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# Strengthening Wood Structures Against Climate Change: Approaches from Türkiye and Different Countries

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**Abstract** − This study examines the durability and strengthening strategies of wooden structures in Türkiye against climate change and extreme weather conditions. The effects of climate change challenge the resistance of structures to fire, water and other natural events. Although wood continues to be used as a traditional building material, it needs to be adapted to these new conditions. Wood that is not protected in any way will deteriorate, change shape, crack, develop dimensional differences, change colour, lose gloss, increase surface roughness and lose properties with similar negative effects over time due to climate change and weather conditions. This study discusses fire and water protection strategies, material renewal techniques and sustainability enhancement methods to assess the current status of wood structures in Türkiye, Canada and Finland and their durability against climate change. The study provides suggestions to ensure the sustainability of both existing and newly constructed wood structures against climate change. In addition, this article provides important information from studies in the literature on how to protect and develop wood structures against climate change in the modern world, and discusses new protection strategies against ever-changing climate differences.

***Keywords*** − *Climate change, Wooden structures, Reinforcement methods, Sustainability, Strengthening*.

# Ahşap Yapıların İklim Değişikliğine Karşı Güçlendirilmesi: Türkiye ve Farklı Ülkelerden Yaklaşımlar

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***Araştırma Makalesi***

**Öz** − Bu çalışmada, Türkiye'de iklim değişikliği ve aşırı hava koşullarına karşı ahşap yapıların dayanıklılığı ve güçlendirme stratejileri incelenmektedir. İklim değişikliğinin etkileri, yapıların yangına, suya ve diğer doğa olaylarına karşı dayanıklılığını zorlamaktadır. Ahşap, geleneksel bir yapı malzemesi olarak kullanılmaya devam etse de, bu yeni koşullara adapte edilmesi gerekmektedir. Hiçbir şekilde korunmayan ahşap, iklim değişikliği ve hava koşulları nedeniyle zamanla bozulacak, şekil değiştirecek, çatlayacak, boyut farklılıkları geliştirecek, renk değiştirecek, parlaklığını kaybedecek, yüzey pürüzlülüğü artacak ve benzer olumsuz etkilerle özelliklerini kaybedecektir. Bu çalışmada, Türkiye, Kanada ve Finlandiya'daki ahşap yapıların mevcut durumunu ve iklim değişikliğine karşı dayanıklılıklarını değerlendirmek için yangın ve su koruma stratejileri, malzeme yenileme teknikleri ve sürdürülebilirlik artırma yöntemleri tartışılmaktadır. Çalışma, hem mevcut hem de yeni inşa edilen ahşap yapıların iklim değişikliğine karşı sürdürülebilirliğini sağlamak için öneriler sunmaktadır. Ayrıca, bu makale, modern dünyada ahşap yapıların iklim değişikliğine karşı nasıl korunacağı ve geliştirileceği konusunda literatürdeki çalışmalardan önemli bilgiler sunmakta ve sürekli değişen iklim farklılıklarına karşı yeni koruma stratejilerini tartışmaktadır.

***Anahtar Kelimeler*** − *İklim değişikliği, Ahşap yapılar, Güçlendirme yöntemleri, Sürdürülebilirlik, Güçlendirme.*

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## 1. Introduction

Wood has been used in construction for far longer than concrete and steel. The development process of wooden structures, from the earliest times to today's construction systems, has been slow, despite the fact that wood is readily available from nature and easy to use in the construction phase (Batur, 2004). The development of wood construction systems and its use as a supporting skeleton in structures dates back to the beginning of the 20th century. The needs arising from growing and increasingly widespread industrialisation and the withdrawal of steel, a valuable raw material for weapons before and during the First World War, led to the need to use wood in structures with different functions and in a more rational way. During this period, the mechanical and physical properties of wood were studied, studies were carried out on connecting elements (nails, wedges, bolts, etc.) and materials and methods were developed to protect wood against external influences (Çalışkan, 2019). Today, it is possible to produce and design wooden construction elements of all kinds of sections and lengths with static and strength calculations.

According to the General Directorate of Forestry (OGM), the total forest area in Turkey is 23 million 245 thousand hectares. While the north of the country stands out for its extensive forest areas, the forest area per capita is the highest in this region. In 2023, 29.8% of Turkey's total area will be covered by forests. The south of Turkey has extensive forest areas and contains a significant proportion of the country's forests. The Mediterranean coasts are particularly densely forested, and these regions account for a significant proportion of Turkey's total forest area (OGM, 2023). The forest map of Türkiye's provinces by area is shown in Figure 1. The map shows forest density in numbers, with increasing numbers indicating greater density. In Figure 2, visual examples of wood structures in different regions of Türkiye are shown.

In recent years, the concept of "tiny house", which is built with wooden construction materials, has become popular in order to contribute to nature in terms of efficient energy use, protection of people's health, contribution to the ecological environment, water saving, etc. This situation makes a significant contribution to building environmentally friendly structures and ensuring sustainability in the Türkiye. The image of tiny house structures (interior and ceiling wall) built with wood materials is shown in Figure 3 (Öztürk, 2024). Tiny houses contributes to the overall framework of the study from the perspective of sustainable building solutions and climate change adaptation. As small-scale and environmentally friendly structures, tiny houses utilize renewable materials such as wood, reducing their carbon footprint while enhancing energy efficiency. In this context, the study can examine the impact of tiny houses on wooden construction systems, their resilience to climate change, and their relationship with innovative approaches implemented in different countries. Thus, a comprehensive perspective on global trends in sustainable wooden building design can be provided.

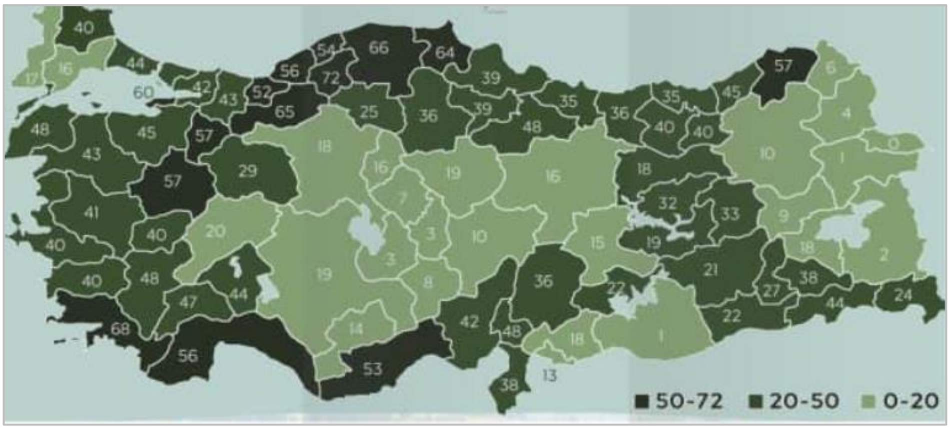
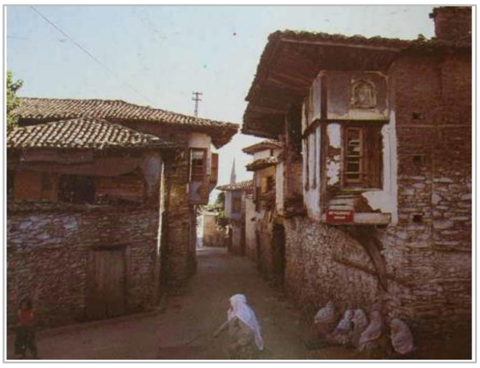



Figure 1. Distribution of forests in Türkiye by provincial area in percent

Over the next century, average annual air temperatures in Canada (British Columbia) are expected to increase by 1°C to 4°C, accompanied by increased precipitation events of increasing intensity and magnitude. These climate changes are certain to affect Canada's forests and are expected to result in fundamental changes in the cellular structure of wood, productivity and wood quality (Temel, 2024). To manage the social and economic impacts of these changes, Canada must develop conscious management plans that take into account climate-related changes in wood quality in future forests (Wood, 2016). Finland is a northern country with a forested landscape. The boreal forest covers about 22.8 million hectares of the country's 30.4 million hectares. Finland has a long history of solid wood construction; wood construction techniques have been used as the traditional method of building houses in Finland for thousands of years. Today, almost all recreational buildings, such as Finland's cottages, are made of wood, mostly in log construction. Residential buildings are increasingly made of wood, especially cross-laminated wood and laminated veneer lumber. The most common way of building wooden apartments is to use volumetric elements as opposed to large load-bearing elements and joist systems. Today in Finland, as in many European countries, growing environmental awareness is increasing the popularity of wood construction, which in turn is leading to the search for innovative and environmentally friendly wood product solutions (*e.g.* dovetailed solid wood panel elements) as a vision for the future (Ilgin, 2022).

*Rize – Wooden stack houses (Web-1)*

*Eskişehir – Odunpazarı houses (Erşan and Demirarslan, 2020)*



*Kula – Wooden structure emerging from wooden beamed stone walls (Sözen, 1996)*

*Alanya – Baghdadi laths nailed to the carcass (Halaç and Demir, 2017)*

Figure 2. Images of examples of wood constructions from different regions of Türkiye

In recent years, interest in high-rise buildings and wood construction has increased significantly in Finland. The main reason for this increase is related to the rapid development of urbanisation and population growth in large cities. The increasing population density in cities has increased the demand for high-rise buildings due to the efficiency of land use and the advantages of vertical construction (Kaste, 2004). Figure 4 shows the 14-storey Lighthouse in Joensuu, Finland, which will be completed in 2019 and will contain 117 student apartments and, at 48 metres, will be the tallest wooden high-rise building in Finland (Caştur, 2021).

Figure 3. Interior and ceiling wall cladding made using wooden building materials

Figure 4. Lighthouse structure (Finland)

Climate change is the biggest problem for wood structures, affecting both plants and animals. In addition to the rise in global temperature, the increase in the amount of $CO_2$ in the atmosphere, together with changes in the rainfall regime, affects the structure and function of trees. This climate change interacts with trees throughout their lives and can leave permanent marks on the wood (Pandey, 2021). The performance of wood cladding depends on the quality of the wood material, the surface treatment, the construction details and the climatic effects to which it is exposed. Climate indices, which allow a quantitative assessment of the conservation performance of buildings, can be an important element in the development of adaptation measures to the future risks of climate change in different parts of the world. The quantitative relationships established between climate impacts and material behaviour or building performance can determine the changes that can be made to the structure (Robert, 2006). In addition, the construction sector is a significant source of global greenhouse gas emissions. $CO_2$ emissions from construction amount to 5.7 billion tonnes and accounted for 23% of emissions from global economic activities in 2009 (Huang, 2018). More recently, in 2018, the construction and operation of buildings accounted for the largest share of both global final energy consumption (36%) and energy-related $CO_2$ emissions (39%) (UNEP, 2019). The construction sector is even more important given the impending wave of 2.3 billion new urban dwellers, with the global building stock expected to double by 2060. Achieving net zero carbon requires changes in all aspects of building operations (electricity, lighting, heating, cooling, etc.). This enables both increased energy efficiency and the production and supply of renewable energy (Wiik, 2018). As buildings become more energy efficient, embodied energy - the energy used in the production, transport, construction, maintenance and demolition/reuse of building materials -

becomes relatively more important (Huang, 2018; Cabeza, 2014; Lolli, 2019). The embodied energy of a building can be reduced by replacing carbon intensive materials such as concrete and steel with wood (Gustavsson, 2017; Sathre, 2010). Increasing the amount of wood used in buildings to replace more carbon intensive materials has the potential to reduce overall emissions from the construction sector (Hill, 2019). Oliver, (2014) estimates that replacing concrete and steel with wood in the construction of buildings and bridges could reduce global $CO_2$ emissions by between 14% and 31%.

In recent years, the development of mass wood technology has paved the way for the construction of mid-rise and high-rise wood buildings to meet the built environment needs of the world's rapidly growing urban population (Brandner, 2017; Harte, 2017). Mass wood is a wood-based construction category characterised by the use of large solid wood panels for wall, floor and roof construction (Harte, 2017). Cross-Laminated Wood (CLT) is the most widely used solid wood product in the construction of multi-family homes and multi-storey commercial buildings (Brandner, 2017; Harte, 2017). Unlike concrete and steel, which emit $CO_2$ during production, the trees used to make mass wood products naturally absorb and store $CO_2$ as they grow. In sustainably managed forests, new trees grow to replace those harvested, ensuring no net loss of forest carbon (Gustavsson, 2017).

There are many positive characteristics of wood structures produced in forests. These can be listed as: natural, beautiful texture and colour, easy to work, renewable and sustainable, light, flexible, surface treatments, increased thermal and sound insulation and energy saving, high durability, long life with maintenance. In addition, wood materials have the property of reducing the $CO_2$ effect compared to other building materials. Wooden materials have disadvantages as well as advantages. In particular, changing climatic conditions negatively affect the structural properties of wood materials. For example, wood's ability to easily absorb and release moisture makes it very sensitive to changes in climate. It can swell in a high humidity environment and shrink by drying in a low humidity environment. In addition, the risk of decay and deterioration of wood materials increases with increasing temperature and humidity. Temperature changes can also cause cracks or deformations in the structure of wood. UV rays from the sun can cause fading of wood surfaces and deterioration of structural integrity. Another factor, air pollution, can increase the rate of deterioration by causing chemical reactions on the surface of wood materials. With climate change, the spread of some insect species in wood materials increases, which can damage wood materials. In addition, the outdoor effect, or "weathering", is an important risk factor for wood-based materials. Weathering is defined as the change in colour, surface roughness and cracks that occur on the surface as a result of exposure to light (UV, IR), moisture (rain, snow, damp, dew), mechanical forces (wind, sand, dirt) and temperature. As a result of these effects, there are changes in the colour, chemical and physical properties of the wood material. All the negative effects mentioned above can shorten the durability and life of wood, so it is necessary to preserve the wooden material with appropriate protection and maintenance methods. In addition, the provision of appropriate climatic conditions for wood materials (appropriate temperature and humidity levels) is important for the design of high-quality and long-lasting wooden structures and for sustainability.

In today's climatic conditions, the recycling of materials used in construction and the prevention of environmental pollution are important factors. The recycling stages of wood are shown schematically in Figure 5. Basically, each anatomical feature of wood fibre, including tracheid diameter, lumen diameter, cell wall thickness and microfibril angle (MFA), controls the mechanical properties of wood and the quality of fibre-based products. Functional properties of wood products, such as axial stiffness and longitudinal shrinkage, are properties that are largely dependent on the MFA in the S2 layer of the secondary cell wall. As MFA increases, longitudinal shrinkage increases exponentially and axial stiffness decreases (Neagu et al., 2006).When designing wood structures, it is necessary to follow some design rules in order to be an ecological building (Tönük, 2001). These can be summerized as: Ensure that the design and construction of the wooden structure does not result in the depletion of natural resources, placing it in a way that is compatible with the environment and topography during the design phase of the structure, be appropriate to the climatic conditions and topographical features of the region when positioning the structure; Use materials that can be easily recycled, design wet areas and circulation areas on the north side as much as possible in the horizontal layout during the structure design phase, paying attention to this principle in the vertical layout as well as in the horizontal layout during the structure design phase, consider modularity in the design, designing spaces as multifunctional, allow for the use of solar energy.

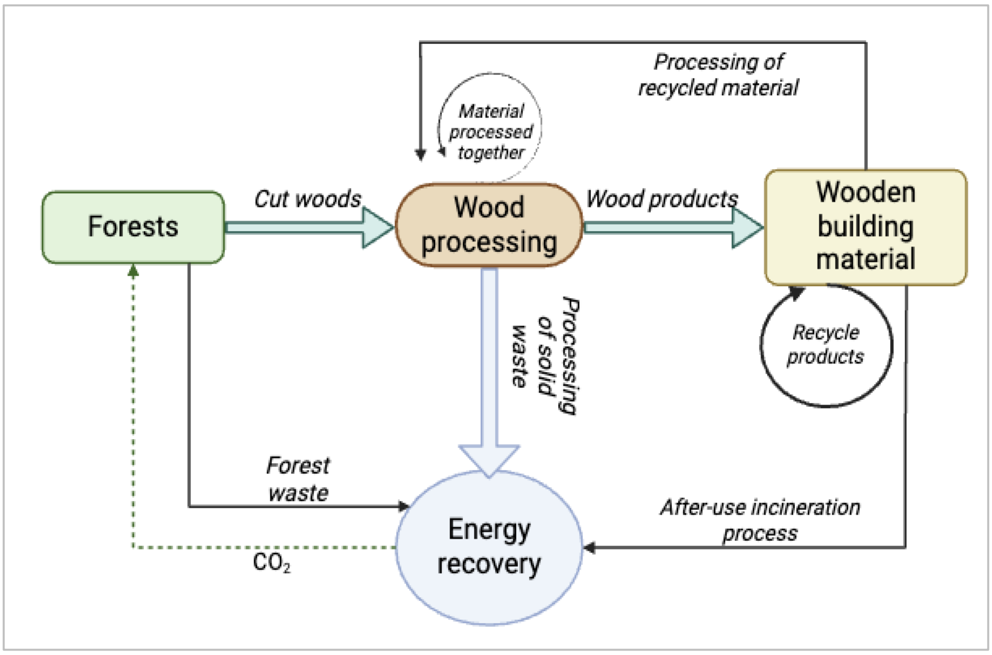



Figure 5. Lifecycle of wood-based materials (Serengil, 2018)

One of the factors causing environmental problems is the activity of the building sector. The need to reduce the negative effects of this activity leads us to ecological design and the use of ecological materials in buildings. This study considers wood as one of the ecological building materials. The criteria, categories and indicators to be used in assessing the sustainability of this material are examined and the sustainability of this material is examined in the light of these. Climate change has a major impact on nature and people, as well as on the transfer of an existing structure into the future. The change in the temperature factor in the future determines the concentration of heating and cooling demand in buildings. In this context, future scenarios against climate change are created in order to see the attitude of structures against climate change. The purpose of this review study is to compare the climatic resistance of wooden structures in Türkiye, Canada and Finland as different countries and to determine what measures should be taken to strengthen these structures in harsh climatic conditions.

This study discusses the effects of climate change on timber structures and strategies to increase their durability. Research carried out in different countries on the environmental sustainability and durability of wooden structures will be reviewed and approaches applied in Turkey and other countries will be compared. The literature review will evaluate academic studies on the protection of wood materials, new generation coating and processing techniques, engineering solutions to increase durability and climate change adaptation strategies. In this context, both current practices and innovative methods to be developed in the future will be discussed.

## 2. Methods

This review study used case study as a method, which is a qualitative research technique. In this context, examples of climate-resilient wood structures on different countries (Canada and Finland), as well as in Türkiye, were used to compare successful applications. Forest structures in Türkiye, Canada and Finland were studied and the changes in these structures against climate change were investigated. Based on the data obtained from the research, the strategies that can be applied for the adaptation of wood structures in Türkiye to climate change were determined. In addition, material, design and building protection strategies to adapt to climate change and increase durability were proposed based on the research results. The effects of different climatic conditions on wooden building materials and construction, and the general stages of the studies to be carried out for the strengthening of wooden structures are shown in Figure 6.

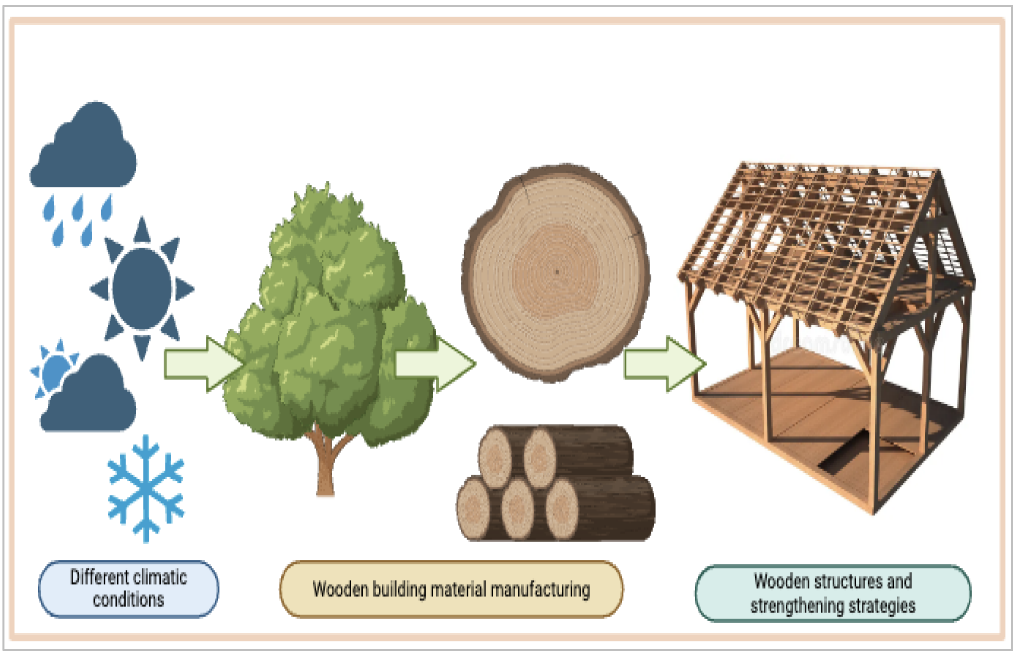



Figure 6. A general graphical presentation of the effects of different climatic conditions on wood building materials and construction, and on the reinforcement of wood structures.

## 3. Results and Discussion

### 3.1. Türkiye's Forest Structure And Climate Change Policies

Türkiye is surrounded by sea on three sides and lies between the subtropical and temperate zones. While the coastal areas of Türkiye have a milder climate due to the effect of the sea, the North Anatolian and Taurus Mountains prevent this effect from penetrating into the interior of the country. For this reason, while the inner parts of our country have continental climate characteristics, a large part of Türkiye is located in the dry summer subtropical Mediterranean climate zone. According to international and national literature, Türkiye is divided into 8 ecological regions. The interactions between the ecological regions and climate types determined by Serengil, (2018) are shown in Table 1. In this way, the evaluation of ecological regions, more homogeneous calculations and the use of more specific emission factors and coefficients can be provided. Wood, which is the most used building material in traditional Turkish architecture with a rate of 60-75%, is used as a structural element in regions where it is easily available. The rate of use in the structural system varies according to the climatic conditions of the region where the wooden structures are located.

In our country, traditional wooden structures can be found in the area south of the eastern Black Sea region, west of Gaziantep, as well as in the Western Black Sea region, parts of the Aegean region, and certain rural areas of Central Anatolia. In other words, the properties of wood and the extent to which it can be used in construction are significantly affected by the climatic conditions of the region where the structure is to be built. The distribution of forests and the map of wooden structures in Türkiye are shown in Figure 7 (Şahin, 2021).

Table 1
Ecological regions in Türkiye and their relationships with climate classification

| Ecozone | Biome | Climate type | IPCC climate type |
|---|---|---|---|
| Euxine-Colchic deciduous forest | Temperate deciduous and mixed forest | Black Sea coastal zone | Warm temperate humid |
| Northern Anatolian deciduous, coniferous and mixed forest | Temperate deciduous, coniferous and mixed forest | Black Sea coastal back temperate climate zone | Warm temperate dry |
| Mediterranean Coastal Zone deciduous and coniferous forest | Mediterranean forests and shrubs | Mediterranean coastal zone | Warm temperate humid-dry |
| Mediterranean Mountain Zone | Mediterranean forests and shrubs | Mediterranean coastal back temperate mountain climate | Warm temperate dry |
| Inner Aegean deciduous and coniferous forest | Mediterranean forests and shrubs | Mediterranean coastal back temperate climate | Warm temperate dry |
| Central Anatolian Steppe | Temperate deciduous and mixed forest | Semiarid steppe climate | Warm-cool temperate dry |
| Eastern Anatolian deciduous forest zone | Temperate deciduous and mixed forest | Temperate continental climate | Warm temperate dry |
| Eastern Anatolian Steppe | Temperate pasture, shrub and steppe | Mountainous continental climate | Warm temperate dry-humid |

Climate change and the disasters it causes have a negative impact on urban structures and increase their vulnerability. In this process, it is important to identify the climatic conditions and determine which region is more vulnerable. It is very important that the current plans and the decision support tools used are well designed. Correctly identifying the problem areas and studying their characteristics is very important in order to take the right steps in the process of developing solutions (Dursun, 2004). The IPCC climate classification is not sufficient when considering the conditions in Türkiye and needs to be detailed by associating it with phytogeographical regions (Black Sea Main Climate, Mediterranean Main Climate, Continental Climate Region) and altitude.

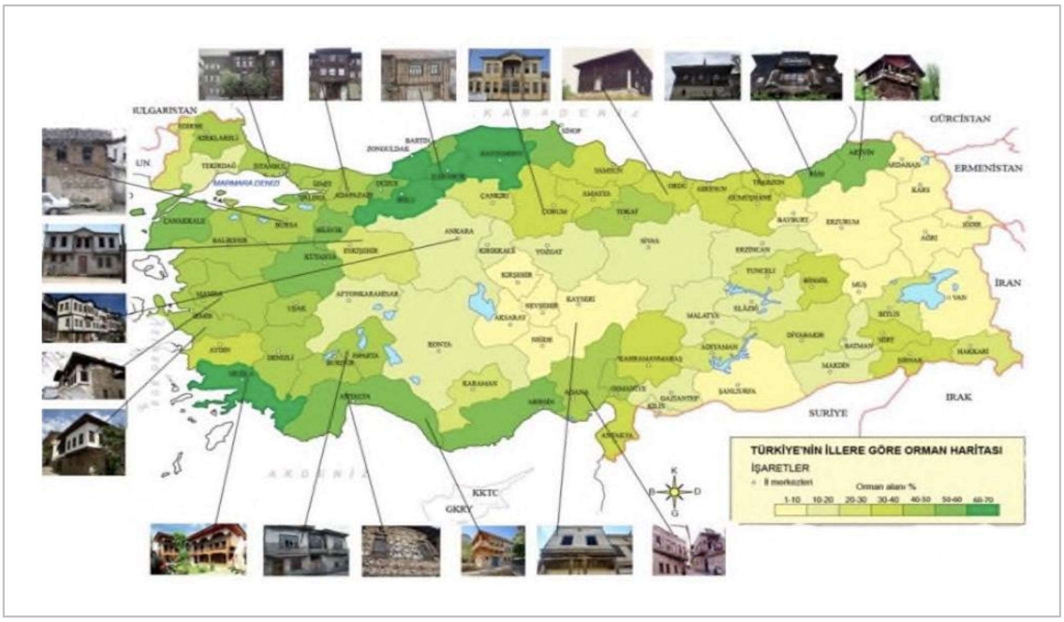



Figure 7. Map of the distribution of the forests and of the wooden constructions in Türkiye

Türkiye's overall climate change policy is framed by various intersectoral and sectoral policies, strategies and action plans based on national legislation. The forestry sector is included in the national strategies and action plans, which emphasise the importance of focusing on climate change adaptation measures. Türkiye's objectives for the forestry sector are as follows: Identifying drought-resistant tree species and planting them, especially in arid and semi-arid areas, plan and implement forest areas and forestry activities that are essential for the protection and management of water resources within the framework of sustainability principles and based on the principles of headwater catchment management (MEUCC, 2010), limiting the negative impacts of land uses and changes, such as forests, pastures, agriculture and settlements, on climate change, strengthen the legal and institutional structure for addressing climate change in land use and forestry, integrate climate change adaptation into ecosystem services, biodiversity and forestry policies, identify and monitor climate change impacts on biodiversity and ecosystem services (MEUCC, 2011a; MEUCC, 2011b).

Considering the effects of climate change in Türkiye, various measures and strategies should be implemented to increase the durability of wooden structures and ensure environmental sustainability. Firstly, naturally durable wood species should be preferred and these materials should be protected against moisture, pests and fungi by using techniques such as heat treatment, impregnation or carbonisation. The use of local and certified wood is important to reduce the carbon footprint. In terms of design, solutions should be adopted that are appropriate to the climatic conditions. For example, insulation should be provided against extreme hot and cold weather conditions, and roofs and external facades should be covered with waterproof materials. In addition, natural ventilation systems reduce the effects of moisture, while sunshades or shading systems can minimise the direct effects of sunlight. Regular maintenance is essential to maintain the durability of wood structures. Water-repellent coatings should be applied regularly, and cracks or warping should be detected and repaired early. Foundations should be insulated against moisture and damp and effective drainage systems should be installed. Reinforcement should also be provided at joints to increase resistance to natural hazards such as wind and storm, and flexible design principles should be adopted in accordance with seismic regulations. To ensure the sustainability of wood structures, it is also important to protect the carbon storage potential, use energy-efficient systems and develop them with innovative technologies such as nanotechnology coatings.

Finally, it is necessary to develop climate-friendly building codes within the legal and policy framework and to promote sustainable projects such as rainwater management, green roofs or vertical gardens around wooden structures. These comprehensive approaches can be adapted to Türkiye's different climate zones and supported by training and awareness activities for the construction sector.

### 3.2. British Columbia (Canada) Forest Structure and Climate Change Policies

British Columbia's (BC) forests are characterised by a high degree of ecological diversity. Particularly for species with a wide distribution, the ecological characteristics of their natural range can vary greatly. It is therefore important to be able to match the regeneration area with the right species and the right origin of the species. Rapid climate change makes it difficult to make these matches in a healthy way. The negative effects of climate change are expected to be felt in BC above the world average (Spittlehouse, 2008). Currently, the negative effects of climate change are manifested in changes to hydrological systems (Leith, 1998), forest fires (Gillett, 2004), and damage from insects (Carroll, 2004) and fungi (Woods, 2005). The natural ranges of forest tree species are also expected to change (Hamann, 2006; Johnston, 2009). As a result, research on safe seed transfer is being conducted together with tree breeding studies, and the information gained is being considered in an integrated way in breeding programmes. The main objective of these tree breeding and seed transfer efforts is to increase wood production per unit area by 20% in terms of quantity and quality compared to natural stands (Temel, 2001).

Three major research projects are underway to make BC's forests and forestry sector more resilient to the adverse effects of climate change. The Assisted Migration and Adaptation Trial (AMAT) was initiated to provide the information needed to transition from a geographically based seed transfer system to a climate-based seed transfer system. A total of 15 forest tree species were planted in 48 two-hectare trial plots in BC and neighbouring Canadian provinces. Twelve trials were established each year between 2009 and 2013, and survival and growth measurements have been taken every five years since 2014. The means and variances of survival and growth variables for each provenance are loaded into the Tree and Stand Simulator to estimate the volume of wood that can be harvested from a unit area (ha) at the end of the management period. By modelling the relationship between volume growth and differences in climatic variables between the source and experimental sites, it will be possible to predict where species and seed sources will be most productive under future climatic conditions in the face of climate change (Temel, 2001).

There have also been some innovations in the use of wood and reinforcement in Canada. For example, a solid wood factory clad in vertical cedar slats was built in the Squamish Valley of British Columbia. In 2021, Hemsworth Architecture designed a 2,700 $m^2$ industrial facility for Leon Lebeniste Fine Furnishings & Architectural Woodworking in the Vancouver area. The sustainable architecture of the Leon Lebeniste facility was designed with an emphasis on the use of sustainable materials, a large area of glass along the street, and a shared green roof and deck (Web-2) (Figure 8). The three-storey building, which is an example of sustainable architecture, is clad in vertical red cedar slats treated with a natural preservative to increase the durability of the material and minimise maintenance. The nearly rectangular structure is constructed of glulam post and beam columns supporting solid wood CLT panels and concrete slabs for the floor and roof. The solid wood structure is left exposed in places and clad in plywood in others to create a warm atmosphere. Therefore, materials used in sustainable architecture were preferred (Web-2) (Figure 8).

**(a)** **(b)**

**Figure 8.** Leon Lebeniste facility (a) and Leon Lebeniste internal structure of the facility(b)

British Columbia is one of the most densely forested regions in Canada and has developed several strategies to address the effects of climate change. The region has a wide range of ecosystems, including boreal, temperate rainforest and subalpine forest. Tree species such as spruce, cedar, fir and Douglas fir form the foundation of these forests and are important for carbon storage, biodiversity, watershed protection and wood production. As part of the climate change response, reforestation studies are being carried out using sustainable forestry practices and fire management methods such as early warning systems and controlled burns. Forest health is also protected through pest and disease control.

Forest-based carbon credits have been developed to reduce carbon emissions, and degraded areas have been rehabilitated. Ecosystem resilience has been increased and wildlife corridors created by promoting native and climate-resilient species to adapt to changing climate conditions. Traditional knowledge of indigenous peoples has been integrated into forest management, and awareness of climate change has been raised in society. Forest health and long-term responses are continuously monitored using remote sensing technologies and climate change models. Through these proactive policies and scientific approaches, British Columbia is playing an important role in both protecting ecosystem health and reducing the impacts of global warming.

### 3.3. Finland's Forest Structure and Climate Change Policies

Among European countries, the wood building industry in Finland is extensive and deep-rooted, and the government's policy to increase the wood building stock is examined in detail in this compilation in order to set an example for our country. In Finland, increasing the use of wood in construction has become a government policy and has been promoted by the authorities through various wood promotion programmes and legislative changes for about thirty years. Increasing the processing capacity of the wood industry, developing exports and supporting local ecology are among the basic strategies implemented to promote wood construction (Karjalainen, 2002). In the 2010s, climate change has become an important driver for the wood construction industry (Ijäs, 2013)

In recent years, reinforced concrete has still accounted for about 70% of residential construction in Finland. However, in recent years there has been a significant increase in the use of wood construction systems. This development has been accompanied by a growing awareness of the advantages and sustainability of wood construction. Fire regulations have played a central role in the spread of wood construction. In 1997, a revised version of the fire regulations led to the construction of residential and office buildings with wood frames and facades of up to four storeys in height, which resulted in a sharp increase in the construction of wood housing in Finland. In 2011, the zoning regulations were revised to allow the construction of wood apartment buildings up to 8 storeys high under certain conditions.

In Finland, wooden multi-family dwellings are currently constructed using three different structural systems: the modular mass construction system, the load-bearing large element system and the post and beam system. The post and beam system is widely used in Finland, especially for low-rise wooden apartment buildings with a maximum of 5 storeys. The chosen structural system, together with the location of the load-bearing lines and the potential spans of the subfloors, influences the architectural design of the building. Wood structures are usually connected with steel or bolted connections. The method of connection is influenced by the choice of structural system. Subfloors in wood residential buildings tend to have slightly shorter spans than reinforced concrete structures. Depending on the construction method, spans of approximately 4-7 metres can be cost-effectively achieved with wood subfloors. At the same time, the load-bearing structures and partition walls between apartments are usually thicker than those of reinforced concrete structures. These features ensure that wood apartment buildings are strong and durable. The 18-storey, 85-metre high Mjøstårnet in Brumunddal (Norway) is the tallest wooden apartment building in the world (Figure 9) (Erdoğan and Begeç, 2021). In Finland, the implementation of wood apartment buildings with different structural systems provides architectural flexibility and enables different design options. This increases the diversity and aesthetic potential of wood construction (Tulonen, 2018).

Helsinki-based Anttinen Oiva Architects has built Katajanokan Laituri, a solid wood office and hotel building on the south bank of Katajanokka in Helsinki. This wood building in Finland demonstrates the country's continuing achievements in innovative and contemporary large-scale wood architecture. Wood construction is an important step towards Finland's goal of carbon neutrality. It promotes wood construction in a country where forests cover around 75% of the land area.

Figure 9. The building of Mjøstårnet

Sustainable forest management is at the forefront of Finland's efforts to combat climate change. Selective felling and reforestation studies are being carried out to increase the growth rate of forests. Biological control methods and early warning systems have been developed to combat pests and diseases. Forest roads and firebreaks have been created to reduce the risk of fires, and the use of advanced technology to quickly detect and control fires has been increased. Finland is also investing in projects to increase the carbon sink capacity of forests. To reduce carbon emissions, the forestry sector is supported through carbon trading and innovative technologies, and degraded areas are reforested to increase their carbon storage capacity.

To build resilience, priority is given to resilient and native species that can adapt to climate change. Protected areas have been expanded to preserve the biodiversity of forest ecosystems and projects have been implemented to support natural processes. Finland is also working to reduce dependence on fossil fuels by promoting renewable energy sources from forests. In the area of research and innovation, institutions such as the Finnish Climate Change Panel are working to monitor forest responses to climate change and develop adaptation strategies. As a result, Finland is using scientific and innovative approaches to protect its large forest areas and increase their resilience to the effects of climate change. These efforts make a significant contribution not only to Finland's natural resources, but also to the fight against climate change on a global scale.

## 4. Conclusion

Strengthening wooden structures against climate change demands both traditional and modern approaches, as evidenced by examples from Türkiye and beyond. When selecting wood building materials, preference should be given to species that are resistant to moisture, temperature changes and biological threats caused by climate change. For example, wood from coniferous trees may not be as durable as certain hardwoods, which tend to offer higher resistance to decay, as observed in diverse forest ecosystems such as those in İğneada and other regions. Options such as modified wood species with increased durability and thermally or chemically treated wood should be considered for construction. Waterproof coatings, varnishes and protective impregnants can be applied to protect wood surfaces. These applications increase the wood's resistance to moisture and water and also provide protection against biological pests such as insects and fungi. The increased amount and intensity of rainfall associated with climate change may increase the risk of water damage to wood structures. It is therefore important to install drainage systems and reduce the contact of the wood structure with the ground. Creating moisture barriers between the foundation and the walls of the structure will help prevent water accumulation. Wood structures can be designed to withstand natural factors such as wind, rain and snow. For example, wide eaves on wood roofs can extend the life of the structure by reducing the amount of rain that comes into contact with the façade. In addition, designs that allow for air circulation can prevent moisture from building up in the structure. Using wood from sustainable and certified sources is an important step in combating climate change. Wood from sustainable forestry minimises the environmental impact as it is produced without harming nature and by reducing carbon emissions. Wooden structures require regular maintenance and repair, even if they are made resistant to climate change. Regular checks should be carried out, particularly on areas such as the exterior cladding, roof and foundation. Rapid replacement of rotten or damaged parts will maintain the overall durability of the structure. Increased temperature fluctuations with climate change make it necessary to protect the thermal performance of wood. Energy-saving insulation materials and airtight coatings reduce energy consumption by maintaining the internal temperature of the wood structure. Bio-resistant wood applications developed using innovative biotechnological methods are becoming more durable against threats such as fungi, insects and decay. Wood species with increased bio-resistance can withstand climate change conditions for longer periods of time than traditional materials. Raising awareness of climate-resilient wood applications among wood building owners and the construction industry supports the long-term and sustainable use of buildings. Educational programmes ensure the preservation of the structure by teaching proper maintenance practices.

## Author Contributions

Author İbrahim Engin Öztürk: He planned and designed the study, performed statistical analyses and wrote the manuscript.

Author Çağlar Altay: He collected the data and contributed to the writing of the manuscript.

Author Esra Gençdağ Gözen: She contributed to the writing of the manuscript.

## Conflict of Interest

The authors declare no conflict of interest.

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