Abstract

The evolving landscape of environmental and economic challenges in the construction sector underscores the need for innovative material solutions. Wood is increasingly considered a viable alternative, offering a potential path forward. With its renewable nature, carbon sequestration potential, and favourable mechanical properties for its relatively low weight, wood differentiates itself from conventional materials. However, environmental crises and evolving climate conditions threaten the long-term stability of wood resources, underscoring the need for proactive and diversified strategies in resource management.

To address these challenges, this study presents *TUP4C* (Timber Utilisation Potential for Construction), a decision-support approach designed to assist multiple stakeholders in selecting suitable wood species for construction. The tool integrates economic, environmental, social and technical criteria within a holistic, multi-criteria decision-making framework. Its adaptable design allows for customisation to various stakeholder profiles, aligning with their priorities, targeted product categories, and strategic timeframes. In the preliminary phase of a project, the tool reveals diversification opportunities by considering new wood species aligned with a defined product and vision. An application in Wallonia (Belgium) demonstrates its ability to highlight lesser-known hardwoods while confirming spruce's industrial predominance for structural and exterior joinery applications.

By promoting the use of diversified wood species, *TUP4C* contributes to a more resilient and adaptive forestry-wood-construction sector, fostering sustainable resource management and strategic decision-making.

Keywords

- → Sustainable building materials
- → Wood species selection
- → Forest resource management
- → Multi-criteria decision analysis (MCDA)
- → Holistic selection methods

Article

Timber Species Selection for Sustainable Construction: A Holistic Approach to Species Assessment and Decision Support

1. INTRODUCTION

1.1 Wood Construction Sector

In recent years, the wooden building sector has generated increasing interest, driven by its potential role in mitigating climate change [1]. There has been a notable rise in scientific production in the field [2], [3]. This momentum aligns with the context of pressing environmental concerns. The buildings construction industry, driven by concrete, aluminium, and steel, is particularly energy-intensive and responsible for 6% of global CO_2 emissions in 2021 [4], [5]. In this context, wood stands out as a favoured material. It is a renewable resource that stores carbon, on average, 50% of a weight-to-weight basis [6] and plays a crucial role in substitution, reducing overall emissions by replacing carbon-intensive materials. In addition to its environmental benefits, wood presents attractive properties for construction, including good mechanical properties, the potential for prefabrication, and advantageous characteristics related to thermal comfort, aesthetics and lightness. [1], [7].

From an economic point of view, although the construction of wooden high-rise buildings is growing [8], the market share of wooden construction has remained at around 8 to 10% on average in Europe over the last few decades [9]. Although widely used in the Nordic countries, this method of construction remains relatively minor in several European countries [9], [10], [11], [12]. In Belgium, for instance, new wooden housing construction represented 6.75% of residential building construction in 2022, and the sector's growth seems to be slowing, with the share of wooden constructions stagnating in recent years [13]. Several factors may explain this phenomenon, including the COVID-19 pandemic and the net increase in energy prices during this period [13]. However, if current interest in scientific research is followed by the construction market and public policies promoting the use of renewable materials are implemented, an increase in demand for wood in the construction sector can be expected [14], [15], [16], [17], [18].

1.2 Contemporary Challenges

The forest-based sector currently faces numerous challenges, with pressures likely to intensify as the market evolves and environmental conditions change. One of the sector's critical challenges concerns the role of forest carbon sinks in mitigating climate change [19], [20], [21]. Forest carbon sink represents the difference between stored and emitted CO_2 flux from forest resources. Maintaining a positive sink is crucial for absorbing fossil carbon emissions and regulating atmospheric greenhouse gases [21]. However, balancing production and conservation is complex due to increasing wood demand [22] and external pressures from decarbonisation strategies, including carbon offset systems and substitution [23], [24].

Besides, climate change has complex effects on forests. While increased temperatures and CO_2 levels could enhance forest productivity in coming years [19], [20], [22], [25] , more frequent extreme weather events and exotic pathogens threaten forest health [19], [25], [26]. The slow migration rates of tree species can hardly match the pace of climate change [26], endangering forest ecosystem sustainability. Although diversified silvicultural practices could strengthen forest resilience [27], [28], [29], [30], [31], [32], current monoculture systems and intensive softwood species exploitation increase vulnerability to disturbances [32], [33], [34].

Environmental crises complicate wood industry supply chains [35]. Climate events and biological disturbances cause resource availability fluctuations, while recent health (COVID-19) [36] and geopolitical [37] crises have highlighted regional supply dependencies.

Raw material supply instability generates high volatility in wood resource prices and directly affects construction stakeholders [38], [39]. It also creates a risk of wood losing competitiveness against materials with more stable prices or produced by better-capitalised industries, whether foreign wood products or other construction materials. Competition between wood uses (construction, furniture, packaging, energy) intensifies resource pressure [40], [41]. This competition is exacerbated by specific dynamics, such as the strong competitiveness of wood energy in terms of processing and potential incentives provided by public policies promoting renewable energy use in line with EU objectives. This competition necessitates usage prioritisation for optimal carbon and material conservation [42], [43], [44].

These considerations highlight, namely, the importance of local resource production and consumption [45]. However, the forest-wood industry's fragmented structure hinders sector-wide strategy implementation [18]. Additionally, forests' multifunctional nature providing various ecosystem services (economic, ecological, recreational, cultural) [46] requires careful balance of local forestry activities with public perception, demanding clear communication about sustainable forest management.

1.3 Proactive Resource Management

The forest-wood sector requires proactive resource management to address current and future crises. Several techniques have been developed at the European level to promote sustainable forest management, including dynamic silviculture methods based on species diversity and forest cover maintenance such as continuous cover forestry (CCF) [33], [47], or assisted migration to help species occupy more appropriate environments [48]. At the regional level, in Belgium, these innovative practices have been implemented in projects such as *Pro Silva* [49] and *Trees For Future* [50]. The development of new value chains for certain underutilised broadleaf species [51] or the establishment of micro and mobile-sawmills to process marginal species in peri-urban areas [52] are also projects attempting to develop alternatives to traditional exploitation methods in Belgium.

Given the growing interest in wood and the need to prioritise sustainable resource management, the forest-wood-construction sector require comprehensive shared tools to support collective and coherent decision-making. Aligning the strategies of diverse stakeholders—such as forest managers, architects, builders, and policymakers—is essential to address future challenges. I Such considerations outline the interest for decision-support tools promoting wood species diversification, namely allowing reducing pressure on softwood species such as spruce, which is suffering from bark beetles in Belgium [53].

This paper proposes a decision-support tool designed to evaluate the suitability of wood species for the construction sector. It evaluates the relevance of these species based on sustainability criteria and their technical performance for specific applications. The tool is designed to accommodate the diverse contexts and decision-making needs of stakeholders across the forest-wood-construction value chain. The structure of the article is as follows. First, the issue of material selection is introduced, with a focus on existing tools for selecting wood species in relation to the previously outlined challenges. Next, a holistic framework is presented, detailing the hierarchical structure of the approach and the indicators identified as relevant for analysis. This theoretical section is intentionally separated from the practical evaluation methods, which are addressed in Chapter 4, including the multi-criteria assessment approach and weighting principles. Chapter 5 provides an application of the tool in Wallonia (Belgium), using two

user profiles to illustrate its versatility. Finally, the conclusion summarises the tool's contributions and limitations and suggests potential improvements. Key insights from the case studies are also highlighted.