

The favorability of orographic and edaphic factors for the main species that comprise urban forests from Brasov City

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Abstract: Urban forests, which means all trees, shrubs, lawns, and other vegetation from cities are very important spaces that are protected in order to protect and conserve biodiversity and the region's structure. These forests have economic, social, and ecological functions. The research was realized in urban forests from Brasov city. The favorability of certain orographic and edaphic factors were determined for the selected species (by using these property values and sheets regarding the species ecological requirements (Norway spruce, silver fir, beech and sycamore). If we consider the ecological requirements of the main species that comprise the studied stands and a series of orographic (altitude) and edaphic factors (reaction, base saturation degree, edaphic volume, potential global trophicity), we were able to calculate the favorability of species based on grades. The conclusion was that Norway spruce has the highest favorability, followed by common beech. Even though silver fir has a lower favorability than Norway spruce, all plots have fir and Norway spruce in their composition. Furthermore, it can be observed that a higher favorability, as in the case of sycamore, does not necessarily determine its presence in more areas. On the contrary, sycamore appears only in a very low number of plots.

1. Introduction

Urban forests, which means all trees, shrubs, lawns, and other vegetation from cities (Escobedo et al., 2011; Gomez-Baggethun and Barton, 2013) are very important spaces that are protected in order to protect and conserve biodiversity and the region's structure (Oleyar et al., 2008). These forests have economic, social, and ecological functions (Nordth et al., 2011; Pataki et al., 2011; Tiwary et al., 2020). One of the economic functions consists in the price effects that urban forests can have on some types of public and private goods (Rothenberg et al., 1991).

The social functions of urban forests are: the use of outdoor spaces by the inhabitants (Coley and Kuo, 1997), connections that are established between neighbors in the same neighborhood (Kuo et al., 1998), numerous other benefits correlated with physical activity and recreation as well as air quality improvements (Frumkin et al., 2004).

Regarding ecological functions, urban forests have a strong impact for both plant and animal species (Hansen et al., 2005). Native plant species diversity may increase with the size of these forests (Dawe, 1995) while birds, the most sensitive native species will no longer be affected by the reduction and fragmentation of native vegetation (Marzluff and Ewing, 2011; Hansen et al., 2005).

A very important thing in urban forests is structural diversity for avoiding even-aged conditions where all the trees reach the end of their functional lifecycle at the same time.

In this way, structural diversity makes forest stands less vulnerable to wind damage (Mitchell, 1995).

Urban forests often experience warmer temperatures due to an urban heatsink (Broshot, 2011). For this reason, tree species that are tolerant to drought and heat and that benefit from high nutrient levels are favored in these forests. Furthermore, tree species must be resistant to continuous and repeated anthropogenic factors that are specific to urban forests. Anthropogenic factors as forest floor trampling disturbs tree regeneration, damaging tree roots, and increase soil compaction. This causes chemical changes that can be observed on and besides path through a decrease of soil pH and nutrient levels (Malmivaara-Lämsä et al., 2008; Hauru et al., 2021).

In addition, forests have numerous ecosystem functions such as rejuvenating degraded ecosystems (Vlad et al., 2019; Dincă et al., 2019), hydrological role (Dincă et al., 2020) and producing non-wood forest products (Vasile et al., 2016; Vasile et al., 2018).

Soil from urban forests is also very important by serving as a habitat for macro and micro biota. These transforms living and dead organic matter and influences the uptake of nutrients and water by tree species while also facilitating the growth life cycle. The tree species that grow in this soil provide long-term environmental benefits through nutrient retention and recycling, and evapotranspiration. Furthermore, by providing shade, they reduce urban heat carbon storage, they purify water and reduce pollution while maintaining the entire biodiversity (Smith, 2006; Akbari et al., 2001).

The growth of tree species in a given site is influenced by pH who is a measure of the acidity or alkalinity of soil and can be used for determining nutrient availability. However, soil pH is only one factor affecting tree survival and growth. There are other soil conditions that affect tree growth, such as soil texture, drainage (Londo et al., 2006).

The aim of this paper is to examine the relationship between four tree species (Norway spruce, Silver fir, beech and sycamore) from the urban forest of Brasov based on orographic and edaphic factors, more precisely to see the favorability of these factors for the studied species. This includes whether and in what way these factors favor the development and spread of these species depending on their environmental requirements.

2. Materials and Methods

The research was realized in urban forests from Brasov city managed by RPLP Kronstadt (Kronstadt Local Public Directorate of Forests). RPLP Kronstadt is a private forest district who manage 14.647,1 ha forest fund which is public property of Brasov Municipality (www.rplpkronstadt.ro). These forests were framed as urban and peri-urban forests based on a series of criteria among which we mention: to be located at approximately 1 km (10-15 minutes of walking) from an inhabited place or transportation mean; to have at least an area of 2ha; to include or to allow the introduction of areas for free time activities etc. (Enescu et al., 2019). Twenty long-term experimental plots were installed within these forests (Figure 1). These plots were installed in 2019 and wants to be long-term research plots to return to them whenever is necessary for a period of least 20 years. The plots have a rounded shape and an area of 500 m² (R = 12,62 m).

A soil profile was executed for each plot, allowing us to collect soil samples on pedo-genetic horizons, amounting to a total of 39 soil samples. The soil profile was located in a representative place, undisturbed and at a sufficient distance from the trees so that the profile not be influenced by their thick roots. The shape of the profile is parallelepiped, with a front wall upstream, with two side walls and stairs downstream. The collection of soil samples, delimitation of the genetic horizons and the study of any other properties were done on the front wall of the profile. Physical and chemical properties were then determined in the laboratory for each sample separately (one sample = one genetic horizon), including soil pH (reaction), humus content, and base saturation degree (V) and then was calculated a mean for the whole soil profile. These

properties were then used for calculating the edaphic volume and global potential trophicity (T_p) as well as to determine the type of soil.

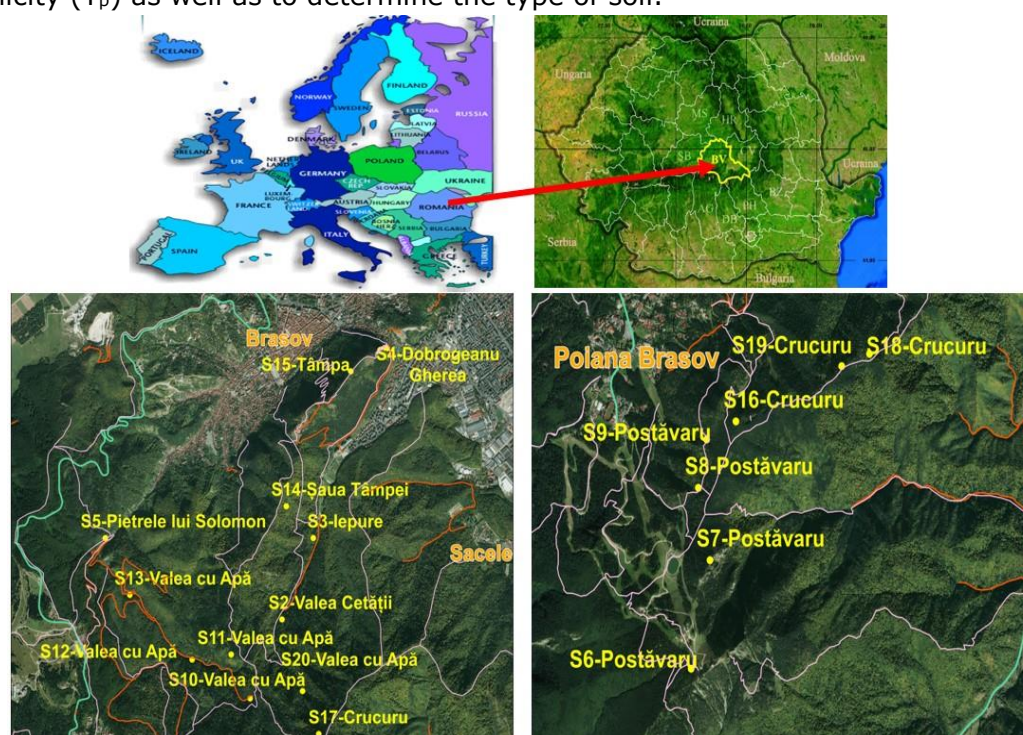


Figure 1. Location of research plots

The favorability of certain orographic (altitude) and edaphic factors (soil pH, V, edaphic volume, T_p) were determined for the selected species by using these property values and sheets with the ecological requirements of species (Șofletea and Curtu, 2007). The main species found in the composition of urban and peri-urban areas from Brasov city are Norway spruce (*Picea abies*), silver fir (*Abies alba*), beech (*Fagus sylvatica*), and sycamore (*Acer pseudoplatanus*). For each species, we have selected only the plots that included the specie in their composition. Afterwards, each factor was framed based on the ecological requirements of each species in one of three classes: limiting, suboptimal and optimum (Șofletea and Curtu, 2007). As such, a series of graphics have resulted for each species.

In order to have a better overview of each species ecological requirements, we have created a series of tables in which each studied factor (orographic – altitude and edaphic – pH, base saturation degree, edaphic volume, global potential trophicity) received a grade based on its framing area (optimum area – grade 3, suboptimal area – grade 2, limiting area – grade 1). The assignation of these three grades in accordance with ecological requirements of species is the original approach of authors. These tables were realized separately for each species by taking into account the five factors that received a grade, followed by a total for each plot.

The present study belongs to a larger research realized for urban and peri-urban forests from Brasov city that also studied biodiversity aspects of herbaceous plants (Fedorca et al., 2020; Vasile et al., 2021; Fedorca et al., 2021) or ways in which stakeholders can develop infrastructure in these types of forests (Davidescu et al., 2020).

3. Results

Taking into account the species from the composition of stands from the experimental areas and by using each species ecological sheet (Șofletea and Curtu, 2007) we have realized a series of graphics that show the framing of soil properties. This also includes the orographic characteristic (altitude) in report with the specie's ecological

requirements. The graphs were realized for the following species: Norway spruce, silver fir, European beech, and sycamore.

Norway spruce was the first species used for the graphs as it is present in 17 out of the 20 experimental plots (Figure 2).

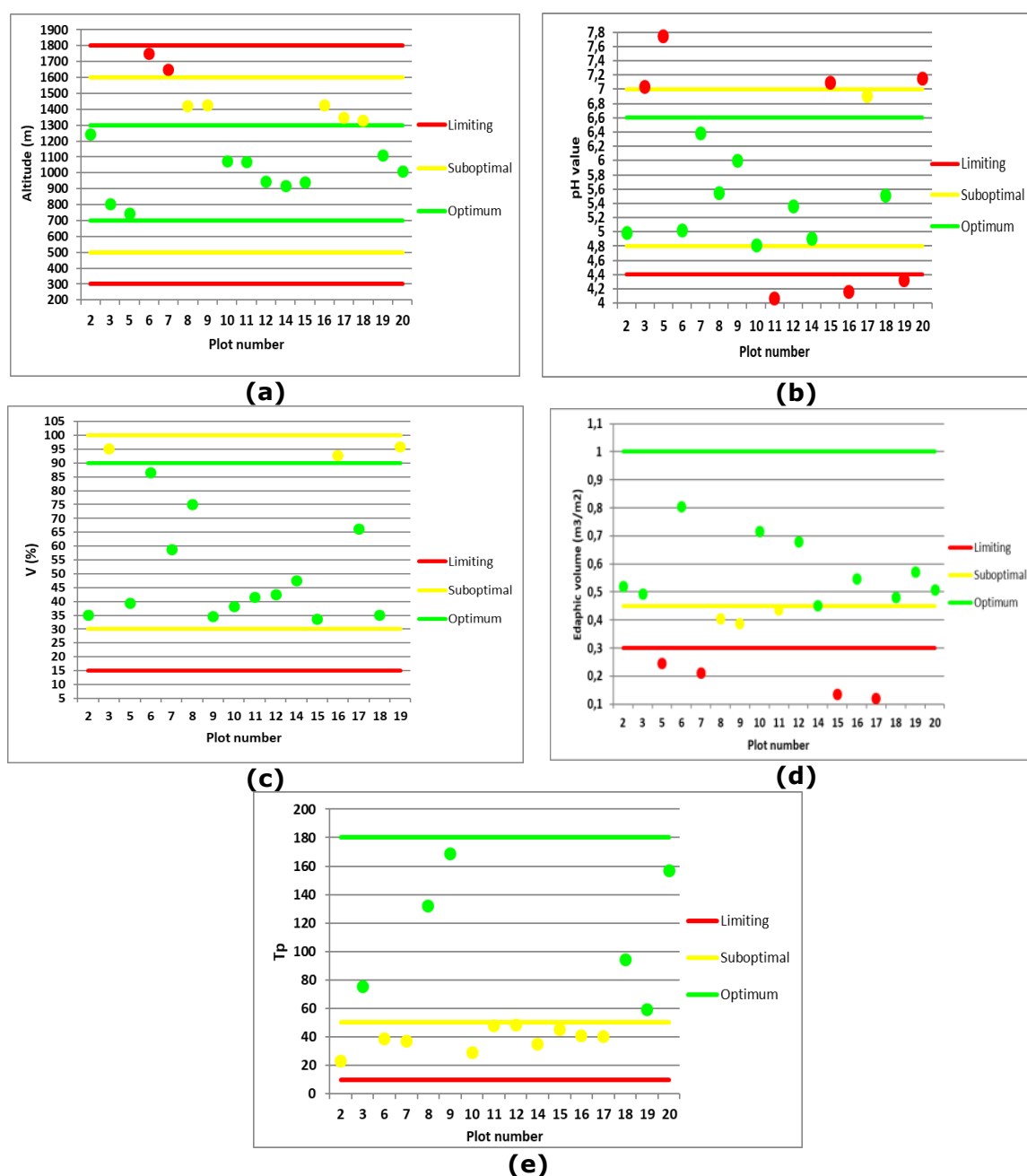


Figure 2. Variation of edaphic and orographic properties in report with the ecological requirements of Norway spruce

In regard to altitude, it can be seen (Figure 2) that 10 out of the 17 plots are situated in the optimal area. Two plots are located at the tolerating Norway spruce limit from an altitudinal perspective. They are located in Postavaru Massif, at an altitude of 1750 m and 1650 m, where Norway spruce has a slow vegetation state and a low consistency as can be seen in the images below (Figure 3). Similar results were obtained by other studies (Dincă and Acim, 2019; Murariu et al., 2021) including some studies on spruce in the French Alps (Rolland et al., 2000; Frank and Esper, 2005; Lebourgeois, 2007; Bouriaud and Popa, 2009; Lebourgeois et al., 2010).



Figure 3. Norway spruce with slow vegetation from S6 (left) and S7 (right) experimental surfaces located in Postăvaru Massif

Analyzing the edaphic characteristics, in relation to the requirements of the species, it is found that the property that has the most plots that are located in the limit area is the reaction of the soil (pH), namely 7 of the 17 plots (Figure 2b). pH records values under the inferior limit for three of these plots, having dystric cambisols and lithosols (S9, S13, S16). The remaining four (S2, S3, S12 and S17), situated on phaeozem and rendzins, have a pH that exceeds the superior limit. As for the remaining edaphic characteristics, only edaphic volume situates four plots in a limitative area (S5, S7, S15, S17). These are located on rendzina or lithosols, namely soils that have a high skeletal content and rocks located close to the surface (Figure 2d). In regard to global potential trophicity, the majority of plots are situated in the suboptimal area, while only six of them are in the optimum area (Figure 2e). The soil type from these plots is mainly eutric cambisol, a rich soil, with high trophicity values (Spârchez et al., 2017; Dincă et al. 2018; Oneț et al., 2019; Crișan et al., 2021).

The second species analyzed from the perspective of its ecological requirements is also a resinous species, namely silver fir. Fir appears in the composition of 12 out of the 20 experimental plots located in urban and periurban forests from RPLP Kronstadt (Figure 4).

Regarding the altitude, the plots are equally distributed on the three areas of ecological requirements, four in each area (Figure 4a). The plots over 1200 m (S2, S9, S17, S18) are situated at the tolerating limit from an altitudinal perspective.

If we consider the edaphic factors, the plots that are situated in the limitative areas are fewer than in the case of Norway spruce, with two for each characteristic (Figure 4b, d, e). The exception is represented by base saturation degree where half are situated in the optimum area and the other half in the suboptimal area (Figure 4c). As for soil reaction (Figure 4b), even if only two plots are at the tolerance limit, the same number are in the optimum area, while the majority are located in the suboptimal area. However, if we make a general analysis of all edaphic factors studied, we can see that the most numerous plots with silver fir in their composition are located in the suboptimal area, meaning not the ideal condition for silver fir. Fir is behaving similarly in other mountain areas from our country (Murariu et al., 2021; Bouriaud and Popa, 2009; Dincă et al., 2020).

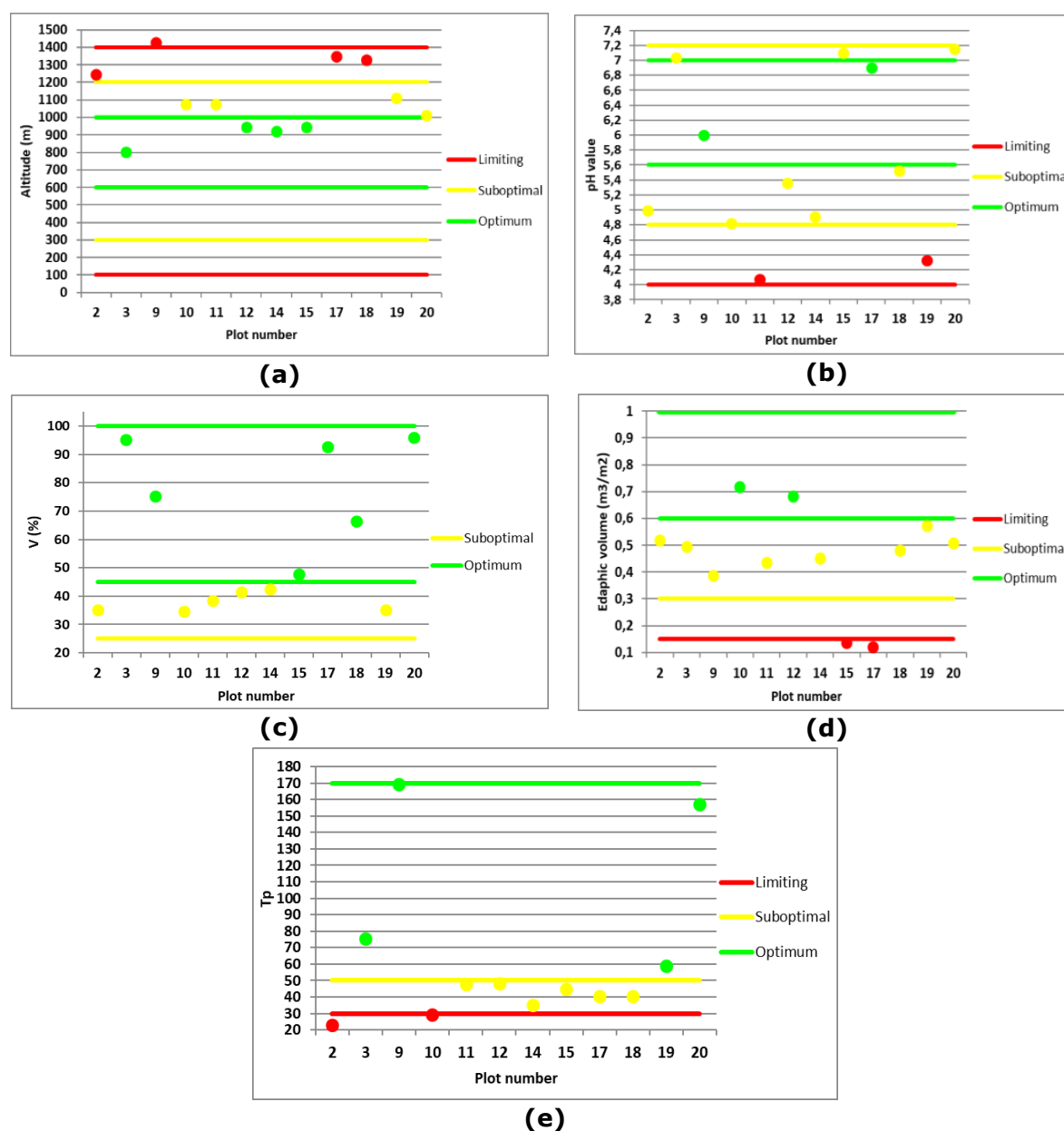


Figure 4. Variation of edaphic and orographic properties in report with the ecological requirements of silver fir

The next analysed species is a broad-leaved one (common beech) which was found in the composition of 10 of the analyzed plots (Figure 5).

If for the previous two resinous species (Norway spruce and silver fir) the plots were distributed on all three areas based on their ecological requests, common beech has a different situation. As such, the majority are located in the optimum ecological area, while the ones located in the limitative area are just an exception. According to the soil reaction requirements of this species, only one plot is located in the tolerance limit, namely S19 located on Crucuru Mare Peak having dystric cambisol with a very acid reaction (Figure 5b). Another plot located in the limitative ecologic area based on edaphic volume is S17 which has lithosol with rocks located at 20 cm depth (Figure 5d). Compared to soil trophicity, the edaphic requirements of common beech are situated at the tolerance limit in S2 and S10 where the soil is a dystric cambisol, poor and with only a 60 cm depth (Figure 5e). Recent environmental changes may be responsible in the future for some changes in 'ecological fitness' of common beech in higher altitude sites (Dittmar et al., 2003; Wilkens and Wagner, 2021).

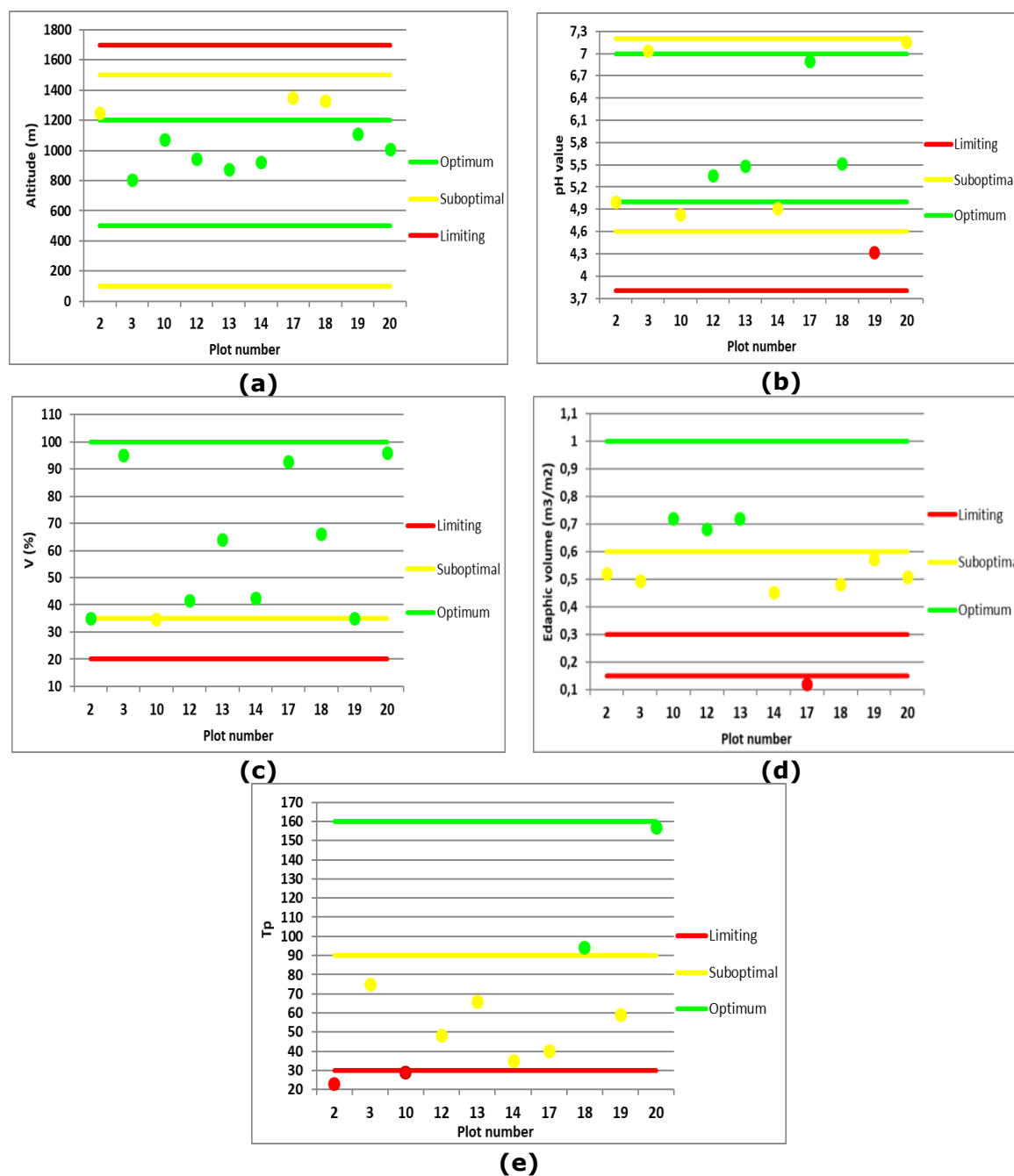


Figure 5. Variation of edaphic and orographic properties in report with the ecological requirements of common beech

The last species is sycamore, found in the composition of 5 out of the 20 experimental plots, namely S4, S9, S18, S19, and S20 (Figure 6).

Regarding the ecological requirements of sycamore, if we analyze all five studied characteristics, the species is situated in the tolerance limit in a single plot (S19) and only based on the reaction. Here we have a dystic cambisol with a very strong acid reaction that was also mentioned for common beech and that placed it also in the limitative area. Some studies suggest that on acid soils the sycamore has poor performance (Jensen et al., 2008).

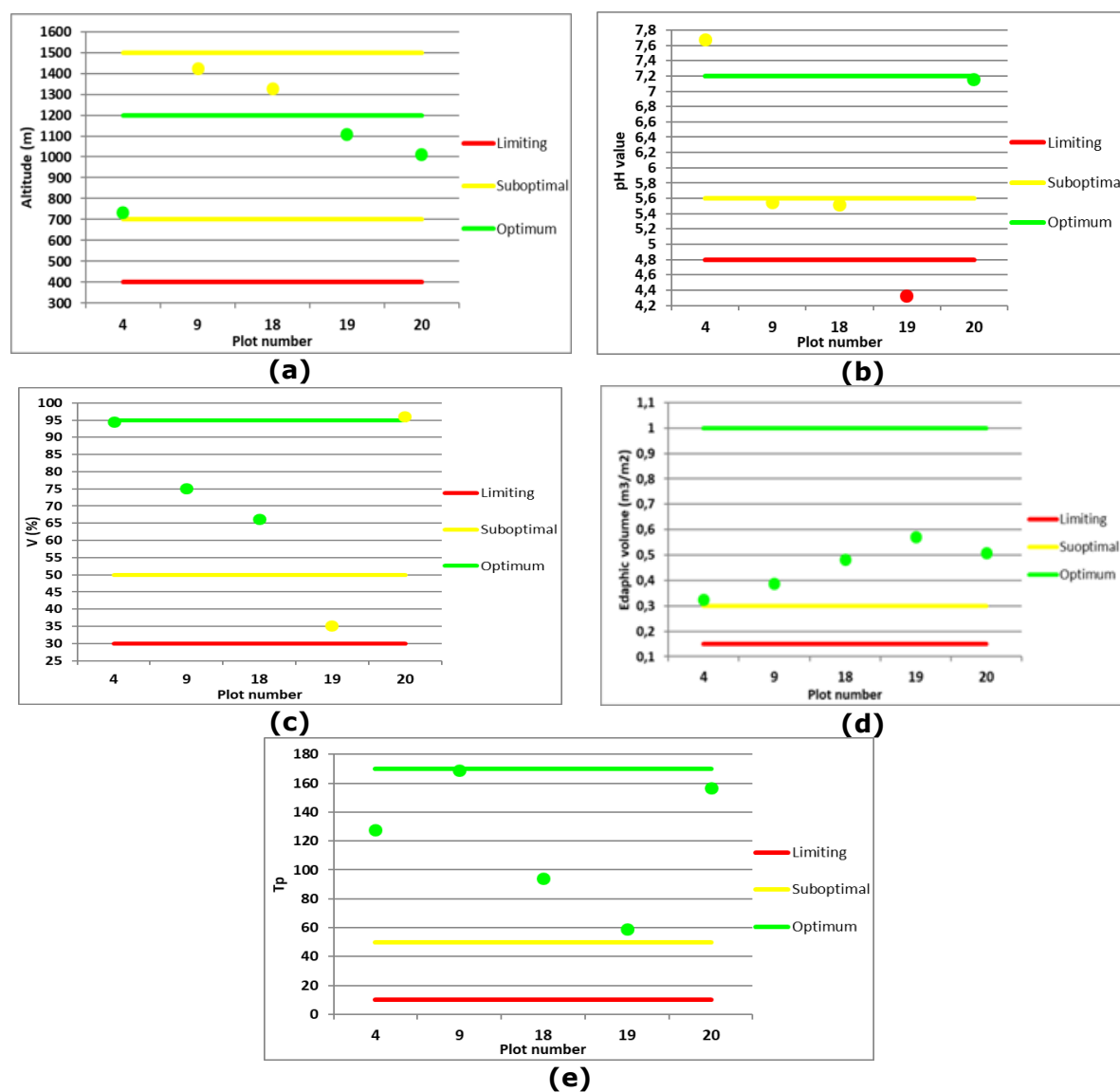


Figure 6. Variation of edaphic and orographic properties in report with the ecological requirements of Mountain sycamore

Following this, in order to understand better the favorability of all the studied factors for each species, we have created tables with grades for each factor, and a total for each plot (Tables 1-4).

Table 1. Grades of ecologic factors for Norway spruce

Experimental plot	Altitude	pH	Base saturation degree	Global potential troficity	Edaphic volume	Total
2	3	3	3	2	3	14
3	3	1	2	3	3	12
6	1	3	3	2	3	12
7	1	3	3	2	1	10
8	2	3	3	3	2	13
9	2	3	3	3	2	13
10	3	3	3	2	3	14
11	3	1	3	2	2	11
12	3	3	3	2	3	14
14	3	3	3	2	3	14

Experimental plot	Altitude	pH	Base saturation degree	Global potential troficity	Edaphic volume	Total
15	3	1	3	2	1	10
16	2	1	3	2	3	11
17	2	2	2	2	1	9
18	2	3	3	3	3	14
19	3	1	3	3	3	13
20	3	1	2	3	3	12
Average						12,25

The first table refers to Norway spruce which was found in the composition of 17 experimental plots (Table 1). If we take into account that five ecological factors were analyzed, the maximum grade that can be obtained for a plot is 15. However, if we analyze Table 1, we can see that this grade was not obtained by any plot. However, five plots have obtained the 14 grades, while the lowest grade was 9 (in S17 situated on lithosol). The average of all plots is 12,25 of a maximum of 15, representing 81,66%. If we consider the analyzed characteristics and the obtained grade for Norway spruce, we can affirm that the favorability of Norway spruce for the analyzed plots is situated around the value of 82%. A complex limiting factor for Norway spruce is drought stress. This stress appears due to heat waves, soil water depletion, intensive solar radiation, and their combination (Taiz and Zeiger, 2010).

For the second resinous species analyzed (silver fir), which was found in the composition of 12 plots, we have applied a similar method as for Norway spruce (Table 2). As such, the maximum grade was not obtained for fir, but in addition, no 14 grades were recorded in any plot. The obtained grades are generally smaller than Norway spruce, a fact that is very well reflected in the obtained average which is way lower, namely 10,83. The lowest grade is 8, compared with the 9 obtained by Norway spruce. All the plots that contain fir also have Norway spruce, so both species vegetate in the same conditions. If we compare these plots with both species in their composition, we can identify 8 plots with a higher favorability for Norway spruce and only three with a higher grade for silver fir. At the same time, one plot (S20) has the same grade. If we estimate the average as for Norway spruce, silver fir favorability amounts to 72%, compared with 82% for Norway spruce. By using the t test, we have tested the significance between the two calculated averages (12,25 and 10,83) and we have obtained a difference from a statistical perspective.

Table 2. Grades of ecologic factors for fir

Experimental plot	Altitude	pH	Base saturation degree	Global potential troficity	Edaphic volume	Total
2	1	2	2	1	2	8
3	3	2	3	3	2	13
9	1	3	3	3	2	12
10	2	2	2	1	3	10
11	2	1	2	2	2	9
12	3	2	2	2	3	12
14	3	2	2	2	2	11
15	3	2	3	2	1	11
17	1	3	3	2	1	10
18	1	2	3	2	3	11
19	2	1	2	3	3	11
20	2	2	3	2	3	12
Average						10,83

Under similar site conditions, in the absence of disturbances and with adequate water supply, spruce is more productive than fir and most other species (Pretzsch, 2005; Bottero et al., 2021).

Moving forward to broad-leaved species, common beech is present in the composition of 10 plots out of 20. Similarly with the previous species, we have applied the same methods (Table 3). If we refer to the obtained average, this is similar with Norway spruce, namely 12,1. The maximum grade was also not obtained for this species, while only one plot has obtained the grade 14. The lowest grade was 10, which appeared in a single case (S2) where dystic cambisol is present, having a very low global potential trophicity and a lower edaphic volume. Nine out of the 10 plots contain in their composition the previous species, Norway spruce and silver fir. If we analyze the grades of these nine plots for all three species, the highest values were obtained for Norway spruce, followed by common beech and then by silver fir. This fact is also reflected in the averages calculated for these three species. Plot S13 is interesting to analyze as it contains only common beech. The grade for this plot is almost maximum (14), with only soil trophicity not recording a maximum value and being situated in the suboptimal ecologic area. The soil is eutric cambisol, with a moderately acid reaction, but with a trophicity within T_{III}, but with a field average slope of 34°. If we test the statistical significance (with the t test) between the Norway spruce and common beech averages, we can observe as it was expected that the two species do not present significant differences. However, if we apply the same test on common beech and silver fir, the difference is significant. Based on the considered factors, common beech's favorability is of 80,66%, similar with Norway spruce. The mixture between Norway spruce and common beech can have both positive and negative effects on beech, whereas the superior height growth of spruce trees could lead to growth reduction in beech due to increase the shading effect (Pretzsch et al., 2005; Pretzsch and Schütze, 2009) but in favourable climatic conditions the productivity of mixed stands has an upward trend (Pretzsch et al., 2012).

Table 3. Grades of ecologic factors for common beech

Experimental plot	Altitude	pH	Base saturation degree	Global potential trophicity	Edaphic volume	Total
2	2	2	3	1	2	10
3	3	2	3	2	2	12
10	3	2	2	1	3	11
12	3	3	3	2	3	14
13	3	3	3	2	3	14
14	3	2	3	2	2	12
17	2	3	3	2	1	11
18	2	3	3	3	2	13
19	3	1	3	2	2	11
20	3	2	3	3	2	13
Average						12,1

The last species, sycamore, is present in the composition of only 5 experimental plots. As it was observed for previous species, this species follows the same rules and does not obtain the maximum grade (Table 4). Nevertheless, the lowest value is 12, a value that is higher than all the lowest values recorded by previous species. Furthermore, two out of the five plots have obtained the 14 grade. If we calculate the average of grades obtained by each plot (13,2), we can see that this is the highest of all five species. However, if we consider the low number of plots which have this species in their composition, the conclusion that sycamore has a favorability of 88% might be wrong. By

testing the average significance with the t test, we can see significant differences from a statistical perspective only for silver fir.

Table 4. Grades of ecologic factors for sycamore

Experimental plot	Altitude	pH	Base saturation degree	Global potential troficity	Edaphic volume	Total
4	3	2	3	3	3	14
9	2	2	3	3	3	13
18	2	2	3	3	3	13
19	3	1	2	3	3	12
20	3	3	2	3	3	14
Average						13,2

5. Conclusions

If we consider the ecological requirements of the main species that comprise the studied stands (Norway spruce, silver fir, common beech, sycamore) and a series of orographic (altitude) and edaphic factors (reaction, base saturation degree, edaphic volume, potential global trophicity), we were able to calculate the favorability of species based on grades. The conclusion was that Norway spruce has the highest favorability, followed by common beech. Even though silver fir has a lower favorability than Norway spruce, all plots have silver fir and Norway spruce in their composition. This means that the two species vegetate in similar conditions.

Furthermore, it can be observed that a higher favorability, as in the case of sycamore, does not necessarily determine its presence in more plots. On the contrary, sycamore appears only in a very low number of plots.

In the future the studied stands (Norway spruce, silver fir, common beech, sycamore) from the urban forests, will be further monitored to observe any changes to the relationship between the four tree species (Norway spruce, Silver fir, beech and sycamore) that may occur due to climate change caused by uncontrolled emissions of greenhouse gases or due to anthropogenic factors.

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