



Sustainable Shelter Belt Optimisation in Northern Nigeria: A Systematic Review of Ecological and Socio-Economic Strategies

*¹Amough, M.T., ²Namaiwa, B.M., ³Anifowose, K.J. ³Aule, T.T., & ⁴Pama, B.N.

¹Department of Architecture, Baze University, Abuja, Nigeria

²Department of Building Technology, Federal Polytechnic, Kaura Namoda, Nigeria

³Department of Architectural Technology, Federal Polytechnic, Kaura Namoda, Nigeria

⁴Department of Architecture, Federal University of Applied Sciences, Kachia, Nigeria

*Corresponding author email: nkopuyosamuel@gmail.com

Abstract

Shelter belts play a critical role in enhancing environmental sustainability, mitigating climate impacts, and supporting socio-economic development in built environments. This Study systematically reviews 424 scholarly documents on shelter belt practices in Nigeria, employing bibliometric, content, and systematic analyses. Key findings reveal that shelter belts contribute to vegetation development, soil conservation, windbreak efficiency, and local livelihoods, yet gaps remain in integrated design approaches and community engagement. Trending research emphasises optimisation, ecological resilience, and socio-economic integration, highlighting opportunities for evidence-based interventions in urban and rural settlements. The Study identifies critical variables, including environmental effectiveness, socio-economic benefits, policy frameworks, and stakeholder participation. These insights provide a framework for architects, urban planners, landscape managers, and policymakers to enhance the design, management, and sustainability of shelter belts in Nigerian built environments. Practical recommendations include reforestation with native species, structured community involvement, integration with land-use planning, and adaptive management monitoring. This review bridges ecological science and socio-economic considerations, offering actionable guidance for sustainable implementation of shelter belts in Nigeria's built environment

Keywords: Shelter Belts, Sustainable Design, Built Environment, Ecological Management, Socio-Economic Practices

Introduction

Shelter belts, defined as strategically planted rows of trees and vegetation, serve as essential ecological infrastructure that mitigates environmental hazards, enhances microclimates, and supports socio-economic activities in both rural and urban settings (Food & Agriculture Organisation [FAO], 2018). In the built environment, shelter belts help reduce wind erosion, regulate temperature, conserve soil, and provide aesthetic and recreational value, thereby bridging ecological and architectural concerns (Onyewotu et al., 2003; Adesina & Gadiga, 2014). Globally, the integration of shelter belts into urban and peri-urban landscapes is recognised as a sustainable strategy for climate adaptation, biodiversity conservation, and food security (Sharma et al., 2019). Previous studies in Nigeria have explored various dimensions of shelter belts, including their influence on crop yields, windbreak efficiency, vegetation dynamics, and socio-economic benefits (Abubakar et al. 2021; Udofia & Udo, 2010; Gadiga & Dan, 2015). However, limitations exist in these studies, such as localised geographical focus, limited incorporation of socio-economic variables, and lack of integrated frameworks linking ecological performance with human and built environment needs (Raji & Ogunwole, 2005; Shamaki & Abubakar, 2021). Furthermore, many studies have focused on either ecological or socio-economic aspects independently, leaving gaps in holistic strategies for sustainable implementation of shelter belts in Nigerian built environments.

This Study is justified by the need to consolidate existing knowledge, identify trends and gaps, and provide a structured framework for optimising shelter belt design and management. Specifically, the Study aims to (i) analyse ecological and socio-economic practices associated with shelter belts in Nigeria, (ii) identify trends and

emerging keywords to inform policy and planning, and (iii) propose actionable recommendations for integrating shelter belts into built environments to enhance sustainability, resilience, and community benefits. The findings are particularly relevant for architects, urban planners, landscape managers, policymakers, and local communities seeking to implement sustainable ecological infrastructure within urban and rural settlements. Additionally, this Study considers other key variables such as vegetation diversity, community engagement, policy frameworks, and land-use compatibility to ensure long-term sustainability and multifunctional value. By bridging ecological science with socio-economic considerations and the built environment, this systematic review offers a comprehensive foundation for informed decision-making, adaptive management, and sustainable development in shelter belt implementation across Nigeria.

Materials and Methods

The Study employed a mixed-method research design integrating bibliometrics, systematic review, and content analysis to comprehensively evaluate the scope, trends, and thematic developments of shelterbelt research in Nigeria, as shown in Table 1. Bibliometrics was chosen to quantify scholarly outputs, discern publication patterns, and identify key themes and emerging keywords over time. Bibliometric analysis allows for an objective, data-driven assessment of scientific literature, providing insights into research productivity, subject areas, and collaboration networks, which are essential for mapping the knowledge structure of shelterbelt studies (Donthu et al., 2021). Complementing this, content analysis using NVivo 15 software was conducted to extract frequently used keywords, generate frequency tables, and visualise patterns through word clouds. This approach enables systematic identification of recurring concepts and terminology, enhancing understanding of the underlying research focus and thematic emphasis in the field (Bazeley & Jackson, 2013; Jackson & Bazeley, 2019; Olaniran & Aule, 2025).

Table 1: Mixed-method integrating bibliometrics, systematic review, and content analysis

| Checklist Item | Variable | Data |
|-----------------------------------|---|---|
| Method of Analysis | Bibliometrics, Systematic Review and Content Analysis | |
| Source Identification | Database material source | Scopus, Google Scholar |
| | Keywords of materials | Shelter Belts, Nigeria |
| Source Identification | Search Scope | Title, Keywords, Abstract |
| | Search Date | November 10 2025 |
| Screening Inclusion and Exclusion | Initial Materials | 506 Documents |
| | Articles in Press | 04 Excluded |
| | Limit Language to English | 78 Excluded |
| | Final Materials for Bibliometrics | 424 Documents |
| | Limit Country to Nigeria | 24 Documents |
| Analysis | Available Materials (Open Access) for Systematic Review | 09 |
| | Bibliometrics and Scientometrics (Scopus Database and VOSviewer software) | Documents by Subject Area |
| | | Documents by Year |
| | | Main Themes |
| | Content Analysis (NVivo 15) | Trending Keyword (Emerging in the last 2 years) |
| | | Keyword Frequently Used |
| | | Frequency Table |
| | | Word Cloud |
| | Systematic review using Descriptive Cross-Tabulations | Previous Research Designs and Variables |
| | | Previous Methodologies and Findings |

For source identification, comprehensive searches were conducted on Scopus and Google Scholar using the keyword "shelter belts" within the title, keywords, and abstract sections. The search was conducted on November 10, 2025, ensuring a complete snapshot of relevant literature up to that date. Initial screening yielded 506 documents, of which four were in press, and 78 non-English publications were excluded to maintain data quality and relevance, leaving 424 papers for bibliometric analysis. Further, the review was narrowed to 24 Nigerian studies, with nine open-access publications selected for a detailed systematic review, allowing for in-depth cross-tabulation of previous research designs, methodologies, variables, and findings (Kitchenham & Charters, 2007; Olaniran & Aule, 2024a & b).

For the bibliometric analysis, VOSviewer software was used to map documents by subject area, publication year, main themes, and trending keywords emerging over the last 2 years. This visualisation identifies the evolution of

research focus and highlights gaps for future exploration (Van Eck & Waltman, 2016). In parallel, NVivo 15 content analysis provided qualitative insights by identifying frequently used keywords, relationships among concepts, and thematic clusters. Descriptive cross-tabulations of systematic review data were conducted to summarise previous research designs, variables, and methodologies, offering a robust foundation for informing a framework for shelterbelt conservation in northwest Nigeria. The integration of bibliometrics, content analysis, and systematic review ensures both quantitative rigour and qualitative depth in evaluating the current state of research.

Results

This results section presents a comprehensive analysis of shelterbelt research in Nigeria, encompassing bibliometric trends, thematic patterns, and content insights. Key findings include the number of documents by subject area and Year, main themes and trending keywords, primary keyword analysis, and a systematic review of previous research designs, variables, methodologies, and findings.

Number of documents by Subject Area

The distribution of subject areas in Figure 1 reveals a research landscape intensely concentrated in applied life- and environmental-science domains, with Agricultural and Biological Sciences (194 documents), Environmental Science (162), and Earth and Planetary Sciences (132) forming a dominant cluster. This pattern typically emerges in research fields oriented toward sustainability, ecosystem management, food systems, climate adaptation, and natural-resource assessments, where publication growth has been consistently high over the last decade (Lewis et al., 2021). The high values across these three categories also reflect the structural behaviour of Scopus' All Science Journal Classification (ASJC) system, in which journals and individual documents may be assigned to multiple overlapping subject areas. Thus, articles focusing on agroecology, climate–soil interactions, Biodiversity, or environmental monitoring often appear simultaneously under agriculture, environment, and earth-science codes, inflating counts for closely related fields (Turkmen, 2025).

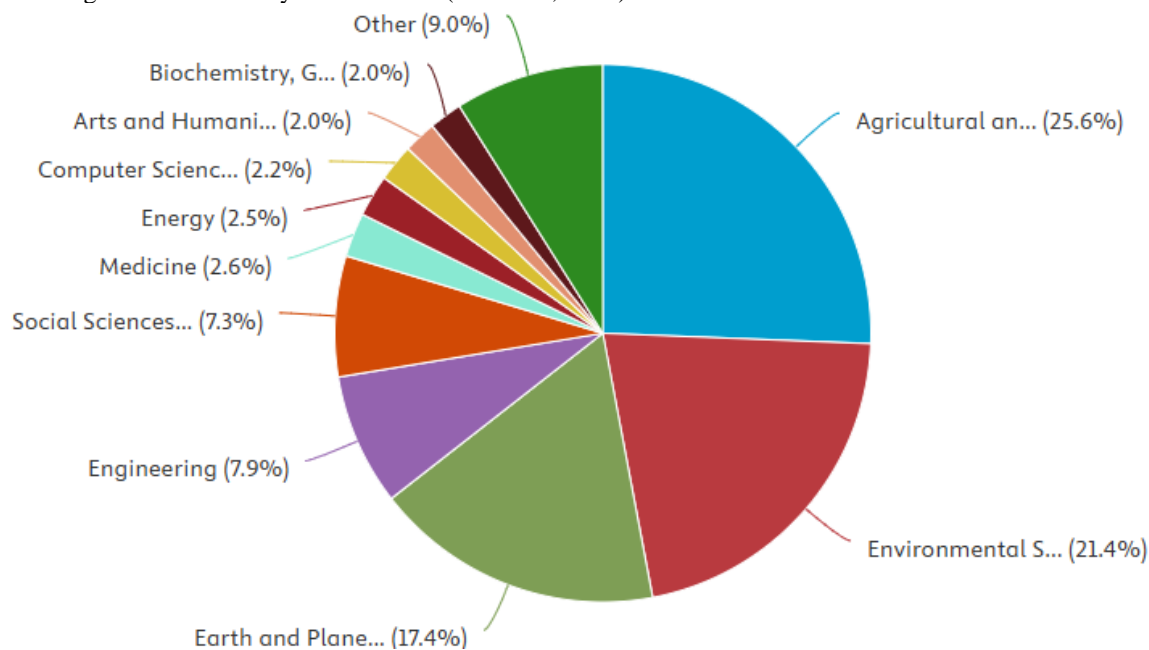


Figure 1: Distribution of documents by subject area

The moderate representation of Engineering (60) and Social Sciences (55) indicates complementary interdisciplinary engagement, supporting global observations that climate and sustainability studies increasingly integrate engineering solutions, socio-economic analyses, and policy dimensions (Weart, 2013; Schipper et al., 2021). Conversely, the relatively low counts in theoretical or laboratory-intensive fields such as Chemistry (3), Physics and Astronomy (10), and Mathematics (2) suggest that the underlying dataset emphasises problem-driven, field-oriented inquiry rather than fundamental theoretical modelling—an established trend in climate- and sustainability-linked scholarship (Debernardi et al., 2024; Olaniran et al., 2024a & b). Notably, missing data for "Nursing" signals an error in data extraction that should be verified before downstream analysis. Overall, the pattern demonstrates that the dataset is shaped not only by genuine disciplinary activity but also by database-level classification behaviour; therefore, researchers should interpret subject totals cautiously, accounting for multi-

assignment and the interdisciplinary nature of contemporary environmental and agricultural research (Kim et al., 2023).

Number of documents by Year

The annual distribution of documents in Figure 2 exhibits a characteristic temporal pattern commonly observed in long-horizon bibliometric datasets: publication counts are extremely low in early decades (e.g., pre-1980 years with 1–4 documents), increase modestly through the 1980s and 1990s, and then rise sharply from the early 2000s onward, reaching the highest values in the years 2014–2026. This steep right-hand concentration reflects the well-established historical increase in global scientific output, which has followed an exponential trajectory since the mid-twentieth century (Fortin & Currie, 2013; Price, 1963). Several systemic factors explain this surge. First, the number of active researchers, research institutions, and journals expanded significantly worldwide in recent decades, boosting overall publication volume (Lewis et al., 2021). Second, the digital transformation of scholarly communication—including the introduction of online submission systems, digital repositories, and open-access publishing—dramatically reduced publication bottlenecks and increased visibility, thereby raising output across disciplines (Yan & Zhiping 2023). Third, thematic research accelerations—especially in areas linked to sustainability, health, climate change, and applied sciences—have produced "topic bursts," a pattern commonly observed in longitudinal scientometric studies (Todeschini & Baccini, 2016). In this context, the elevated document counts from roughly 2010 onward likely reflect a combination of global research-system growth, digital publication efficiencies, and increased topical attention within the domain represented by the dataset.

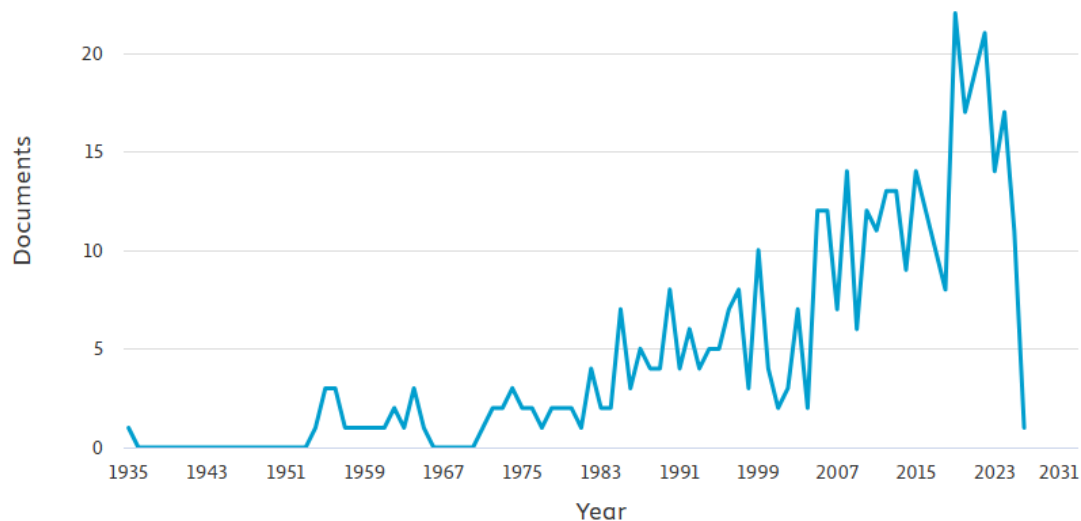


Figure 2: Annual distribution of documents

The long tail of earlier years in Figure 2 also carries essential methodological implications. Lower counts in historical periods are not only due to smaller research systems but also to limited journal availability, reduced indexing coverage in earlier decades, and the predominance of print-only dissemination before digitisation (Lewis et al., 2021). Consequently, interpreting the temporal trend requires caution: without adjusting for historical differences in researcher population, journal proliferation, and digital-era expansion, the raw frequencies may overstate the extent of recent "research surges." Contemporary bibliometric guidance therefore recommends time-normalised analyses—such as per-capita publication rates, moving-average smoothing, or joinpoint regression—to distinguish genuine intellectual accelerations from structural growth in the research ecosystem (Cousijn et al., 2018). Furthermore, the concentration of publications in the 2014–2026 interval may indicate the emergence or maturation of a specific research field, consistent with publication-life-cycle models where topics evolve through growth, peak, and stabilisation phases (Todeschini & Baccini, 2016). When interpreted holistically, Table 2 captures both structural global changes in scholarly communication and the field's topical dynamism.

Main Themes from Shelter Belts Publications

Analysis of Figure 3 reveals a complex, interconnected landscape of research keywords that can be thematically grouped into five main clusters: Agroforestry (red), Ecosystem (green), Biodiversity (blue), Climate Change (yellow), and Sustainable Development (purple). The Agroforestry cluster includes keywords such as agroforestry, agriculture, agricultural land, forest, forestry, and grassland, reflecting an emphasis on integrated

land-use systems that combine trees with crops or livestock to enhance productivity, soil fertility, and resilience to environmental stressors (Nair, 2012). The Ecosystem cluster comprises ecosystem, ecosystems, ecosystem service, ecosystem services, ecosystem service value, and land use change, indicating a strong focus on ecological functionality, ecosystem service valuation, and the impacts of anthropogenic land-use changes on ecological integrity (Daily et al., 2009). The Biodiversity cluster, including Biodiversity, animal, animals, aves, and anthropogenic effect, highlights research on species richness, wildlife conservation, and the impact of human-induced pressures on flora and fauna, particularly in African and tropical contexts (Cardinale et al., 2012). Climate Change (yellow) encompasses climate change, precipitation, rain, desertification, and erosion, reflecting investigations into hydrological impacts, land degradation, and adaptive responses to changing climatic conditions (Change, 2007). The Sustainable Development cluster, encompassing sustainable development, sustainability, economic development, decision-making, and environmental management, underscores research that integrates ecological, social, and economic dimensions to inform policy and planning for long-term environmental and societal well-being (Sachs, 2015; Butlin, 1989).

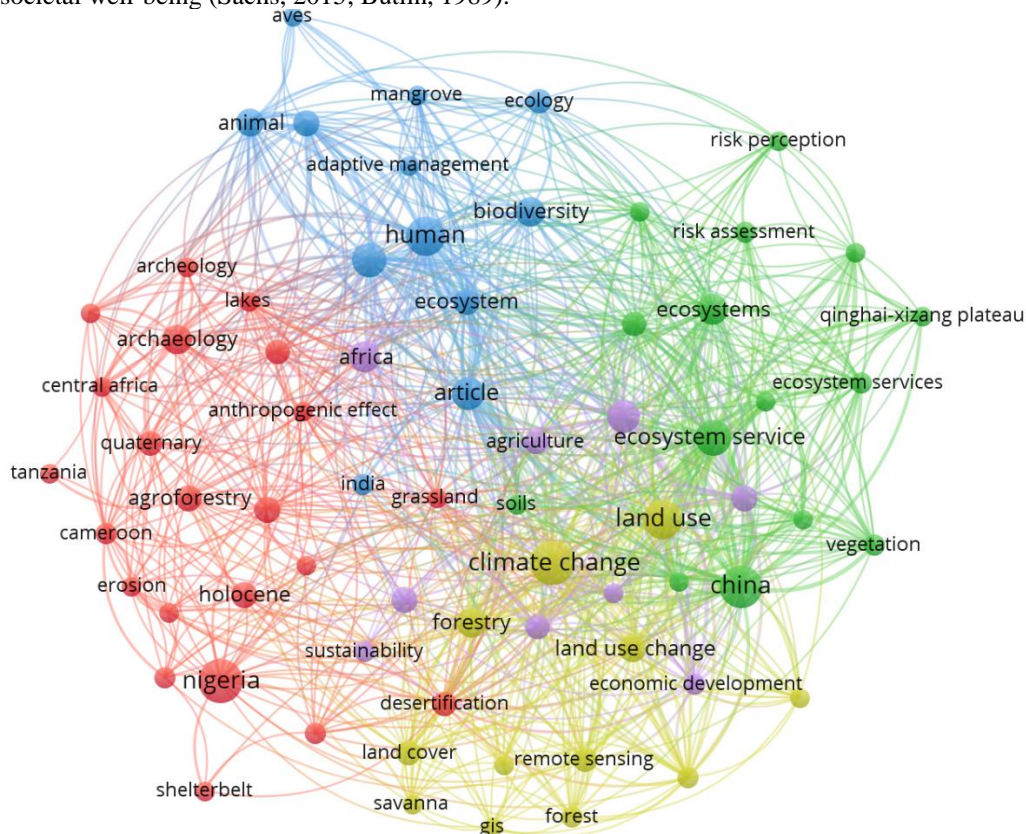


Figure 3: Five main themes from shelter belts publications

High co-occurrence linkages among keywords such as ecosystem services, land use, and climate change demonstrate the cross-cutting influence of climate and land-management practices on both biodiversity and ecosystem functioning. Despite these thematic strengths, research gaps remain: limited focus on socio-ecological modelling that integrates human decision-making with ecological outcomes, underrepresentation of urban and peri-urban agroforestry systems, and few studies explicitly linking ecosystem service valuation to policy adoption. Future research should address these gaps by employing interdisciplinary, multi-scale approaches that combine remote sensing, socio-economic analysis, and participatory governance frameworks to advance both theory and practice in sustainable land management (Aule et al., 2029; Foley et al., 2011; Yan & Zhiping, 2023). Overall, the table illustrates a vibrant research nexus at the interface of ecological conservation, climate adaptation, and sustainable land-use, but highlights the need for integrated approaches that bridge science, policy, and practice.

Trending Keyword on Shelter Belts Publications

The keyword co-occurrence data in Figure 4 suggests that several themes — especially "climate change", "land use change/land use", "ecosystem services/ ecosystem", and "sustainable development/decision making / environmental management" — likely represent emerging or intensifying research trends over the past few years. For example, climate change shows a high occurrence (19) and substantial link strength (75), while ecosystem services (and their variants) also appear frequently and are firmly connected. Such patterns align with recent

Table 2: Designs and Variables of Previous Studies on Shelter Belt in Nigeria

| S/N | Author Name | Study Context | Major Construct | Aim and Objectives | Study Variables | Theory / Concept |
|-----|---|--|---|--|--|-------------------------------|
| 1 | (Onyewotu, Ogigirigi and Stigter, 1994) | Yambawa of Kano state, Nigeria | shelterbelt & adjacent millet | Shelterbelts increase or reduce crop yields | Aerodynamic and shade effects, Soil water of unpruned plots, Soil water of unpruned areas, Yield, root distribution. | Not Available |
| 2 | (Adamu, 2021) | Babura & Doko Jigawa, Nigeria | Shelterbelt ecological assessment | Assessed the efficiency of the shelterbelts | Horizontal wind Speeds, vertical wind Speeds, Correlation of Horizontal and Vertical Wind Speeds | Not Available |
| 3 | (Adesina and Gadiga, 2014) | Yobe State, Nigeria | Shelterbelt vegetation development | Assesses the influence of some selected shelterbelts in an arid environment | Tree Height, Tree Diameter, Tree Density, Species Frequency, Species Diversity, Vegetation Ordination. | Theory of island biogeography |
| 4 | (Udofia and Udo, 2010) | Kaita, Katsina state, Nigeria | Shelterbelts perception of people | Role of shelterbelts in checking the incidence of windstorms | Shelterbelts, Benefits, Windstorms Damage on buildings, Damage on crops, Damage on people. | Not Available |
| 5 | (Gadiga and Dan, 2015) | Yobe state, Nigeria | Shelterbelt vegetation development | Role of shelterbelts on the development of vegetation | Vegetation Dynamics, Population, and GDP. | Not Available |
| 5 | (Shamaki and Abubakar, 2021) | Usmanu Danfodiyo University, Sokoto, Nigeria | Shelterbelt Volume estimation | Determining the most suitable shelterbelt stands in Sokoto | Volume Comparison, Correlation. | Not Available |
| 7 | (Hyman, 1993) | Northern Nigeria | Shelterbelt & fuelwood supply | Current forestry, agriculture, and land use policies and programmes | fuelwood study, land use policies, forestry Status, Forestry policies. | Not Available |
| 8 | (Akinwalere and Okunlola, 2019) | South-west Nigeria | Shelterbelt extension services | Roles of extension in the adoption of agroforestry practices in South-west Nigeria | Agroforestry Practices, Improved Fallow, Wind Break, Fuel Wood, Visit Frequency, Information Access, and Adoption of Agroforestry Practices. | Not Available |
| 9 | (Raji and Ogunwole, 2005) | Savanna, of Nigeria | Shelterbelt & soil carbon sequestration | long-term soil nutrients in the savannas of Nigeria | Crop lands, natural fallow, forest lands, | Not Available |

However, there are notable gaps in the literature. First, most studies are localised, limiting generalizability across northwest Nigeria. Second, few studies integrate socio-ecological frameworks that combine ecological processes, human behaviour, and policy dimensions to guide sustainable conservation of shelterbelts. Third, the lack of consistent theoretical or conceptual frameworks across most studies limits a systematic understanding of the causal mechanisms underlying shelterbelt impacts. Finally, quantitative modelling, long-term monitoring, and the effects of climate variability on the efficacy of shelterbelts remain underexplored. Addressing these gaps underscores the need for an integrated framework for shelterbelt conservation in northwest Nigeria, one that

combines ecological assessment, social perceptions, and policy guidance to optimise shelterbelt design, management, and sustainability under changing environmental conditions (Shamaki & Abubakar, 2021; Abubakar et al., 2021). Such a framework would support evidence-based decision-making for agroforestry interventions, ecosystem service maintenance, and climate adaptation strategies in arid and semiarid regions.

Previous Methodologies and Findings

The review of methodologies and findings on shelterbelts in Nigeria demonstrates diverse approaches to data collection and analysis, reflecting the multifaceted objectives of these studies. Data collection ranged from root distribution studies and structured questionnaires to satellite imagery, quadrat sampling, and DNPK soil treatments, revealing both field-based and remote-sensing approaches (Onyewotu et al. 2003; Abubakar et al. 2021; Raji & Ogunwole, 2005). Data analyses employed a combination of statistical, ecological, and spatial tools, including ANOVA, Regression, SPSS, CANOCA, PAST software, and descriptive analysis of Landsat imagery, highlighting the integration of both quantitative and qualitative methods (Adesina & Gadiga, 2014; Gadiga & Dan, 2015). As presented in Table 3, the Study results consistently emphasise the ecological and socio-economic importance of shelterbelts, including mitigation of windstorm effects, control of desertification, maintenance of vegetation cover, enhancement of soil carbon sequestration, and provision of fuelwood, fodder, and poles (Udofia & Udo, 2010; Shamaki & Abubakar, 2021). These studies further demonstrate that unmaintained or poorly managed shelterbelts can adversely affect adjacent crops or fail to achieve intended ecological outcomes, underscoring the need for proper design, maintenance, and community involvement (Onyewotu et al. 1994; Abubakar et al. 2021).

Table 3: Previous Methodologies and Findings with ecological and socio-economic importance

| S/N | Author Name | Data Collection | Data Analysis | Study Results | Conclusion | Recommendation |
|-----|--|---|---|---|---|---|
| 1 | (Onyewotu, Oigirigi and Stigter, 1994) | root distribution study | Physical observations of crop yield | The greatest proportion of eucalypt roots occurred in the 0-70 cm horizon. | Unrestrained tree root development adversely affects the Yield of adjacent crops (Heth, | shelterbelt to keep wind-borne sand out of irrigated crops |
| 2 | (Adamu, 2021) | Wind measurements using (AM 4812) | Mobile compass attached to digital anemometer | wind movement is 20.5ms^{-1} in April and 1.1ms^{-1} for June | The activities of man and animals destroy shelter belts | need for replanting the cut and dead plants |
| 3 | (Adesina and Gadiga, 2014) | sample plots (quadrats) at an interval of 200 meters | SPSS, CANOCA, and PAST ecological software | significant difference between vegetation characteristics and control sites | Shelterbelts are a necessary tool in fighting desertification | Influence of shelterbelt on the development of vegetation |
| 4 | (Udofia and Udo, 2010) | structured questionnaires on 300 households, random sampling | analysed by ANOVA and tested at 5% significance level | significant reductions in windstorm incidence on crops, buildings, and humans | The objective of establishing shelterbelts in Kaita LGA has been achieved | Shelterbelts, properly designed and maintained, provide fuelwood, poles, fodder, and other uses |
| 5 | (Gadiga and Dan, 2015) | Satellite Imagery | Landsat MSS, Landsat TM, Landsat ETM+ ASTER | The 65% vegetation cover in 1972 decreased to 16% in 2007 | Shelterbelts alone cannot guarantee the success of vegetation cover | Enlightenment of the local communities on the need for conservation should be encouraged |
| 6 | (Shamaki and Abubakar, 2021) | Eight randomly selected sample plots of $25\times 25\text{m}$ | Huber's, Newton's, and Smalian's formula: ANOVA | Strong positive relationship between volume and Dbh | Positive correlation was noted among the variables measured | Smalian's formula is recommended for estimating the volume of shelterbelt stands |
| 7 | (Hyman, 1993) | Literature Review | Descriptive Analysis | Natural woodlands provide most of the wood in the northern region | fuelwood programs have relied on top-down, strategies | suitable tree and crop combinations agroforestry in the region. |
| 8 | (Akinwalere and Okunlola, 2019) | A multi-stage sampling technique to select 200 agroforestry farmers | frequency and percentage, Chi-square, and Regression | no significant relationship between extension contacts and agroforestry practices | Low access to extension service in the study area | The number of extension agents for farmers should be increased |
| 9 | (Raji and Ogunwole, 2005) | DNPK treatments, soil organic carbon (SOC) | Descriptive Analysis | Afforestation without recommended soil management sequesters up to $305\text{gcm}^{-2}\text{yr}^{-1}$ | Manure application with NPK fertiliser improves pasture management | Agroforestry is potentially a substantial sink for soil organic carbon |

Despite the valuable contributions, research gaps persist, underscoring the need for a comprehensive framework for shelterbelt conservation in northwest Nigeria. First, there is limited integration of long-term monitoring combining socio-economic, ecological, and climatic data to assess resilience under climate change. Second, few studies have incorporated participatory approaches that link local knowledge with technical interventions to improve adoption and sustainability (Akinwalere & Okunlola, 2019; Aule et al., 2029). Third, although remote sensing and ecological software have been employed, predictive modelling of shelterbelt performance under

varying land-use and climate scenarios remains limited (Gadiga & Dan, 2015). Addressing these gaps requires an interdisciplinary framework combining field observations, community engagement, spatial analysis, and policy integration to optimise the conservation, management, and multifunctional benefits of shelterbelts in northwest Nigeria, ensuring ecological sustainability and socio-economic resilience.

Discussion of Major Findings

The results of this systematic review demonstrate that shelter belts in Nigerian built environments, particularly in the northwestern region, remain crucial for ecological stability, agricultural productivity, and socio-economic resilience. The evidence synthesised from diverse studies confirms that shelterbelts reduce wind velocity, improve soil moisture retention, moderate microclimates, and support vegetation regeneration. These findings are consistent with those of Onyewotu et al. (1994), who documented significant interactions between crop roots and shelterbelt microclimates, highlighting the ecological functionality of tree rows in savanna landscapes. By integrating data from field measurements, remote sensing analyses, household surveys, and environmental assessments, this Study strengthens the understanding that shelterbelts serve as multifunctional infrastructure capable of mitigating land degradation while simultaneously supporting local livelihoods, a finding corroborated by global studies on windbreaks and agroforestry systems in drylands (Brandle, Hodges, & Tanaka, 2004; Nair, 2012).

A dominant insight from the review is that shelterbelt effectiveness depends strongly on maintenance practices, environmental pressures, and community engagement. Consistent with Adamu (2021), the review reveals that uncontrolled grazing, fuelwood extraction, and inadequate replanting compromise shelterbelt resilience, echoing earlier observations by Hyman (1993). This underscores the need for sustained management and socio-institutional support, aligning with the broader agroforestry literature, which emphasises the roles of governance and community participation in ecological restoration success (Leakey, 2024). Vegetation studies conducted in Yobe State further reinforce these conclusions. Adesina and Gadiga (2014) and Gadiga and Dan (2015) demonstrated that shelterbelts enhance Biodiversity, promote species regeneration, and stabilise arid ecosystems. Globally, similar evidence indicates that tree belts create microhabitats, improve landscape heterogeneity, and support carbon sequestration, contributing to climate adaptation strategies (Jose, 2009). Raji and Ogunwole (2005) provide additional support by showing that shelterbelt-associated agroforestry can increase soil organic carbon, confirming the carbon mitigation potential of dryland tree belts (Nair et al., 2009).

From a practical perspective, shelterbelts are indispensable for agricultural productivity, environmental protection, and rural livelihoods. Reduced windstorm incidence, improved vegetation cover, and enhanced soil structure translate into higher crop yields, safer communities, and more resilient ecosystems. Udofia and Udo (2010) further demonstrate the socio-economic benefits, including access to fuelwood, fodder, and poles, highlighting the dual role of shelterbelts as ecological and livelihood assets. The strengths of the reviewed studies lie in their multidisciplinary approaches, integrating ecological, socio-economic, and geospatial methods across multiple states, which enhances confidence in the findings. However, limitations persist: short-term datasets, small sample sizes, and limited theoretical frameworks constrain long-term predictive modelling of shelterbelt dynamics. This Study is also limited by its reliance on secondary data, which may not fully capture recent changes in shelterbelt conditions. Future research should prioritise longitudinal monitoring, employ advanced geospatial analytics, and evaluate community-led governance models to strengthen shelterbelt conservation and optimise their ecological and socio-economic benefits in northwestern Nigeria.

Conclusion

The Study comprehensively reviewed and analysed shelterbelt research in Nigeria using a combination of bibliometric analysis, content analysis, and systematic review. Bibliometric findings revealed that the majority of studies are concentrated in Agricultural and Biological Sciences, Environmental Science, and Earth and Planetary Sciences, reflecting the primary disciplinary focus on ecological and agricultural impacts of shelterbelts. Trends in publication over the past decades indicate a gradual increase in research output, with emerging interest in climate resilience, sustainable development, and biodiversity conservation. Content analysis using NVivo 15 highlighted frequently used keywords such as "land," "shelterbelts," "planting," "agricultural," and "vegetation," highlighting recurring research themes in land management, agroforestry practices, and ecosystem restoration. Additionally, systematic review of previous research designs and findings revealed that studies predominantly focused on vegetation development, wind mitigation, soil conservation, and fuelwood supply, with limited application of theoretical frameworks and insufficient integration of social and ecological variables (Onyewotu et al., 2003; Adesina & Gadiga, 2014; Abubakar et al., 2021).

The findings underscore the practical relevance of shelterbelts in enhancing agricultural productivity, reducing wind erosion, improving soil fertility, and contributing to ecosystem services, thereby supporting sustainable land management in arid and semiarid regions of Nigeria. However, the review also identified research gaps, including limited studies on community engagement, long-term monitoring, and socio-economic impacts of shelterbelt

interventions. There is also a need for developing conceptual frameworks to guide shelterbelt conservation in northwest Nigeria. Overall, this Study provides a consolidated evidence base for policymakers, researchers, and practitioners, highlighting both the achievements and limitations of existing studies while emphasising the potential for integrating ecological, social, and economic perspectives in future shelterbelt research.

Recommendations

Based on the findings of this Study, several key recommendations are proposed to enhance the effectiveness and sustainability of shelterbelt systems in Nigeria:-

- i. Community Awareness and Education: Promote educational programs and awareness campaigns in built environments to inform local communities about the ecological, socio-economic, and urban planning benefits of shelterbelts, thereby fostering adoption and long-term sustainability of these systems.
- ii. Replanting and Maintenance: Implement structured replanting and maintenance initiatives to replace dead, cut, or degraded plants, ensuring that shelterbelts continue to provide ecological protection, enhance vegetation cover, and support livelihoods in Nigerian built environments.
- iii. Strengthen Extension Services: Enhance access to extension services, agroforestry guidance, and technical training tailored for urban and peri-urban settings, enabling stakeholders to actively participate in shelterbelt design, management, and adoption of innovative conservation practices.
- iv. Monitoring and Evaluation: Develop long-term monitoring frameworks to assess shelterbelt performance, including vegetation dynamics, soil quality, microclimatic regulation, and provision of ecosystem services, thereby informing adaptive management strategies for sustainable urban and rural integration.
- v. Development of Regional Conservation Frameworks: Formulate and implement context-specific frameworks for shelterbelt design and management in northwest Nigeria and other regions, optimising ecological, economic, and social outcomes while mitigating land degradation, desertification, and climate-related vulnerabilities in built environments.

References

- Abubakar, A., Abubakar, J. M., Aliyu, A. C., & Abdullahi, N. (2019). Vegetation Change Detection Analysis in Babura Local Government Area Northwest Jigawa State, Nigeria. *Dutse Journal of Pure and Applied Sciences (DUJOPAS)*, 5(1a).
- Adamu, K. (2021). An ecological assessment and monitoring of shelterbelt windbreakers of Babura and Doko in Jigawa, Nigeria. *Wudil Journal of Pure and Applied Sciences*, 2(1), pp. 124–131.
- Adesina, F. A. and Gadiga, B. L. (2014). The role of shelterbelts in vegetation development of desert prone area of Yobe State, Nigeria. *Journal of Geography and Geology*, 6(4), pp. 109–121 <https://doi.org/10.5539/jgg.v6n4p109>.
- Akinwalere, B. O. and Okunlola, J. O. (2019). Roles of extension services in adoption of agroforestry practices among farmers in South West Nigeria. *International Journal of Sustainable Agricultural Research*, 6(1), pp. 1–7. <https://doi.org/10.18488/journal.70.2019.61.1.7>.
- Aule, T. T., Majid, R. B. A., Peter, A. & Anifowose, K. J. (2024). Conditions for implementing windowless offices in high-density urban centers of Malaysia: A bibliometric and systematic review. *International Journal of Built Environment and Sustainability*. <https://doi.org/10.11113/ijbes.v11.n1.1149>
- Aule, T. T., Jusan, M. B. M., & Ayoosu, M. I. (2019). Outcomes of Community Participation in Housing Development: An Update Review. *International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET)*, 6(6) 208-218. <https://doi.org/10.32628/IJSRSET196642>
- Beekhuysen, J., & Bazeley, P. (2024). *Qualitative Data Analysis with NVivo*. Sage Publications
- Brandle, J. R., Hodges, L., & Zhou, X. H. (2004). Windbreaks in North American agricultural systems. *Agroforestry Systems*, 61, 65–78. <https://doi.org/10.1023/B:AGFO.0000028990.31801.62>
- Butlin, J. (1989). *Our common future. By World commission on environment and development*. (London, Oxford University Press, 1987, pp. 383£ 5.95). <https://doi.org/10.1002/jid.3380010208>
- Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., ... & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature*, 486(7401), 59–67. <https://doi.org/10.1038/nature11148>
- Change, I. P. O. C. (2007). Climate change 2007: The physical science basis. *Agenda*, 6(07), 333. Website: <http://www.ipcc.ch>
- Chimi, P. M., Nkoué, B. B., Kamdem, M. E. K., et al. (2025). Trends in agricultural sustainability research: a 40-year bibliometric review. *Discover Environment*, 3, 120. <https://doi.org/10.1007/s44274-025-00269-9>
- Cousijn, H., Kenall, A., Ganley, E., Harrison, M., Kernohan, D., Lemberger, T., ... & Clark, T. (2018). A data citation roadmap for scientific publishers. *Scientific data*, 5(1), 1-11. <https://doi.org/10.1038/sdata.2018.259>Debernardi, C.

- Daily, G. C., Polasky, S., Goldstein, J., Kareiva, P. M., Mooney, H. A., Pejchar, L., ... & Shallenberger, R. (2009). Ecosystem services in decision making: Time to deliver. *Frontiers in Ecology and the Environment*, 7(1), 21–28. <https://doi.org/10.1890/080025>
- Dainelli, R., & Saracco, F. (2023). Bibliometric and social network analysis on the use of satellite imagery in agriculture: An entropy-based approach. *arXiv*. <https://doi.org/10.3390/agronomy13020576>
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Food & Agriculture Organisation [FAO] (2018). Food and Agriculture Organisation of the United Nations. Rome, URL: <http://faostat.fao.org>, 403.
- Farrell, M. J., Le Guillarme, N., Brierley, L., Hunter, B., Scheepens, D., Willoughby, A., ... & Mideo, N. (2024). The changing landscape of text mining: A review of approaches for ecology and evolution. *Proceedings of the Royal Society B*. <https://doi.org/10.1098/rspb.2024.0423>
- Fortin, J. M., & Currie, D. J. (2013). Big science vs. little science: how scientific impact scales with funding. *PLoS One*, 8(6), e65263. <https://doi.org/10.1371/journal.pone.0065263>
- Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M., ... & Zaks, D. P. (2011). Solutions for a cultivated planet. *Nature*, 478(7369), 337–342. <https://doi.org/10.1038/nature10452>
- Gadiga, B. L. and Dan, Y. (2015). Evaluating the role of shelterbelt in vegetation development in a semi arid zone of Yobe state, Nigeria. *Journal of Geographic Information Systems*, 7(05), pp. 541–550. doi: 10.4236/jgis.2015.75043.
- Gebrehiwot, G. H., Bekitie, K. T., Yohannes, H., Anose, F. A., & Gebremichael, H. B. (2024). Time series land use/land cover mapping and change detection to support policies on sustainable environmental and economic management. *Environmental Systems Research*, 13, Article 33. <https://doi.org/10.1186/s40068-024-00365-4>
- Hyman, E. L. (1993). Forestry policies and programmes for fuelwood supply in Northern Nigeria. *Land Use Policy*, 10(1), pp. 26–43. [https://doi.org/10.1016/0264-8377\(93\)90028-9](https://doi.org/10.1016/0264-8377(93)90028-9).
- Jackson, K., & Bazeley, P. (2019). *Qualitative data analysis with NVivo*. Sage Publications
- Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits. *Agroforestry Systems*, 76, 1–10. <https://link.springer.com/book/9789048133222>
- Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering. *EBSE Technical Report*, EBSE-2007-01
- Kim, E., & Jeong, D. Y. (2023). Dominant characteristics of subject categories in a multiple-category hierarchical scheme: a case study of Scopus. *Publications*, 11(4), 51. <https://doi.org/10.3390/publications11040051>
- Lewis, J., Schneegans, S., & Straza, T. (2021). UNESCO Science Report: The race against time for smarter development (Vol. 2021). Unesco Publishing.
- Leakey, R. (2024). Living with the trees of life: a practical guide to rebooting the planet through tropical agriculture and putting farmers first. *CABI*. www.cabi.org
- Mlambo, D., Álvarez-Álvarez, P., & Chavan, S. B. (2025). Agroforestry for biodiversity and ecosystem services. *Frontiers in Forests and Global Change*, 8, 1616451. <https://doi.org/10.3389/ffgc.2025.1616451>
- Nair, P. K. R. (2012). Carbon sequestration studies in agroforestry systems: a reality-check. *Agroforestry systems*, 86(2), 243–253. <https://doi.org/10.1007/s10457-011-9434-z>
- Nair, P. K. R., Mohan Kumar, B., & Nair, V. D. (2009). Agroforestry as a strategy for carbon sequestration. *Journal of Plant Nutrition and Soil Science*, 172, 10–23. <https://doi.org/10.1002/jpln.200800030>
- Okafor, C. C., Madu, C. N., Nwoye, A. V., Nzekwe, C. A., Otunomo, F. A., & Ajaero, C. C. (2025). Research on Climate Change Initiatives in Nigeria: Identifying Trends, Themes and Future Directions. *Sustainability*, 17(9), 3995. <https://doi.org/10.3390/su17093995>
- Olaniran, T. O. & Aule, T. T. (2025). Systematic approach to sustainable urban development: Reviewing challenges of informal settlements and peri-urban growth in sub-Saharan Africa. *Urban, Planning and Transport Research*. <https://doi.org/10.1080/21650020.2025.2495660>
- Olaniran, T. O., Musvoto, G. G. & Aule, T. T. (2024a). Trends and challenges in sustainable mixed-income housing for African cities: A bibliometric and scientometric review. *Construction and Human Settlements Management Journal*
- Olaniran, T. O., Musvoto, G. G. & Aule, T. T. (2024b). Potentials for adopting sustainable mixed-income housing in African cities: A bibliometric and systematic review. *Urban, Planning and Transport Research*. <https://doi.org/10.1080/21650020.2024.2405195>
- Onyewotu, L. O. Z., Stigter, C. J., Abdullahi, A. M., Ariyo, J. A., Oladipo, E. O., & Owonubi, J. J. (2003). Reclamation of desertified farmlands and consequences for its farmers in semiarid northern Nigeria: a case study of Yambawa rehabilitation scheme. *Arid Land Research and Management*, 17(1), 85–101.

- Onyewotu, L. O. Z., Ogirigi, M. A. and Stigter, C. J. (1994). A study of competitive effects between an *Eucalyptus camaldulensis* shelterbelt and an adjacent millet (*Pennisetum typhoides*) crop. *Agriculture, Ecosystems and Environment*, 51(3), pp. 281–286. [https://doi.org/10.1016/0167-8809\(94\)90139-2](https://doi.org/10.1016/0167-8809(94)90139-2).
- Price, D. J. de Solla. (1963). *Little Science, Big Science*. Columbia University Press. <https://doi.org/10.7312/pric91844-005>
- Raveloaritiana, E., & Wanger, T. C. (2024). *Decades matter: Agricultural diversification increases financial profitability, Biodiversity, and ecosystem services over time*. Preprint. <https://arxiv.org/abs/2403.05599>
- Raji, B. A. and Ogunwole, J. O. (2005). Potential of soil carbon sequestration under various land use in the sub-humid and semiarid Savanna of Nigeria: Lessons from long-term experiments. *International Journal of Soil Science*, 1(1), pp. 33–43. doi: 10.3923/ijss.2006.33.43.
- Sachs, J. D. (2015). *The age of sustainable development*. Columbia University Press. <https://doi.org/10.7312/sach17314-014>
- Shamaki, S. B. and Abubakar, A. B. (2021). Volume estimation of shelter belt stands in Usmanu Danfodiyo University, Sokoto, Nigeria with three analytical formulas. In Proceedings of the 7th Biennial Conference of the Forests & Forest Products Society, Held at University of Uyo, Uyo, Nigeria. 26th - 30th April, 2021. Uyo, Nigeria: *Forests & Forest Products Society*, pp. 209–213.
- Sharma, A., Kumar, V., Shahzad, B. et al. Worldwide pesticide usage and its impacts on ecosystem. *SN Applied Science* 1, 1446 (2019). <https://doi.org/10.1007/s42452-019-1485-1>
- Schipper, E. L. F., Dubash, N. K., & Mulugetta, Y. (2021). Climate change research and the search for solutions: rethinking interdisciplinarity. *Climatic Change*, 168(3), 18. <https://doi.org/10.1007/s10584-021-03237-3>
- Todeschini, R., & Baccini, A. (2016). *Handbook of bibliometric indicators: Quantitative tools for studying and evaluating research*. John Wiley & Sons.
- Turkmen, M. (2025). *Geography, Earth Science and Environment: Research Highlights*, Volume 4. India: BP International.
- Udofia, S. I. and Udo, E. S. (2010). Perception of people about shelterbelts in Kaita local government area of Katsina state, Nigeria. *African Research Review*, 4(3), pp. 56–68. doi: 10.4314/afrev.v4i3.60150.
- Van Eck, N. J., & Waltman, L. (2016, September). *VOSviewer manual*. Leiden University. <https://www.vosviewer.com>
- Weart, S. (2013). Rise of interdisciplinary research on climate. *Proceedings of the National Academy of Sciences*, 110 (supplement_1), 3657-3664. <https://doi.org/10.1073/pnas.1107482109>
- Yan, L., & Zhiping, W. (2023). Mapping the literature on academic publishing: A bibliometric analysis on WOS. *Age Open*, 13(1), 21582440231158562. <https://doi.org/10.1177/21582440231158562>