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Bamboo in a temperate climate: what potential for integration and application(s) in sustainable, low-carbon, and circular architecture?

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Abstract. This research examines the potential of bamboo as a sustainable construction alternative in temperate climates, focusing on Wallonia (Belgium) as the study area. It aligns with European objectives for transitioning toward a circular and carbon-neutral economy, as well as the ambition to make the existing building stock more energy-efficient by 2050. In response to growing pressure on forest resources, bamboo offers a promising solution for the building sector, particularly in terms of thermal insulation. The study has two main objectives: to assess the adaptability of certain species to temperate climates and to demonstrate their potential for sustainable renovation. The methodology is structured into four components, combining literature review, fieldwork, laboratory experimentation, and case analysis. The current focus of the research is on the first step, which aims to validate the adaptability of selected bamboo species to Wallonia. A preliminary assessment identified three promising species, *Phyllostachys edulis*, *P. iridescens*, and *P. makinoi*, due to their favorable morphological characteristics. Initial mapping highlights the northwest of Wallonia as a favorable cultivation area. These landscapes, which face significant ecological challenges, could benefit from the ecosystem services provided by bamboo. A detailed protocol for the morphological characterization of the species is being developed to support the next phases of the study. This research lays the groundwork for the integration of locally grown bamboo into sustainable construction practices, particularly as a low-impact, bio-based insulation material.

1. Context and background

Europe aims for a circular, eco-responsible, and carbon-neutral transition of its economic system. At the same time, it strives to make its existing building stock energy-efficient by 2050 through long-term renovation strategies. The construction sector, a major consumer of natural and energy resources, must increase its annual renovation rate to 3%, prioritizing materials with low environmental impact, long lifespan, and high potential for reuse and recycling. Among these materials, biobased materials, particularly wood, are regarded as environmentally friendly alternatives.

However, the increasing pressure on forest resources calls for new solutions. Bamboo, recognized for its mechanical strength, rapid growth, ecological sustainability, lightness, flexibility, and versatility, has long been valued in construction, especially in tropical and subtropical regions ^[1,2]. In recent years, it has also attracted increasing attention in Europe for its potential as an innovative, renewable, and eco-friendly material ^[3,4].



Recent research has highlighted bamboo's impressive tensile strength and ductility, sometimes exceeding those of wood or lightweight metals, though performance depends on species, age, growing conditions, and treatment methods. Physical properties such as density and moisture content are closely linked to durability and strength ^[1]. While thermal studies are less common, some bamboo-based panels have shown lower thermal conductivity than equivalent wood products ^[1,5,6], indicating potential for insulation use.

Despite this promise, bamboo remains underutilized as a thermal insulator, especially in non-structural forms like loose fill, flakes, or blocks. Most current applications focus on structural composites or innovative connection systems ^[1].

At the regulatory level, several international standards already govern the use of bamboo in construction (quality assessment, testing methods, durability, etc.) ^[7-11]. However, these standards remain largely unadapted to European national or regional contexts. Yet, the adaptability of certain bamboo species to specific European climates reinforces its potential as a complementary resource to wood for the construction sector. Such adaptation is essential to reflect local realities: specific climatic conditions, regulatory requirements, bamboo species available locally, or dimensional variations induced by changes in biotope/climate ^[12,13].

With growing demand for biobased insulation materials across Europe, bamboo presents a strategic opportunity. This research seeks to address two gaps: (1) the lack of data on bamboo's thermal performance in underexplored forms, and (2) the dual necessity of aligning international standards with national practices and formulating a technical reference framework for constructive applications to facilitate its integration into sustainable construction systems.

It also takes part in a broader strategy aiming to diversify locally available bio-based resources, reduce pressure on forests, and support the development of an emerging bamboo sector. Several hectares of bamboo are already cultivated in Wallonia, reinforcing the relevance of this region as a testing ground for sustainable innovation.

2. Goal and focus of the research

In this context, the research has two main objectives: (1) to demonstrate that certain bamboo species can be sustainably cultivated in European temperate climates, and (2) to show that these "adapted" species can contribute to European goals for sustainable and circular renovation, notably through an in-depth analysis of their constructive potential and environmental performance.

The first objective focuses on the Walloon region (south part of Belgium), an ideal study area due to its temperate climate (Cfb and Dfb), varied soils, landscapes, and the growing interest in bamboo cultivation and bio-based materials. The second objective explores the potential of bamboo for insulation applications, studying all parts of the plant (stems and leaves). Among the various forms available on the market (bulk, mattress, rigid panel), the research specifically focuses on bulk form, with fibre flakes-shaped and crushed granules-shaped materials, either raw and/or mixed with lime or earth. These minimally processed and low-energy materials are easy to implement in partitions (walls, roofs, floors) in a reversible manner ^[14].

3. Description of the methodological steps

The research methodology relies on an interdisciplinary, exploratory and eco-design approach to evaluate the potential integration of bamboo in temperate climates and within the European building sector. It consists of four parts (*Figure 1*): (1) the assessment of species adaptability in temperate climates; (2) the preparation of samples from selected species and the characterization of their physical properties as an insulation material; (3) the study of potential architectural applications of bamboo; and (4) the analysis of the environmental impact and circularity of the developed materials.

Only the first part of the research will be presented in this contribution, along with the preliminary results.

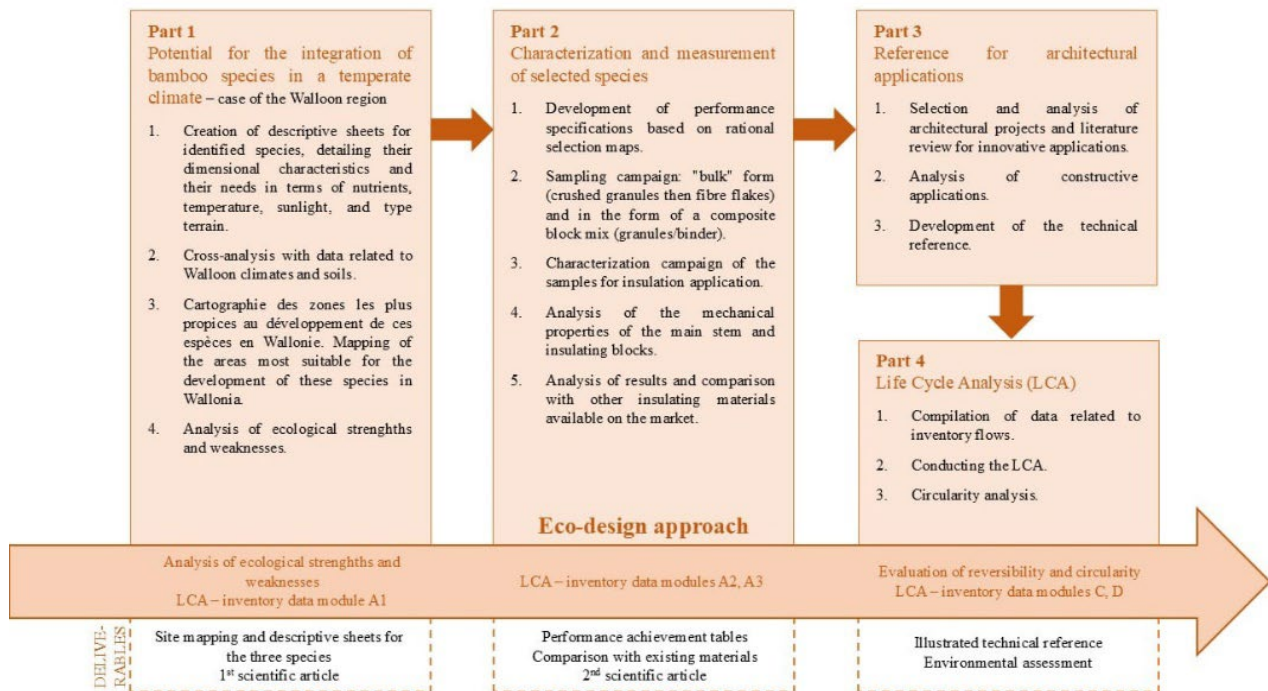


Figure 1. Diagram outlining the methodological steps of the research project – Source: A. Romboux

4. Deepening: Evaluation of species adaptability

Context and previous work

The first step of this research relies on a preliminary study developed in a master thesis, to explore the potential adaptability of specific bamboo species to the Walloon region and assess their suitability for sustainable construction applications. This study was developed in three steps, with the objective of: (1) identifying a selection of bamboo species compatible with temperate climates and sustainable construction uses; (2) identifying the most suitable areas in Wallonia for their cultivation; and (3) assessing the environmental relevance of such cultivation within the Walloon landscape.

The methodological approach has included an analysis of 50 species from the *Phyllostachys* genus, known for their compatibility with temperate climates, an analysis of the climatic and soil data in the Walloon region; and across referencing of the biological requirements of the species (nutritional, climatic, hydrological, pedological) with regional parameters (climate and soil). Those three analysis were developed based on scientific literature and consultations with local experts as well as data from the Royal Meteorological Institute of Belgium (IRM)^[15], the Walloon Environmental State^[16], and the Wallonia Geoportail^[17]

Preliminary results

Three species were selected as promising candidates based on their adaptability to Wallonia and their favorable morphological characteristics for construction: *Phyllostachys edulis*, *P. iridescens*, and *P. makinoi*. This selection was based on their capacity to produce large-diameter culms with thick walls.

The maps resulting from cross-referencing analysis highlighted the potential of the agricultural landscapes in northwest Wallonia (**Figure 2**), which offer favorable conditions for bamboo cultivation while also facing several ecological challenges: increased flood risk, poor ecological status of water bodies, and soil erosion due to diffuse water runoff. Although the area is predominantly agricultural, it also includes densely populated urban centers, where bamboo could play a key role in environmental management. Introducing bamboo into these territories would not only help stabilize soils and improve water retention but also enhance ecological resilience in urban areas by increasing biodiversity, reducing

urban heat islands, and mitigating flood risk. With its dense root system and evergreen foliage, bamboo thus represents a multifunctional nature-based solution that addresses the combined challenges of agriculture, ecology, and urban planning. It also contributes to carbon sequestration and climate change mitigation [2,18].

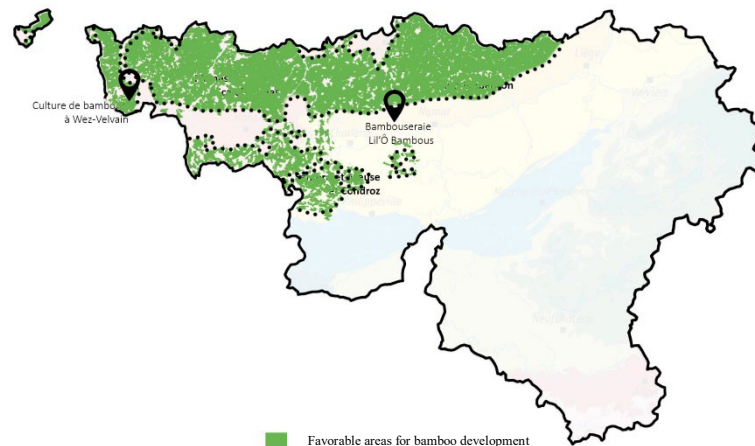


Figure 2. Favorable areas for bamboo development in Wallonia – Results of preliminary studies - Source: A. Romboux

However, several limitations were identified. First, the ecological impact of introducing these bamboo species remains uncertain, particularly regarding their potential invasiveness and interactions with local flora. Second, the existing literature does not provide a clear distinction between the specific requirements of individual *Phyllostachys* species, which complicates the selection of species best suited to temperate climates. Finally, the morphological and physiological characteristics of bamboo under local Walloon conditions are still under-documented. These characteristics may differ significantly from those observed in their native environments, potentially affecting the mechanical and physical performance of the material.

The first step of research seeks to address these current gaps to ensure the responsible and effective integration of bamboo into construction practices in temperate climates. Following the initial cartographic analyses and preliminary species selection, the study is now advancing along two complementary methodological axes: the development of detailed species-specific descriptive sheets and the establishment of a morphological characterization protocol to guide upcoming fieldwork phases.

Development of descriptive sheets

These sheets aim to systematically document the optimal ecological conditions, climatic sensitivities, locally observed morphological characteristics, and physiological behavior of each species. Inspired by the *Fichier Écologique des Essences* (Ecological Tree Database) [19], they integrate bibliographic sources, interviews with local cultivators, and initial field observations. The goal is to fill existing knowledge gaps regarding the targeted species.

4.1. Development of a measurement protocol and revision of species selection

A measurement protocol is currently being developed, drawing on ISO 19624, relating to the classification of bamboo culms, and methodologies from recent literature [20–23]. This protocol aims to establish a reproducible methodology that can be transferred to other European regions where bamboo cultivation is developing.

It includes three main phases:

1. Identification of plantations: location, surface area, age, cultivated species.

This phase will inform the definitive selection of a limited number of species for advanced physical and mechanical property testing.

2. Sampling and drying: selection of standard culms per selected species, air-drying, and collection of environmental parameters (age, management, exposure, soil type, temperature, altitude).
3. Morphological measurements: total height, number of internodes, diameters (base, middle, top), and wall thickness. These morphological characteristics are directly linked to the mechanical and physical properties that influence the architectural applications of bamboo.

In parallel, an analysis of bamboo buildings applications in Europe and abroad is being carried out to identify the species most used in construction, and the key morphological traits that make them suitable for architectural purposes.

5. Conclusions and perspectives

This research aims to demonstrate the feasibility of sustainable bamboo development and cultivation in temperate climates and its potential applications in buildings supporting a more sustainable and circular architecture. Preliminary studies have identified Northwest Wallonia as a suitable area, with three species adapted for construction. Despite their high potential for the construction sector, their integration must be strengthened through studies on potential applications, such as insulation materials and assembly techniques.

The research is guided by an eco-design approach, to develop contextually adapted constructive solutions. This approach will consider the ecological strengths and limitations of the species, the technical reversibility of architectural applications, and the environmental impact of the materials developed.

The data from the first research step will serve as a foundation for the next steps of the study. On the one hand, they will help identify the species most suitable for local conditions, facilitating their selection for upcoming physical and mechanical testing. On the other hand, they will help anticipate constraints related to the supply, exploitation, and transformation of bamboo at the regional level.

These results align with the European objectives of a circular economy and address the growing demand for sustainable and locally sourced construction materials, and particularly insulation materials. By integrating bamboo into the built environment, this research contributes to the development of innovative and environmentally friendly solutions, enhancing the resilience of regions in the face of climate challenges while supporting the transition to a circular economy and carbon neutrality.

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References

- [1] Adier, M. F. V., Sevilla, M. E. P., Valerio, D. N. R., & Ongpeng, J. M. C. (2023). Bamboo as Sustainable Building Materials: A Systematic Review of Properties, Treatment Methods, and Standards. *Buildings*, 13(10), Article 10. <https://doi.org/10.3390/buildings13102449>
- [2] Liese, W., & Köhl, M. (Éds.). (2015). *Bamboo: The Plant and its Uses* (Vol. 10). Springer International Publishing. <https://doi.org/10.1007/978-3-319-14133-6>
- [3] Borowski, P. (2019). Bamboo as an innovative material for many branches of world industry. *Annals of WULS, Forestry and Wood Technology*, 107, 13-18. <https://doi.org/10.5604/01.3001.0013.7632>
- [4] Fritz, H., & Kraus, M. (2024). Natural geometrical variations of Italian *Phyllostachys edulis* bamboo culms for construction purposes. *Advances in Bamboo Science*, 9, 100116. <https://doi.org/10.1016/j.bamboo.2024.100116>

- [5] Shah, D., Bock, M., Mulligan, H., & Ramage, M. (2016). Thermal conductivity of engineered bamboo composites. *Journal of Materials Science*, 51. <https://doi.org/10.1007/s10853-015-9610-z>
- [6] Wang, J. S., Demartino, C., Xiao, Y., & Li, Y. Y. (2018). Thermal insulation performance of bamboo- and wood-based shear walls in light-frame buildings. *Energy and Buildings*, 168, 167-179. <https://doi.org/10.1016/j.enbuild.2018.03.017>
- [7] ISO 22156:2021. Bamboo structures - Bamboo culms - Structural design. <https://www.iso.org/fr/standard/73831.html>
- [8] ISO 22157:2019. Bamboo structures - Determination of physical and mechanical properties of bamboo culm - Test methods. <https://www.iso.org/fr/standard/65950.html>
- [9] ISO 21625:2020. Vocabulary related to bamboo and bamboo products. <https://www.iso.org/fr/standard/71279.html>
- [10] ISO 23478:2022. Bamboo structures - Reconstituted bamboo products - Test method for the determination of physical and mechanical properties. <https://www.iso.org/fr/standard/75683.html>
- [11] ISO 19624:2018. Classification of bamboo culms for structural applications. <https://www.iso.org/fr/standard/65528.html>
- [12] Minke, G. (2022). Building with bamboo : Design and technology of a sustainable architecture. Birkhäuser.
- [13] Kaminski, S., Lawrence, A., & Trujillo, D. (2016). Structural use of bamboo. Part 1 : Introduction to bamboo. *The Structural Engineer*, 94(8), 40-43. <https://doi.org/10.56330/PNSC8891>
- [14] Trachte, S., & Stiernon, D. (2023). Thermal insulation materials in renovation: Making a balanced choice between comfort, energy performance, environmental approach and circular resource management [in French]. EPFL press.
- [15] Royal Meteorological Institute of Belgium. (n.d.). *Climate data* [in French]. Retrieved October 25, 2024, from <https://www.meteo.be/fr/climat>
- [16] Public Service of Wallonia. (n.d.). *State of the Walloon environment* [in French]. Retrieved October 25, 2024, from http://etat.environnement.wallonie.be/cms/render/live/fr_BE/sites/eew/home.html
- [17] Wallonia Geoportal. (n. d.). *Homepage* [in French]. Retrieved March 18, 2025, from <https://geoportail.wallonie.be/home.html>
- [18] International Network for Bamboo and Rattan (INBAR). (2014). Bamboo: A strategic resource to help countries mitigate the impacts of climate change - Strategic Synthesis Report 1 [in French].
- [19] Ecological Tree Database. (n. d.). *Ecological file of species* [in French]. Retrieved February 26, 2025, from <https://www.fichierecologique.be/#/>
- [20] Wang, Y., Qiao, G., Xu, J., Jin, K., Fan, M., Ding, Y., Wei, Q., & Zhuo, R. (2022). Anatomical Characteristics and Variation Mechanisms on the Thick-Walled and Dwarfed Culm of Shidu Bamboo (*Phyllostachys nidularia* f. *Farcta*). *Frontiers in Plant Science*, 13. <https://doi.org/10.3389/fpls.2022.876658>
- [21] Glele Kakaï, R. L., Salako, V., & Lykke, A. M. (2016). Sampling techniques in vegetation studies [in French]. *Annals of Agricultural Sciences*, 20, 1-4.
- [22] Zhang, Z., Rao, F., & Wang, Y. (2022). Morphological, Chemical, and Physical–Mechanical Properties of a Clumping Bamboo (*Thyrsostachys oliveri*) for Construction Applications. *Polymers*, 14(17), 3681. <https://doi.org/10.3390/polym14173681>
- [23] Zheng, S., Wei, S., Li, J., Wang, J., Deng, Z., Gu, R., Fan, S., & Liu, G. (2024). The Phenotypic Variation in Moso Bamboo and the Selection of Key Traits. *Plants*, 13(12), Article 12. <https://doi.org/10.3390/plants13121625>