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Ecological Evaluation and Sustainable Management of the Riparian Forest in Central Greece

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The aim of this research is the ecological evaluation of the trees of a riparian peri-urban park, with measurement, inventory and processing of qualitative and quantitative variables of trees (Dendometry) in the riparian forest of the river Karpenissiotis in Central Greece. Each tree is recorded in relation to its species (structural elements) including the diameter at breast height (DBH), the height (H), the ruggedness coefficient (H/D), the height of the crown (Hk), the length of the crown (Lk), the diameter of the crown (Dk), the order of the crown, the order of vitality, the tendency of evolution, the position of the trunk, the shape of the crown, the problems in the space of the roots, the crown, pruning, insect infestations, fungi, and runoff. From the statistical analysis and processing of the measurements, assessment was made of the condition of their health and stability; and necessary measures are proposed in order to significantly improve the ecological conditions of a riparian forest. Thus, the main problems presented by the forest species of trees concerned mainly the sloping, crooked and serpentine trunks, asymmetrical crown shape, insect and fungal infestations. The riparian peri-urban plane forest studied is dominated by trees, which are classified as remaining, normally growing with long asymmetrical crowns with a moderate health status and moderate stability. For the sustainable management and sustainable development of the riparian forest, measures are proposed which are necessary for the forest protection of the trees including their health and safe growth.

Keywords: forest protection, riparian forest, selection of items, tree register.

Introduction

A riparian forest is one that grows on flat banks, which are not constantly wet, but rather the soil is being supplied with large amounts of water through flooding, and do not suffer from prolonged drought during times of the water level drop. The riparian ecosystems are found next to or near rivers or lakes and the vegetation depends directly or indirectly on the existence of water (Efthimiou, 2010).

According to Wenger et al. (1990), while the riparian forests of Europe covered an area of about one million ha until the 18th century, today their area has been reduced to about 350,000 ha (Efthimiou, 2000). Nowadays, in a large number of cases, riparian forests are preserved as relics along rivers and on the shores of lakes. In Greece, there were many hydrocephalus forests (Papaioannou, 1953): in Manolada, Lake Lysimacheia, the plain of Giannitsa, the intermediate plain of Xanthi–Komotini and Kotza-Orman (Nestos Delta). Most of them have been destroyed, degraded or drastically reduced in the last 50 years, with the largest current remnant being the riverside forest of Nestos (Kotza–Orman) (Efthimiou, 2000). The 1992 Greek forest inventory mentions only the plane tree forests, which constitute 1.33% of the country's forests (Efthimiou and Jerrentrup, 2006). There are 378 wetlands in the country, 17 of which cover a total of about two million acres (Tsiouris and Gerakis, 1991).

The urban and peri-urban forests provided various kinds of goods and services, such as improvement of air quality, water and temperature regulation, noise reduction, and sites of recreation. From a social perspective, urban and peri-urban forests can be seen as places of particular interest (Brockerhoff et al., 2017; Borrelli et al., 2017; Dlamini, 2020). In Italy, urban and peri-urban forests are generally considered as important places for promoting social activities (Salbitano and Sanesi, 2010). Urban forestry, in its broadest sense, has shown its potential to play an important role in the context of emergencies, such as climate change, risk of desertification and rehabilitation of degraded sites. The multi-functionality of forests including cultural and social aspects (involve local populations in the planning and managing these resources) assumes significant importance.

According to Suárez (2002), vegetation is directly related to the diversification of the landscape, the regulation of water temperature, the organic material and nutrients input, and it even has the capacity to design micro-environments used by different organisms (Calderon et al., 2014). The composition of vegetation is a key element in assessing the environmental quality of a river.

The originality of the present research is the creation for the first time of a tree registry in a peri-urban riparian forest in central Greece. The findings and recordings highlight the problems and infestations of trees as well as human activities. The formulation of proposals for the improvement of the ecological conditions of growth and forest protection of the trees thus improves the state of health, stability (Papadopoulos, 2015) and their sustainability (Kalfas, 2019; Papadopoulos et al., 2020).

The aim of this research is to address the following questions in the riparian forest of the river Karpenissiotis in Central Greece:

a What is the ecological condition of the trees of a riverside suburban park?

b How can the qualitative and quantitative variables of trees be used in their evaluation?

The present study extensively investigates the terrestrial measurement and inventory of all qualitative and quantitative variables of riparian vegetation trees, for the first time, with the aim of compiling a register of trees and highlighting problems, including climatic conditions, human activities and disease outbreaks, and for the safety of visitors to the riparian forest.

Materials and Methods

Study area

The peri-urban riparian forest in Kefalovrysso Park was selected as the research area, which is a suburban amusement park and is located on the river

Karpenissiotis, next to the town of Karpenissi (*Fig. 1*), capital of the prefecture of Evritania, in central Greece. The study area is located next to the river Karpenissiotis and its dominant vegetation consists mainly of riparian forest species, such as *Platanus orientalis* L. and *Salix alba* L., while there are also *Juglans regia* L., *Sambucus nigra* L., *Alnus glutinosa* Miller, *Acer pseudoplatanus* L,. *Rubus* L. *sp*., *Smilax excelsa* L., with pronounced aesthetic, and ecological value as well as rich biodiversity.

In the research area, there is a lot of traffic due to the operation of a refreshment room, a restaurant, a botanical garden and a trout fish farm. In the wider area of Kefalovrysso Park (*Fig. 2*), there are sports facilities (tennis courts), a traffic education park, a church and a historical event site 'The Botsaria' (from the name of the hero Markos Botsaris) for the liberation of the country from Turkey. It is a peri-urban area attracting a lot of people and hosting numerous events throughout the year.

Fig. 1. *The location of study area (Google maps)*

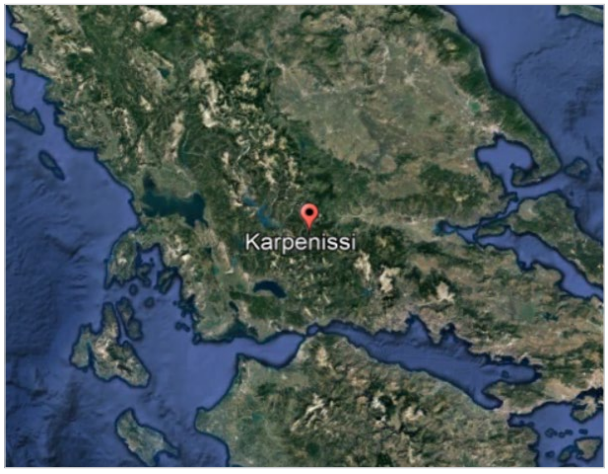


Fig. 2. *Study area (Google maps)*

Research method

In Kefalovrysso Park, representative sampling plots of similar forest stands were established for the measurements of system elements (dendro-metric information for each tree) in order to ecologically evaluate the condition of the trees. The sampled plots were obtained on the basis of the dominance of four species *(Platanus orientalis, Juglans regia, Salix alba, Acer pseudoplatanus)*, which ecologically characterize the whole ecosystem. A total of 396 trees belonging to these species were measured. The survey was conducted from March to November 2020.

In more detail, all the trees in the forest were numbered and the height (H) and crown height (Hk) of each tree was measured with the Haga altitude, and the breast high diameter (DBH) with the caliper. The length of the crown was calculated as the difference between the height and the starting height of the crown (Lk = H–Hk).

The recordings of the problems in the roots and the trunk from pruning or the attacks by insects, fungi, and occurrence of outflow of liquids were assigned to two categories (YES/NO), while the trunk position was evaluated in three categories according to the deviation from the vertical position (*Yes* when the trunk position is vertical, *Slightly Inclined* trunk position when there is a little deviation from the vertical position, and *No* when the trunk position deviates significantly from the vertical position) as well as for the state of health and stability (good, poor and moderate) to three. Crown and vitality classes and evolution tendency were calculated according to the IUFRO classification system (International Union of Forest Research Organizations).

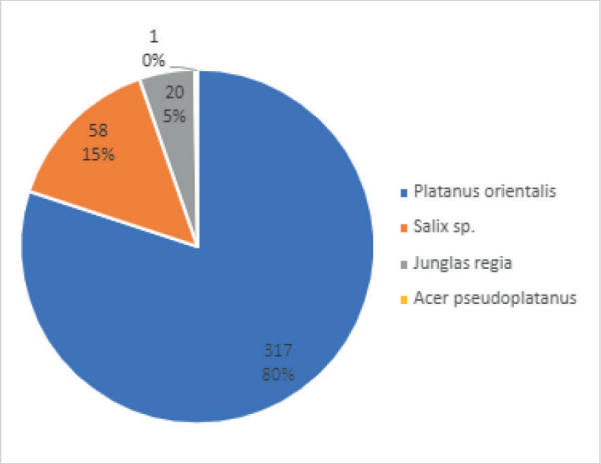
The values of height (H) and diameter (D) were used to calculate the compressible factor (H/D); the smaller the value, the more stable the tree. More specifically when H/D >100, the tree is characterized as very unstable, when H/D = 80–100 is unstable, when H/D < 80 is stable, and when H/D < 45, then

it is characterized as very stable. Statistical analysis, tables and graphs were prepared with the Microsoft Office Excel program.

Results and Discussion

From the recording and statistical processing of 396 trees of the total population of the riparian forest, it appears that it consists of 4 different riparian species of broadleaves, specifically, *Platanus orientalis*, with 317 trees (80.05%), *Salix alba* with 58 individuals (14.65%), *Juglans regia* with 20 individuals (5.05%), and *Acer pseudoplatanus* with 1 tree (0.25%) (*Fig. 3*).

Fig. 3. *Frequencies and percentages of the Riverside Sampling Population*



The long-crown ones with a percentage of 73.23% dominate, followed by the short-crown with 14.65% and finally the middle-crown with 12.12%. The majority (99.24%) of the trees are growing normally, while 0.76% are growing poorly. Regarding the evolution trend, 89.14% of the trees are classified as remaining, 10.1% as ascending while 0.76% belong to the remaining ones. The majority of the trees (69.19%) show an asymmetrical crown and only 30.81% show symmetrical. A deviation from the vertical position is shown by 4.04% of the trees; 37.37% show no deviation at all; and slightly inclined are 58.59%. Problems in the trunk were found in 59.6% and those from pruning in 26.26% (*Fig. 4*), while the problems from insects were found in 80.05% (*Fig. 5*), problems in the crown were observed in 25.76% (*Fig. 6*) and fungi (55.30%) were also important.

The vast majority of the total population of trees (194 trees, 48.99%) show moderate health status, 44 trees (11.11%) of the total population show good health, while 158 trees (39.9%) show poor health (*Fig. 7*). Of the total 396 trees, 43 trees (10.86%) have good stability, 222 (50.06%) have poor stability and the remaining 79 (45.2%) are moderately stable (*Fig. 8*). Besides, 333 trees (84.09%) from the total number of the counted trees do not show any problem in the root area (regarding diseases, root coverage, soil compaction, root cutting, sidewalk elevation, soil pollution, etc.), as well as the majority of the trees, 371 trees (93.69%), do not show an outflow of fluids from the central trunk and of individual branches.

Appropriate graphs were used for the best presence of the results.

Fig. 4. *Frequencies and percentages of problems from pruning of the total population*

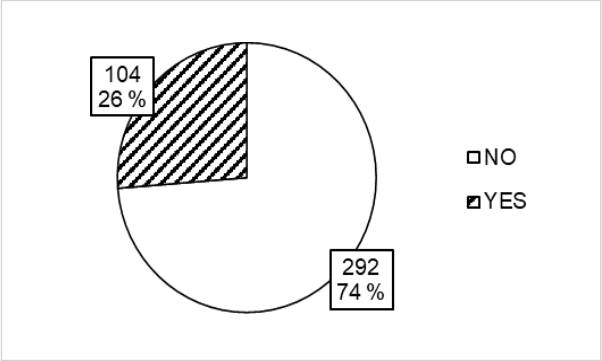


Fig. 5. *Frequencies and percentages of insect infections of the total population*

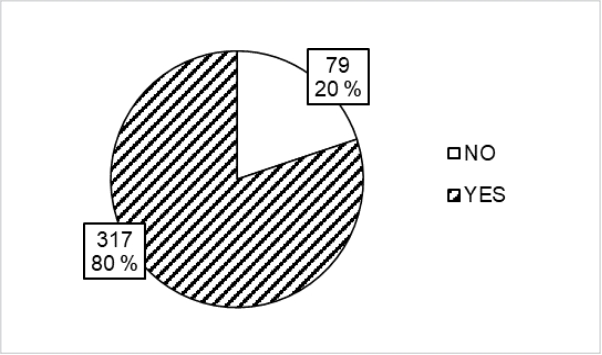


Fig. 6. *Frequencies and percentages of problems of the crown of the total population*

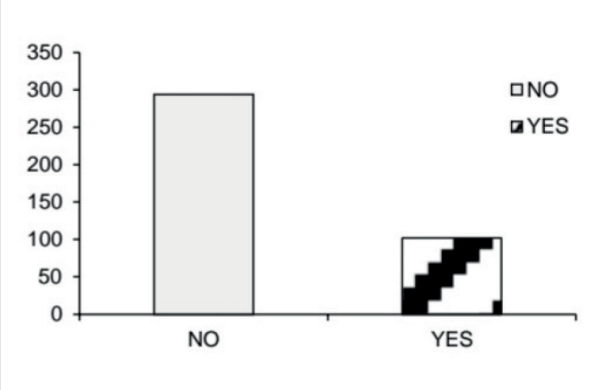


Fig. 7. *Frequencies and percentages of the health status of the total population*

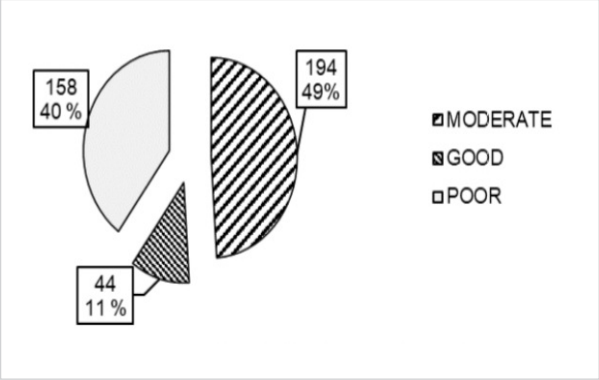
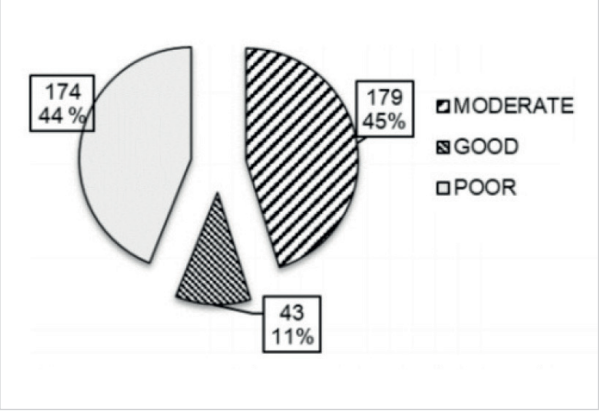


Fig. 8. *Frequencies and percentages of the stability of the total population*



In *Figs. 9–14*, the percentages of two qualitative variables are correlated each time, namely stability with the rest, with the health status (*Fig. 9*), vital classes (*Fig. 10*), evolution trends (*Fig. 11*), pruning problems (*Fig. 12*), trunk problem (*Fig. 13*) and crown problems (*Fig. 14*).

In more detail in each figure, the bars refer to the individual evaluation categories of all the remaining qualitative variables per category of stability.

Stability / Health status

It is of particular interest that 32.40% of the trees with moderate stability (49.86% of the total number of trees studied) had moderate health and 13.16% showed good health (*Fig. 9*).

Stability / Vitality classes

It is remarkable that 47.84% of the trees with moderate stability (48.84 % of the total number of trees studied), were normally developed. All the trees with good stability (movement 44.05% of the total number of trees studied) were normally developed (*Fig. 10*).

Stability / Evolution Trends

It is worth emphasizing that of the total number of the trees with good stability (44.55% of the total number of trees studied), 41.77% were remaining; of the trees with moderate stability (49.86% of the total number of trees studied), 43.03 % were remaining; and of the trees with poor stability (5.55% of the total number of trees studied), 4.55% were also remaining (*Fig. 11*).

Stability / Pruning problems

The majority of the trees in various stability categories did not show pruning problems, and particularly among trees with moderate stability (49.86% of the total number of trees studied), 34.68% did not show problems with pruning, while the remaining 15.18% had problems (*Fig. 12*).

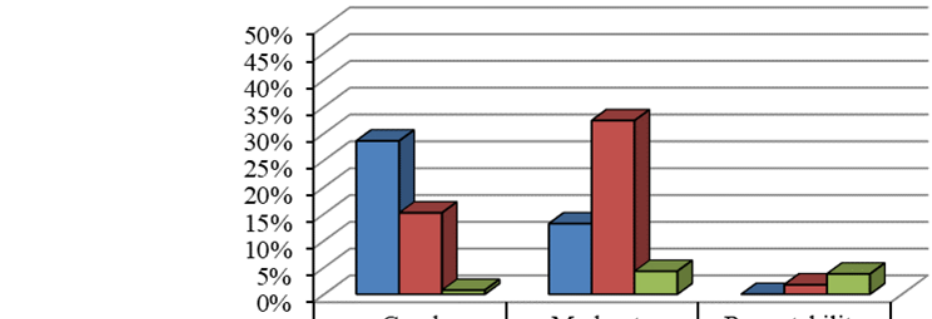
Stability / Trunk problem

Among trees with moderate stability (49.87% of the total number of trees studied), 33.67% showed trunk problems, and among trees with good stability (Fig. 11), (44.54% of the total number of trees studied), 20.75% had trunk problems (*Fig. 13*).

Stability / Crown problems

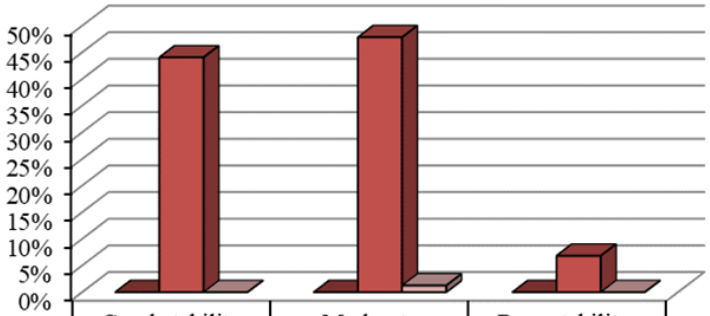
As shown in *Fig. 14*, 37.46% of the trees did not show crown problems and had good stability. Besides, 34.3% of the trees had moderate stability and zero crown problems. There is also a small percentage (15.44%) that had problems in the crown and moderate stability; these were are old tree species.

Fig. 9. *Frequencies and percentages of health status and stability*



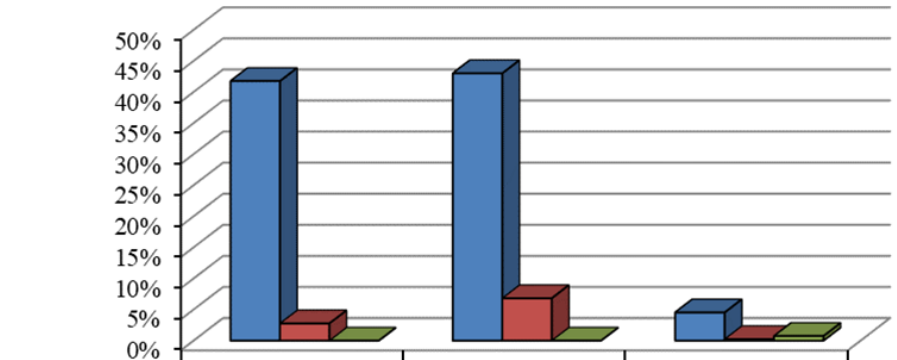
	Good stability	Moderate stability	Poor stability
Good health	28.6 %	13.16 %	0 %
Moderate health condition	15.18 %	32.4 %	1.77 %
Poor health	0.75 %	4.3 %	3.79 %

Fig. 10. *Frequencies and percentages of vitality and stability classes*



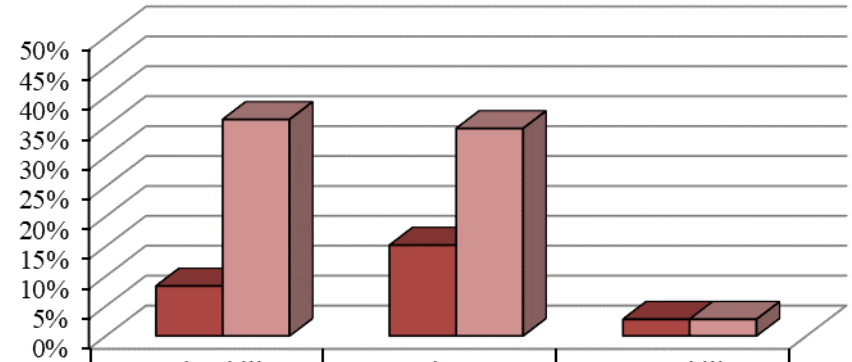
	Good stability	Moderate stability	Poor stability
Poorly developed	0 %	0 %	0 %
Normally developed	44.05 %	47.84 %	7 %
Cachectic developed	0 %	1 %	0 %

Fig. 11. *Frequencies and percentages of evolution trends and stability*



	Good stability	Moderate stability	Poor stability
REMAINING	41.77 %	43.03 %	4.55 %
ASCENDING	2.78 %	6,83%	0.25 %
REMAINING	0 %	0 %	0.75 %

Fig. 12. *Frequencies and percentages of problems from pruning and stability*



	Good stability	Moderate stability	Poor stability
YES	8.35 %	15.18 %	2.78 %
NO	36.2 %	34.68 %	2.78 %

Fig. 13. *Frequencies and percentages of trunk problems and stability*

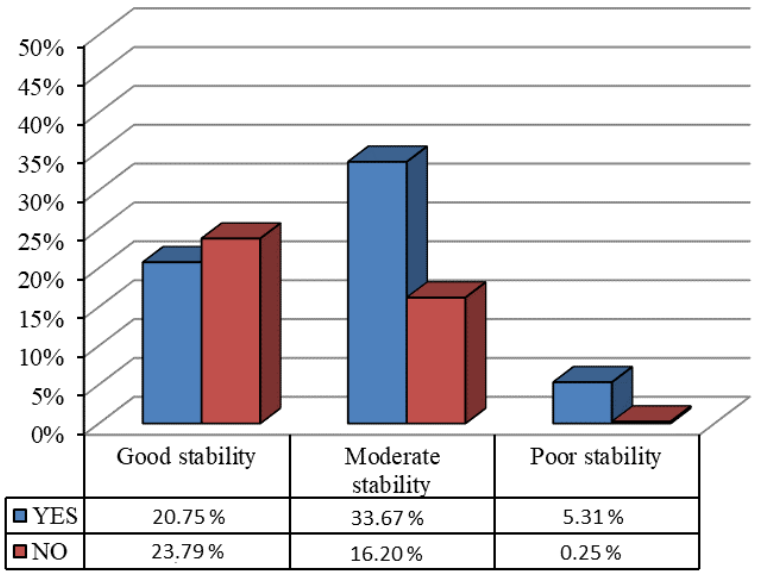
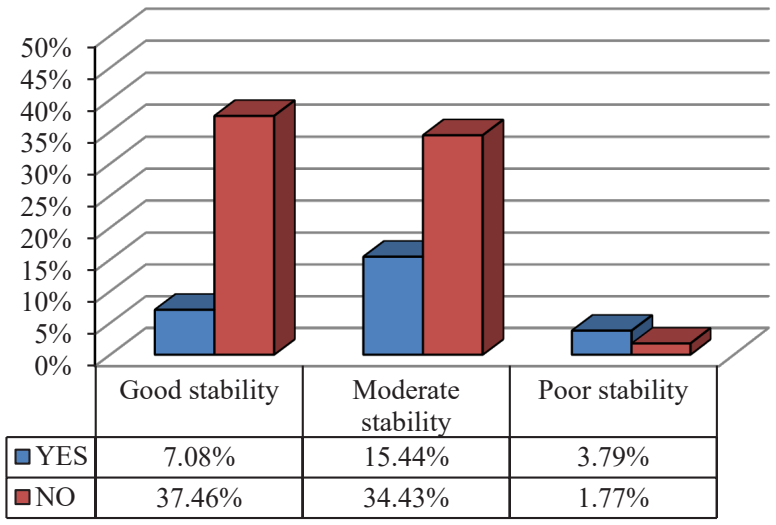


Fig. 14. *Frequencies and percentages of canopy problems and stability*



From this research, the following problems and diseases were recorded in the peri-urban riparian forest of the Karpenissiotis River:

- Absence of regular and organized forestry interventions, such as pruning, resulting in open incisions – wounds and pits (hollows);
- Existence of forking and bifurcation;
- Open wounds and incisions have not healed all these years, resulting in the creation of 'carcinomas', deformities and rot in the central trunk and in the thicker and thinner branches;
- Insect infestations by fungi as well as effluent, especially important for the sustainable presence of trees; root cuts from human activities.

Other problems that indirectly affect the ecological situation of the riparian forest of Karpenissiotis are as follows: a) pollution of the riparian ecosystem of Kefalovrysso Park from the disposal of household waste and construction materials, i.e., rubble next to the riverbed of the river Karpenissiotis; b) floods that carry materials resulting in alteration of banks and degradation of water quality; and c) a risk of invasion of the riparian plane forest by *Acer negundo*, an alien species planted during the regeneration of the adjacent area of the Karpenisiotis river.

In the riparian forest of the river Karpenissiotis, pure and mixed clusters of *Platanus orientalis, Salix alba* and *Juglans regia* were found. The mixed stand of trees with a complex and multilevel vegetation structure contribute to: a) an increase in the biodiversity of the ecosystem, b) an increase in their resistance to damage due to biotic and abiotic factors, c) their sustainable presence, and d) their aesthetic upgrade (Daniels and Kirkpatrick, 2006; González-García et al., 2009; Goddard et al., 2010; Papadopoulos, 2015; Kontogianni, 2017).

In the riparian forest, at the bottom of the trees, there is dense bush vegetation, mainly from *Rubus* species, which is particularly important in terms of protection and safety of young, old and elderly who use the area, as it is not visible from anywhere (Walker, 1991; Papadopoulos and Zagas, 2019).

Conclusions and proposed optimization and protection measures

In the riparian forest of Kefalovrysso Park, pure and mixed clusters of *Platanus orientalis, Salix alba* and *Juglans regia* are found. It is a plane forest with willows into which *Juglans regia* and *Acer pseudoplatanus* have entered naturally or artificially. The pressure from the intense human presence is reflected in the problems mentioned in the riparian forest species of the peri-urban area. In conclusion, the riparian peri-urban plane study forest is dominated by trees remaining, normally growing with long crowns with moderate health status and moderate stability.

For the sustainable management and sustainable development of the riparian forest in Kefalovrysso Park, some immediately applicable measures are the following.

Pruning the trees of the riparian forest of Karpenissiotis river (Kefalovrysso Park) should solve problems of public safety, tree health and aesthetic degradation (Samara and Tsitsoni, 2003; Papadopoulos and Zagas, 2019) to improve the ecological growing conditions of trees with moderate and poor stability (Daniels and Kirkpatrick, 2006).

It is proposed to directly enrich the riparian vegetation of the pure clusters with native riparian forest species in order to ultimately increase the biodiversity and ecological stability of the ecosystem. The continuous monitoring of the riparian forest is required, and especially of the plane trees for immediate detection of possible infestation by the fungus *Ceratocystis fibriata f. sp platani* which has been detected in a plane forest of the prefecture of Evritania.

Cleaning of the riparian ecosystem of Kefalovrysso Park from household waste and building materials, i.e., rubble next to the Karpenissiotis riverbed is required, as well as support of the banks with smaller or larger technical projects to prevent damage to the banks and degradation of water quality. Preparation of a strategic plan for the tourist development of

Kefalovrysso Park based on the natural landscape, tradition and culture is needed (Tsitsoni et al., 2005; Goddard et al., 2010; Varras and Efthimiou, 2018).

The control of diseases can be achieved to a large extent by scientifically appropriate pruning by applying relaxing pruning renewal-discharge pruning, by removing all dead and rotten branches or parts of them as well as greedy shoots (Papadopoulos, 2015). Dangerous trees with poor stability must be removed after the issuance of the relevant logging permits and if all possible conservation measures have been exhausted first. It is necessary to heal wounds of the bark and open incisions from old prunings with the application of ecological preparations as well as handle open pits (hollows)m especially in old plane trees and willows, by cleaning them, so as to stop the spread of rot and improve stability of trees (Dafis, 2001).

The maintenance of the register of trees in combination with its constant updating will effectively contribute to the preparation of management plans, the presentation of appropriate forestry interventions and forest protection measures, and maintenance for the promotion, strengthening and improvement of the specific ecosystem (Dafis, 2001; Tsitsoni et al., 2005; Manolis et al., 2009; Tsitsoni et al., 2013; Papadopoulos, 2015; Papadopoulos and Zagas, 2019).

The results of the research work show that with the overall implementation of the proposed measures in the riparian ecosystem of Kefalovrysso Park, in the context of their sustainable management, the existing ecological conditions for growth and forest protection, the protection of trees will significantly improve their health and stability (Groombridge and-Jenkins, 2002; Papadopoulos, 2015; Papadopoulos, 2021), as well as water quality (Zogkaris et al., 2007; Tasoulas et al., 2013; Varras and Efthimiou, 2018; Kalfas, 2019; Papadopoulos et al., 2020; Papadopoulos et al., 2021).

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