

Building a Greener Future: How Earth Blocks Are Reshaping Sustainability and Circular Economy in Construction

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Abstract: Sustainability has become an important focus in the construction industry due to growing environmental concerns, resource depletion, and the urgency to reduce greenhouse gas emissions. The construction sector contributes significantly to the world's carbon emissions and energy consumption, making it a prime candidate for sustainable transformation. In response to these challenges, there has been a shift towards utilizing earth-based products, especially earth blocks, as sustainable alternatives. Compressed stabilized earth blocks (CSEBs) are garnering increased attention because of their ability to lower environmental impact. These blocks are made from locally sourced materials, reducing the transportation-related emissions and energy use. Their production processes typically require far less energy than traditional building blocks, which results in reduced carbon footprints. Earth blocks also contribute to sustainability through their thermal performance, which can enhance energy efficiency in buildings by naturally regulating indoor temperatures. As a result, less artificial heating and cooling is required, leading to further energy savings. Furthermore, CSEBs and other earth blocks can incorporate waste materials promoting a circular economy and resource efficiency. This paper explores the multifaceted role of earth blocks in sustainable construction by conducting a comprehensive systematic and bibliometric analysis. By evaluating research trends, the evolution of the field, and the broader impact of these materials, this study aims to provide a deeper understanding of the contributions of earth blocks to sustainability. Key areas of focus include identifying prominent research themes, emerging technologies, and future opportunities for incorporating earth blocks into mainstream construction practices. This approach aligns with the vision of advancing sustainable architecture and green buildings to minimize environmental pollution and resource consumption while supporting the transition to a circular economy in the built environment.

Keywords: sustainability; compressed stabilized earth blocks (CSEB); circular economy; sustainable architecture; green buildings; built environment



Academic Editor: Antonio Formisano

Received: 24 February 2025

Revised: 24 March 2025

Accepted: 28 March 2025

Published: 31 March 2025

Citation: Sinha, S.; Sudarsan, J.S. Building a Greener Future: How Earth Blocks Are Reshaping Sustainability and Circular Economy in Construction. *Architecture* **2025**, *5*, 25. <https://doi.org/10.3390/architecture5020025>

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1. Introduction

The construction industry (CI) is a major contributor to worldwide environmental deterioration, accounting for substantial carbon emissions, energy consumption, and loss of natural resources [1]. The Global Status Report for Buildings and Construction indicates that the industry is responsible for around 39% of global carbon dioxide emissions and 36% of global energy consumption [2]. The escalating environmental effect highlights the pressing necessity to transition to more sustainable construction methods. Sustainable development, as articulated by the Brundtland Commission, is “development that satisfies

the needs of the present without jeopardizing the capacity of future generations to fulfill their own needs” [3]. Sustainable building aims to minimize environmental effects by enhancing energy efficiency, utilizing resources responsibly, and decreasing waste [4].

A promising approach to achieving sustainability in CI is the use of alternative building materials that are both energy-efficient and environmentally friendly [5,6]. Earth blocks, particularly compressed stabilized earth blocks (CSEBs), are gaining widespread attention as such alternatives [5,6]. Earth blocks are made from natural materials such as soil, sand, and stabilizers like lime or cement [7]. CSEBs have a rich history in traditional construction, especially in rural and low-cost housing, and are currently being reassessed for contemporary sustainable architecture [8]. Earth blocks, especially CSEBs, have emerged as versatile building materials due to their strength, durability, and low carbon footprint [9]. They offer sustainability benefits in construction by using locally sourced materials, reducing environmental costs, and consuming less energy than conventional materials [10]. They also provide excellent thermal insulation, which reduces the energy consumption in buildings and contributes to a circular economy (CE) by incorporating waste materials [11].

1.1. Earth Blocks in Sustainable Construction

Earth blocks are gaining increasing recognition in the CI as a sustainable alternative to conventional building blocks. These blocks, particularly CSEBs, offer a range of benefits that contribute to the sustainability of the built environment [9]. Earth blocks are construction materials produced by compressing a mixture of soil, water, and stabilizers into block form utilizing either manual or mechanical presses. These blocks have been utilized in conventional construction for millennia and are currently witnessing a revival as part of the shift towards sustainable building techniques worldwide. The primary types of earth blocks are presented in Figure 1.

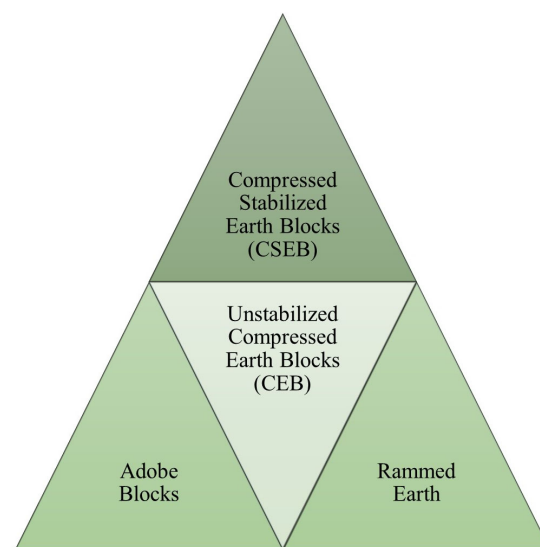


Figure 1. Types of earth blocks.

CSEBs are one of the most advanced and accepted forms of earth blocks. They are an eco-friendly and energy-efficient alternative to traditional building blocks and are produced by compacting soil with stabilizers like cement or lime [12]. The soil is pressed into blocks using either a manual or mechanical press, creating uniform and strong blocks with minimal energy input [13]. CSEBs do not require burning, unlike the traditional fired bricks, which reduces CO₂ emissions and energy consumption [14]. The use of local materials further reduces the expense of transportation and environmental impact. CSEBs are known for their ability to lessen the effects of building on the environment [15].

Another type of earth block is adobe blocks. They are made from a mixture of clay, sand, water, and often organic materials such as straw [16]. Unlike CSEBs, adobe blocks are sun-dried rather than mechanically compressed. While adobe blocks are more traditional and still widely used in regions with dry climates, their durability is lower compared to that of CSEBs, especially in wetter conditions [17]. Some researchers have also studied unstabilized compressed earth blocks. These blocks are similar to CSEBs but do not include any stabilizing agents like cement. While they are more environmentally friendly due to the absence of additives, they may be less durable and weather-resistant, limiting their use in certain climates [9]. One of the oldest techniques of earth construction is the rammed earth technique. Though not typically used to shape blocks, rammed earth involves compressing moist soil into large wall forms [18]. Like earth blocks, it uses local materials and low energy, making it a sustainable construction method [19]. Earth blocks vary in their advantages and challenges, depending on local resources, climatic conditions, and specific building requirements.

1.2. Sustainability Benefits

Earth blocks have several advantages in terms of environmental, economic, and social sustainability [20]. These benefits make them a significant asset for minimizing the environmental impact of construction activities while fostering sustainable building practices. The production of earth blocks, especially CSEBs, is significantly less energy-intensive than the production of conventional materials such as fired bricks or concrete [14]. Traditional brick production involves firing kilns at high temperatures, which requires large amounts of fuel and releases a significant amount of carbon dioxide [21,22]. In contrast, CSEB production uses a mechanical press to compact the soil, with little or no need for additional energy inputs such as firing [23]. This results in a dramatically lower energy footprint and makes CSEBs a more sustainable alternative [14]. In addition to energy efficiency, earth blocks also help reduce CO₂ emissions [24]. The use of cement or lime as a stabilizer in CSEBs is minimal compared to the amount used in any conventional concrete construction [12,25]. Since cement production is a significant source of CO₂ emissions worldwide, the reduced use of stabilizers in CSEBs has a direct positive impact on lowering emissions [12].

Using locally available soil as the primary raw material is one of earth blocks' most significant sustainability benefits [16]. This helps lessen the effects on the environment of transporting building materials over long distances by minimizing fuel consumption and the emissions associated with it [14]. In rural and semi-urban areas, soil for earth blocks can be sourced directly from the construction site or nearby areas, reducing the need for external resources. Additionally, by incorporating waste materials, earth blocks can be part of a CE model that promotes resource efficiency and waste reduction [26,27]. They provide excellent thermal insulation, assisting in the overall energy efficiency of buildings [28,29]. The ability of these blocks to store and release heat gradually due to their high thermal mass contributes to a more consistent indoor temperature. Buildings made of earth blocks use less energy as a result of the decreased requirement for artificial heating in the winter and cooling in the summer. Studies have shown that buildings made from CSEBs can achieve significant energy savings in comparison to those made from conventional materials [30].

Earth blocks are a sustainable alternative to conventional building blocks as they are biodegradable and can easily be recycled at the end of their life cycle [31]. Unused or broken blocks can be crushed and reused to produce new blocks, ensuring minimal waste generation. This recyclability conforms to the principles of sustainable management of resources and contributes to a reduction in construction waste [32]. Earth block construction methods tend to have a minimal environmental impact. They do not require extensive

industrial processing, and the equipment used (such as mechanical presses for CSEBs) is energy-efficient [23]. In contrast, the extraction, transportation, and production of conventional materials such as cement, steel, and concrete often cause significant environmental degradation through resource depletion, energy consumption, and pollution [33]. The use of earth blocks can also contribute to local economic development [34]. Since the materials and production techniques are simple and locally accessible, they can generate employment opportunities in rural and underdeveloped areas [14]. Earth block construction can also be incorporated into low-cost housing initiatives, providing affordable and sustainable housing options for low-income populations [35].

1.3. Earth Blocks and the Circular Economy (CE)

The principles of a CE revolve around maximizing resource efficiency, minimizing waste, and closing material loops by reusing and recycling materials [36]. Earth blocks incorporating recycled materials like industrial or agricultural waste align with these principles (Figure 2). The ability to reuse earth blocks at the end of their life cycle and to integrate waste into their production allows them to significantly contribute to the adoption of a CE in construction [32].

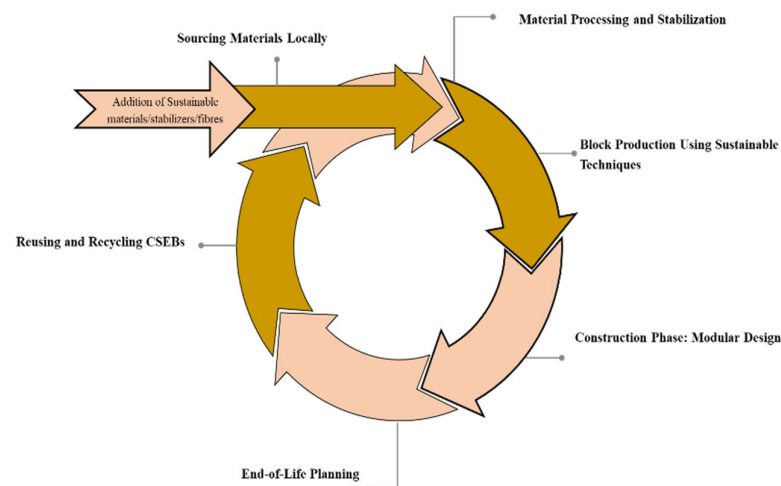


Figure 2. Earth blocks and the circular economy.

Earth blocks promote local material sourcing and thus reduce transportation needs by supporting local economies and reducing the carbon footprint of construction activities [34]. Local resource utilization and earth block recyclability enhance their importance in sustainable and circular building practices [37]. CSEBs provide a promising alternative for sustainable construction with significant environmental and economic benefits. Their function in enhancing resource efficiency, diminishing carbon emissions, and facilitating the CE renders them an increasingly vital material in the transition to more sustainable construction techniques.

Even though earth blocks have numerous sustainability advantages, they face obstacles in their widespread implementation. These factors include the accessibility and quality of the local soil, the durability of blocks in different climates, and a lack of awareness or regulatory backing in some areas [38]. On top of that, the mechanical apparatus necessary for the production of CSEBs may not be easily accessible or economically viable in certain developing regions [39]. Overcoming these issues necessitates more study, research, technology progress, and policy interventions.

This research paper aims to investigate the role of earth blocks (CSEBs) in achieving sustainability in the CI. This study involves a systematic and bibliometric analysis to

evaluate the trends, evolution, and impact of research on CSEBs with an emphasis on the aspect of their sustainability. By examining the existing body of literature, this study identifies key areas of research, emerging themes, and future directions for integrating earth blocks into modern construction practices. The findings from the paper aim to present a thorough summary of how earth blocks can support the transition to more sustainable and resource-efficient building practices while also highlighting the challenges and opportunities for their widespread acceptance in the CI.

2. Materials and Methods

This study utilizes PRISMA systematic review and bibliometric analysis to evaluate the progression of academic works on earth blocks, specifically concerning sustainability. This section delineates the methodology of this bibliometric study, elucidates publishing patterns, and highlights the most prominent research, authors, and themes within the discipline.

Methodology of Bibliometric Analysis

The systematic and bibliometric analysis for this research was conducted using data from the Scopus database. The subsequent stages were executed to ensure a thorough analysis.

The literature search was conducted using the Scopus database with the following query: (TITLE-ABS-KEY (compressed AND stabilised OR stabilized) AND TITLE-ABS-KEY (sustainability OR sustainable) AND TITLE-ABS-KEY (earth OR soil AND blocks OR bricks)) AND PUBYEAR > 2000 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")). This search strategy ensured a comprehensive selection of articles focusing on the role of CSEBs in sustainability. The dataset was further refined by applying inclusion and exclusion criteria—only peer-reviewed journal articles were considered. At the same time, conference papers, non-English publications, and studies unrelated to construction and sustainability were excluded. A manual screening process was conducted to eliminate irrelevant studies, particularly those focused solely on geotechnical properties without sustainability considerations. The final dataset was analyzed using VOSviewer, version 1.6.20, facilitating network mapping and co-occurrence analysis of key research trends. These refinements ensure the robustness and replicability of our bibliometric approach, addressing the concerns raised. A systematic search, illustrated in Figure 3, was conducted to identify research articles.

Using the selected keywords, academic papers published from 2000 to 2024 were gathered from the Scopus database (See Figure 3). This time period was chosen to reflect both early research and the more recent resurgence of interest in sustainable materials in construction. Bibliometric tools such as VOSviewer, version 1.6.20, and R's bibliometrix package, version 4.3.0, were used to process the data. These tools facilitated the generation of citation networks, co-authorship maps, and keyword co-occurrence networks. They also helped in identifying high-impact publications and key research clusters in the field. Key metrics used in the analysis included the total number of publications, keyword analysis, and the geographical distribution of research. These metrics provide insight into the research impact, collaboration patterns, and geographic focus of studies on earth blocks and sustainability.

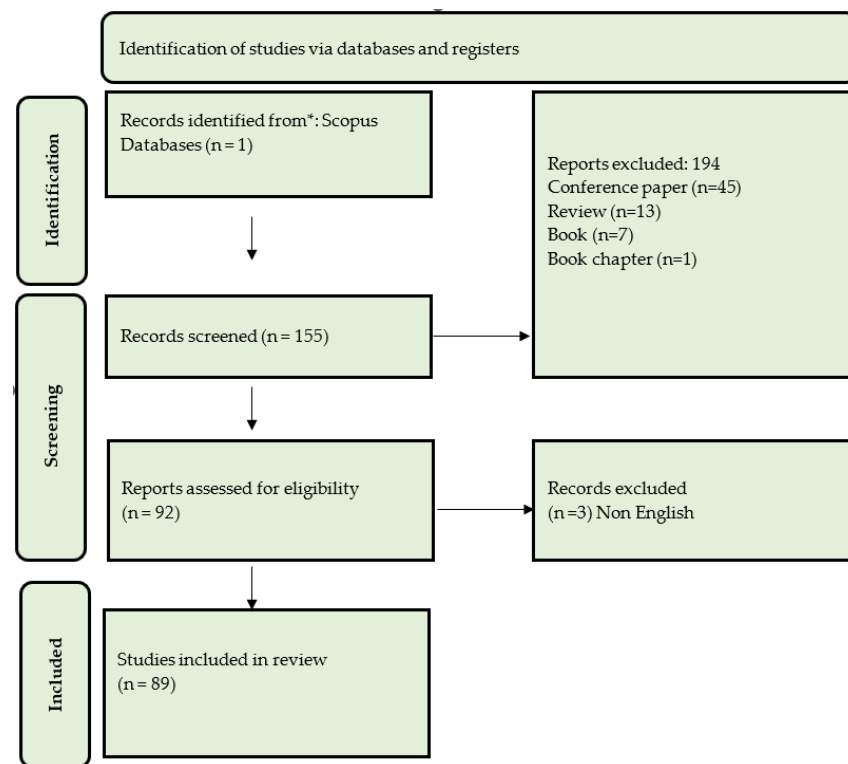


Figure 3. Methodology used for identification of research articles.

3. Results

3.1. Publication Trends over Time

The bibliometric analysis reveals a steady increase in publications on earth blocks and their sustainability potential, particularly in the last decade (See Figure 4). This trend mirrors the growing interest in sustainable construction and the adoption of CE principles across industries.

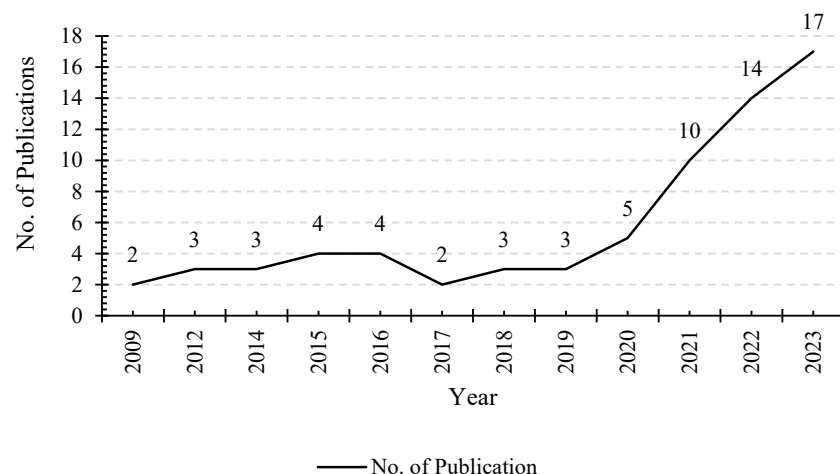


Figure 4. Publication trend of (n = 89) articles.

The bibliometric analysis revealed a notable rise in research on earth blocks and sustainability, particularly after 2010 and accelerating post-2020. This surge corresponds with global policy shifts toward sustainable construction, increased awareness of climate change, and the push for low-carbon alternatives to conventional building materials. The introduction of international sustainability frameworks such as the Paris Agreement (2015) and the United Nations Sustainable Development Goals (SDGs) provided strong incentives

for exploring eco-friendly construction techniques. Additionally, concerns over resource depletion, energy-intensive construction practices, and greenhouse gas emissions have encouraged researchers to investigate CSEBs as a viable alternative.

Sustainability, particularly in terms of reducing carbon emissions and energy use, became a central theme in many studies. In the last five years, a notable increase has been observed in the number of publications on earth blocks and sustainability. Post-2020, the emphasis on resilient and self-sufficient construction solutions intensified, partly due to the COVID-19 pandemic, which exposed vulnerabilities in global material supply chains. With an increased focus on local materials and cost-effective housing, research on earth-based construction saw a renewed interest. Research during this period became more interdisciplinary, which can be seen as a result of incorporating fields such as material science, environmental engineering, and policy studies. Topics such as the use of agricultural and industry waste in earth blocks, life cycle assessment (LCA), and thermal performance analysis have also gained prominence. This shift highlights the growing recognition of earth blocks as an accessible, sustainable, and low-energy building solution, particularly for regions facing housing shortages and environmental concerns.

3.2. Geographical Distribution of Research

The bibliometric analysis also provides insights into the geographical distribution of research on earth blocks. The findings indicate that research on earth blocks is highly concentrated in countries with a strong tradition of earth-based construction, such as India and Bangladesh (Figure 5). However, recent years have seen a growing body of research from developed nations, particularly in Europe, where the sustainability agenda has driven interest in alternative building materials.

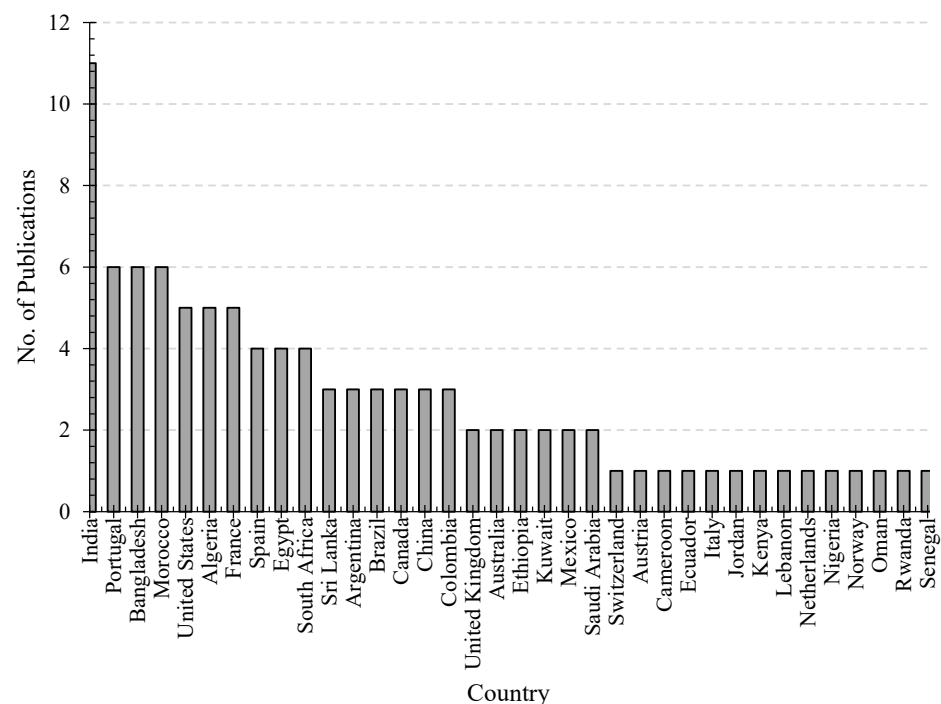


Figure 5. Publications by country.

As a major center for CSEB research, India has produced a significant portion of the global literature on earth blocks. Indian researchers have explored the technical performance of CSEBs in low-cost housing as well as their potential to reduce construction waste and energy consumption. Earth block construction is also prevalent in rural Brazil, where researchers have explored the socio-economic benefits of CSEBs for providing affordable

housing solutions. Brazilian studies have also examined the potential for scaling up earth block production for urban housing projects. European countries, particularly France and the UK, have increasingly contributed to research on earth blocks as part of their sustainability initiatives. European studies have focused on life cycle assessments and the integration of earth blocks into contemporary architectural designs.

The findings highlight the growing global interest in earth blocks as a sustainable construction material, emphasizing their potential to reduce carbon footprints, energy consumption, and reliance on conventional materials. Policymakers can leverage this trend by strengthening regulations and incentives that promote the adoption of earth-based construction techniques. This includes updating building codes, offering subsidies for eco-friendly materials, and integrating circular economy principles into waste management policies.

The adoption and scalability of earth block technologies are closely tied to geographical distribution, as regional variations in soil composition, climate, and construction practices significantly impact production feasibility and market acceptance. For industry stakeholders, scaling up production requires an understanding of the locally available raw materials, particularly soil types, which vary across different regions. Stabilization techniques must be adapted to suit these regional differences to ensure optimal strength and durability of the blocks. Localized production units can play a vital role in making earth blocks more accessible and cost-effective, reducing transportation costs and emissions associated with long-distance material movement. For instance, in regions with high clay content, stabilization methods may differ from those in areas with sandy or lateritic soils. Furthermore, geographical factors influence regulatory policies and market demand, necessitating region-specific strategies for awareness and acceptance.

Collaboration between academia, construction firms, and policymakers should also be geographically contextualized. While urban centers may require large-scale automated production facilities, rural and semi-urban areas can benefit from decentralized, small-scale units that cater to local construction needs. Skill development programs tailored to regional labor markets can ensure workforce readiness for earth block production and application. By addressing these geographical considerations, policymakers and industry leaders can facilitate the mainstream adoption of earth blocks, promoting resource-efficient and sustainable construction practices that align with regional development goals.

3.3. Most Influential Publications and Authors

The bibliometric study identified the most influential publications and authors in the field through citation analysis. These papers and authors have significantly influenced the direction of research on earth blocks and sustainability, earning frequent citations from other scholars. They emphasize CSEBs' role in sustainable construction, discussing their technical performance and environmental advantages. Studies that explored the carbon footprint reduction potential of CSEBs and their thermal efficiency have received widespread recognition in academic circles. Papers that conducted life cycle assessments (LCAs) of earth block construction by comparing CSEBs to conventional building materials are particularly influential. These studies provide quantitative evidence of the environmental benefits of earth blocks.

The bibliometric analysis identified a few key authors (see Figure 6) and institutions (see Figure 7) who have made significant contributions to the field. These authors have consistently published research on the development of CSEBs, the integration of waste materials into earth blocks, and the role of earth blocks in the CE. Leading research institutions in countries such as India, Brazil, and Morocco have played a central role in advancing earth block research.

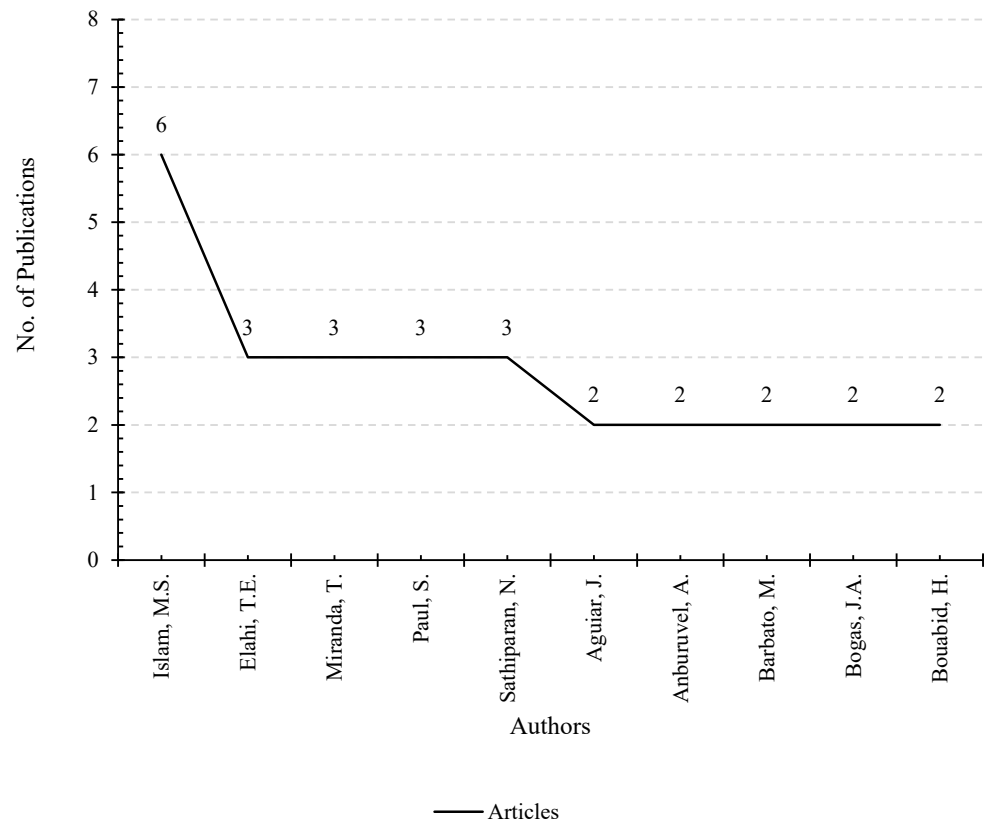


Figure 6. Leading authors.

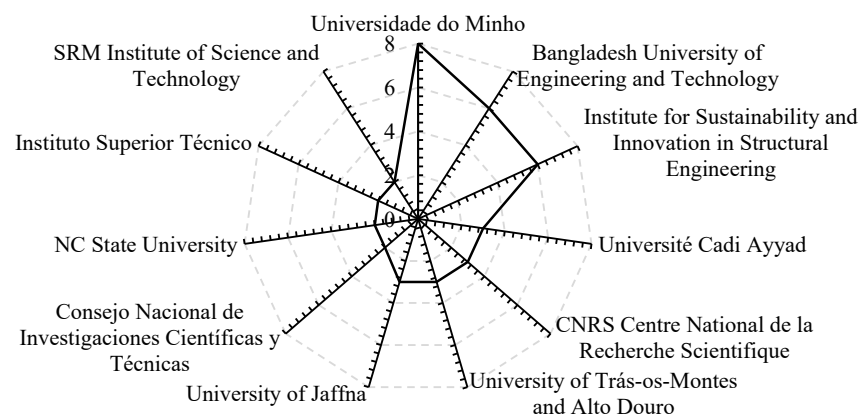


Figure 7. Most relevant affiliations.

3.4. Co-Authorship and Collaboration Networks

The co-authorship network analysis highlights the growing globalization and interdisciplinary nature of research on earth blocks and sustainability. Over the years, collaborations have expanded beyond individual institutions and national boundaries, reflecting a shared recognition of earth-based materials as a viable solution for sustainable construction. Researchers from civil engineering, architecture, environmental science, and material engineering are increasingly working together, demonstrating the multifaceted challenges and opportunities in adopting earth blocks at scale.

A significant observation from the co-authorship network visualization is the emergence of strong research clusters centered around key institutions and countries. Nations such as India have established well-connected research networks, often collaborating on topics such as material stabilization, energy efficiency, and policy frameworks for earth-

based construction (Figure 8). These collaborations are crucial in bridging knowledge gaps, standardizing methodologies, and advancing technological innovations.



Figure 8. Most relevant countries by corresponding authors.

The network also reveals the influence of highly cited researchers and institutional collaborations, where leading universities and research centers act as hubs for knowledge dissemination. This suggests that interdisciplinary and international partnerships are critical in accelerating the adoption and refinement of earth block technologies. However, some regions, like Canada, show limited representation in high-impact collaborations, indicating potential areas where enhanced research funding, knowledge exchange, and policy support could foster greater participation.

While collaborations within engineering disciplines remain dominant, an increasing number of studies highlight the involvement of environmental scientists, suggesting a shift toward a holistic approach to sustainable construction. Strengthening cross-sector partnerships with industry stakeholders, policymakers, and non-academic organizations will ensure that research findings translate into real-world applications.

To further enhance global research impact, increasing collaborations, promoting open-access knowledge sharing, and integrating circular economy principles into collaborative research agendas will be vital steps in making earth blocks a mainstream sustainable construction material.

The geographical distribution of earth block research underscores differences in regional priorities (Figure 9). Countries like India, the UK, and France, where earth blocks are traditionally used in construction, have contributed significantly to the field, but their research focuses vary. India emphasizes affordable housing, rural applications, and circular-economy-driven material reuse, given its rapid urbanization and sustainability mandates, such as the C&D Waste Management Rule 2016. European research, particularly from France and the UK, prioritizes technical improvements, energy efficiency, and regulatory integration, aiming to make earth blocks compliant with modern construction standards. Brazil focuses on adapting earth blocks to high-humidity climates, improving mechanical properties, and ensuring long-term durability. This reflects the global interest in sustainable building practices and the adaptation of traditional techniques for modern construction needs. International projects funded by sustainability initiatives, such as the United Nations' Sustainable Development Goals (SDGs), have further promoted research and collaboration on eco-friendly building materials.

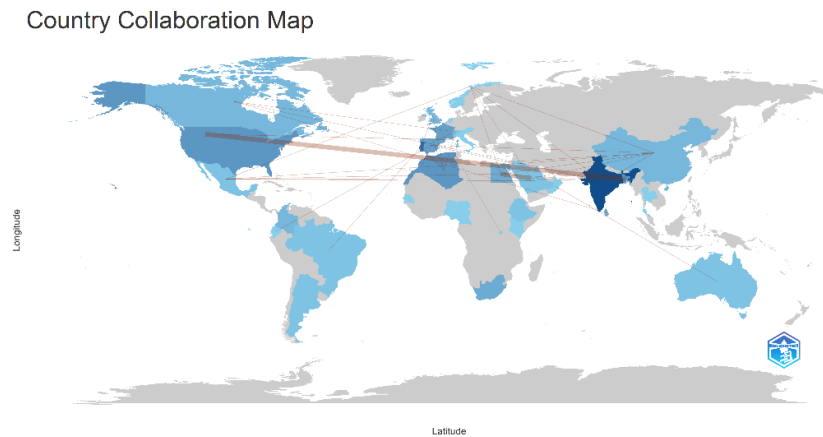


Figure 9. Country collaboration map.

Despite these regional efforts, scaling up CSEBs for mainstream adoption remains a challenge worldwide. Barriers include limited policy frameworks, a lack of standardized guidelines, and resistance from conventional construction sectors. Addressing these obstacles will require cross-sector collaboration, financial incentives, and increased industry participation to facilitate the transition to sustainable earth-based construction.

3.5. Keyword Co-Occurrence and Emerging Themes

Analyzing the co-occurrence of keywords in academic papers reveals the central themes and emerging trends in earth block research. Some of the most frequently occurring keywords, apart from the physical properties of the blocks, include sustainable development, compressed stabilized earth blocks (CSEBs), eco-friendly, thermal performance, life cycle assessment (LCA), environmental protection, energy efficiency, and circular economy, (Figure 10). These keywords highlight the broad research focus on lowering the impact of construction materials on the environment and increasing the energy efficiency of structures built with earth blocks.

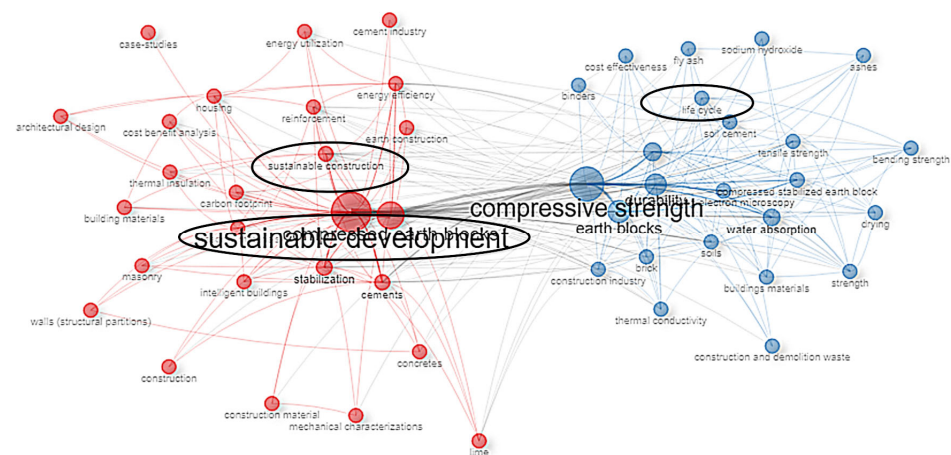


Figure 10. Co-occurrence network.

Figures 11 and 12 illustrate that the primary focus of the researchers has been sustainable development in relation to CSEBs. Additionally, other areas of research include the mechanical and durability properties of the blocks.



Figure 11. Keyword occurrences.

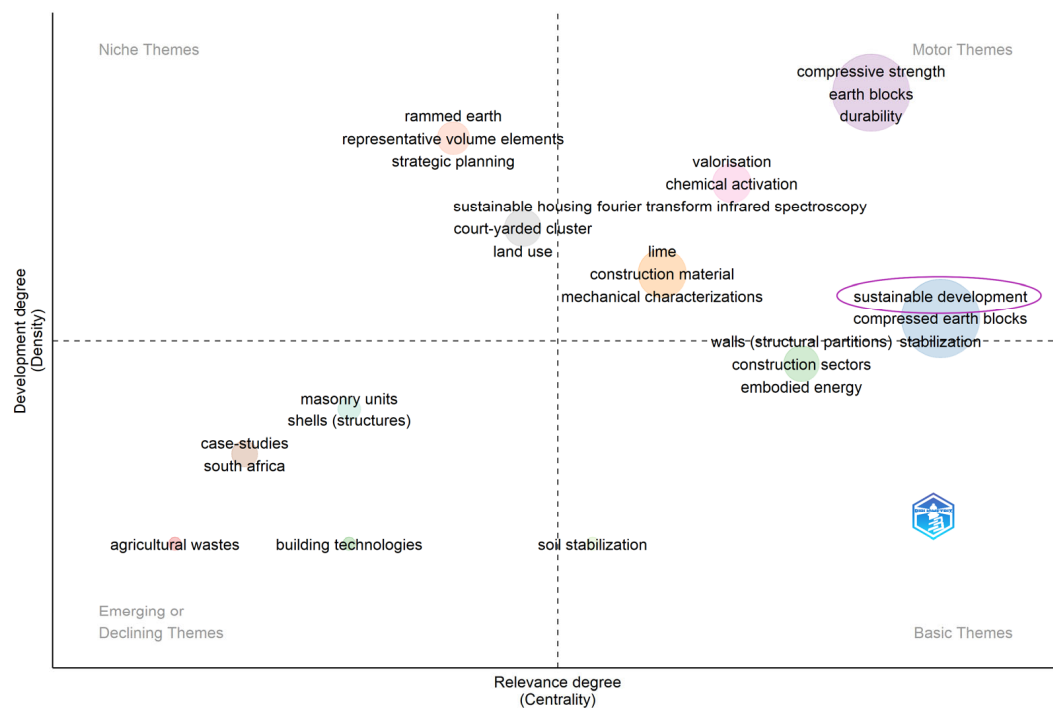


Figure 12. Clustering by coupling, showing how sustainable development is at the high–high position in the matrix.

3.6. Emerging Themes Identified Through the Keyword Analysis

Sustainable Development: Researchers have focused mainly on environmental sustainability, as shown in Table 1. Social sustainability was least discussed, even though it affects the acceptability of any material. Economic sustainability is another factor which pushes the adoption of CSEBs worldwide and in all economies.

Table 1. Pillars of sustainability explored by researchers.

Title	Environmental Sustainability	Social Sustainability	Economic Sustainability
[8]	✓	✓	
[9]	✓		✓
[11]	✓		
[25]			✓
[40]	✓		
[41]	✓		✓
[42]	✓		
[43]	✓		
[44]	✓		✓
[45]	✓		
[46]	✓		
[47]	✓		
[48]	✓	✓	✓
[49]	✓		
[50]	✓	✓	✓
[51]			✓
[52]	✓		
[53]	✓		✓
[54]	✓		
[55]	✓		✓
[56]	✓		✓
[57]	✓		✓
[58]	✓	✓	✓
[59]	✓		
[60]	✓	✓	✓
[61]	✓		✓
[62]	✓		✓
[63]	✓		
[64]	✓		✓
[65]	✓		
[66]	✓	✓	✓
[67]	✓		✓
[68]	✓		
[69]	✓	✓	✓
[70]	✓		
[71]		✓	✓
[72]	✓		
[73]	✓	✓	✓
[74]	✓		
[75]	✓		
[76]	✓		
[77]	✓		
[78]	✓		
[79]	✓		✓
[80]	✓		
[81]	✓		
[82]	✓		
[83]	✓		
[84]	✓		✓
[85]	✓		

Table 1. Cont.

Title	Environmental Sustainability	Social Sustainability	Economic Sustainability
[86]	✓		✓
[87]	✓		
[88]	✓		✓
[89]	✓		✓
[90]	✓		
[91]	✓		✓
[92]	✓		
[93]	✓		
[94]	✓	✓	✓
[95]	✓		
[96]	✓		
[97]	✓		✓
[98]	✓		
[99]	✓		
[100]	✓		
[101]	✓	✓	✓
[102]	✓		✓
[103]	✓		
[104]	✓		
[105]	✓	✓	✓
[106]	✓		✓
[107]			✓
[108]	✓		✓
[109]	✓		✓
[110]	✓		
[111]	✓	✓	
[112]	✓		

Note: The checkmarks (✓) indicate which pillar(s) of sustainability—Environmental, Social, or Economic—are explored in each study.

Integration of Waste Materials: The most recent research has increasingly demonstrated the potential of incorporating waste materials such as fibers and industrial by-products like fly ash into earth blocks (see Table 2). This trend aligns with the growing interest in CE principles and resource recovery in construction (see Table 3).

Table 2. Integration of materials into CSEBs.

Title	Stabilizer	Fiber
[11]		Wheat straw (WS), cork granules (CGs), ground olive stone (GOS)
[25]	Cement	Sisal fibers (SFs) treated with NaOH
[40]	Grewia bicolor bark powder (GBBP), ordinary Portland cement (OPC)	
[43]	Cement	Natural fibers (sisal, Rhecktophyllum Camerunense (RC), oil palm mesocarp fibers (OPMFs))
[44]	Municipal solid waste incineration bottom ash (MSWIBA)	Sisal fibers (SFs)
[46]	Alkali activation of fly ash	
[47]		Bio-binders (animal glue, xanthan gum)
[48]	Cement	
[49]	Rice husk biochar	
[50]	Cement	Areca fiber

Table 2. Cont.

Title	Stabilizer	Fiber
[51]	Cement	Juncus fibers (JFs)
[52]	Recycled cement (RCP), cement, construction and demolition waste (CDW)	
[54]	Cement	
[56]	Cement	Steel fibre
[57]	Rice husk ash (RHA), cement	
[58]		Chrysopogon Zizanioides (Vetiver)
[59]	Cement, egg shell powder (ESP)	
[61]	Groundnut shell ash (GSA)	
[62]	Cement, red marls, phosphate waste rock (PWR)	
[63]	Cement	Sisal fibers, brick waste (BW)
[64]		Date palm stems (DPSs)
[65]		Olive mill wastewater (OMWW), Dry olive pomace (DOP)
[67]	Rice husk ash (RHA), cement	
[68]	Waste concrete powder (WCP), cement	
[70]	Fly ash (FA) with sodium hydroxide (NaOH)	
[72]	Hydraulic lime, cement	
[113]	Cement	Sugarcane bagasse fibers (Scbfs)
[74]	Cement	Phase change materials (PCMs)
[79]	Cement	
[81]	Alkaline solution	Coal fly ash, glass waste
[83]	Cement, fly ash (FA)	
[84]	Rice husk ash, eggshell powder, caustic soda	
[114]	Olive pomace fly ash (OPFA), calcined clays (CCs)	
[85]	Water lily ash (Eichornnia Crassipes), cement	
[86]	Cement	
[87]	Cement	
[88]	Cement	
[90]	Cement	
[91]	Flay ash, cement	
[92]	Ground olive stone (GOS)	
[93]	Natural hydraulic lime	
[94]	Cement	
[95]		Waste polymer sack fibers
[96]	Cement	
[115]	Lime and cement, RFA	
[100]	Palm oil fuel ash (POFA)	
[102]	Rice husk ash, lime	
[116]	Polycarboxylate ether superplastizer, calcium Sulfoaluminate cement (CSA)	
[117]	Lime, cement	
[104]		Natural fibers, alginates
[105]		Banana fibers
[107]	Cement	
[108]	Lime, cement	
[109]	Sugarcane bagasse ash	

Circular Economy: Emerging research themes indicate a growing emphasis on affordable housing, climate resilience, and circular economy integration within the CSEB domain. Notably, while many studies implicitly incorporate circular economy principles—such as resource efficiency, waste reduction, and life cycle sustainability—only a small fraction

explicitly mention “circular economy” in their research. This is evident in Table 3, which highlights the limited number of papers that directly reference the concept despite aligning with its principles. This suggests a need for greater recognition and articulation of circular economy frameworks within CSEB research to reinforce its role in closing material loops and minimizing construction waste. Moreover, the intersection of affordability, sustainability, and climate resilience presents an opportunity for future studies to explore policy-driven incentives, financial viability models, and regional adoption strategies for mainstream earth-based construction techniques.

Table 3. Studies which explicitly mention circular economy.

Title	Studies Focused on Circular Economy
[41]	✓
[49]	✓
[63]	✓

Note: The checkmark (✓) indicates that the respective study explicitly discusses Circular Economy principles.

Life Cycle Sustainability Assessments: Researchers have also focused on the LCA of buildings constructed with earth blocks by examining the environmental impacts from production to end-of-life disposal (see Table 4). These studies provide comprehensive evaluations of the sustainability benefits of earth blocks over the entire building life cycle. Other themes which were identified are shown in Figure 13 below.

Table 4. Studies which included LCA as part of their study.

Title	LCA
[44]	✓
[57]	✓
[60]	✓
[73]	✓*
[83]	✓
[104]	✓

* Note: The checkmark (✓) indicates that the respective study explicitly carried out life cycle cost (LCC) analysis.

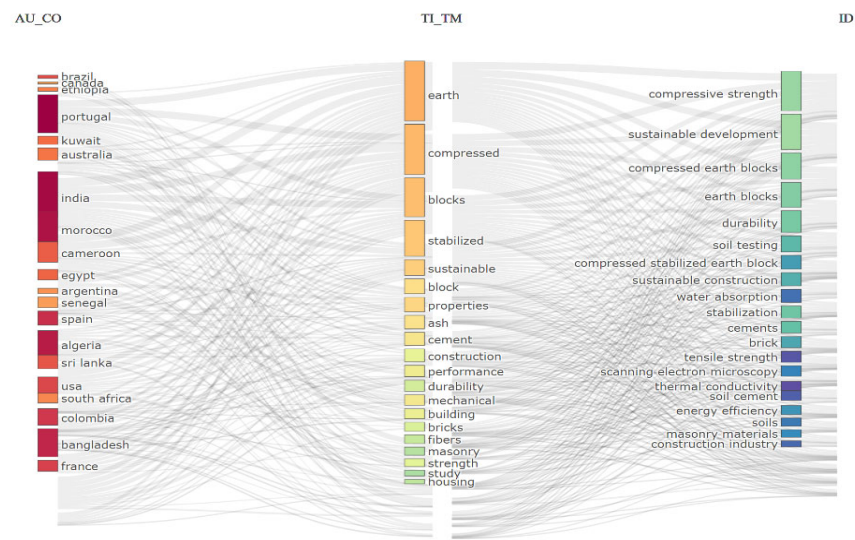


Figure 13. Three-plot diagram showing the themes identified by different countries.

The bibliometric analysis offers a comprehensive overview of the research landscape on earth blocks and their contributions to sustainability. It highlights the growing im-

portance of earth blocks in the quest for sustainable construction solutions by analyzing publication trends, influential studies, and emerging themes.

4. Discussion

The increasing research interest in earth blocks and sustainability, particularly post-2010 and more significantly after 2020, aligns with global initiatives toward sustainable construction and circular economy adoption. This surge in publications coincides with international commitments such as the Paris Agreement (2015) and the United Nations Sustainable Development Goals (SDGs), which have prompted governments, researchers, and industries to explore low-carbon, resource-efficient alternatives in construction. Additionally, growing concerns over climate change, resource depletion, and carbon emissions from conventional building materials have accelerated research efforts toward earth-based materials, particularly CSEBs. However, while the increase in research activity is evident, the regional focus and thematic distribution of studies suggest disparities in priorities and challenges across different geographies.

The majority of research publications originate from Europe, Asia, and Africa, regions where earth-based construction has historical roots and is gaining renewed interest due to modern sustainability mandates. European research, particularly from France and the United Kingdom, emphasizes material characterization, energy efficiency, and regulatory integration within contemporary construction practices. In contrast, Indian and African studies focus more on affordable housing solutions, socio-economic benefits, and the use of locally available materials. The significant contributions from India reflect the country's ongoing efforts to reduce dependence on energy-intensive materials like fired bricks and cement blocks while promoting regional construction techniques that align with sustainable development policies. However, research output from South Africa remains relatively limited, suggesting that CSEBs and similar sustainable earth block technologies have not yet gained widespread traction in these regions. This highlights a potential area for future exploration, particularly in the context of urban sustainability policies and alternative material adoption in high-income nations.

Collaboration networks between institutions, particularly those in India, France, North America, and the United Kingdom, play a crucial role in advancing earth block research and technology transfer. Strong international alliances have facilitated knowledge exchange, standardization efforts, and the development of hybrid construction techniques that merge traditional and modern building practices. However, a closer look at these collaborations reveals that while they have contributed to scientific advancements, there is limited engagement with industry stakeholders, policymakers, and construction practitioners. Expanding these networks to include government bodies and private sector innovators could enhance the practical application of research findings, supporting the large-scale adoption of CSEBs in commercial and residential projects.

One of the critical challenges in CSEB research is innovation in stabilization techniques, which remains a key focus area. While traditional stabilizers such as cement and lime have been widely used, there is an increasing interest in alternative, eco-friendly stabilizers, including geopolymers, bio-based binders, and nanomaterial-enhanced composites. These emerging technologies aim to enhance the mechanical performance of CSEBs while further reducing their carbon footprint, making them more adaptable to diverse climatic and structural conditions. However, scaling these solutions to urban construction remains a complex challenge, given the need for regulatory approvals, supply chain adjustments, and cost considerations. Future research should investigate pathways for integrating CSEBs into mainstream urban housing policies, construction codes, and industrial-scale production models to ensure broader adoption.

To promote earth block adoption, standardized regulations and certification mechanisms are needed to ensure quality and encourage industry confidence. Financial incentives, such as tax benefits and subsidies, can make sustainable materials more competitive. Training programs for engineers and builders will enhance technical expertise, while awareness campaigns can drive industry acceptance. Decentralized local production units can reduce costs and improve accessibility. Integrating C&D waste into earth blocks supports circular economy goals. Public–private partnerships and green procurement policies can further drive adoption, ensuring a more sustainable construction sector.

Overall, the findings underscore the growing relevance of earth blocks in sustainable construction while also highlighting the regional disparities, research gaps, and innovation challenges that need to be addressed. Strengthening global collaborations, increasing industry involvement, and explicitly framing research within circular economy principles will be crucial for advancing the practical implementation of CSEB technologies. Future studies should focus on bridging the gap between laboratory research and real-world application, ensuring that sustainable earth blocks can contribute meaningfully to decarbonizing the built environment and supporting the transition to a circular and sustainable construction sector.

5. Conclusions

The systematic and bibliometric analysis confirms the growing relevance of earth blocks as a key element in sustainable construction practices. Earth blocks, particularly CSEBs, have garnered increased attention due to their ability to reduce energy consumption in both the production and life cycle stages of construction. One of the primary reasons for their sustainability is their reliance on locally available materials, which reduces the need for energy-intensive transportation and the carbon footprint associated with the life cycle of materials like cement. By utilizing resources such as locally available soil and stabilizers like RHA, C&D waste, FA, etc., earth blocks also contribute to waste minimization as they can be produced using recycled materials.

The growing body of research in this area reflects a global interest in exploring alternatives to traditional construction methods driven by increasing concerns over environmental degradation, resource depletion, and the need for climate-resilient infrastructure. The analysis highlights how earth blocks are being reconsidered not only in rural or traditional construction but also as viable solutions for modern urban settings where sustainability is a critical concern.

However, the path to the wider adoption of earth blocks as a mainstream building material requires further research. Key areas for future exploration include improving stabilization processes to improve the strength and durability of earth blocks, making them more competitive with conventional materials. Additionally, research should focus on developing innovative applications of earth blocks in modern construction, particularly in urban environments, where structural and aesthetic demands are higher. The collaboration between academic institutions, industry stakeholders, and policymakers will be essential in advancing these efforts to facilitate knowledge exchange, technological innovation, and the creation of regulatory frameworks that support the integration of earth blocks into sustainable building practices. The potential for earth blocks to contribute significantly to the shift to a CE and carbon-neutral construction is substantial, but achieving this will require sustained research and cooperation at a global scale.

Author Contributions: Conceptualization, S.S. and J.S.S.; methodology, S.S.; software, S.S.; validation, S.S. and J.S.S.; formal analysis, S.S.; investigation, S.S.; resources, S.S.; data curation, S.S.; writing—original draft preparation, S.S.; writing—review and editing, S.S. and J.S.S.; visualization, S.S.; supervision, J.S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors upon request.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CE	circular economy
CI	construction industry
CSEBs	compressed stabilized earth blocks/bricks

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