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Risk Assessment and Dendrochronology of Monumental Plane Trees in the Municipality of Thessaloniki

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ABSTRACT: Trees that grow within the urban fabric are under pressures that affect their health and shorten their life span. Some of them, however, manage to survive, grow old and acquire monumental features. Their significant value, along with the risks that occur both for themselves and their environment require a special inventory and continuous monitoring. This research consists of measurements and estimates of biometric parameters, which were applied to four elderly individuals of the Platanus orientalis species that grow in the Municipality of Thessaloniki. Finally, this study identified a limited knowledge and experience concerning the static and dynamic analysis of urban monumental trees in Greece, regarding safety and conservation matters.

KEYWORDS:oriental plane, monumental tree, parameters, dendrochronology, risk assessment.

I. INTRODUCTION

In Greece, the statutory method for the protection of perennial trees is their proclamation as "Preserved Monuments of Nature", according to article 6 of Law 3739/2011. This category generally includes individual elements of nature of particular ecological, biological, scientific and aesthetic value, which are of great monumental character and are inextricably linked to the historical and cultural identity of the place.

The majority the "Preserved Monuments of Nature" in the Greek area, worthy of protection for national purposes, are the oriental plane trees. This species are also seen as a tool in the field of reconstruction of religious and national memories [6,7,8,17]. The oriental plane tree, or Platanus orientalis, is a widespread tree, found in Southeast Europe and throughout the Middle East and West Asia. It is a deciduous tree, which grows quickly to large size, and is characterized by longevity. In Europe, the species declines both due to degradation of its habitats and due to the Ceratocystis platani fungus [4].

For the declaration of the old trees as "Preserved Monuments of Nature", specialized scientists prepare Scientific Reports in order to assess their current status, their risk of failure and their age. In this context, and after an invitation by the Department of Trees and Nurseries of the Directorate of Urban Environment Management of the Municipality of Thessaloniki, a team of scientists set up to prepare a Report with the aim of declaring four old plane trees in the administrative boundaries of the Municipality of Thessaloniki, all rescued from the 1917 fire [1,25].

The purpose of the present study is (1) to assess the risk of selected individuals using the ISA [3] Tree Risk Assessment Form and (2) to assess the status of the internal trunk (analysis - dendrochronology).

II. MATERIAL AND METHOD

Thessaloniki is developed along the northeast coast of the Thermaikos Gulf (BP40-38΄, AD22-257’). The geomorphology of the area was a decisive element in the choice of place for the founding of the city [15]. The climate of the region is Mediterranean. The average annual relative humidity of the air is 68%. The average annual temperature is 16.08 ° C and the average maximum 26.9 ° C. The rainy season during the vegetation period (March-September) is 204.3 mm, according to data from the Department of Environmental

Action in the Municipality of Thessaloniki, concerning the period 1995-2003. The winds that affect the city of Thessaloniki are strong (40 km / h) and have direction B, NE, N, and SW. Vardaris (NW) in particular, is a wind that must be taken in account seriously because of its coolness and dryness, but also in combination with days of total frost. The rocks on which the city was founded are both metamorphosed and pyrogenic of the Paleozoic-Mesozoic background, as well as neogenic quaternary deposits [16]. In particular, the area of the Historic Center is covered by recent and historical excavation materials. In general, the embankments are loose and with poor geomechanical behavior, with thicknesses up to 20 meters, mainly covering neonate formations [10,11,12]. The area is part of the Mediterranean vegetation zone (Quercetalia Pubescentis), which is a special transitional vegetation zone from evergreen broadleaf to deciduous (hilly, subterranean). In particular, it belongs to the Ostryo-Carpinion sub-zone and the Coccifero-Carpinetum growing area [13].

The present study was conducted from March 2019 to June of the same year in the area of the Municipality of Thessaloniki. Specifically, a visual description, risk assessment and dendrochronology was applied on four individuals of the species Platanus orientalis, as proposed by the Department of Trees and Nurseries of the Directorate of Urban Environmental Management of the Municipality of Thessaloniki due to their remarkable age and ecological value.

The Tree Risk Assessment Form (by ISA) was used to assess the proposed plane trees regarding their general condition, health and level of danger towards citizens, infrastructures, environment and any material damage that may occur if we have a limb failure. Based on the input data, the protocol classifies the risk of each tree at four levels (1.Low, 2.Medium, 3.High, 4.Extreme) with respect to each target (human factor, infrastructure, other material damage, environment).

The final evaluation is performed through a risk assessment of the individual problematic tissues concerning the aforementioned objectives and the highest risk value is then accepted for each tissue. To complete the protocol, visual descriptions and photographs of the individuals and the surrounding area were taken, as well as forestry measurements. Tree height measurements were performed using a vertex electronic instrument, measuring the circumference by means of a tape measure and the crown was measured at eight points (N, NE, A, SE, N, SW, D, NW).

Data acquisition for tree dating took place in April 2019. It included an extraction of 12 cores from the 4 trees of interest, and of four cores from 2 trees of similar conditions. The sampling was directed from the outer (living) part of the tree to the interior of the central part (at a height of 1.30 m) and in vertical incisions, around each tree. The cores were extracted using a Pressler's drill (60 cm long), which is an effective sampling method to measure the age of standing trees - 5mm diameter drills are the most suitable for density analysis. The extracted cores were immediately placed on a special wooden base with notches proportional to the thickness of the drill. Also, any holes resulting from sampling were disinfected and then sealed with an appropriate material [9].

The cores were then transferred to the Wood Technology Laboratory (Department of Forestry and Natural Environment, AUTH), where tree age, annual growth width and density were calculated with the aid of Lignostation growth ring width and wood density analyzer. Preparation of the samples for measurement included grinding the cross sections using the cutting head, visual scanning of the wood surface using the LignoScop high resolution digital camera, scanning the surface using the Lignoscan HF detector, and analyzing the growth rings width and density with the respective software. Final age values were obtained using the logarithmic model.

III. RESULTS

Plane tree D1

The plane tree D1 (Castles) is located at the crossroad of the Acropoleos and Eptapyrgiou Streets at an altitude of about 139 m. According to Blionis and Tremopoulos (2017) "Rotonda stream", which was the product of two smaller streams, originated in the area. The riverbed of this stream seems to follow a path in which we also find most of the plane trees of interest.

Today, its diameter is 122 cm and its height is 12 m. Most of its trunk is dead, supported by a reinforced concrete pillar, which residents say was constructed over thirty years to protect it from falling. The trunk of the plane tree D1 is inclined 26o to the east while the living part of the trunk is on the west side. According to the cores extracted from the living section, the thickness of the healthy tissue does not exceed 6.5 cm (the size of its radius is 61 cm) in the south, while in the west, healthy tissue is limited to 3.4 cm. The remaining tissue of the tree inward to the heartwood, is either completely missing (eastern part) or extremely rotten.

The crown size is 80,3 sq.m. asymmetrical to the north-south axis, with the southern part of the crown being almost twice the north, in terms of size. Some dead and broken branches of a maximum diameter of 3 cm are also observed. Also, the absence of a large part of the trunk suggests a possible hit by a lightning strike.

Its root system has suffered severe losses from the pillar foundations as well as multiple road construction projects. The root collar is buried due to cement coating. The soil in the area is covered with asphalt and concrete, which impedes ventilation and increases compression. The general appearance of the trunk predisposes to possible rot of the main roots.

According to the above general description, the trunk of plane tree D1 was rated to be as of severe risk, the root system was rated as of high risk and the crown was rated as of low risk.

Plane tree D2

The plane tree D2 is located on Apostolou Pavlou Street (No. 162) at an altitude of 52 m, next to the Turkish Consulate. Today's height is 21 m and its diameter is 117 cm. In the past, this plane tree has been hit multiple times by large passing vehicles, since the road was not marked with a warning sign.

Its trunk is particularly inclined (53o east) and appears to have been affected by fungi on the same side, as a result of injuries sustained by passing vehicles that failed to heal. To the north east, there is a limited occurrence of moss. Based on extracted core samples, it appears that the inside of the trunk has a living tissue ranging from 17.8 cm in the western part to 23.5 cm in the eastern part (about 65% of the radius of plane tree D2 is rotten, a size that varies slightly, depending on the direction from which the core was extracted).

The crown is medium sized, with asymmetry on the west-east axis and covers an area of 273.7 sq. m. There is also an overextended branch to the north, which is a growth response of the tree trying to balance the trunk forces. The dead branches are small and have a diameter between 2-5 cm. Residents in the area testify that a thick branch (20cm) broke and fell four years ago, fortunately without dramatic impact.

Regarding the root system of tree D2, as mentioned above, it has suffered repeated injuries resulting in the potential loss of primary roots. The area has recently been reconstructed, but the root system seems to be particularly burdened, both by older and modern road projects. In addition, until recently poor soil ventilation makes it possible that the roots are rotten.

According to the above general description, the trunk of the plane D2 was rated to be of high risk, the root system was also rated as of high risk and the crown was rated as of low risk.

Plane tree D3

The plane tree D3 is the largest, with a 26.4 m height and a 140 cm diameter. It is located in Tsirogianni Park, just opposite the White Tower, at an altitude of 18 m and is estimated to have been at the estuary of the Rotonda stream - the terrain was mainly formed by advection (Blionis and Tremopoulos, 2017).

Its trunk has a 19o north-east inclination and exhibits relatively conical shape. Its base is swollen and there are signs of possible older fork and enclosed bark tissue. Despite its old age and the adversities it encounters within the urban environment, the interior of the trunk has been found to carry a low rate of advanced sepsis compared to other individuals. Specifically, the extracted cores were on average 47% healthy compared to the total size (the shortest length of healthy tissue was found in the south, 38%).

The open space where it grows has favored its development and today carries a dense large crown covering an area of 500.4 sq. M. In several main branches 25-30 cm in diameter, there are wounds, bumps and hollow cavities covering about 20-30% of their total area.

The root plate is not visible due to embankment of the coastal front. Safe conclusions about the state of the roots cannot be drawn with the available data; however, the remodeling of the surrounding area has caused some loss of support roots. Still, the constant passing of vehicles burdens the ground with debris from worn tires and the lack of a tree trunk or peripheral holes makes it difficult to ventilate.

Plane tree D3 was assessed through the protocol to be of moderate risk, both for the trunk and the crown.

Plane tree D4

The plane tree D4 is located next to the entrance of the archaeological site of the Galerian Complex at an altitude of 20 m, has a diameter of 124 cm and a height of 24 m. Navarino Square in recent years is a park-square that provides the tree with enough space to grow, however, successive projects have caused significant changes in soil and possibly affected the root system.

The trunk of plane D4 has a northeast inclination of 40 ° and is marked by earlier codominant stems. There are also fungal infections in the cavities, multiple-site sap leakage, and many conks, which even increase over time. It is also important that the rate of rotting wood found at the time of drilling was at least 67% on the NE side (where most of the living tissue was found), with the same rate increasing to 85% on the NE side. The NA and D drills give similar results within the range of the aforementioned percentages.

Its crown is small in size and presents asymmetry in both the north-south axis and the east-west axis with most of the weight concentrating on the eastern part of the crown. Specifically, the total area of the crown is 218.7 sq.m. of which about 160 sq.m. are on the east side. Also a decade ago, the charging of the crown changed due to the loss of a major northern development industry, about 40 cm in diameter.

Due to the excavation of this part of Thessaloniki, it is not possible to have visual contact with the root collar. But the proximity of the archaeological site and the history of the area give us evidence of serious loss of support. Still the rotting observed in hardwood may also be present within the main roots.

The risk of the trunk and crown according to the protocol was assessed as high.

Dendrochronology (D1, D2, D3, D4)

The age of the four plane trees was measured with the help of extracted cores (12 from the selected trees and 4 from test trees). Table 1 shows both the ages of the cores obtained and the total age obtained through the logarithmic model. Also, the lengths of the cores depending on the ages of the trees indicate the time at which the cavities were created on the plane trees, that is, when the plane tree approaches a 50 cm radius (100 cm diameter diameter) or 100 years of age. It is further confirmed by the analysis of cores that as we approach the center, the thickness of the growth rings increases.

Furthermore, based on the ages given by the logarithmic model, we observe that the smaller the sample extracted in proportion to the radius (due to the rot inside the trunk), the higher the resulting age (D1, D4), which indicates the need to develop new dating models specifically tailored to the properties of the species. In addition, within the urban fabric, where trees are subject to drastic changes, such data need to be taken into account in order to allow accurate dating. A characteristic result of these changes is the plane D1, which has the smallest average growth ring widths and the highest mean densities in the extracted cores (Figure 1, 2). Taking into account the preceding description in the risk assessment, it is clear that this plane tree is in decline (very small annual growth). It is also worth noticing that the age of the plane D1 needs to be reconsidered beyond the result of the model, due to the reasons mentioned above and in relation to the photographic documents available.

Table 1. Overall table of data measured for every extracted core

A/A	RADIUS (cm)	DIRECTION	CORE LENGTH (mm)	MEAN RING WIDTH (mm)	MEAN CORE DENSITY (kg/m3)	CORE AGE (YEARS)	TREE AGE (YEARS)	DEVIATION (± YEARS)
D1	61,0	Δ	64,46	0,678	512,5	95	828	± 40
		N	61,75	0,471	508,1	131		
D2	58,7	A	233	2,137	494,5	109	205	± 15
		Δ	212,5	1,968	484,6	108		
		N	201,2	2,718	480	74		
D3	70,0	B	387,6	2,47	463	157	235	± 15
		A	323,5	2,527	486,8	128		
		N	427,2	2,83	469,1	151		
D4	62,0	BA	280	2,8	467,5	100	310	± 20
		Δ	112,3	1,35	462,5	83		
		NA	214,5	2,26	448,1	95		
		B	110	1,206	467,3	91		
D5	62,5	B	441,1	3,106	486,8			
		A	421,4	2,946	489,9			
T1	27,8	1.1	278,4	3,663	506,8	76	76 *	
		1.2	249,8	3,287	464,4	76		
*= CORE IS THE SAME LENGTH WITH RADIUS (HEALTHY)								

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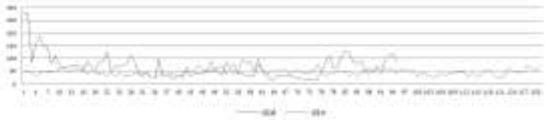

Figure 1. Diagram of annual ring width (pith to bark direction)

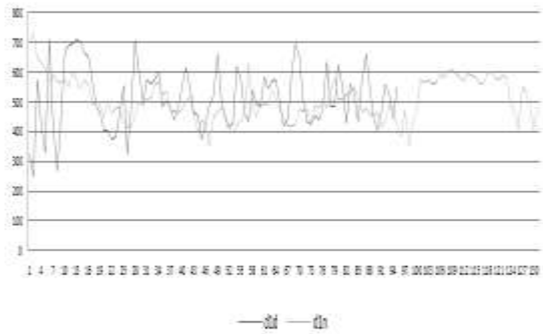

Figure 2. Diagram of average radial density (pith to bark

IV. DISCUSSION-CONCLUSION

According to the aforementioned growth and morphological data as well as the soil analysis currently at the stage of determination, the four plane trees (D1, D2, D3, D4) of Thessaloniki have all those necessary characteristics defined by law to be declared as Nature Monuments. From their description, monumental trees appear to be in advanced age with serious static, dynamic, health and safety problems for both themselves and their environment. The degree of risk was rated high for most of them, with dominant problematic tissues the trunk and the root system. The need for immediate measures to protect them has therefore been identified. In many cases their survival is linked to the presence of groundwater and older proximity to water supply facilities such as aqueducts, taps etc. Their spatial distribution (Figure 1) is located on the same current in the eastern part within the walls [14]. Concerning tree dating, there is a need to develop models specifically tailored to species properties that take into account urban conditions. Ages as a whole appear to be consistent with estimates from previous research based on photographic documentation, with the exception of plane tree D1 [5]. In conclusion, these trees should immediately be declared Monuments of Nature, while launching a series of special studies (nutrition, static, etc.) with the aim of preserving them for future generations. In particular, there was a lack of specialized knowledge and experience regarding Monumental Trees, which indicates the need to develop related research activity particularly in Greece, which hosts a large number of perennial trees, mostly Oriental planes.

Figure 3. Map detail of Thessaloniki showing the hydrology and geomorphology of the area in relation to the trees of interest in 1915 (within the smaller frame). Source: Edited from original map by Gkala - Georgila (2015)

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Appendix

Table 2. Total tree risk assessment categorization

RISK ASSESSMENT																					
TREE PART	CONCERNES	TARGET DISTANCE (m)	ΑΡΙΘΜΟΣ ΣΤΟΧΟΥ*	LIKELYHOOD												CONSEQUENCES				RISK RATING OF PART*
				FAILURE				IMPACT				FAILURE & IMPACT								
				IMPROBABLE	POSIIBLE	PROBABLE	IMMINENT	VERY LOW	LOW	MODERATE	HIGH	UNLIKELY	AT	LIKELY	VERY LIKELY	NEGLIGIBLE	MINOR	SIGNIFICANT	SEVERE	
TR	PILLA	12	1				X				X				X				X	SEVE

	UNK	R FAILURE																			RE
				2				X			X				X				X		HIGH
				3				X			X				X				X		HIGH
	ROOTS	ROT, CUT		1			X					X			X					X	HIGH
				2			X					X			X				X		HIGH
				3			X					X			X				X		HIGH
	CROWN	DEAD BRANCES	8	1			X			X			X				X				LOW
D2	TRUNK	DECAY, INCLINATION	15	1			X					X			X					X	HIGH
				2			X					X			X				X		HIGH
				3			X					X			X			X			MODERATE
	CROWN	DEAD BRANCHES		1			X		X				X				X				LOW
	ROOTS	POSSIBLE DECAY, CUT		1			X					X			X					X	HIGH
				2			X					X			X				X		HIGH
				3			X					X			X			X			MODERATE
D3	CROWN	WIND, CAVITIES, WOUNDS	16,7	1		X						X		X						X	MODERATE
				3		X					X		X						X		LOW
	TRUNK	INTERNAL DECAY		1		X						X		X						X	MODERATE
				2		X					X		X					X			LOW
				3		X					X		X					X			LOW
				4		X					X		X						X		LOW
D4	CROWN	INTERNAL DECAY, WIND	24	1			X					X			X					X	HIGH
	TRUNK	INTERNAL DECAY		1			X					X			X					X	HIGH
				2			X				X			X				X			LOW

*Target number:1=People, 2=Infrastructures, 3=Private Damages, 4=Environment

Matrix 1. Likelihood matrix.

Likelihood of Failure	Likelihood of Impacting Target			
	Very low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

Matrix 2. Risk rating matrix.

Likelihood of Failure & Impact	Consequences of Failure			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

Matrix 1. Likelihood matrix.

Likelihood of Failure	Likelihood of Impacting Target			
	Very low	Low	Medium	High
Imminent	Unlikely	Somewhat likely	Likely	Very likely
Probable	Unlikely	Unlikely	Somewhat likely	Likely
Possible	Unlikely	Unlikely	Unlikely	Somewhat likely
Improbable	Unlikely	Unlikely	Unlikely	Unlikely

Matrix 2. Risk rating matrix.

Likelihood of Failure & Impact	Consequences of Failure			
	Negligible	Minor	Significant	Severe
Very likely	Low	Moderate	High	Extreme
Likely	Low	Moderate	High	High
Somewhat likely	Low	Low	Moderate	Moderate
Unlikely	Low	Low	Low	Low

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