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# Forest management for urban environment-nature connection

In the evolutionary history of the human species, the time spent living in industrialised cities is much less than that spent in almost natural contexts. The concept of promoting the so-called regenerative environments is spreading. These are types of places that promote the well-being of individuals, groups, and communities. The wild natural environment itself is the proper regenerative environment. But people who are not used to spending time in nature cannot have the direct ability to come into contact with it. So, promoting the presence of natural elements in urban contexts would be desirable. The first step is choosing wood as the primary building material. It constitutes a viable answer accepted by the scientific community to the issue of sustainable building as a renewable resource with the ability to store CO2. However, the use of this resource depends on the study of proper forest management, which is the only guarantee for obtaining a certified product to use in construction. South Italy has no managed forest areas, so it cannot have locally certified woods that are usable for structural purposes. In this scenario, this study aims at the dual objective of: (i) analyse and promote the short wood supply chain in South Italy (ii) propose an experimental case study, Euterpe©, to be realised with wood species of South Italy.
Euterpe© is an island/musical classroom, acoustically adequate and entirely autonomous, usable not only for teaching music in high schools but also to offer the opportunity to listen to natural sounds, recorded even during direct forest therapy practices. It is becoming, in effect, an indirect driving force to approach such practices.

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Keywords:
forest management; wood; indirect forest therapy; short wood supply chain; South Italy


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## INTRODUCTION

The construction industry has a significant environmental impact and must address sustainability throughout a structure's lifecycle. Urbanized living environments in the Western world contribute to rising mental health issues, yet opportunities to connect with nature remain rare.
In this context, wood, as a natural and renewable resource, plays a key role in modern construction. Its technical, economic, and environmental benefits enhance occupant well-being and comfort (Frunzio et al., 2023). Previously, achieving comfort in buildings was linked to higher costs (Legros et al., 2020), but today, comfort aligns with energy efficiency. Wood buildings are increasingly valued for reducing environmental impact while improving comfort (Legros et al., 2019, 2020; Nore et al., 2017). Thanks to its hygroscopic properties, wood provides excellent thermal and acoustic insulation, olfactory perception, and moisture control (Ojanen, 2014).
Studies in France (Legros et al., 2020), China, and Canada (Rice et al., 2007) indicate that users perceive wood positively based on age and gender (de Simone & Fajilla, 2019; Hermawan et al., 2020). However, housing problems are often not addressed through user experience (Gram-Hanssen, 2014). Understanding expectations is crucial for bio-economy enterprises, as neglecting them can lead to failure (Caru A. & Cova B., 2007; Toppinen et al., 2018). Users prioritize aesthetics and well-being over environmental concerns, considering social, cultural, economic, and psychological factors more than technical ones (Gold & Rubik, 2009; Hakala et al., 2015; Larasatie et al., 2018; Roos & Hugosson, 2008).
Promoting regenerative environments is gaining popularity, as these spaces foster well-being, reduce stress, restore attention to nature, and improve social relationships (Kylkilahti et al., 2020).

| | | | | | |
|---|---|---|---|---|---|
| *floor area* | [m²] | 100 | 150 | 200 | 250 |
| *wooden volume used* | [m³] | 9.0 – 13.0 | 13.0-16.0 | 16.0-21.0 | 21.0-25.0 |
| *$CO_2$ stored* | ton $CO_2$eq. | 9.2 | 11.3 | 14.9 | 17.7 |

Table 1. C02 stored in wooden buildings.

Familiarity with timber is key to its appreciation, economic and social benefits, and environmental respect. The wild natural environment itself is the ultimate regenerative setting. Practices such as forest bathing are rapidly spreading (Mazzoleni et al., 2024). Since forests have been a raw material source for centuries, it is crucial to address the issue of limited contact with nature, particularly for urban dwellers. Encouraging design solutions that integrate natural elements in cities can strengthen this connection. Choosing wood as a primary building material is a fundamental step due to its strength and natural properties.
The wood supply chain starts with forests, where proper management ensures sustainable raw material harvesting (Lewark, 2022; Motta & Larsen, 2022; Yamada, 2018). The next step is grading and processing the wood into structural elements, which offer low environmental impact, quick construction, lightweight, and versatility. Wood contributes to urban regeneration, facilitating interventions in schools, museums, residential buildings, offices, sports facilities, and more (Di Gennaro et al., 2022; Di Gennaro, Frunzio, et al., 2023; Di Gennaro, Guadagnuolo, et al., 2023; Frunzio et al., 2019) through volumetric additions (Frunzio et al., 2022) and elevations. In urban contexts, wood enables targeted, adaptable, and non-invasive interventions that merge structure and architecture. It is increasingly used not only for new buildings but also for structural and energy retrofits of existing ones.
Given the current climate, there is a growing need for sustainable, structurally safe solutions that comply with energy-saving policies through effective thermal insulation. Wood meets these requirements, offering strong structural and energy performance. Wood-based systems can be used for framed structures and endoskeletons or to enhance masonry walls' local in-plane and out-of-plane performance using reinforced mortars or panels.
This paper analyzes the benefits of proper local forest management, focusing on the short wood supply chain in Southern Italy. It also presents an experimental case study, Euterpe©, a musical

Figure 1. Example of Mediterranean forest (photo by Luigi Massaro).

Figure 2. Carbon sink of a forest (photo by Luigi Massaro).



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classroom designed as an island-like space that reconnects people with nature.

## FOREST MANAGEMENT

Forests (Figure 1) cover about 30% of the Earth's surface. Tree species vary widely, even within the same area, due to diverse geographic conditions. In the past, skilled carpenters relied on common sense, knowledge, and experience to select and categorize wood (Massaro et al., 2023, 2024). Given the broad range of mechanical properties, regulatory classification is now essential to ensure consistency in structural design. Enlightened forest management is the only way to achieve this today.

Forest management and regulations developed differently across nations, and in some areas, they have yet to be implemented. The regulatory framework remains fragmented (Table 1). In Italy, the Consolidated Law for Forests and Forest Supply Chains (TUFF) (Testo Unico in Materia Di Foreste e Filiere Forestali (TUFF) - D.Lgs. 3 Aprile 2018, n. 34, 2018) was only introduced in 2018.

Many companies contribute to wood production, a sector aligned with the principles of the circular bio-economy and environmental sustainability. Wood has become a key component of the global economy. Public and private investments in sustainable infrastructure and construction are crucial for advancing sustainability and digitalization (Green Deal). According to the EU Climate Change Commission (Committee on Climate Change, 2019), timber construction helps mitigate global warming.

This study is based on Life Cycle Assessment data and Environmental Product Declarations (EPDs) for construction materials. The increasing use of

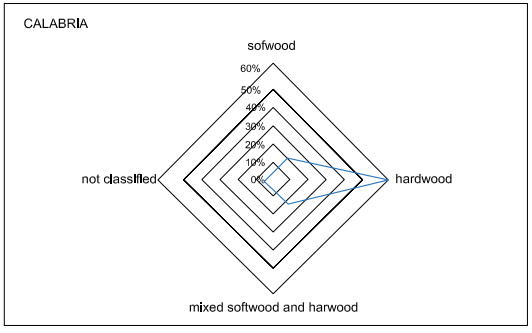
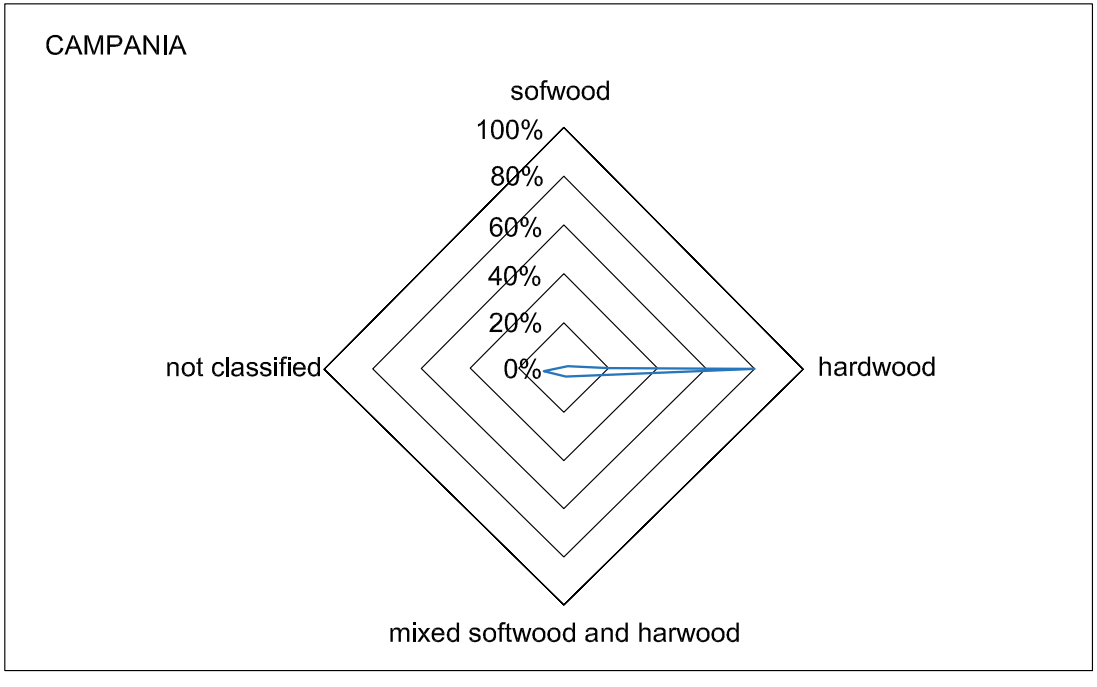
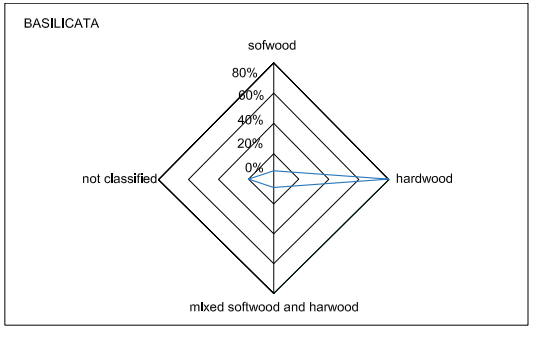



Figure 3. The resources available in Calabria.




On the left
Figure 4. The resources available in Campania.

At the bottom
Figure 5. The resources available in Basilicata.





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wood in the building industry presents a significant opportunity to lower greenhouse gas emissions, primarily due to its carbon storage capacity. To illustrate this, Table 1 shows the amount of carbon stored in a wooden house, based on data from the Italian Federation of Wood Industries, Federlegno®, assuming the use of Cross Laminated Timber panels made of spruce layers (FederlegnoArredo, 2021).

*Wood and the management of CO2 emissions*

The forest is a reliable resource that can meet the requirement for reducing greenhouse gas emissions as indicated in the (Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997). It imposes on the most industrialized countries to reduce greenhouse gas emissions, considering the forest carbon sinks and emission sources that result from land use change (afforestation and deforestation). Ecosystems' net absorption balance of CO2 is known as a carbon sink. The impact of human afforestation, deforestation, and forest or agricultural management on carbon stock levels is significant, while forest management and wood use help to decrease CO2 emissions.
The carbon cycle is largely a function of plant ecosystems. Acting as a reservoir and storage, they regulate fluxes between the atmosphere and the biosphere and indicate climate change. The CO2 stored by vegetation plays a crucial role in this framework. Various indices are chosen to estimate based on the available data and the type of analysis to be performed. In the literature, the total biomass is the primary parameter used. Above-ground biomass (AGB) (Das & Singh, 2012) and below-ground biomass (e.g., live roots, fine and coarse dead litter associated with the soil) are both part of this (Figure 2).
The focus is on AGB because of the difficulty in gathering remote sensing data on underground biomass (Lu et al., 2016). It is the dry mass of living or dead trees or shrubs (woody) matter above ground, expressed as mass per unit area (Penman et al., 2003). By calculating the AGB, it is possible to determine how much carbon vegetation sequesters, around 47.5% and 50% of dry biomass composed of carbon (de Gier & Roy, 2003).
Three methods can be employed in order to estimate AGB in general: the direct or physical method, the semi-empirical indirect method (allometric equations), and the indirect method (retro-sensing). Precision forestry is the name given to these operations.
The wood industry is centred around increasing the value of a product, tracing its origins, and verifying its characteristics through the possibility of turning greenhouse gas (GHG) emission reduction into tradable carbon credits. A carbon credit represents an emission reduction of one ton of CO2 or an equivalent amount of other greenhouse gases that can be traded on the market. (for this reason, the unit of measurement of credits is called CO2 e). Credit buyers can offset some or all of their greenhouse gas emissions with them. In developing countries, a carbon credits market makes it possible to reward the most efficient solution for reducing the greenhouse gases in the atmosphere. This is strongly joined to investments. For example, planting a forest in a developing country is easier than in Europe. However, this is not a "right to pollute". However, rapid climate change mitigation can be achieved through land use, forestry management, and conservation of existing forest carbon stocks (Bonan, 2008).
Two systems are provided by the Kyoto Agreement (Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997) for managing these credits:
•The Emission Trading System (ETS) is known as "cap and trade". Under the agreement, there is a cap on emissions, and those who exceed it can purchase (trade) the credits of those who emit less. One can compensate for emissions without reducing their own by buying them from others.
•Clean Development Mechanism, CDM. Under this system, CO2 emitters can offset their emissions by financing projects that reduce CO2 emissions in developing countries.
The ETS, the initial system, is predicted to trigger a 'cost-effective' cycle in which the price of carbon credits will tend to increase over time, which will encourage low-carbon production.
This scenario encourages countries to enhance and utilize their internal resources. Current data shows that the forest volume in Italy is increasing, but the annual harvest is lower than the growth rate. This means that Italy won't have to import wood from other countries for its industry. The current law requires certified wood, but the Italian woods are not certified, so the import is mandatory.
It is worth pointing out that the lack of certification is not due to the poor quality of the wood or to its defects but to the absence of proper forest management, which is the starting point of the wood supply chain.
As shown, forest management could allow the enhancement of an internal resource that is massively present in the territory.

## ITALIAN FOREST MANAGEMENT

Italian forests, which cover about 11 million hectares, are responsible for safeguarding the environmental heritage by preserving biodiversity in terms of biology, ecosystem, and culture. Additionally, they have the potential to play a crucial role in minimizing global climate change, and their management becomes a challenge to directly contribute to addressing the current climate crisis.
Wood and forest are commonly associated, but there is a distinct difference between them. The area of an Italian forest is typically at least 2.000 m2 and is usually maintained or controlled by humans. Instead, a forest is an uncultivated and wildland (Figure 4) with a much larger dimension of at least 10,000 m2.
The regulatory framework called 'Consolidated text on forests and forest chains' strongly impacts forest-related activities and protects them. (Testo Unico in Materia Di Foreste e Filiere Forestali (TUFF) - D.Lgs. 3 Aprile 2018, n. 34, 2018).
This framework also defines areas that "do not


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fall" within the definition of a forest: artificial origin formations on agricultural land.
In other words, new forest plantings are not connected to the forest discipline and are, therefore not subject to a set of strongly limiting constraints. This process complements the substantial revaluation of the use of solid and engineered wood in construction.
This method regains the centrality and implementation of forest management in forest planning. It also ensures the public's interest and establishes a National Forest Strategy to enhance the stakeholders who work with wood and non-wood products.

*The use of local wood: the Mediterranean area*
Improving the sustainability of the structure requires making it more resource-efficient and utilizing green technologies. Reviving the short forest-wood supply chain can be facilitated by using local wood as a driving force. Proper management of forests encourages the life of the forest, which involves controlling the felling of shrubs and cutting wood, which can be used to produce wooden structural elements. The production of heat can be achieved through the use of production waste, such as pellets and firewood.
It's worth noting that wood products will keep storing CO2. The CO2 saved must be added to the saved amount by selecting wood instead of another building material like steel or concrete. The percentage of emissions that are held must be combined with the significant decrease in transportation required to supply raw material when it is not in the production territory.
In the scenario, using local woods would represent a way to enhance the value of the Mediterranean forests. (Fragiacomo et al., 2015).
Starting from the data available from the last Forest Inventory for 2015 (Gasparini et al., 2022), Figure 3, Figure 4 and Figure 5 show the frame of the resources available in Campania, Basilicata and Calabria .
The data presented shows that there are a large number of internal resources available. The encouragement of using local wood could be linked to the need to re-connect the urban environment and nature.


Figure 6. The "forest" is "the therapy". (photo by Luigi Massaro)



Figure 7. Biblioteca of Viipuri, Lecture hall. (Photo Gustaf Welin © Alvar Aalto -säätiö Foundation).

## URBAN ENVIRONMENT-NATURE CONNECTION

Since it is now known that exposure to natural elements increases human well-being and increases the likelihood of adopting conscious behaviours, as well as aiding in the performance of significant recreational and cultural functions, interest in the use of natural resources in urban environments has grown in recent years (Figure 6). However, it is important to remember that those who are raised


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and born in highly anthropomorphized environments may find it difficult to experience direct contact with wild nature. Because of this, several studies demonstrate that cultivating a sense of connection with natural components in daily life might raise one's desire to interact with natural environments (Mencagli & Nieri, 2020; Mohamad Yahaya et al., 2023). Therefore, it is necessary to build vectors that encourage a connection to nature and environmental education in order to enhance the urban environment and encourage the reappropriation of its natural living environment. The building material, the purpose of these vectors, and the involvement of the local community —which is given a chance to reestablish an emotional connection with its primordial nature through naturalistic and environmental redevelopment— all play a crucial part in this context.

When it comes to construction materials, numerous credible examples have demonstrated—and continue to demonstrate—that wood is sometimes the best option for both architectural design and human-use goods ("Legnoarchitettura," 2022; Pettinau, 2015). A decision driven by the technical qualities of the material's low heat conductivity and astonishingly tactile comfort rather than a simple nostalgia for bygone eras.

A mention of Alvar Aalto and his wooden creations that are in direct contact with the surrounding natural environment would seem appropriate among these examples, ranging from the scale of detail to the architectural public and private: the Armchair 41 Paimio; Stool 60; the church of the Three Crosses; villa Mairea; villa Kokkonen; library of Viipuri, characterized by an auditorium room with wooden.

The years that separate the realization of these artefacts and the beginning of the new Millennium were characterized by a lack of interest in wooden buildings, but recently, these are subject to a new interest and wood as a building material is undergoing a new impetus. Examples include: the Kuokkala Church (OOPEAA Office for Peripheral Architecture), Finland, 2010; the Mjosa Tower (Voll Arkitekter), Norway, 2019, the tallest building in the world made entirely of wood; the Cross Lam Tower (DEMOGO), Jesolo, 2019, the tallest building in Europe almost totally made of wood; the Office Off (heri&salli), Burgenland, 2013; the Kilden Performing Arts Centre (ALA Architects), Kristiansand, 2012; Scuola di Danza (Mario Cucinella Architects), Reggiolo, 2018; the Auditorium Parco della Musica (Renzo Piano), L'Aquila, 2012, the first to have recognized the ARCA certification; the kindergarten (Mario Cucinella Architects), Guastalla, 2015 (Figure 8, Figure 9, Figure 10).

Figure 8. Left: Kilden Performing Arts Centre, ALA Architects (photo by Hufton+Crow); Right from top to bottom: Auditorium Parco della Musica, Renzo Piano; the Mjosa Tower, Voll Arkitekter (www. Infobuildenergia.it), Kuokkala Church, OOPEAA Office for Peripheral Architecture (flicrk Jyväskylän Seurakunta).


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On the left
Figure 9. The kindergarten, Mario Cucinella Architects ©Moreno Maggi.

At the top
Figure 10. Scuola di Danza, Mario Cucinella Architects. Top: photos by © Bellipario Geraldina. Below: © Paris render studio.

The bold forms of these examples demonstrate wood's versatility, as evidenced by government approval for its use in various structures. Beyond its adaptability, wood significantly reduces CO2 emissions throughout its life cycle, from production to disposal, enhancing environmental sustainability. The construction industry is a major source of global CO2 emissions, mainly due to energy-intensive production of cement, steel, and bricks. Wood, however, is renewable and absorbs CO2 through photosynthesis during growth. Wooden structures not only avoid the high emissions of other materials but also contribute to carbon sequestration. Wood processing is far less energy-intensive than conventional materials. Transforming timber into structural elements consumes much less energy than producing cement or steel, reducing fossil fuel use and emissions. Additionally, wood's lighter weight compared to concrete lowers transportation-related emissions. Future trends should minimize or eliminate the need for additional materials, maximizing wood's regenerative and renewable qualities. As seen in analyzed cases, a key advantage is its ability to be disassembled and reused, fostering circularity in construction and reducing environmental impact. Extending wood's lifespan limits construction waste and decreases demand for new materials, further cutting CO2 emissions. Wood also excels in bioclimatic architecture and energy efficiency. Its insulating properties improve buildings' thermal performance, reducing heating and cooling needs and lowering HVAC-related energy consumption and emissions. Since any designed space initiates a learning process where interaction with nature is essential, wood is more than an aesthetic or functional choice—it fosters ecological awareness and redefines sustainability. The future of architecture


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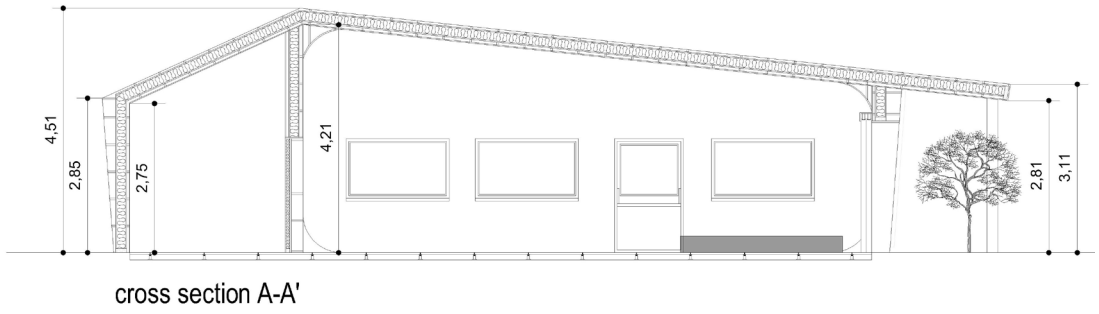


Figure 11.Cross section A-A' of Euterpe ©

Figure 12. External view of the three-dimensional model of the music classroom Euterpe©.
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depends on low-impact materials, and wood is among the most promising solutions for reducing the construction sector's carbon footprint.

## EUTERPE ©

Euterpe© is an island/musical classroom (Figure 11, Figure 12), acoustically adequate and entirely autonomous (Figure 13, Figure 14), usable not only for teaching music in high schools but also to offer the opportunity to listen to natural sounds, recorded even during direct forest therapy practices.
The inclusion of Euterpe © in schools would favour both reconnections with nature. It has a broad educational value. From an early age, users can develop the ability to listen and know both the music and the harmonies of nature. They can develop the ability to reproduce simple and complex sounds, achieving important pedagogical goals regarding attention, concentration, memory, hearing, verbal and expressive skills.
Being designed entirely of wood, its presence in an educational/training context could allow the spread of wood culture, improve the working/study environment by trying to reconnect closer to the natural elements and increase its use within urban contexts.
In other words, it represents a good vector to encourage people to reappropriate the natural living environment and reestablish an emotional connection with primordial nature.
Moreover, creating these eco-multifunctional areas that respect the environment favours the achievement of particular international Community objectives proposed in the 2030 Agenda like minimum land consumption and minimum consumption of resources (United Nations General Assembly, 2015) and in the Kyoto Protocol (storage of CO2).

## CONCLUSION

The connection between the urban environment and nature can only be achieved through an educational process that raises awareness about the


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importance of environmental sustainability. In this context, the idea of Euterpe, an eco-multifunctional area integrated within schools, presents an opportunity to bring nature into educational and urban spaces. This model not only fosters direct interaction with ecosystems but also introduces a new approach to the short wood supply chain, using it as a means to bring the community closer to sustainable resource management. Since the starting point of this supply chain is forest management, it serves as a key design element to establish a lasting bond between cities and nature. The short wood supply chain, particularly in the Mediterranean region, offers multiple environmental, economic, and social benefits. From an environmental perspective, it reduces the impact of material transportation, lowering the CO emissions associated with logistics. Moreover, the responsible use of forest resources helps mitigate deforestation risks and preserve biodiversity, promoting sustainable land management. From an economic standpoint, encouraging the short wood supply chain supports the development of a local economy based on renewable resources, creating job opportunities in forestry, craftsmanship, and wood construction, with a positive impact on local communities. Additionally, enhancing forests through sustainable management can contribute to the growth of eco-tourism, encouraging activities such as forest bathing and nature-based experiential tourism. However, challenges remain. One of the main obstacles concerns the availability and quality of local timber, which may not always meet the structural and technological requirements demanded by the construction industry. Furthermore, the creation of an efficient short supply chain requires significant initial investments to improve infrastructure, logistics, and wood certification processes. Raising awareness and training local communities are thus crucial to overcoming these challenges and ensuring the success of the proposed model. Looking ahead, promoting the short wood supply chain and designing eco-multifunctional spaces like Euterpe could mark a turning point for sustainable urban planning. Cities could evolve into more resilient systems, capable of integrating natural resources into their development models without compromising their availability for future generations. One of the most promising scenarios is the integration of green building practices with urban planning, encouraging the use of wood in construction to reduce reliance on highly polluting materials such as concrete and steel. In parallel, strengthening reforestation policies and creating "green belts" around urban centers could expand access to natural spaces and improve citizens'

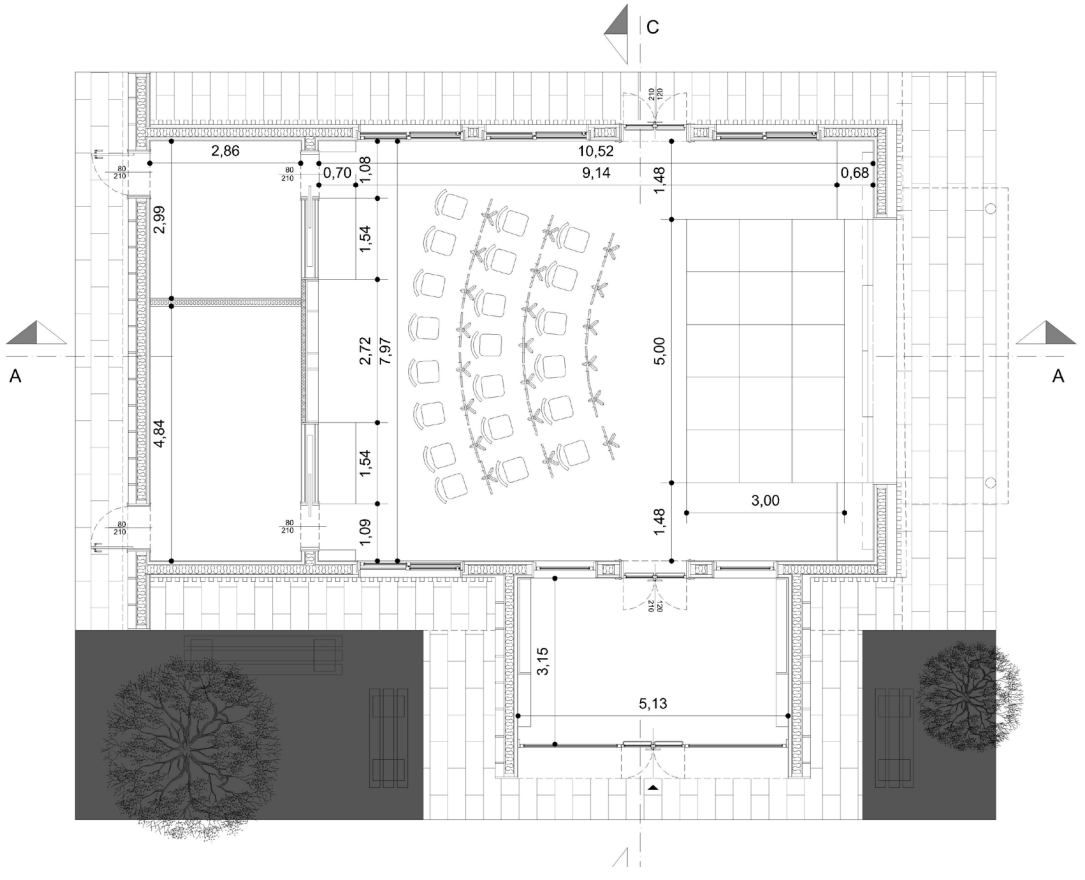


Figure 13. Layout of Euterpe ©


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quality of life. Finally, environmental education will play a key role in reinforcing the connection between the urban environment and nature. Targeted educational projects focusing on sustainable forest management and the ecological value of wood could help shape a new generation of aware citizens, ready to adopt more sustainable lifestyles and production models. In this context, the forest is not only a resource, but it becomes a therapy for the cities of the future: an essential element for human well-being, an ally in the fight against climate change, and an opportunity to establish a new balance between humans and the environment.

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CREDITS
This contribution is the result of a collaborative research effort and has been developed accordingly. However, the attribution of specific sections can be assigned as follows: Forest Management and Italian Forest Management by Luigi Massaro; Urban Environment-Nature Connection and Conclusion by Rosina Iaderosa; Euterpe by Luigi Massaro and Giorgio Frunzio. Any content not explicitly attributed is considered to have been developed equally among the authors.

Figure 14. Internal view of the three-dimensional model of the music classroom Euterpe©
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