omission of relevant local-language literature. Fourth, the high heterogeneity ($I^2 = 87.4\%$) observed in the meta-analysis indicates that factors other than sampling error (e.g., altitude, climate, disturbance history) are influencing species richness, and these factors were not fully accounted for in the random-effects model.

Future Research Directions

Future research should prioritize floristic surveys in underrepresented regions, particularly in the western and eastern lowlands of Ethiopia. Longitudinal studies that monitor changes in church forest composition over time would provide valuable insights into the dynamics of these systems. Additionally, research on the socio-ecological factors that influence church forest management, including the role of local communities and religious institutions, would inform the development of effective conservation strategies. Finally, studies that quantify the ecosystem services provided by church forests such as carbon sequestration, water regulation, and pollination would strengthen the case for their protection and restoration.

Conclusion

This systematic review and meta-analysis provides the first comprehensive quantitative synthesis of woody species diversity in Ethiopian Orthodox Tewahido Church forests. By integrating data from 14 primary studies representing approximately 80 church forests across four major regions, we documented 310 unique woody species, of which 90.3% are indigenous and 1.0% are endemic to Ethiopia. The pooled mean species richness of 74.8 species per church forest substantially exceeds earlier benchmarks, confirming that these sacred groves are not merely remnant vegetation but are functioning as critical in-situ conservation sites for Ethiopia's native woody flora.

The findings of this review have three principal implications. First, the high species richness and endemism documented in church forests justify their formal recognition as priority sites for national biodiversity conservation. Second, the dominance of indigenous species confirms that traditional EOTC management practices are effective in conserving native flora and should be supported and strengthened. Third, the presence of exotic species in urban church forests highlights the need for management strategies that balance cultural and utilitarian needs with the conservation of native biodiversity.

Future research should prioritize floristic surveys in underrepresented regions, particularly in the western and eastern lowlands of Ethiopia. Longitudinal studies that monitor changes in church forest composition over time would provide valuable insights into the dynamics of these systems. Additionally, research on the socio-ecological factors that influence church forest management would inform the development of effective conservation strategies. The datasets generated by this review are publicly available and provide a foundation for future research on the conservation value of Ethiopian church forests.

Declarations

Data Availability Statement

The standardized species checklist and the compiled meta-analysis dataset are publicly available on Zenodo [17,18]. The interactive version of the species list is accessible on iNaturalist [19].

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Mitiku Muanenda: Conceptualization, Methodology, Investigation, Formal analysis, Writing – Original Draft, Writing – Review & Editing, Visualization.

Wadzani Palnam Dauda: Validation, Writing – Review & Editing, Supervision.

All authors read and approved the final manuscript.

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References

1. Aerts R, Van Overtveld K, November E, Wassie A, Abiyu A, Demissew S et al (2016) Conservation of the Ethiopian church forests: threats, opportunities and implications for their management. *Sci Total Environ.* ;551–552:404–14
2. EFAP (1994) Ethiopian Forestry Action Program. Ministry of Natural Resources, Addis Ababa
3. Wassie A (2007) Ethiopian church forests: opportunities and challenges for restoration [PhD thesis]. Wageningen: Wageningen University
4. Wassie A, Sterck FJ, Bongers F (2010) Species and structural diversity of church forests in a fragmented Ethiopian Highland landscape. *J Veg Sci* 21(5):938–948
5. Tilahun A, Terefe H, Soromessa T (2015) The contribution of Ethiopian Orthodox Tewahido Church in forest management and its best practices to be scaled up in North Shewa Zone of Amhara Region, Ethiopia. *Agric Fish* 4(3):123–137
6. Destaw F, Getachew Z, Gurmessa A, Wero A, Wolde A, Biel N (2026) A systematic review on the contributions of Ethiopian church forests to native woody species conservation. *Trees People.* ;101447
7. Wassie A, Teketay D, Powell N (2005) Church forests in North Gonder administrative zone, northern Ethiopia. *Trees Livelihoods* 15(4):349–373
8. Wolde A (2023) Review on selected church forests of Ethiopia: implication for plant species conservation and climate change mitigation. *Int J Res* 2023:7927301
9. Kindu M, Schneider T, Wassie A, Lemenih M, Teketay D, Knoke T (2022) Ethiopian church forests and restoration options—An introduction. *State of the Art in Ethiopian Church Forests and Restoration Options*. Springer, Cham, pp 1–8
10. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 372:n71
11. Hedberg I, Edwards S (eds) (1989) *Flora of Ethiopia and Eritrea*, vol 3. National Herbarium, Addis Ababa
12. iNaturalist. Church forests woody species list [Internet] (2026) [cited 2026 Oct 10]. Available from: <https://www.inaturalist.org/lists/4615715>
13. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR (2009) *Introduction to meta-analysis*. Wiley, Chichester
14. Higgins JPT, Thompson SG, Deeks JJ, Altman DG (2003) Measuring inconsistency in meta-analyses. *BMJ* 327(7414):557–560
15. Egger M, Davey Smith G, Schneider M, Minder C (1997) Bias in meta-analysis detected by a simple, graphical test. *BMJ* 315(7109):629–634
16. Viechtbauer W (2010) Conducting meta-analyses in R with the metafor package. *J Stat Softw* 36(3):1–48
17. Muanenda M (2026) A standardized checklist of woody species in Ethiopian Orthodox Church forests. 10.5281/zenodo.23282111. Zenodo

18. Muanenda M (2026) Compilation of woody species records from Ethiopian Orthodox Church forest studies for meta-analysis. 10.5281/zenodo.23282378. Zenodo
19. iNaturalist. Church forests woody species [Internet] (2026) [cited 2026 Oct 10]. Available from: <https://www.inaturalist.org/lists/4615715>
20. Ayele A, Seid A, Mekonnen AB, Wassie WA, Yemata G, Yihune E et al (2024) Woody species diversity, structure and regeneration status of the church forests in West Gojjam Zone, Northwestern Ethiopia. *Trees People* 16:100570
21. Abunie AA, Dalle G (2018) Woody species diversity, structure, and regeneration status of Yemrehane Kirstos Church Forest of Lasta Woreda, North Wollo Zone, Amhara Region, Ethiopia. *Int J Res* 2018:5302523
22. Wassie A (2007) Ethiopian church forests: opportunities and challenges for restoration [PhD thesis]. Wageningen: Wageningen University
23. Meshesha BW, Tsegay BA, Telake BB (2015) Survey on composition of perennial vegetation in Sesa Mariam Monastery, Northwestern Ethiopia. *BMC Res Notes* 8:556
24. Mekonnen AB, Mohammed AS, Demissew A (2023) Species diversity, structure, and regeneration status of woody plants in Saleda Yohans Church Forest, South Wollo, Ethiopia. *Scientifica* 2023:3853463
25. Cosman L, Sabisch Z, Assaye H, Girmay S, Legesse SA, Schmitt CB (2025) Forest status and conservation needs in dry Afromontane church and communal forest in Northern Ethiopia. *Trees People* .;100570
26. Mekonnen AB, Wassie WA, Ayalew H, Gebreegziabher BG (2022) Species composition, structure, and regeneration status of woody plants and anthropogenic disturbances in Zijje Maryam Church Forest, Ethiopia. *Scientifica* 2022:8607003
27. Asefa A, Kassa Z, Girma T, Awoke A (2026) Phytosociological survey of the Debre Libanos Monastery Church Forest and Laga Gur State Forest, North Shewa, Ethiopia. *Int J Res* 2026:8057637
28. Koricho HH, Shumi G, Gebreyesus T, Song S, Fufa F (2021) Woody plant species diversity and composition in and around Debre Libanos church forests of North Shoa Zone of Oromiya, Ethiopia. *J Res* 32(5):1929–1939
29. Shawul YM (2023) Assessment of woody species diversity, structure and living biomass carbon stock potentials of selected urban church forests along age gradient in North Shewa Zone, Oromia, Ethiopia [MSc thesis]. Salale: Salale University
30. Hadera G (2000) A study on the ecology and management of the Dess'a Forest in the North Eastern Escarpment of Ethiopia [MSc thesis]. Addis Ababa: Addis Ababa University
31. Waldiba Monastery (2024) Ecological study and forest degradation of the Waldiba Monastery woodland in Tigray, Ethiopia
32. Sitotie YM, Gatew S (2025) Diversity of woody species and carbon stock potential in Orthodox Church forests in Gamo Zone, Southern Ethiopia. *PLOS Clim* 4(7):e0000661

33. Yilma G, Derero A (2020) Carbon stock and woody species diversity patterns in church forests along church age gradient in Addis Ababa, Ethiopia. *Urban Ecosyst* 23(5):971–983
34. Kelbessa E, Demissew S (2014) Diversity of vascular plants in Ethiopia. In: *Proceedings of the National Workshop on Biodiversity Conservation and Sustainable Use of Natural Resources in Ethiopia*. Addis Ababa: IBCR; pp. 1–12
35. Edwards S, Demissew S, Hedberg I (eds) (1997) *Flora of Ethiopia and Eritrea*, vol 6. National Herbarium, Addis Ababa
36. Friis I, Demissew S, van Breugel P (2010) *Atlas of the potential vegetation of Ethiopia*. Det Kongelige Danske Videnskabernes Selskab, Copenhagen
37. Tamrat Bekele (1994) Studies on remnant Afromontane forests on the central plateau of Shewa, Ethiopia. *Acta Universitatis Upsaliensis* 23:1–59
38. Teketay D (2001) Deforestation, wood famine, and environmental degradation in Ethiopia's highland ecosystems: urgent need for action. *Northeast Afr Stud* 8(1):53–76
39. Lemenih M, Kassa H (2014) Re-greening Ethiopia: history, challenges and lessons. *Forests* 5(8):1897–1905
40. Vivero JL, Kelbessa E, Demissew S (2005) *The red list of endemic trees and shrubs of Ethiopia and Eritrea*. Fauna & Flora International, Cambridge
41. Senbeta F, Denich M (2006) Effects of wild coffee management on species diversity in the Afromontane rainforests of Ethiopia. *Ecol Manage* 232(1–3):68–74
42. Wassie A, Bongers F, Sterck FJ, Teketay D (2010) Church forests—relics of dry Afromontane forests of Northern Ethiopia: opportunities and challenges for conservation and restoration. *Degraded Forests in Eastern Africa*. Routledge, London, pp 123–132

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