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Woody Species Dynamics in the Priority Habitat 91E0* in Nestos, Greece †

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Abstract: Tree species composition, stand structure, and growth dynamics were evaluated within the priority habitat 91E0* (alluvial forests with *Alnus glutinosa* (L.) Gaertn., and *Fraxinus excelsior* L.) in the Nestos region of northeastern Greece. This study aimed to understand the ecological dynamics of this unique habitat and to properly plan restoration actions. Measurements were conducted in May and July 2023 across 14 plots distributed randomly along both banks of the Nestos River (east and west). A total of 667 trees with a DBH $\geq$ 2.5 cm were recorded, representing 13 species and 10 families. Tree densities ranged from 14 to 541 stems ha^{-1}, and the average basal area was 8.77 m^2 ha^{-1}. Both density and basal area significantly differed between the two riverbanks. Our results indicate that *Alnus glutinosa* dominates in the alluvial forest, forming more resilient communities with *Populus alba* L., *Populus nigra* L., and *Salix alba* L. However, *Fraxinus angustifolia* Vahl was not as prevalent as expected. These findings highlight the need for conservation actions and draw attention to the threats facing the alluvial forest.

Keywords: alluvial forests; *Alnus glutinosa*; tree species composition; stand structure; biodiversity

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1. Introduction

The priority habitat 91E0*, which comprises alluvial forests with *A. glutinosa* and *F. excelsior*, represents a critical ecosystem found along riverbanks and floodplains in Europe. These forests are vital for maintaining biodiversity, regulating water cycles, and providing ecosystem services such as flood mitigation and habitats for wildlife. In Greece, the alluvial forests along the Nestos Delta are particularly noteworthy due to their unique composition and ecological significance. The Nestos Delta hosts 22 habitat types (Annex I Dir. 92/43/EEC) and 307 different bird species [1].

Understanding the dynamics of woody species within these habitats is essential for effective conservation and restoration planning. The Nestos River's alluvial forests face numerous challenges, including hydrological changes, invasive species, and human activities that threaten their stability and biodiversity. Recent studies have highlighted the expansion of the alien and invasive species *Amorpha fruticosa* on the ecosystem [2].

Therefore, it is crucial to monitor tree species composition, stand structure, and growth dynamics to inform targeted conservation actions and ensure the long-term sustainability of these ecosystems.

2. Materials and Methods

2.1. Study Area

The study area is located in SCI GR1150010 (Natura 2000 site) in the northeastern region of Greece and includes alluvial forests of the priority habitat 91E0 in the Nestos Delta. The Nestos River, also known as the Mesta River in Bulgaria, flows for approximately 234 km, with about 130 km within Greece, eventually emptying into the Aegean Sea. The river serves as a natural border between Greece and Bulgaria and is one of the most ecologically significant rivers in the Balkans. Alluvial forests are found in the floodplain areas and are influenced by the river's hydrological dynamics, which create a unique environment for diverse plant and animal species.

Fifteen (15) circular permanent plots, with a radius of 15 m each, were established in May 2019. They were randomly and homogeneously distributed along the habitat (Figure 1) [3].

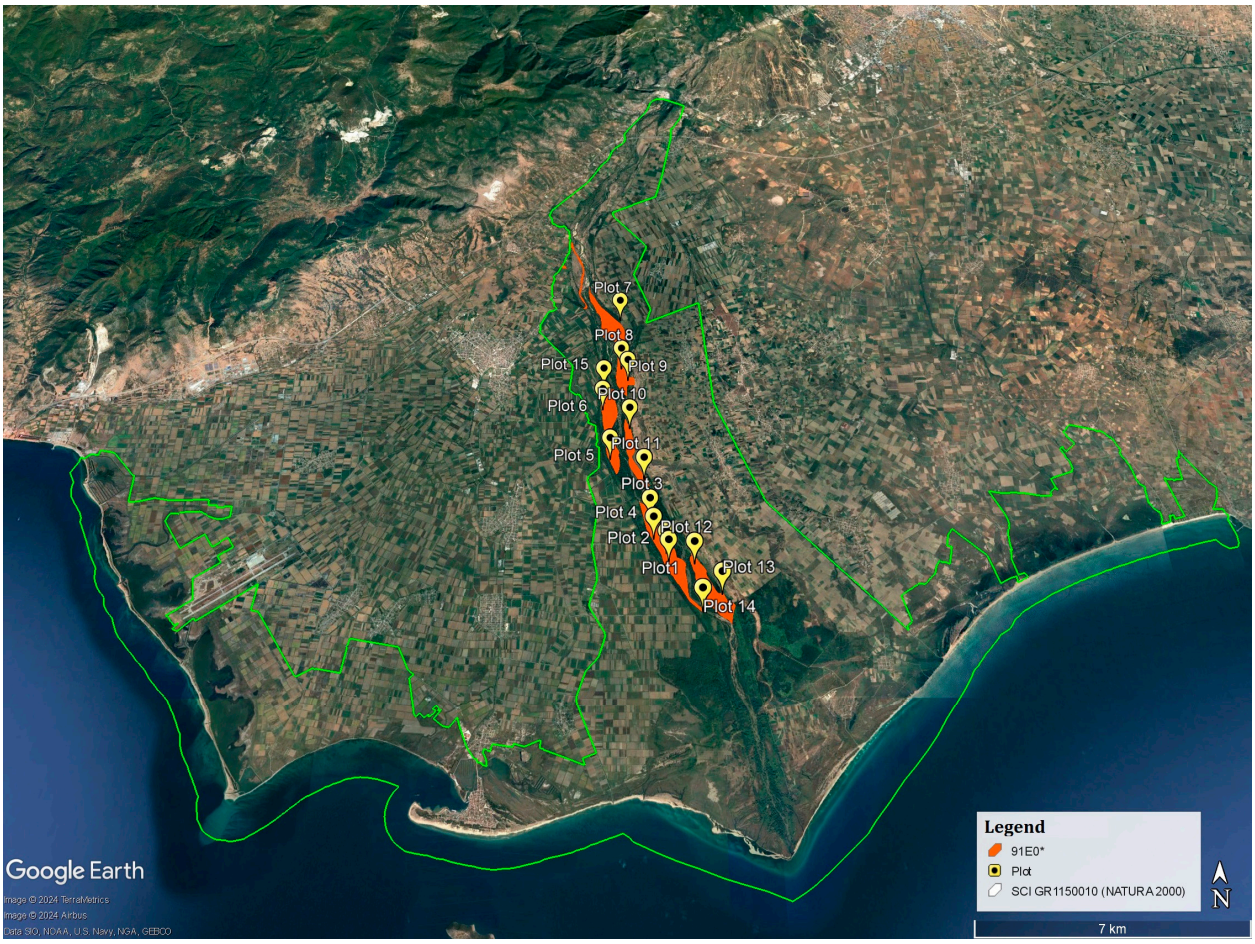

Figure 1. Distribution of the fifteen permanent plots along habitat 91E0*. Seven plots in the east and eight plots on the west bank of the Nestos river (Map @ Google Earth V 7.3.6.9796, June 2024).

2.2. Environmental Variables

The region's climate is humid according to the UNEP [3] Climate Zone Classification System. However, the translocation of rainfall during the last 50 years in the Nestos Delta has been identified [4] with significant precipitation decreases in the coastal area (where

the alluvial forest extends). To monitor environmental parameters, a meteorological station was installed in a forest opening in early July 2019 at the eastern bank of the river where the priority habitat 91E0* expands. The recorded parameters included air temperature, air relative humidity, global solar radiation, wind speed and direction, precipitation, soil water content, and temperature at a 10 cm depth. Meteorological variables monitored from July 2019 to July 2023 were used for this analysis.

2.3. Tree Species Dynamics

In each of the 14 plots, tree species were recorded, along with individual tree diameters at breast height (DBH, cm), as well as tree heights (m). For this analysis, only trees with a DBH equal to or greater than 2.5 cm were considered. Data collection was carried out in May and July 2023 across 14 of the 15 plots, as one plot (plot #6) was inaccessible due to flooding events. Tree species composition, density, and basal area were analyzed. Additionally, diameter distributions were analyzed using the three-parameter Weibull distribution [5,6]. Similar measurements carried out in the 15 plots in May 2019 [3] will be used for comparative analysis.

3. Results

3.1. Environmental Variables

The mean monthly variations in air temperature (Tair) and soil water content (θ) at a 10 cm depth and cumulative precipitation and reference evapotranspiration (ETo) are presented in Figure 2. The mean monthly value of air temperature was 14.1 °C, soil water content was 33.69%, the mean monthly ETo was 77.19 mm month^{-1}, and the total rainfall was 2059.8 mm.

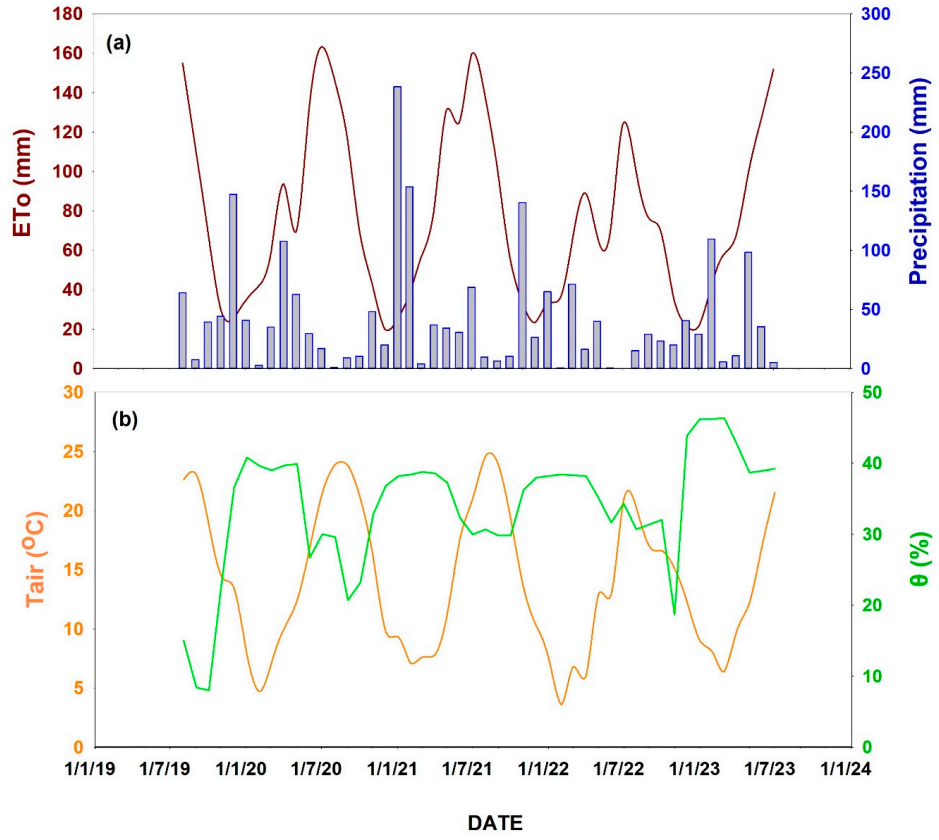

Figure 2. Monthly values of (**a**) reference evapotranspiration (ETo) and precipitation and (**b**) mean air temperature (Tair) and soil water content (θ) at 10 cm depth.

On average, the drier period, spanning from early June to late September each year, exhibited higher average air and lower soil water content. During this time, the mean monthly reference evapotranspiration was high and ranged from 68.69 mm month^{-1} in June 2022 to 163.23 mm month^{-1} in July 2020.

3.2. Tree Species Dynamics

A total of 667 trees with a DBH $\geq$ 2.5 cm was recorded, representing 13 species and 10 families. The recorded species were *Acer negundo*, *A. glutinosa*, *Celtis australis* L., *Cornus sanguinea* L., *Ficus carica* L., *Morus alba* L., *Platanus orientalis* L., *P. alba*, *P nigra*, *Prunus cocomilia* Ten., *Robinia pseudoacacia* L., *Sambucus nigra* L., and *S. alba*.

Mean tree densities varied from 14 to 541 stems ha^{-1}, with *A. glutinosa* being the dominant species in the alluvial forest, while *C. australis*, *P. orientalis*, and *P. cocomilia* had the least presence.

The majority (79%) of trees per ha are concentrated in diameter classes below 44 cm. Specifically, 90% of *A. glutinosa* and all *A. negundo* individuals had diameters below 44 cm. Additionally, 88% of *P. alba* and 74% of *S. alba* trees had diameters below 55 cm, whereas the majority (75%) of *P. nigra* trees had diameters above 55 cm.

The average basal area was 8.77 m^2 ha^{-1}. The canopy of *P. nigra*, *P. orientalis*, *P. alba*, and *S. alba* was much wider than the remaining species, with the basal area of *A. glutinosa* following closely (Table 1).

Table 1. Average basal area (m^2 ha^{-1}) of each tree species estimated by DBH measured in all 14 permanent plots.

Species	Basal Area (m^2 ha^{-1})
Populus nigra	42.28
Platanus orientalis	32.40
Populus alba	12.69
Salix alba	11.35
Alnus glutinosa	6.84
Acer negundo	3.78
Robinia pseudoacacia	2.17
Prunus cocomilia	1.49
Sabucus nigra	0.36
Morus alba	0.26
Celtis australis	0.18
Ficus carica	0.16
Cornus saguinea	0.12

Both tree density and basal area significantly differed between the two riverbanks ($p < 0.0001$, *t*-test). The density of *A. glutinosa* is higher on the west bank of the Nestos River, but its canopy is much wider on the east bank. Conversely, the canopies of *P. alba* and *S. alba* are much wider on the west bank of the Nestos River, though their densities are lower than on the east bank. Both the density and the canopy of *P. nigra* are greater on the east riverbank.

4. Concluding Remarks

Our results indicate that *A. glutinosa* is the dominant species in the alluvial forest, with a significantly ($p < 0.01$) higher density than the remaining species. A significant decrease in the average density of the alien species *A. negundo* was observed, dropping from 80 to 26 plants ha^{-1}, but this result was expected since in 2021, *A. fruticosa* and *A. negundo* individuals were removed from 10 out of the 15 plots to restrict the spread of these alien

species, particularly *A. fruticosa*, which poses a major threat to alluvial forests by rapidly invading moist, flood-prone areas, and outcompeting native tree species [7–9].

The percentage of the basal area of *A. glutinosa* in the habitat reached 6.3%, and it was increased compared to 4.8% measured during an earlier assessment [3]. Additionally, *A. glutinosa* was present across a wide range of diameter classes, indicating species ecological stability and forming more resilient communities with *P. alba*., *P. nigra*, and *S. alba*.

Evapotranspiration monitoring reveals that the annual ETo values are circa 930 mm year^{-1}, which is relatively low compared to typical ETo values in Mediterranean climates, often ranging from 1100 to 1300 mm year^{-1} [10]. This suggests that the alluvial forest requires less water for evapotranspiration than typical Mediterranean forest ecosystems, reflecting lower overall water loss from the soil and plant surfaces. The humid environment of the Nestos Delta, along with the apparent hydraulic connection of the alluvial forest to the river, ensures that the evapotranspiration needs are met, and the forests dynamics not expected to alter soon. However, due to changes in rainfall patterns and decreases in available precipitation over the last 50 years in the Nestos Delta [4], continuous monitoring of the 91E0* habitat is necessary to ensure its long-term sustainability.

Lastly, since *F. angustifolia* was not found in the 14 sample plots, restoration activities should be considered for this species. It is not prominently present in the forest stands and exhibits only limited regeneration on the west bank of the Nestos River.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

UNEP	United Nations Environment Programme
DBH	Diameters at Breast Height
ETo	Evapotranspiration

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