IFES International Forestry & Environment Symposium
07-10 NOVEMBER 2017, TRABZON-TURKEY

The impact of climate change on the expanding of Ailanthus species and its utilization potential

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Abstract

Climate change, as well as the rise of average air temperature could result in significant effects on forest vegetation. Many forest species will be threatened with extinction or forced to migrate to colder regions, and species more adaptable to the new climatic conditions that will be established, mainly exotic plants, will inevitably replace the older species. Ailanthus tree consists a fast growing plant, considered as a species native to China regions, which spread in Europe and North America since the mid - 18th century. This species presents a preference to warmer and dryer areas, but has also the ability to thrive in a variety of habitats and withstand industrial pollution. It is characterized as a multipurpose species, as it can be used as animal feed, fuel, timber, in pharmaceutical uses etc. Its wood has an appealing appearance and properties similar to those of other hardwood species of similar average density. This article presents some of the most significant properties of Ailanthus wood that grows in North Greece and additionally, the properties of plywood manufactured with this species material.

Keywords: ailanthus, mechanical strength, plywood, properties, utilization

Introduction, scope and main objectives

A. Climate change and its effects on vegetation

Global warming is an undeniable phenomenon, evidenced by the observations of the increase in average global air and ocean temperatures, the extended melting of snow and ice and the elevation of the global average sea level. A greenhouse gases layer that consists mainly by water vapors, which include much smaller amounts of carbon dioxide, methane and nitrous oxide, acts as a thermal blanket for the Earth, absorbing heat and parallel heating its surface at a temperature suitable for the growth of living organisms.

Most scientists agree that the main cause of the current global warming tendency is attributed to the anthropogenic impact of the "greenhouse effect" increase. Carbon dioxide (CO_2) is only a small, but very important component of the atmosphere, as it is the most significant factor of the climate change. It is released through natural processes, such as breathing and volcanic eruptions but also by human activities such as deforestation, land use change and fossil fuel combustion. The humanity has increased the concentration of CO_2 in the atmosphere by one third since the Industrial Revolution began (NASA 2015). Scientists estimate that, during human processes, a total of 305 billion metric tons of CO_2 have been released in the atmosphere since 1751, of which half of these emissions has been produced since the mid-1970s (Sharp 2007). This rapid increase in atmospheric concentrations of CO_2, as well as other greenhouse gases can lead to significant changes in the climate that could greatly affect the diversity and distribution of species and thus have an impact on ecosystems and biodiversity. The research results across continents and most oceans reveal that many natural systems are affected by regional climate changes, especially the temperature rise. Certain systems, sectors or areas are likely to be greatly affected by climate change, in particular, the terrestrial ecosystems of tundra, arctic forests and mountainous areas due to their sensitivity to warming, the Mediterranean ecosystems, due to the reduction of rainfall, and the tropical forests due to the potential of humidity reduction (Bernstein et al. 2007).

Climate change can have a significant impact on forest vegetation through changes in the frequency and intensity of fires, drought, imported species, insects and pathogenic outbreaks, hurricanes, precipitation or landslides (Dale et al. 2001). Extreme weather events will be multiplied in frequency and duration, and in combination with an increase in average temperature will increase the sensitivity of tree species to secondary attacks by various parasites and pathogens. Moreover, the reduced vitality of the trees makes them more prone to falls (Schlyter et al. 2006). Observations show that the last 30 years, climate change has created many changes in the distribution and the number of species and is partly associated with some species extinction. Researchers, using the predictions of species distributions based on climate-change scenarios for 2050, estimate that 15-37% of the sample species of their study will be led to extinction (Thomas et al. 2004). The results of another study, where about 1400 plants were included, using the climate data for the period 1990-2050, show significant changes in biodiversity by 2050. On average, 32% of the European plant species that were present on a specific area in 1990, will disappear from it and as it is estimated, this will happen in the 44% of the European area (Bakkenes et al. 2002)

Also, a study that examines 1350 European plant species under seven climate change scenarios shows that more than half of the species studied could be vulnerable or threatened by the year 2080. Despite the coarse scale of the analysis, species from the mountains could be considered to be disproportionately sensitive to climate change (-60% loss of species). The Arctic region is expected to lose some species, although will gain more from migration. The largest changes are expected in the areas between the Mediterranean and Euro-Siberia. As it has been found, the risks of extinction of some European plants can be great, even in moderate climate change scenarios (Thuiller et al 2005). Another study referring to 287 plant species in an area of the western Swiss Alps showed that significant species extinctions referring to the study area could not take place before the period of 2080-2100, because of the possibility of a large number of species to shift their spread to higher altitudes (Engler et al. 2009).

Laboratory experiments have shown that CO_2 increase in the atmosphere seems to have a positive effect on the trees efficiency in timber production, although this may be far from reality, because of many other limiting factors such as pests, weeds, competition for resources, soil water, air quality, etc., which can not be taken into account in the experimental simulation systems. It is estimated that the positive effects emerging from the CO_2 concentration increase in the atmosphere would be of even lower significance taking into consideration the negative effect coming from the temperature increase. Therefore, wood production is expected to be declined, while in some locations, species more suitable to the new climatic conditions formed will replace the older species that will no longer be suitable for this climate (Kirilenko and Sedjo 2007, Lindner 2008).

In the Mediterranean region, an average temperature rise of 3-4°C is expected to be recorded, while the annual rainfall to be reduced by up to 20%. In addition, extreme weather events are likely to become more frequent. The direct and indirect potential impacts are the reduction of tree growth and the increase of fire risk that is the most significant threat in the Mediterranean region. The increasing drought will threaten the survival of many forest species (Lindner 2008). The simulations of a study, predict that in a long term, almost all the Mediterranean island ecosystems would be dominated by exotic plants irrespectively of the disturbance rates (Gritti et al. 2006).

B. Ailanthus and the climatic change (advantages - disadvantages of the species)

A species that has the ability to thrive on a variety of habitats and grow on a wide range of soil species is the deciduous tree Ailanthus altissima (Mill) Swingle of the family Simaroubaceae, commonly known as “Tree of Heaven”. It is a fast growing, precursor species in disturbed habitats, withstands a wide range of temperatures and humidity levels, poor air quality and poor soils and presents no significant insect and disease problems. Nowadays, it is considered a species indigenous to areas of China, which was introduced and began to spread in Europe and North America since the mid-18th century (Elzaki and Khider 2013, Asaro et al. 2009, Kowarik and Saumel 2007). However, the widespread of fossil fossils found in the Northern Hemisphere shows that the genus was already spread in Europe, North America and Asia from the Middle Eocene Times (47.8 million to 38 million years ago), but its current limited spread is a remnant of the impact of intense climate change and represents the survivors of that intensive spread accross the northern hemisphere (Corbett and Manchester 2004). “Ecologists" tend to classify this species as a harmful weed, as invasive or as major intruder in many areas and which due to its rapid growth and the formation of dense clusters is considered to compete with local vegetation causing effects on ecosystem (Bajnou and Vila 2006, Kowarik and Saumel 2007). *Robinia pseudoacacia* and Ailanthus, are ranked among the 20 most invasive alien species in Europe (Sheppard et al. 2006). It is thought that it can suppress the natural vegetation, through competition as well as its ability to replicate due to the substance of ailanthone or ailanthin, contained mainly in the root bark and other parts of the plant, and which in laboratory tests was found toxic to numerous plant species but, since its toxic effects are short-lived, it could be considered as a strong, effective and environmentally safe agricultural pesticide (Swearingen and Pannill 2009, Kowarik and Saumel 2007 , Bostan et al. 2014, Lavhate and Mishra 2007)

A study on the spread of Ailanthus showed that climatic factors were consistently the highest indices of its behavior, and revealed its preference for warmer and drier areas. Based on the climate change scenarios for the period 2095 -2099, it is expected to expand northwards and increase from 56% to 82% referring to the study area (Clark 2013). Also it is found in Europe to be developed mostly in warmer places, especially in degraded environments, along the roads on the outskirts and forest clearances, urban areas and coastal zones of the Mediterranean islands (Kowarik and Saumel 2007). Measurements to ascertain the extent of ailanthus spread in the state of Virginia showed that it represents about 0.20% of the 33 billion cubic feet of standing woody volume stock of the state and is found mainly in ecologically troubled areas and along motorways (Asaro et al. 2009). Its drought resistance is also a key factor affecting the remarkably large expansion of this species in Europe and North America because it is able to withstand drought using a highly effective mechanism for saving water with reduced water loss from leaves and reduced root hydraulic conductivity (Trifilo 2004). Ailanthus presents a very high resistance to industrial gases, dust and smoke, and has been described as "the most adaptable and pollution-resistant tree" for urban plantings (Fryer 2010), but also as a species with strong anti-pollution capabilities (Xu 2006). This is due to the high oral conductivity (> 2 cm) which is the main factor for the absorption of gaseous pollutants (Omasa et al 2002). Researchers have found that it has a high absorption capacity and clearance of polluted environment from lead and cadmium (Wang et al. 2007). In a survey, it was found that in the central parts of Warsaw Ailantus had better growth compared to sites located on the outskirts and urban forests, where it remained in the form of shrub (Zaras-Januszkiewicz et al. 2014). The spread of the root system of the Ailanthus allows the installation and development on steep slopes and rocky surfaces and therefore can be used for anti-corrosion purposes (Kumar 2010, Fryer 2010). However, its root system can cause damage to pavements, archaeological monuments, walls and other structures because it causes erosion of substrates and this consists one of its most important problems. Its effect can be chemical, due to the secretion of organic acids from the roots decomposing calcium bicarbonate, which is the main component of the limestone used as building material, or it can be mechanical, by the increase of the pressure of the roots, either above or near the buildings (Almeida et al. 1994). The tree does not withstand shade and is sensitive to ozone. When it is subjected to high concentrations of ozone, the leaves exhibit signs of injury and fall, therefore the species could be used as a biomarker of ozone atmospheric pollution (Bajnou and Vila 2006). The Ailanthus leaves are considered as extremely delicious and nutritious feed for sheep and goats (Kumar et al. 2010), are the food of a silkworm producing thick and durable silk (Fryer 2010), whereas the fraction of the cytoplasmic protein could be used for human consumption (Bostan et al. 2014). Its flowers attract bees producing a greenish honey, bitter and unpleasant at first, but of high quality and taste after aging (Fryer 2010, Aldrich et al. 2008). Ailanthus is widely used in many parts of Asia as a medicinal herb for many purposes. Research has revealed the presence, in various parts of the ailanthus, of substances as casinoids, alkaloids, proteins, triterpenoids, flavonoids and steroidal substances. Casinoids have attracted the attention of scientists in recent years, as many of them have shown promising pharmaceutical activity such as anticancer, antiviral, antimalarial, antileukemic, anti-nutritional, hepatoprotective, anti-asthmatic, etc. (Bostan et al 2014, Kumar et al. 2010).

The wood of Ailanthus is a ring-shaped, white-yellowish, of smooth texture, and although it is thought to be a light and weak wood, its properties are similar to those of medium-density broadleaf wood species, but there are differences between the different areas of growth. It presents a very high increase in strength after drying. The texture of the design is attractive for use as a veneer based panels lining and closely resembles to the species of ash. It is satisfactorily processed, treated, welded and its surfaces can be finished satisfactorily, but it can show stiffening tendencies due to the presence of tensile parts of timber in the logs. It is proved to be not suitable for heavy structural uses, but could be used in many other lighter applications such as furniture, boat construction, lining, decoration, pallets, matches, wood pulp, firewood, charcoal (Moslemi and Bhagwat 1970, Kumar et al. 2010, Elzaki and Khider 2013). According to experiments on the biological durability of various wood species against septic fungi, Ailanthus is classified among moderate resistant species (Zhou 1981).

The spread of Ailanthus in combination with its minimal requirements and rapid growth has led scientists to explore the possibilities of utilization wood as raw material for the production of wood products of high added value. Research on the use of Ailanthus in paper production has shown that its fibers are coarse and wider than those of Eucalyptus, while their length, especially in mature wood, is similar to that of Eucalyptus as well as the properties of the paper produced (Baptista et al 2014). Furthermore, the results of research on the suitability of this species for the construction of LVL (Laminated veneer lumber) showed that veneers of 5.0mm thickness are more suitable than those of lower thickness (Negi et al. 2000). Another study concluded that wood particles from Ailanthus could be a promising raw material for the production of particleboard in Sudan (Elbadawi et al. 2015).

The results of an investigation of Ailanthus wood properties in Bulgaria have shown that it is an underestimated fast-growing species, which can be used successfully in the production of paper and furniture, and in combination with the possibility of pharmaceutical exploitation could be considered as a rich source, but at the same time of low cost raw material and thought to be appropriate to begin testing experimental plantations establishment (Panayotov et al. 201, Kozuharova1 et al. 2014). It is also known, that in several regions of Asia with harsh and adverse climatic conditions and poor soils it holds a key role in the local economy and is characterized as a kind of multiple purposes species, as it is used as animal feed, fuel, wood material, traditional medicine etc. (Jat et al. 2011).

Purpose of this study was to analyze the impact of climate change on vegetation, to present the advantages and disadvantages of the spreading of ailanthus species and to study the basic properties of wood that develops in Greek environment, in order to explore the possibilities of its utilization in furnishing and other woodworking uses, as sawn timber or plywood, and as a fuel for energy production. Part of these results has been presented in previous conferences (Barboutis and Vasiliou 2009, Barboutis and Kamperidou 2011, Vasileiou et al. 2011).

Methodology / approach

The material of this research consisted of native trees of Ailanthus (Ailanthus altissima (Mill.) Swingle), aged between 11-15 years, harvested from the Botanical Garden of Finikas region in Thessaloniki (Campus of Faculty of Forestry and Natural Environment). From each one harvested tree, logs of 1.10 cm length were obtained, measuring in each one the average diameter, the average thickness of bark and the average thickness of their growth rings.

Three of these logs were transported, immediately after felling, to a plywood production plant in the area of Xanthi, where veneers of (A) 1 mm and (B) 1.5 mm thickness were produced by the rotary cut method. Afterwards, these veneers were used for the production of three-ply plywood products following the production process used by the industry. For the manufacture of the plywood samples, the adhesive of urea formaldehyde was used. The samples of plywood were transferred to an air-conditioned room of the laboratory and after the stabilization of moisture content, the test specimens for the properties of the laminates were prepared, according to the requirements of the corresponding standards. From the rest of the logs, prismatic pieces of 5 cm thickness were formed, using parallel cut process, which remained in a conditioned room for natural drying of wood, till their moisture content descent to approximately 10%. Subsequently, from this material, the properties test specimens were prepared (15 for each property), free from defects and in accordance with the requirements of the corresponding standards.

Results and Discussion

The results of the mechanical and physical properties tests of Ailanthus wood are summarized in Table 1.

The mean diameter of the embarked logs (10 pieces) was 18.29 cm (standard deviation of 2.98 cm), the mean thickness of the bark was 3.96 mm (standard deviation 0.586 mm), while the mean width of their annual rings was 7.75 mm (standard deviation of 2.71 mm) and ranged from 2.5 mm to 13.0 mm, indicating the fast growth of the species. The mean value of moisture content of the specimens used in the properties tests was 10.1% (standard deviation 0.32%), while the mean density of wood (referring to the above moisture content) was 0.60 g/cm^3 (standard deviation of 0.031 g/cm^3) and ranged from 0.48 g/cm^3 to 0.57 g/cm^3. According to the results, its density appears to be similar to chestnut, as well as other species of medium wood density, such as plain and maple. However, the values of static bending strength, and the other mechanical properties examined, are higher or at least similar to the respective values of the properties of the above mentioned wood species (Voulgaridis 2008). Contrasting the values of the properties of Ailanthus coming from the present experimental work with the corresponding values given by researchers from other countries, we observe that wood of Ailanthus grown in Greece prevails especially referring to Modulus of Rupture and Axial Compression strength (Moslemi and Bhagwat 1970, Panayotov et al. 2011).

Table 1. Physical and mechanical properties of Ailanthus wood

Property	Present study*		Panayotov et al. 2011	Moslemi, Bhagwat 1970
	X	s	X	X
Density r10 (g/cm³)	0.60	0.031	0.62	0.531
Shrinkage volumetric (%)	-	-	14.85	10.81
Axial Compression strength (N/mm²)	64.47	3.25	55.83	36.3
Bending strength / MOR (N/mm²)	101.29	9.898	71.11	81.50
Bending strength / MOE (N/mm²)	10259.31	1000.5	11.906	10492.41
Impact bending strength (J/cm²)	3.811	0.357		3.94
Hardness radially (N)	5687.8	579.2	4407	7702
Hardness tangendially (N)	5141.5	564.9	5407	6839

*Mean values (X) of 15 samples and standard deviation values (s)

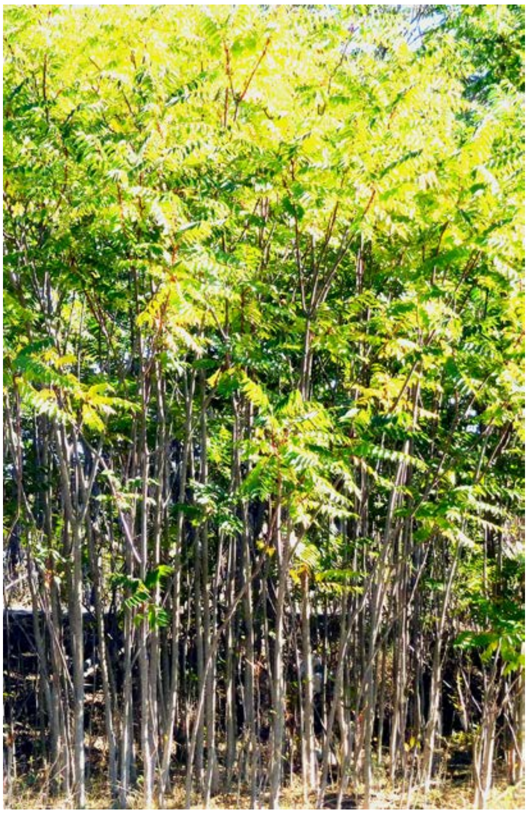

Figure 1. a) cluster of young ailanthus trees in Thessaloniki b) radial texture of sawn wood

As it can be observed in Table 2, the plywood constructed with Ailanthus veneers of 1mm nominal thickness (Ailanthus A) proportionally presented better properties, than those of plywood manufactured with veneers of 1.5 mm nominal thickness (Ailanthus B), except for the case of swelling after immersion in water for 24 hours. Additionally, the corresponding plywood manufactured with veneers of poplar wood, which were intended for industrial veneers production, presented significantly inferior mechanical properties than those of Ailanthus wood, except for the property of swelling. It should also be noted that in wood of Ailanthus, as opposed to that of poplar, there is no presence of knots and, moreover, the veneers appear to have a better design.

Table 2. Mechanical and hygroscopic properties of Ailanthus plywood

Property	Veneer species of plywood		
	Ailanthus A	Ailanthus B	Poplar
Thickness of Plywood (mm)	3.13 (0.07) *	4.58 (0.10)	2.92 (0.08)
Density r08 (g/cm^3)	0.743 (0.013)	0.683 (0.018)	0.407 (0.033)
Bending strength / MOR (N/mm^2)	91.22 (17.16)	88.18 (5.29)	60.85 (10.37)
Bending strength / MOE (N/mm^2)	8716.66 (1264.64)	9870.34 (1003.67)	6251.88 (936.72)
Impact bending strength (J/cm^2)	2.93 (0.88)	2.59 (0.67)	1.01 (0.48)
Screw Withdrawal Capacity (N/mm^2)	29.01 (4.53)	33.35 (5.08)	12.73 (3.11)
Shear Strength dry N/mm^2	2.17 (0.33)	1.52 (0.23)	0.94 (0.19)
Swelling 24h (%)	6.76 (1.14)	5.78 (1.08)	5.05 (1.11)
Absorption 24h (%)	45.13 (2.17)	59.82 (2.26)	77.51 (8.44)

*Mean values of 15 samples and Standard deviation values in parenthesis

Conclusions/outlook

As recorded by the studies till the end of the 21st century, the effects of climate change and particularly, the rise in temperature of the atmosphere will be very important to the ecosystems and vegetation.

In the most vulnerable areas, many endemic species, according to the predictions, will not be able to withstand the new climatic conditions and will be replaced by foreign, more resistant species.

Ailanthus is a fast-growing, precursor species in degraded habitats, withstands a wide range of temperatures, humidity, air and soil quality, and presents satisfying biological durability. Its utilization potential includes a wide range of uses, such as animal feed, fuel, timber, traditional pharmaceutical etc., while its suitability for specialized applications of high added value is constantly being investigated.

This study revealed that the physical and mechanical properties of Ailanthus wood grown in Greek environment are similar to or even better than chestnut wood and other species of medium wood densities.

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