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Bamboo for climate resilience: green gold of ecosystems in the UN SDG Framework

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Background: Bamboo is a strategic resource for poverty alleviation, rural growth, ecological restoration, sustainable jobs, and industrial innovations. The function of bamboo goes beyond conventional uses and extends to the international policy reformation toward sustainable transitions. Its alignment with the United Nations Sustainable Development Goals (SDG) has been increasingly recognized.
Aim: This article aimed to assess bamboo for qualitative and quantitative attainment of the 169 targets of the 17 goals of the UN SDG Framework.
Methodology: The qualitative assessment was classified into three grades: high, medium, and low. The quantitative assessment examined the individual 169 targets on a scale of 1–10.
Key findings: The average percent score (APS) from the qualitative assessment of bamboo was ranked and graded for SDGs 1–17 into five major groups: group A—with APS above 50%, targets achieved (SDGs 7, 13, 1, 11, and 9); group B—with APS 40%–50%, challenges remain (SDGs 12, 6, 15, and 2); group C—with APS 30%–40%, significant challenges (SDGs 4, 5, 8, and 10); group D—with APS 15%–30%, major challenges (SDGs 17, 14, and 3); and group E—with APS below 15%, not achieved (SDG 16). Subsequently, quantitative assessment of each of the 169 UN SDG target achieved by bamboo showed that 45 targets achieved the highest scale of 8–10, 35 medium (on a scale of 4–7), 25 low (on a scale of 1–3), and 64 no connection (on a scale of 0). The highest score of 10 was shown for four targets, i.e., 8.4 (efficiency of resources and circular production), 9.2 (green industrialization, composites, and textiles), 11.6 (minimize city environmental footprint and waste), and 15.3 (land degradation neutrality through revegetation and biochar).
Case studies and policy implications: This article further delved into case studies on bamboo for sustainability from nine countries. Based on these case studies, we derived a seven-point policy intervention integrating the UN SDG Framework for bamboo as the green gold of ecosystems.
Conclusions: In a nutshell, this article could be the first of its kind to quantify the 169 targets for bamboo on a scale of 1–10. This article provides a comprehensive review for policymakers, industries, and researchers for the integration of bamboo into climate-resilient strategies aligned with global sustainability goals.

KEYWORDS
bamboo, sustainable development goals, climate resilience, food security, livelihood improvement

Highlights

- Each of the 169 targets of the UN SDGs was examined on a 1–10 scale.
- A data-driven analysis of bamboo on the 169 targets was performed.
- Success story from nine nations derived on bamboo for sustainability.
- Policy interventions comprehended to achieve SDG targets.

1 Introduction

Bamboo, the green gold of ecosystems, helps in carbon sequestration, soil protection, water control, protection of habitats, and provision of sustainable livelihoods, building materials, green industries, and renewable substitutes for conventional materials (Behera and Balaji, 2021). The ecological and socioeconomic significance of bamboo places it in the center of building climate-resilient societies. Bamboo offers a broad range of ecosystem services that renders it a precious element in natural and managed ecosystems. Its high rate of growth, high biomass productivity, and special root system allow bamboo to provide essential provisioning, regulating, supporting, and cultural services that directly support ecological stability and human wellbeing (Verma et al., 2021). The rise in climate change, the loss of biodiversity, and the depletion of natural resources have raised global alarm for sustainability and resilience (Godfray et al., 2010). With countries working toward the goals of the United Nations Agenda 2030, there is a need to determine nature-based solutions that can simultaneously address ecological stability and socioeconomic development (Bebbington and Unerman, 2017; Zhang et al., 2024). Bamboo is a nature-based solution that has an emerging role in bioeconomy and circular production systems, which are considered in the present article to evaluate the status of bamboo in the United Nations Sustainable Development Goal (UN SDG) Framework.

2 Rationale of the study

The UN SDG Framework covers a number of aspects for sustainability. Bamboo covers various aspects from this framework. Indeed, bamboo offers habitat and food to many species, which aids in increasing biodiversity and promoting resilience in the ecosystem (Wei et al., 2015). Bamboo has an important role in climate regulation as a very efficient carbon sink. Some bamboo types sequester carbon at levels similar to or even greater than many forest tree types, hence playing an important part in global efforts toward greenhouse gas emission mitigation (Yuen et al., 2017). Bamboo sustains millions of livelihoods, particularly in rural and forest-based communities. Bamboo is used in building construction, handicraft, paper, textiles, energy production, and, increasingly, as a plastic substitute, generating a range of income streams (Chen et al., 2021). Bamboo enterprises also enable women and disadvantaged groups through inclusive economic engagement (Yu, 2020). Such socioeconomic advantages make bamboo a strategic resource for poverty alleviation, sustainable jobs, and rural growth, all of which are key to sustainability transitions (Nath et al., 2015).

Thus, the multifaceted bamboo spans from ecological restoration and green infrastructure to industrial innovations, which makes it a unique source of research and innovations capable of bridging environmental and socioeconomic challenges in ways that few other renewable resources can achieve (Nayak and Mishra, 2016; Mustaffa et al., 2025). The research and innovations on bamboo date back from the 19th century (Figure 1A). The Scopus database was searched using the keyword "Bamboo," in particular in the title category to limit specific results on the number of published papers (accessed on August 26, 2025). Our previous research identified technological advancements and patented developments in bamboo, demonstrating its potential for industrial revolution and sustainability (Patel et al., 2025). The PATENTSCOPE database (a patent database from the World Intellectual Property Organization, Geneva) was searched again using the keyword "Bamboo" in the abstracts, titles, and claims to derive specific patent records (the patent records covered PCT publication no. 34/2025, published on August 21, 2025). In the period from 1875 to 1975, there were a total number of 171 published papers and 27 patent records. Later on, paper publication increased, but much rise was observed in the 5-year time period 2006–2010 (i.e., n = 1,614), which was doubled in 2011–2015 and tripled in 2016–2020, while fivefold in 2021–2025 (i.e., n = 8,023, in August 2025) (Figure 1B). These patent and paper publications indicated the industrial and academic attention toward bamboo.

Furthermore, the function of bamboo goes beyond conventional uses and extends to the international policy reformation toward sustainable transitions (Chawla et al., 2022). Its alignment with the UN SDGs has been increasingly recognized, with evidence indicating strong relationships across several goals such as poverty reduction, clean affordable energy, sustainable urbanization, responsible consumption, and climate change (Vagestan et al., 2025a). The present study searched for the number of publications on bamboo related to attainment of the UN SDGs, with the first publication being a book chapter in 2018 (Figure 1C). The time period 2018–2025 has 11,203 publications on bamboo; however, of these publications, only 0.61% was related to attainment of the SDGs, i.e., only 69. Therefore, the present study draws more attention on bamboo attaining the SDGs.

Based on the present literature, none of the articles mapped bamboo with the 169 targets of all SDGs. This study aimed to assess bamboo for qualitative and quantitative attainment of the 169 targets of the 17 UN SDG Framework on a relevant grade (i.e., high, medium, or low) and on a scale from 1 to 10. Furthermore, this article delved into case studies on bamboo for sustainability to derive policy interventions toward achieving the 169 targets on a higher grade.

3 Bamboo and the UN SDG Framework (qualitative assessment)

The UN SDG Framework offers an integrated 17 goals and 169 targets to attain global development until 2030 (Dang et al., 2017). Synchronizing natural resources such as bamboo with this framework has become imperative in order to appreciate their contributory role in the holistic change toward sustainability transitions (Omer and Noguchi, 2019). Although the ecological and socioeconomic functions of bamboo are appreciably well known, an unbiased methodology is needed to analyze its alignment with the entire SDG Framework in quantifiable terms (Kim, 2023).

The study takes a systematic approach to measure the contribution of bamboo to the SDGs. The methodology comprises three steps: i) mapping the ecosystem services and the uses of bamboo against each of the 17 SDGs; ii) determining the relevant 169 targets under each goal where bamboo directly or indirectly makes a contribution; and iii) using a qualitative-to-quantitative scoring tool to determine the level of alignment.

The analytical framework relies on key metrics provided in the dataset: the "relevance category." The relevance category, which is classified into either high (H), medium (M), low (L), or no connections, provides a qualitative assessment toward the linkage of bamboo to a given target. To limit the length of this article, Supplementary Table S1 was prepared to cover a high-level assessment of the contributions of bamboo across 169 targets of all 17 SDGs. Table 1 is derived from Supplementary Table S1 for qualitative assessment. The results indicate that 105 targets, i.e., 62%, had relevance in varying degrees. This qualitative assessment is converted into quantitative assessment in the following section.

4 Quantitative assessment: elucidation of the relevance score on the 169 targets of the 17 SDGs

The purpose of the quantifying framework was to go beyond a simple presentation of the SDG alignment data. The aim was to provide a deeper understanding of the underlying trends, causal relationships, and strategic synergies that characterize the contribution of bamboo to sustainable development. The analysis gives prominence to the major themes and offers a nuanced perspective from high impact to negligible involvement (Mantlana and Maoela, 2019).

A quantitative measure is the relevance score ranging from 1 to 10 for each target. Furthermore, the quantitative assessment is discussed in two sections: for each SDG (section A) and for each target (section B).

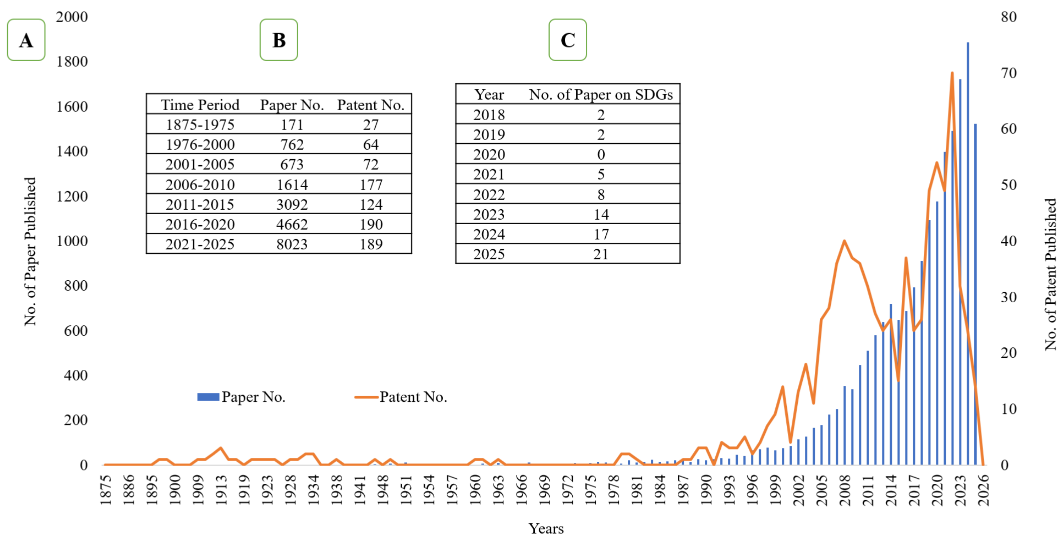
Section A: Average percent score calculation for each SDG and rank derivation

Each SDG has different numbers of targets, and to derive hominization for giving rank, it is important to normalize the data. Thus, an average percent score (APS) was calculated to derive normalized data using the following formula for each SDG:

Average percent score

$$= \frac{\sum(\text{Score obtained for each individual target in SDG out of 10}) \times 100}{\sum(\text{Total targets in given SDG} \times \text{Score 10})}$$

The following is an example of the APS calculation for SDG 9 using the formula. Based on Supplementary Table S1, SDG 9 has a total of eight targets (9.1–9.5 and 9.a–9.c). For each target, a maximum score of 10 is considered, i.e., SDG 9 × 8 target = total score of 80.



Time Period	Paper No.	Patent No.
1875-1975	171	27
1976-2000	762	64
2001-2005	673	72
2006-2010	1614	177
2011-2015	3092	124
2016-2020	4662	190
2021-2025	8023	189

Year	No. of Paper on SDGs
2018	2
2019	2
2020	0
2021	5
2022	8
2023	14
2024	17
2025	21

FIGURE 1
Paper and patent publications on green gold "bamboo". **(A)** Number of patent and paper publications since the 19th century. **(B)** Tabulation of the time frame of the publication counts. **(C)** Tabulation of the number of papers published on bamboo targeting the UN Sustainable Development Goals (SDGs). Paper and patent publication source: Scopus (https://scopus.com) and PATENTSCOPE (https://patentscope.wipo.int/), respectively.

The sum total of the obtained score for bamboo for the eight targets in SDG 9 is 45 out of 80. Thus, the APS for SDG 9 is 56.

A similar tabulation was followed for SDGs 1–17 (Table 2). A rank is given to the SDGs based on the obtained higher percentage to lower percentage results. These results are graphically presented in Figure 2 in attaining the SDG targets. Based on the APS, five major categories/groups were derived and designated with specific colors: group A—with APS above 50%, considered as "targets achieved" (green); group B—with APS between 40% and 50%, considered as "challenges remain" (yellow); group C—with APS between 30% and 40%, considered as "significant challenges" (orange); group D—with APS between 15% and 30%, considered as "major challenges" (red); and group E—with APS below 15%, considered as "not achieved" (brown). Group A comprised the achieved targets from SDGs 7, 13, 1, 11, and 9, which were achieved significantly, while group E comprised SDG 16, for which the targets were not achieved.

Section B: A quantitative data-driven analysis on 169 targets.

This section examines the 169 individual targets with a relevance score in three major categories: high (scores 8+), medium (scores 4–7), and low or no connections (scores 0 to 3) (Table 3). Of the 169 targets, the highest score of 10 was achieved by four targets—8.4, 9.2, 11.6, and 15.3—while a relevance score of 9 was achieved by 14 targets. Figure 3 displays the top 18 targets with scores of 9 and 10.

4.1 High-impact targets (relevance scores 8+)

This section examines the 45 different targets with a relevance score of 8 or higher. These targets represent an area of importance where bamboo has the potential to be a truly transformative agent of change.

4.1.1 Promoting inclusive economic growth and poverty reduction

The data demonstrated the influential role of bamboo in driving economic growth from the grassroots level. With a relevance score of 9, target 1.1 indicates that bamboo cultivation and the creation of micro-, small, and medium enterprises (MSMEs) can directly boost rural household incomes, creating a route to the elimination of extreme poverty (Kartika, 2024). This is complemented by a score of 8 for target 1.2, which highlights how the diversification of livelihoods through bamboo minimizes the vulnerability of the poorest of the poor (Nath et al., 2009). The economic advantages are embedded structurally through linkages such as secure tenure and community forestry models, which provide equal rights over economic resources (target 1.4, score = 8) (Lobovikov et al., 2011), and the development of resilient livelihoods that can avoid climate and economic challenges (target 1.5, score = 8) (Ahammad et al., 2018).

The evidence points to a significant cause-and-effect scenario where the contribution of bamboo to livelihood creation is not a stand-alone benefit but is directly made possible by the contribution to a circular and green industrial pattern (Dwivedi et al., 2019). This is most clearly seen in SDG 8, where enhanced scores were assigned to productivity expansion through increased-value products (target 8.2, score = 8) (Singhal et al., 2021) and the formalization of MSMEs (target 8.3, score = 8) (Rasul et al., 2008). These changes in structure offer a stable and expandable economic base for rural families. The gains are distributed inclusively via social enterprises in the community, which are connected to fostering social inclusion (target 10.2, score = 9) (Das et al., 2016) and ensuring income growth (target 10.1, score = 8) (Wei et al., 2025). Bamboo has become a tool to alleviate poverty by means of creating a sustainable economic system and linking production with formal market access.

4.1.2 A blueprint for a circular economy and green industrialization

The data indicated a paradigm shift toward materials potential to stimulate systemic transformation led by bamboo. A maximum score of 10 was achieved by target 8.4, which aims at improving resource efficiency through circular production (Li et al., 2025). This is paralleled by a similar maximum score of target 9.2, where the position of bamboo in green industrialization takes center stage with the utilization of panel boards, composites, and textiles (Agarwal and Sethi, 2025). These results indicate that bamboo has rapid renewability and versatility, offering a perfect product for a regenerative economic model.

Additional evidence from SDG 12 further narrates this story. Targets 12.2 and 12.4, both with a score of 8, highlight the sustainable management of natural resources (Tamang et al., 2025) and environmentally sound management of processing and chemicals (Cheng et al., 2025a). The score of 9 for target 12.5 highlights how bamboo can greatly reduce waste via recycling, biochar, and the valorization of by-products (Ding et al., 2025). These data indicate that bamboo is not only an alternative material but is also a ground-level source for a less linear "take–make–dispose" industrial model of the future (Merli et al., 2017). This ability is also utilized to foster sustainable public procurement of bamboo products, which has a relevance score of 8 (target 12.7) (De Araujo et al., 2025).

4.1.3 Ecological restoration and climate resilience

Bamboo has shown environmental impact for its intrinsic carbon sequestration potential and for providing systemic landscape-level ecological services (Dutta et al., 2025). A perfect score of 10 was achieved by target 15.3, connecting bamboo with land degradation neutrality via revegetation and biochar (Chaturvedi et al., 2023). This ability to restore land on a large scale provides a basis for a cascading series of other benefits. The data indicate a strong interrelation between the role of bamboo in both land and water environments. For example, land rehabilitation (SDG 15.3, score = 10) naturally mitigates soil erosion that increases recharging of the watershed and decreases sedimentation (target 6.4, score = 8) (Negi et al., 2025). This, in turn, decreases land-based pollution and sediment flow, contributing to the prevention of marine pollution (target 14.1, score = 9) (Kuok et al., 2024). The same principle applies to the utilization of bamboo

TABLE 1 Contribution of bamboo to the 169 targets of the UN sustainable development goal (SDG) framework based on the relevance category.

SDG	169 SDG targets	High	Medium	Low	No connection
SDG 1: No poverty	7	4	2	1	0
SDG 2: Zero hunger	8	1	3	3	1
SDG 3: Good health and well-being	13	1	2	1	9
SDG 4: Quality education	10	2	3	2	3
SDG 5: Gender equality	9	1	4	0	4
SDG 6: Clean water and sanitation	8	3	2	2	1
SDG 7: Affordable and clean energy	5	3	2	0	0
SDG 8: Decent work and economic growth	12	3	2	2	5
SDG 9: Industry, Innovation, and infrastructure	8	3	3	1	1
SDG 10: Reduced inequalities	10	2	2	2	4
SDG 11: Sustainable cities and communities	10	5	2	1	2
SDG 12: Responsible consumption and production	11	5	2	1	3
SDG 13: Climate action	5	3	1	1	0
SDG 14: Life below water	10	1	1	2	6
SDG 15: Life on land	12	5	2	0	5
SDG 16: Peace, justice, and strong institutions	12	0	0	3	9
SDG 17: Partnerships for the goals	19	3	2	3	11
Total	169	45	35	25	64

charcoal in constructed wetlands and for phytoremediation (target 6.3, score = 9) (Narzary et al., 2024).

These data demonstrate the critical role of bamboo in climate action. Its use in landscape restoration enhances the resilience and adaptive capacity to climate-related hazards (target 13.1, score = 8) (Masisi et al., 2022; Yadav and Mandaliya, 2025), while material substitution and bioenergy production lead to emission reductions (target 13.2, score = 9) (Awogbemi and Desai, 2025). It has utilization in agroforestry management and contribution to sustainable forest development (targets 2.4 and 15.2, both scored 9) (Partey et al., 2017; Li et al., 2019). This utility of bamboo shows that it is a systemic, nature-based solution connecting terrestrial and freshwater ecosystems with climate change mitigation and adaptation efforts, as well as showing that it is a perfectly holistic solution to environmental issues.

4.1.4 Building resilient human habitats and social capital

Evidence shows that the contribution of bamboo is not limited to rural development; it has a tangible and decisive connection to urban sustainability. Target 11.6, with a score of 10, identifies that bamboo can reduce the environmental impact of a city by decreasing material impacts and improving air quality through green infrastructure (Zhao et al., 2023). This is accompanied by high scores for its application in affordable and complement housing (target 11.1, score = 9) (Shilar et al., 2025) and its contribution to ensuring safe, accessible public spaces with shading and furnishing (target 11.7, score = 9) (Deng et al., 2023). In addition, the quick growth and the resilience of bamboo make it a suitable material for rapid deployment shelters, minimizing disaster risk and economic loss (target 11.5, score = 9) (Dev and Das, 2021).

Bamboo plays a significant function in urban resilience and thus generates a strong demand for human skills, which in turn encourages education and skills investment in rural regions where it is cultivated (Subasinghe, 2024). From the analysis, bamboo supports vocational training in craftsmanship and construction (target 4.3, score = 8) (Dai and Hwang, 2019) and offers skills for decent work in sustainable industries (target 4.4, score = 9) (Haes and Murti, 2023). This establishes a symbiotic rural–urban value chain where the city benefits from resilient infrastructure and a reduced environmental impact and the rural community benefits from skill development and economic opportunities, directly linking them to a sustainable future (Purbasari, 2023).

4.2 Moderate contributions of bamboo—conditional or indirect impact (relevance scores 4–7)

This section makes finer distinctions concerning the contribution of bamboo in highlighting the targets where its

TABLE 2 Rank and grade derived based on the average percent score (APS) obtained for the total score of bamboo in the 169 targets of sustainable development goals (SDGs) 1–17.

SDG	No. of targets	Total score	Total obtained score	Average % score	Rank	Grade
SDG 7: Affordable and clean energy	5	50	34	68	1	A
SDG 13: Climate action	5	50	33	66	2	A
SDG 1: No poverty	7	70	45	64	3	A
SDG 11: Sustainable cities and communities	10	100	59	59	4	A
SDG 9: Industry, innovation, and infrastructure	8	80	45	56	5	A
SDG 12: Responsible consumption and production	11	110	55	50	6	B
SDG 6: Clean water and sanitation	8	80	39	49	7	B
SDG: 15 Life on land	12	120	53	44	8	B
SDG 2: Zero hunger	8	80	32	40	9	B
SDG 4: Quality education	10	100	37	37	10	C
SDG 5: Gender equality	9	90	32	36	11	C
SDG 8: Decent work and economic growth	12	120	39	33	12	C
SDG 10: Reduced inequalities	10	100	32	32	13	C
SDG 17: Partnerships for the goals	19	190	38	20	14	D
SDG 14: Life below water	10	100	19	19	15	D
SDG 3: Good health and well-being	13	130	24	18	16	D
SDG 16: Peace, justice, and strong institutions	12	120	7	6	17	E

connection is indirect or otherwise dependent on other system drivers.

4.2.1 Conditional contribution to food security and health

The evidence indicates that the involvement of bamboo in food security and health is precise and narrow, playing more as a part of a system than as an isolated solution. In SDG 2, the medium relevance (score = 5) of target 2.1 is linked to the regional, not national, role of bamboo shoots as food (Tian et al., 2025). In the same manner, bamboo can enhance the productivity and income of smallholders (target 2.3, score = 6) (Santosh et al., 2021), which will need the utilization of improved varieties and strong extension systems. Regarding SDG 3, the health benefits are also context-dependent. Bamboo bioenergy can lower air pollution (target 3.9, score = 8) (Hernández-Mena et al., 2024), while indoor hazards can be reduced by affordable housing materials (target 3.8, score = 7) (Huang et al., 2025). This benefit is dependent on the application of advanced combustion techniques and building codes.

4.2.2 Indirect impact on policy and governance

The data clearly distinguish the direct and indirect impacts of bamboo on the abstract concept of governance and policy (Das and Sarma, 2025). Majority of the SDG 1, 8, 10, and 16 targets are focused on institutional and regulatory reform. The evidence suggests the immediate impact of bamboo on livelihoods, landscapes, and materials rather than on the politicized, complicated process of institutional change (Pan et al., 2025). While the success of a value chain in bamboo can prove the effectiveness of a specific policy, the plant itself cannot replace the policy framework (Ayer, 2025; Pathan, 2025).

4.3 Targets with low or no connections (relevance scores 0–3)

A comprehensive analysis requires a clear understanding of the limitations of a resource. The dataset explicitly identifies numerous SDG targets to which bamboo has no direct connection, reinforcing that no single resource can be a universal solution.

4.3.1 Intrinsic disconnects in social and health targets

For instance, its connection to end malnutrition (target 2.2) is weaker (score = 2), except where dedicated programs are undertaken to ensure shoot consumption (Barbhuiya et al., 2025). On the other hand, no relationship is indicated through data with concerns such as reducing maternal mortality (target 3.1), preventing epidemics (target 3.3), or promoting universal access to reproductive health services (target 3.7). Similarly, no direct relationships are made with eradicating gender-based violence (target 5.2) or harmful practices (target 5.3) (Vuving, 2024; Binfield et al., 2025).

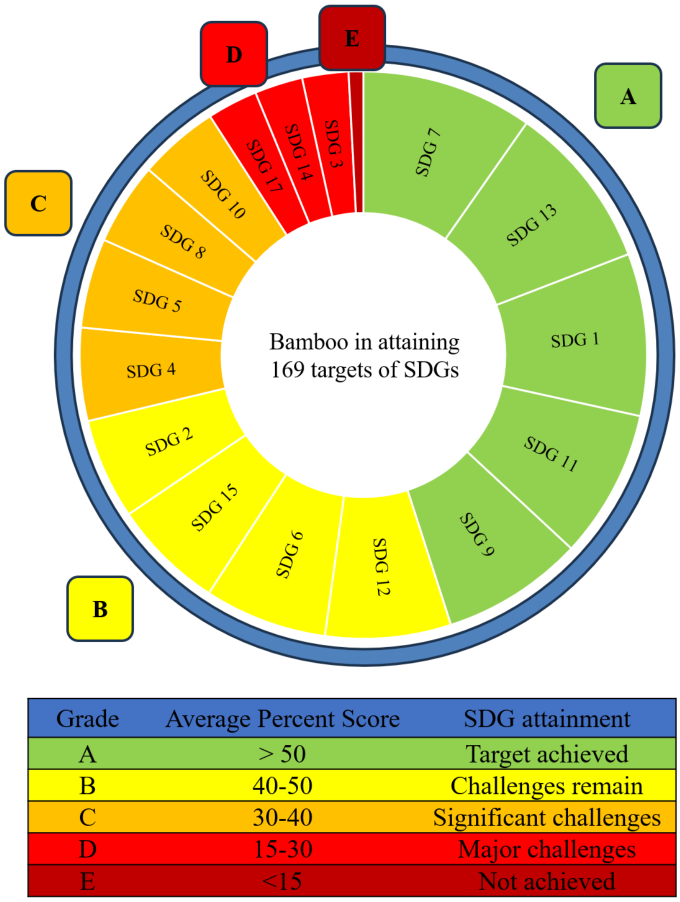


FIGURE 2
Bamboo—the green gold of ecosystem in the United Nations Sustainable Development Goals (UN SDG) Framework. Here, the average percent score was derived for each SDG based on the 169 target matrix. Grades *A* to *E* signify the SDG attainment level. The grade-wise *color code* distinguishes each significant attainment level.

TABLE 3 Data-driven analysis of the 169 targets.

Category	Score	No. of targets scoring	Achieved score	Total score
High (scores 8+)	10	4	40	382
	9	14	126	
	8	27	216	
Medium (scores 4–7)	7	7	49	193
	6	9	54	
	5	14	70	
	4	5	20	
Low or no connections (scores 0–3)	3	7	21	48
	2	9	18	
	1	9	9	
	0	64	0	

4.3.2 Policy, governance, and financial frameworks

Designing a policy for poor (target 1.b) carries a relevance score of 1, while building effective and accountable institutions (target 16.6) carries a score of 3 (Dewi et al., 2025). Furthermore, there are no explicit linkages to maintaining per capita economic growth (target 8.1), enhancing global financial services (target 8.10), or enhancing official development assistance (target 10.b) (Haida et al., 2025). In addition, it has no link to the strengthening of international institutions (target 16.8) or an assured rules-based trading system (target 17.10) (Timko et al., 2024). This shows that, even though a prosperous bamboo value chain would benefit and be impacted by such overarching structures, it does not directly reinforce their reform or application (Liang et al., 2023).

4.4 Limitations of the study

The present study is dependent upon the current status of bamboo, which would vary from time to time. The evaluation was

FIGURE 3
Top 18 targets among the 169 targets of the Sustainable Development Goals (SDG) attained by bamboo with scores of 9 and 10. Here, the SDG, with its number and name, is marked with the top targets attained by the bamboo. Values in green font denote a score of 10, while values in black font indicate a score of 9.

based on data availability, which could vary with the scoring approach and may evolve with future evidence.

5 Case studies on bamboo for sustainability

Bamboo is firmly linked with nations across the globe, both economically and culturally, based on the efforts of various international and national institutions. China is the top global producer and consumer of bamboo, and supporting modern technologies such as engineered bamboo, textiles, and renewable energy. There are research and policies being stimulated by institutions such as the China National Bamboo Research Center (CBRC) and the International Bamboo and Rattan Organization (INBAR, with headquarters in Beijing) (Sedliar and Sedliar, 2025). India is the second largest bamboo reserve in the world. It identifies bamboo as the “poor man’s timber” for its application in housing, handicrafts, paper, and biomass. The National Bamboo Mission has further extended its application in sustainable livelihood and industries (Dubey et al., 2024). In Japan, bamboo continues to play a pivotal role in Shinto and Buddhist rites, tea ceremonies, and cultural landscapes, including Kyoto’s Arashiyama Bamboo Grove (Komatsu et al., 2012). Thailand was the host to the World Bamboo Congress in 2009 and gave birth to World Bamboo Day (September 18), promoted under the auspices of the World Bamboo Organization (WBO) (Koshy, 2023). Outside Asia, countries in the African continent such as Ethiopia and Kenya are starting to see the potential of bamboo as a climate-smart crop for the restoration of lands and generation of livelihoods, with African Bamboo leading the industry and restoration efforts (Böck, 2014). In Colombia, the role of bamboo is especially evident, where Guadua bamboo is internationally recognized for eco-architecture and resilient housing under disaster conditions, complemented by regional bamboo research institutions (Restrepo and Becerra 2016). Together, these national contexts and organizational networks highlight the dual role of bamboo as a cultural symbol and a strategic resource, which has linkage to sustainability. The following details the specific case studies on and success stories of bamboo explored globally for sustainability.

5.1 China

Hogarth (2013) conducted a case study on sustainable bamboo from southern China regarding bamboo shoot management. The research surveyed 240 farmers to determine the primary source of income. The results highlighted bamboo shoots as the main cash income source, and this had a major impact on the household income and livelihoods. Furthermore, the uncontrolled pest problem that led to poor yields was mentioned. In addition, improvements in smallholder bamboo management practices were summarized to optimize productivity. Following this, Xu et al. (2023) conducted research on the economic indicator of the environmental tax given to stakeholders in different parts of China by assessing the environmental benefits of bamboo structures. In their research, extensive differences were found in the willingness of Chinese society to pay for the benefits, especially the lowest willingness observed in Beijing and the highest in Zhejiang. In addition, their comparative study provided proof that the environmental advantages of the use of bamboo buildings in China were improved to precast concrete, hence enabling rational choice of adopting bamboo buildings in China. Recently, Huang et al. (2025) reported on the use of bamboo structures as a systematic solution to low-carbon transformation of rural houses in China. According to them, the building sector necessitates a substantial increase in low-carbon bio-based materials, for which bamboo was found as an option. In this case study, research has introduced a field-validated life cycle carbon emission framework for bamboo houses. The carbon emissions were studied against conventional masonry and global timber structures, which showed carbon reductions by 24.8% and 34.1% over a 50-year period. Furthermore, the researchers proposed low-carbon optimization strategies for bamboo structures and their operation.

5.2 India

Nath and Das (2012) reported on a case study from Barak Valley, Assam, Northeast India. Using a random sampling method, the authors selected a sample of 100 home gardens and 40 bamboo groves. Measurements of the culm growth and carbon storage were taken. It was concluded that village bamboos contributed a significant proportion to local economies, societies, and environments and are a potential tool to counteract global climate change. In addition, the authors suggested the development of bamboo in agroforestry expanding business and the restoration of degraded lands. Studies have emphasized the management of bamboos in villages for rural landscape as a carbon sink under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Recently, Krishanamoorthi et al. (2025) worked on bamboo abundantly available in Tripura, Northeast India. Their study used potential bamboo species, i.e., *Melocanna baccifera*, *Bambusa vulgaris*, and *Bambusa polymorpha*, for the production of high-quality and nutrient-rich leaf-based pellets by mixing with certain food ingredients. They prepared a pellet using a portable pelleting machine. In their observation, *M. baccifera* with 15% groundnut oil cake provided the best-quality pellets with 19.86% protein and 40.10% carbohydrates. In the construction sector, the case study by Barbhuiya et al. (2025) was on the low-cost building of an Assam-type house, Northeast India province. The authors evaluated traditional materials such as bamboo and thatch along with emerging materials such as ferrocement and hempcrete for their potential as eco-friendly alternatives. The authors focused on policy support, in particular on Pradhan Mantri Awas Yojana (PMAY), where innovations in bamboo could be a low-cost building solution in the region.

5.3 Japan

An ecological project in Japan was reported by Horiuchi et al (2010) to revive Satoyama watershed landscapes. Here, stakeholders including the original Satoyama management groups, governmental bodies, residents and non-residents, and non-governmental and non-profit organizations have all joined hands to preserve reed (*Phragmites communis*) communities. The efficient use of wood and bamboo for the construction of wave dissipation structures became the facilitator of the expansion of reed communities. On the other hand, Nagase (2020) evaluated the performance of reused materials in Chiba, Japan. Reused materials were used as alternative materials for commercial substrates and drainage layers. The study used a commercial green roof substrate and cocopeat as the substrate, while drainage layers were made using bamboo stems and nodes and other reused supporting materials. The reused materials were observed to function well as commercial green roof materials. In the drainage layers, reused materials such as polyethylene terephthalate bottle caps and bamboo nodes were better. This suggests that bamboo-based materials could be a sustainable source for inexpensive green roofs. Recently, Sawarkar et al. (2023) documented the medicinal value of bamboo used in China, India, and Japan. High market-demand products derived from bamboo, such as bamboo salt, bamboo dietary silica, bamboo charcoal soap, bamboo tea, Banslochan, and bamboo vinegar, were examined. These products are used in the treatment of obesity, inflammation, heart disease, hypertension, and arteriosclerosis. In addition, the commercialization of bamboo products for future medicinal/therapeutic values was suggested.

5.4 Thailand

Totum (2024) indicated the possible enhancement of the grassroots economy via value-added pickled bamboo shoots in Thailand. The author conducted empirical research for the findings. It was observed that the community is involved in educational activities with regard to hygienic production processes and that their products demonstrated durability, aesthetic value, and consumer acceptance. This study concluded with sustainable economic growth based on pickled bamboo shoots contributing to the preservation of a cultural heritage. Recently, Baur et al. (2025) showed the potential of bamboo with sugarcane leaves in the preparation of biomass pellet quality for sustainable biofuel production in Thailand. The authors combined sugarcane leaves with bamboo at different ratios for combustion properties. The sugarcane–bamboo pellets yielded calorific values parallel to those of essential biomass fuel standards. Their results showed that the pellets made with sugarcane–bamboo at a 3:2 ratio met the International Organization for Standardization (ISO) standards. This study demonstrated bamboo blending as an effective approach to optimizing solid fuel properties.

5.5 Ethiopia

Desalegn and Tadesse (2014) examined the prospect of bamboo for sustainable management and utilization in Ethiopia. The authors also derived challenges such as land use alteration, bamboo mass flowering, inadequate processing with low value addition, and biodeterioration caused by agents such as termites, beetles, and fungi. They emphasized the utmost importance of proper protection methods including Tanalith and motor oil to enhance the durability, service life, and rational use of bamboo-based structures and products as possible alternative furniture and construction material. Concurrently, Mekonnen et al. (2014) highlighted their observations on massive bamboo flowering followed by fall down that needs a management intervention. They noted that the import of bamboo products exceeded the export despite the resource base of the country. This study suggested policy interventions to enhance technological innovation, upgrading and integrating the bamboo value chain and promoting sustainable management of the resource base. In a recent study, Mekonnen et al. (2021) documented the restoration of Bale monkeys (*Chlorocebus djamdjamensis*) and bamboo forests in Ethiopia. The Bale monkey is an endangered primate confined to a limited area in the southern Ethiopian Highlands and is dependent primarily on a single bamboo species. The conservation of both Bale monkeys and bamboo is highly interdependent. The research outcomes demonstrated that Bale monkeys met both the flagship and the umbrella species criteria to restore bamboo forests and conserve threatened co-occurring species. In addition, sustainable harvest and management regime for bamboo contributed toward enhancing the livelihood of both Ethiopians and the local community.

5.6 Kenya and Chad

Besides Ethiopia, African countries such as Kenya and Chad have also shown advanced use of bamboo. Habibi et al. (2023) reported the use of bamboo as a building material in low-income housing projects in Kenya. Their study explored the typical design of a bamboo residential house with bioclimatic design strategies. The authors highlighted the feasibility of bamboo to minimize financial and environmental impacts, which is considered as a "green steel" for its low weight and easy harvesting attributes. Following this, Nadir et al. (2024) reported the hydrological response of bamboo plantations on the soil–water dynamics in humid and semi-arid coastal regions of Kenya. This study evaluated bamboo tree plantations for soil–water infiltration, bulk density, runoff, and soil loss. Their observations showed reductions in the surface runoff volumes and sediment loss. It was concluded that well-managed bamboo plantations could be a soil and water conservation tool in Kenya. A recent study by Zanguim et al. (2024) revealed the potential of bamboo for socioeconomic development, environmental protection, and biodiversity in Chad. Multiple GPS-enabled images were used to map the presence of bamboos in three distinct climatic zones of the country: the Guinean, Sudanian, and Sahelian zones. This study provided a sound basis for the sustainable management of bamboo resources in Chad, as well as the development of policies aimed at reducing rural poverty and integrating bamboo management into systems for combating desertification.

5.7 Brazil

Bonilla et al. (2009) examined the assessment of sustainability of a giant bamboo plantation in Brazil with regard to total energy flow in countries such as Brazil, Australia, and China. In their research, ranked values of the energy sustainability index (ESI) revealed that the Chinese bamboo production ranked first, followed by Brazil and Australia. The introduction of indirect renewability embedded in labor led to adjustments in the ranking, making the plantation in Brazil first, followed by the Australian and Chinese plantations. On this basis, indirect support areas of bamboo production were quantified as a means to analyze the relationship between sustainability and space. Subsequently, De Moraes et al. (2012) emphasized the assessment criteria for non-conventional materials and technologies (NOCMAT). The authors noted the successful outcomes in Brazilian research centers when utilizing NOCMAT from bamboo, vegetable fibers, biocomposites, and recyclable traditional materials, among others. In addition, they proposed the necessity of governmental incentives and the inclusion of private institutions for economic improvement in Brazil. The work by Latini et al. (2024) concerns the use of bamboo in sustainable buildings in Brazil. They observed that South American bamboo species are understudied and are unknown relative to their Asian equivalents. Brazil has been increasingly interested in aqueous disodium octaborate tetrahydrate preservative treatments. The use of disodium octaborate tetrahydrate preservative treatment has promoted the development of a prototype with low costs in the production of bamboo. In addition, the Amazon area, i.e., the Amazon rainforest, is the biggest tropical rainforest globally situated in South America. Rockwell et al. (2007) evaluated the forest in southwestern Amazonia for the impacts of a certified community timber management project. On the other hand, D'Oliveira et al. (2013) gave special emphasis on forest management in a bamboo-dominated western Amazon forest in the Brazilian range. Rockwell et al. (2014), in another research, revealed that the bamboo-dominated forests in southwestern Amazonia have provided opportunities for smallholder forest management.

5.8 Colombia

Archila-Santos et al. (2012) had been working on Guadua Angustifolia Kunth (Guadua), a tropical bamboo species indigenous to South and Central America and primarily utilized as a principal material source of construction in Colombia. The authors documented that Guadua construction was considerably boosted after several Guadua-built structures survived or sustained only minor damage from an earthquake, which was 6.2 on the Richter scale, in 1999, which led to the standardization of Guadua in the seismic-resistant Colombian code. The authors described the case study of a recently constructed holiday home by demonstrating the architectural, structural, environmental, and technical performance of a Guadua building. They emphasized that issues concerning manufacture, biodeterioration, integration with traditional systems, and environmental effects need to be resolved. Recently, Quintero et al. (2022) conducted a structural analysis of a Guadua bamboo bridge in Colombia as per national regulation NSR-10. This footbridge was designed as an overbridge for pedestrians to cross the roads. The research concluded the structural study of the existing bamboo footbridge by providing proof of the viability of the design and construct of this type of structure. It was found that bamboo structures have benefits such as sustainability, affordability, and quick assembly. In addition, this natural material can be utilized for building in isolated parts of developing nations as a solution to infrastructure shortages. In a recent study, Camargo-Caicedo et al. (2025) evaluated the environmental dynamics and ecosystem services of Guadua bamboo in San Jorge River Basin, Colombia. The authors conducted a social assessment through participatory workshops and semi-structured interviews with fishers, artisans, authorities, and non-governmental organization (NGO) representatives. Their findings reflect the dual role of Guadua bamboo as a natural buffer against environmental hazards and as a renewable resource. In addition, they provided suggestions for land use policy and sustainable management practices to sustain species conservation for future prospectus.

5.9 European countries

Although less attention has been given to bamboo in European countries compared with the rest of the world, bamboo has impacts on the construction and music industries. Van Der Lugt (2005) assessed bamboo as a building material in Western countries. The authors identified bamboo culms as environmentally and financially sustainable compared with building materials such as steel, concrete, and timber in Western Europe. Furthermore, a case study on temporary European bamboo buildings, structures, and bridges was presented in order to determine factors of success and failure in building with bamboo. The results of these studies indicate that bamboo is a sustainable source of building material. Later on, Wegst (2008) demonstrated the versatility of bamboo in the music industry. Under the temperate climate of Europe, the grass bamboo prevailed and is often selected for the production of wind, string, and percussion instruments. Moreover, the researcher discussed a material science overview of bamboo for its special and highly optimized structure and properties. Acoustic characteristics such as the speed of sound, the characteristic impedance, the coefficient of sound radiation, and the loss coefficient were compared. The study established that bamboo is perfectly suited for the production of xylophone bars and chimes, flutes and organs, violins and zithers, violin bows, and strings. Recently, Depuydt et al. (2019) had been working on the four bamboo species cultivated in Europe for the study of a long bamboo fiber for composite purposes. The seasonal study in their work showed that harvesting during the autumn or winter resulted in greater extraction yields with greater mechanical properties.

6 Policy interventions for bamboo as the green gold of ecosystems in the UN SDG Framework

Based on a comprehensive analysis of the UN SDG Framework and the various case studies on bamboo, the following strategic interventions are proposed to leverage its unique potential (Figure 4).

6.1 Promote bamboo-based rural livelihoods and poverty alleviation

According to Panda et al. (2022), bamboo cultivation and processing have the potential to generate sustainable rural livelihoods for rural communities, women, indigenous groups, and smallholder farmers. Through inclusive value chains and fair-trade models, governments can decrease poverty levels with assurance of equitable access to markets (Kumari et al., 2024). This is in line with SDG 1.2 (cutting poverty by at least half), SDG 8.3 (supporting small-scale enterprises), and SDG 10.2 (empowering the marginalized). The inclusion of policy interventions should encompass microfinance incentives, cooperatives among farmers, and entrepreneurship training focused on bamboo crafts, housing, energy, and construction materials (Pérez et al., 2004). The integration of bamboo into rural development policies can make it an equalizer economically, lowering rural-to-urban migration stresses and supporting resilient local economies.

6.2 Integrate bamboo into climate change mitigation and adaptation policies

Song et al. (2011) highlighted that the high growth rate and carbon sequestration capacity of bamboo make it a good nature-based climate mitigation solution. Bamboo plantations should be incorporated into national climate action plans (nationally determined contributions, NDCs) and carbon credit programs of governments (Xie et al., 2025). This enhances SDG 13.2 (incorporate climate actions into policy) and SDG 15.2 (encourage sustainable forest management). Maddalwar et al. (2024) emphasized adaptation strategies that must promote bamboo for restoring ecosystems, preventing soil erosion, and making landscapes resilient to flooding. This does not only enhance local adaptation but also provides communities with climate-resilient livelihood opportunities. Strategically oriented bamboo-based adaptation supports the attainment of SDG 11.5 (disaster impact reduction) through enhanced natural defences.

6.3 Strengthen the role of bamboo in sustainable construction and affordable housing

Bamboo is a high strength-to-weight construction material with multiple uses, and it can provide an economical and eco-friendly substitute for conventional materials such as steel and cement (Vagestan et al., 2025b). The inclusion of bamboo into green building standards and city planning can help achieve SDG 9.4 (improve infrastructure for sustainability), SDG 11.1 (ensure safe and secure housing), and SDG 12.2 (sustainable use of resources). Policy measures need to encourage bamboo-based building by offering subsidies, tax relief, or certification schemes (Chilton et al., 2025). Fostering research and standardization in the technologies of bamboo building will enhance the safety, scalability, and confidence among buyers (Huang et al., 2025). This will provide the option of housing using bamboo for low-income groups while minimizing the environmental impact of cities.

6.4 Encourage bamboo in a circular economy and as a bioplastic alternative

Bamboo fibers and extracts provide bio-based alternatives to fossil plastics and synthetic products. Authorities need to promote research, industrial collaborations, and patent-based innovation in bamboo-based bioplastics, textiles, and composites (Cheng et al., 2025b). This promotes SDG 12.5 (minimize waste generation), SDG 9.5 (increase research), and SDG 14.1 (minimize marine pollution). Policy structures can enable the involvement of bamboo in circular economy systems through its incorporation into extended producer responsibility programs and plastic reduction targets (Abo and Areti, 2025). By encouraging eco-innovation, bamboo can promote a shift toward biodegradable packaging and minimize the use of petrochemicals. This enhances sustainability both in the production and consumption phases.

6.5 Strengthen ecosystem services by bamboo-based land restoration

Bamboo plays a critical role in soil stabilization, water conservation, and support for biodiversity (Cao et al., 2025). Land degradation neutrality strategies can directly incorporate bamboo plantations in an effort to meet SDG 15.3 (fight desertification and restore degraded land) and SDG 6.6 (conservation of water-related ecosystems). Policies must favor bamboo agroforestry, watershed conservation, and green buffers around cities (Tomar et al., 2025). These interventions not only restore the ecological balance but also create co-benefits in biodiversity conservation (SDG 15.5) and sustainable agriculture (SDG 2.4). The multi-functionality of bamboo makes it act as a bridge between livelihoods and conservation.

6.6 Advance bamboo research, innovation, and knowledge sharing

Long-term investments in bamboo research and development (R&D) will tap new technologies and uses (Bhatt et al., 2025). Innovation centers, patent creation, and technology transfer should be financed through public–private partnerships to stimulate bamboo-based industries (Dai et al., 2025). This is a direct contribution to SDG 9.5 (increase scientific research) and SDG 17.6 (increase knowledge sharing). The education curricula and capacity development programs must include bamboo science and sustainability topics. International knowledge-sharing platforms, especially in the Global South where bamboo is abundant, can foster innovation while minimizing the duplication of efforts (Iyiola et al., 2025). This promotes south–south cooperation and concurs with SDG 17.9 (capacity building in developing countries).

6.7 Enhance policy synthesis and international partnerships for bamboo

The multifaceted utilization of bamboo necessitates cross-sectoral policy integration between forestry, agriculture, energy, construction, and trade. Governments ought to create national missions on bamboo or inter-ministerial task forces embedding bamboo across various policy streams (Wijewickrama et al., 2019). This facilitates SDG 17.14 (policy coherence for sustainable development). Internationally, multilateral action should facilitate bamboo trade standards, equitable market access, and integration into green financing. Cross-border policy learning and international advocacy can be enabled by institutions such as the INBAR (International Bamboo and Rattan Organization) (Li et al., 2024). Such alliances will increase the global presence of bamboo by ensuring inclusive development strategies (SDG 17.11 and SDG 17.16).

These seven interventions establish a policy agenda that mirror the potential of bamboo in ecosystems, economies, and societies and connect directly to the UN SDG Framework.

7 Limitations and future prospects

Despite its enormous potential, bamboo faces several challenges that limit its large-scale integration into sustainability frameworks. Looking ahead, bamboo holds immense promise as a driver of green growth, climate resilience, and circular economy models. The present article derived a comparative table to highlight the contrast between constraints and opportunities (Table 4).

8 Conclusions

Bamboo has shown ecological and socioeconomic significance that extends to the international policy reformation toward sustainable transitions. The patent and paper publication trend has demonstrated the industrial and academic attention on bamboo. It was found that, within the time period 2018–2025 (August 2025), there were only 69 publications related to bamboo attaining SDGs, which has drawn more attention in the present study to work on bamboo attaining the SDGs. This article could be the first of its kind to quantify the 169 targets for bamboo on a scale of 1–10. The study identified a group of SDG targets that were achieved successfully, and there still is a scope to improve based on the comprehended policy interventions. The integration of artificial intelligence (AI), machine learning (ML), and remote sensing technology would enhance the sustainability metrics for bamboo.

TABLE 4 Contrasting the limitations and emerging prospects of bamboo as the "green gold" in ecosystem sustainability.

Limitations	Future prospects
Lack of standardized benchmarks: Without widely accepted global quality norms and certification mechanisms, the use of bamboo in construction and engineered products is limited.	Global standard development: Certification systems and international collaboration can build confidence, allowing bamboo products to match competing conventional timber and industrial materials.
Perishable nature: Bamboo can deteriorate with no treatment, posing challenges to long-term use in rural and industrial environments.	Technological advancement: Improvements in preservation technology, engineered bamboo products, and applications of nanotechnology will increase durability and open up more high-value applications.
Policy ambiguity: Grass/timber/non-timber forest product classification causes legal and regulatory confusion, hindering inclusion into national policy.	Policy alignment and international cooperation: Explicit recognition of bamboo across forestry, agriculture, and climate policy and efforts such as INBAR will enhance institutional uptake.
Socioeconomic limitations: Insufficient access to credit, markets, and value-chain opportunities prevents smallholder and rural community gains.	Inclusive growth prospects: Bamboo-based businesses, carbon finance, and rural cooperatives can be used to create jobs, empower women, and alleviate poverty.
Sparse data availability: Quantitative measurement of the 169 SDGs remains in its infancy due to limited measurable policy advocacy.	Evidence-based frameworks: Incorporation of bamboo into SDG target-oriented assessments and monitoring can yield strong evidence to inform policy and investment choices.
Regional gaps in adoption: Bamboo, in many regions of the globe, is underutilized, even where ecologically feasible.	Global scalability: The capacity of bamboo to be cultivated in degraded lands and its climate resilience make it a prime choice for extensive restoration and climate action schemes.

INBAR, International Bamboo and Rattan Organization; SDG, sustainable development goals.

FIGURE 4
Policy interventions and strategies for bamboo to leverage its unique potential for maximum achievement in the United Nations Sustainable Development Goals (UN SDG) Framework.

Author contributions

VM: Resources, Supervision, Formal analysis, Writing – original draft, Project administration, Software, Data curation, Visualization, Writing – review & editing, Investigation, Validation, Conceptualization, Methodology, Funding acquisition.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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