Transylvania University of Brașov

HABILITATION THESIS

SUMMARY

Title: **Ecological drivers of plant species abundance and composition in forest communities**

Domain: Sylviculture

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CONTENTS

Summary

Ecological drivers of plant species abundance and composition in forest communities

The knowledge of mechanisms, by which various ecological factors and processes drive the distribution and abundance of plant species in natural forests, represents one the greatest challenge in modern forest ecology, especially in the context of biodiversity conservation under the pressure of the anthropogenic impact, climate change and invasive species. Three large categories of factors/processes, approached within the same conceptual framework, are considered the main drivers of the quantitative and qualitative composition of forest communities: abiotic constraints, dispersal limitation and biotic interactions. All of them act synergically as hierarchical filters at different scales and condition the coexistence of plant species at community level.

Particular topographic and geomorphologic conditions may induce the occurrence of patches of extrazonal forest vegetation embedded within the zonal vegetation, given the strong contrast between the topoclimate and the regional climate. This is the case of the so-called ‘ice holes’ biotopes consisting of coarse screes lying on lower slopes and causing strong air cooling and accumulation in small concave landforms. To estimate the floristic and climatic distinctiveness of the Lases ice holes (at 730 m of elevation, in the Cembra Valley, Italian Alps), hygrothermal and vegetation data were compared between this extrazonal biotope and plots from the neighbouring zonal biotope (control) with identical site conditions, apart from the concave landform. The daily mean temperatures were significantly lower in the ice holes biotope during the whole summer of 1994. However, the daily mean relative humidity was not significantly different between the two contrasting habitats. The Spruce woodlands revealed in the ice holes and assigned to *Homogyno-Piceetum* strongly contrasts with the mixed oak forests (*Luzulo niveae-Quercetum petraeae*) of the neighbouring zonal biotopes. Based on the mean minimum temperatures in July 1994 and their altitudinal lapse rate, the elevation at which the spruce stands of ice holes would develop zonally was estimated at about 1424 m. This elevation seems to be underestimated, given the high floristic similarity with the spruce forests sampled at 1650 m of altitude. Probably a better estimate would result from considering the temperatures recorded along the whole

growing season. Global warming may be responsible for the loss of some subalpine herbaceous species since the first floristic investigation in 1933. Therefore, the extrazonal spruce woodlands from the Lases ice holes might represent the former potential vegetation (post-climax).

The extensive abandonment of crops and meadows in the last century has led to aspen (*Populus tremula*) woodland development in most of Europe. A similar process occurred on the doline bottoms scattered over the Gargano Plateau (Apulia, Italy), where ten new floristic releves were conducted. These stands were analysed syntaxonomically and synecologically in the context of other 35 similar releves carried out previously in distant locations throughout the central-southern Apennines and assigned to four community types (HP: *Holco mollis-Populetum tremulae*; MP: *Melico uniflorae-Populetum tremulae*; FP: *Fraxino orni-Populetum tremulae*; GP: *Geranio versicoloris-Populetum tremulae*). The Garganic stands formed a distinctive group in cluster analysis and were assigned to a new community type, *Stellario holosteae-Populetum tremulae* (SP), which is an Adriatic synvicariant of HP that is distributed in similar habitats but in the Tyrrhenian catchment area. At higher hierarchical levels, the classification of aspen stands in two clusters matches their phytogeographical distinction in the central (MP and FP) and southern Apennines (SP, HP and GP) perfectly, which is determined by floristic differences in the regional species pool. The SP stands out through the discriminant presence of *Stellaria holostea*, *Carex depauperata* and *Allium pendulinum*. The ordination scores of aspen stands presented good correlation with terrain slope and elevation (measured directly) as well as with soil nitrogen, air temperature and light availability (estimated through species indicator values). The FP stands are the most acidophilous (by the preferential occurrence of *Genista tinctoria* and *Juniperus communis*), whereas the MP and GP stands are the most mesophilous, as indicated by the massive presence of typical beech forest herbs. The HP stands are the driest and lightest because of their open canopy that allows the persistence of shade-intolerant, thermophilous understory species. The SP and MP stands display the highest occurrence of nitrophilous species, as remnants of the former manured crops and pastures.

Despite many studies reporting no or very weak relationships between forest overstory and understory vegetation, there is increasing evidence of negative and positive interactions between these strata depending on habitat positioning along environmental gradients. For instance, a stronger association between species from different forest strata has been suggested under harsher climatic conditions. In order to test whether that is due to higher beta-diversity or positive biotic interactions, 290 spruce and fir stands from the external (oceanic, wet) and inner (continental, dry) Alps were compared. The ecological response of species from different strata (with respect to soil moisture) is in contradiction with the increasing habitat differentiation along the rainshadow gradient. The understory species composition does not differ significantly between spruce and fir stands under favourable soil moisture conditions (in external Alps), despite the two forest habitat types are well differentiated in terms of water input from rainfall. The only exception is the significant floristic divergence between sprucewood and firwood understories observed on sunny slopes of the inner Alps, even though here, the spruce and fir forests occur in similar climatic conditions. The most xerophilous understory species occur under spruce canopies, although the spruce has higher requirements than the fir with respect to soil moisture. The stronger association between forest overstory and understory is in part due to differences in summer soil moisture between southern and northern aspects in the inner Alps. The species association between strata is also higher in the spruce than in the fir forests located on the sunny slopes of the inner Alps, which suggests a major importance of positive biotic interactions (facilitation) over habitat differentiation under abiotic stress. Whereas tree canopies buffer the difference in soil moisture between spruce and fir forest in the external Alps, the spruce canopy seems to exert stronger effects than fir canopy upon the understory in the inner Alps. Unlike at the wet ends of moisture gradients where species distribution may be continuous, relatively discrete species assemblages appear to develop at dry ends of moisture gradients.

The herbaceous layer may act as a filter with respect to tree seedlings/saplings, as certain herbs are able to inhibit the development of the former, especially in fertile forest sites. However, this process may be prevented or mediated by shrubs or canopy trees. These hypotheses were tested based on floristic inventories and site measurements performed in 610 plots distributed in southern Appalachian forests. The abundance of the herbaceous layer increases with soil manganese/calcium content. The evergreen shrub cover has a strong, negative effect on both herb and tree sapling abundance and, therefore, the two understory components appear to be positively related. Unlike the negative exponential curves observed in stands with a well developed herbaceous layer, the distribution of tree density by diameter class is unimodal in stands with low herb cover, very likely because of the suppressive effects of evergreen shrubs. When considering only the subset of 150 plots free of evergreen shrubs, the herb cover becomes independent of soil pH and the relationship between herbs and tree saplings vanishes as they are negatively affected by evergreen trees and nitrogen-fixing trees, respectively. However, if tall herb cover, instead of total herb cover, is involved in the analysis of the evergreen shrub-free plots, the manganese displays a positive effect on the tall herbs, which in turn exerts a strong negative effect on tree sapling density. In conclusion, evergreenness represents a key factor in the complex ecological determination of the understory composition and structure in the southern Appalachian forests, as the interference of herbs on tree saplings is much released by the suppressive effect of evergreen shrubs and trees on herbaceous layer vegetation.

Neighbourhood models are useful tools for understanding the role of positive and negative interactions in maintaining the tree species diversity in mixed forests. Several hypotheses concerning the mechanisms of autogenic species coexistence in an old-growth, beech-fir-spruce stand were tested. Various spatial analyses were applied on data concerning the position and allometry of all saplings and trees occurring within a 0.24 ha plot (Slătioara forest reserve, eastern Carpathians). The monospecific distribution of either beech or spruce saplings did not support the spatial segregation hypothesis. There was no evidence of conspecific negative distance dependence, as no spatial segregation was detected between the saplings and trees of any species. Within 4 m-neighbourhood, the beech saplings appeared as diversity accumulators, which might be indicative of indirect facilitation (e.g., herd protection hypothesis). At tree stage, none of the three species showed either accumulator or repeller patterns in their neighbourhood with respect to sapling species richness. Signals of positive and negative interspecific association were found in tree-sized beech (at scales of 10 to 20 m) and spruce (at scales of 4 to 17 m), respectively. The former, highly interspersed pattern is in accordance with the hypothesis of positive complementary effects, whereas the latter, poorly intermingled pattern is probably linked to the unexpected, positive neighbouring effect of spruce trees on the stem growth of their conspecific saplings. Such a self-favouring process might be due to a facilitative below-ground mechanism. Conversely, the beech saplings were suppressed through interference from the neighbouring conspecific trees. The beech appears to be the key promoter of tree species coexistence in the study forest stand, in contrast to the low interspersion of spruce in the overstorey leading to lower local tree diversity.

(B) Scientific and professional achievements

1. Introductive considerations

The knowledge of mechanisms, by which various ecological factors and processes drive the distribution and abundance of plant species in natural forests, represents one the greatest challenge in modern forest ecology, especially in the context of biodiversity conservation under the pressure of the anthropogenic impact, climate change and invasive species. Recent studies have demonstrated the importance of taxonomic and functional diversity of canopy trees on the composition and abundance of herb species in forests.

The classification of forests in a reasonable number of relatively homogeneous types is crucial for undertaking inventory, monitoring, recovery, management and conservation programs. The phytosociological classification of forest vegetation plays an important role in forest typology, because the floristic releve represents a synthetic outcome and bio-diagnosis of the determinant abiotic factors. Nevertheless, the herb layer has been much overlooked in forest research, in spite of their role in the functioning, regeneration and stability of forest ecosystems.

Three large categories of factors/processes, approached within the same conceptual framework, are considered the main drivers of the quantitative and qualitative composition of forest communities: abiotic constraints, dispersal limitation and biotic interactions. They all act synergically as hierarchical filters at different scales and condition the coexistence of plant species at community level.

The climatic factors are relevant for the specific composition of forests at relatively large scales. However, topographic factors (e.g., slope, aspects) have generally indirect effects on forest composition by modifying the climatic parameters. The resulting topoclimate can sometimes determine the development of extrazonal forest vegetation, in contrast to the surrounding zonal vegetation. Such a case is represented by the extrazonal spruce forests or even subalpine-like scrubs occurring in the colline belt of the southern Alps.

Under (sub)optimal environmental conditions, a relative independence of the herb layer composition from the forest overstory has been documented in many studies. On the other side, under stress conditions the association between the two layers is more evident. Another facet of this relationship is the ability of herb layer to act as a filter with respect to tree seedlings/saplings, being either protective or inhibitor. The latter case has been observed on fertile sites. Some shrubs can also have a negative effect of tree regeneration.

The biotic interactions between trees take place at different scales during the ontogenetic development. That is why, the use of spatial analyses is mandatory to detect signals of interspecific interactions. Several biological mechanisms have been invoked to explain the coexistence of tree species. For instance, the escape hypothesis may be responsible for the segregation of saplings from their conspecific trees and the alternation of species may cause the aggregation of saplings in the neighbourhood of heterospecific trees. Often the spatial modelling of tree distribution allows the detection of various relationships between the intensity of the asymmetric competition and the tree growth.

The study of the determinants of qualitative and quantitative species composition of forest communities was based on a general paradigm, according to which any ecological process affecting directly or indirectly several species correlates or even, generates non-random patterns in the distribution and abundance of those species.

The results presented in the chapters 2, 3, 5 and 6 in section B were published in journals indexed in Web of Science (3) or SCOPUS (1). The chapter 4 includes the results from a paper already submitted to an ISI journal. Beside these, below are listed the most relevant papers publishes after the award of the doctorate degree in 1994. Apart from the book chapter, all of them were published in journals indexed in international reference databases.

Gafta D. (2002) The anthropo-zoogenic influence on peri-urban forests. In: Cristea V., Baciu C., Gafta D. (eds.), The city of Cluj-Napoca and the peri-urban area, pp. 241-274. Editura Accent, Cluj-Napoca. [in Romanian]

Gafta D., Incze R., Poliţă M. (2002) The influence of forest site fertility and sampling scale on species-area curves. Contribuţii Botanice 37: 73-83.

Michalet R., Rolland C., Joud D., **Gafta D.**, Callaway R.M. (2003) Associations between canopy and understory species increase along a rainshadow gradient in the Alps: habitat heterogeneity or facilitation? Plant Ecology 165: 145-160.

Gafta D. (2006) Eco-coenotic distinctiveness of an extrazonal ‘Ice Hole’ biotope in the valley of Cembra (southern central Alps, Trentino). Polish Botanical Studies 22: 195-206.

Horj P., **Gafta D.** (2006) Spatial structure and dendrometric architecture of an ash-maple forest stand on the valley of Vaser (Vişeu forest district). Revista Pădurilor 3: 20-26. [in Romanian]

Gafta D., Crişan F. (2010) Scaling allometric relationships in pure, crowded, even-aged stands: do tree shade-tolerance, reproductive mode and wood productivity matter? Annals of Forest Research 53: 141-149

Goia I., **Gafta D.** (2019) Beech versus spruce deadwood as forest microhabitat: does it make any difference to bryophytes? Plant Biosystems 153: 187-194.

Gafta D., Peet R.K. (2020) Interaction of herbs and tree saplings is mediated by soil fertility and stand evergreenness in southern Appalachian forests. Journal of Vegetation Science 31: 95-106.

Russo G., Pedrotti F., **Gafta D.** (2020) Typology and synecology of aspen woodlands in the central-southern Apennines (Italy): new findings and synthesis. iForest 13: 202-208.

Gafta D., Schnitzler A., Closset-Kopp D., Cristea V. (2020) Neighbourhood-based evidence of tree diversity promotion by beech in an old-growth deciduous-coniferous mixed forest (Eastern Carpathians). Annals of Forest Research (submitted).

2. Habitat differentiation and facilitation as drivers of canopy-understory species association within the fir- and spruce-dominated forests across a rainshadow gradient in the Alps

Apart from the numerous evidence of negative interactions between species, a series of studies demonstrated the occurrence of positive interaction, especially under extreme environmental conditions. Thus, a positive association between vegetation layers in forests seems to occur under conditions of water deficit in soil. To test this hypothesis, 290 fir (*Abies alba*) and spruce (*Picea abies*) stands from the external (pre-alpine) and inner (intra-alpine) parts of the central and western Alps were taken under study. The external mountain ranges are characterised by a humid, oceanic climate, whereas the inner ranges are affected by a strong rainshadow effect resulting in a dry, continental climate. The following working hypotheses were addressed: i) there are larger differences between the herbaceous layers of spruce and fir forests in the inner Alps; ii) the habitat differentiation and positive biotic interactions control the weaker or stronger overstory - understory association along the climatic gradient.

Complete floristic inventories of vascular species and main site condition measurements (altitude, slope, aspect) were gathered for each forest stand. Monthly means of rainfall and maximum/minimum temperatures were collected from 300 meteo stations. Climatic interpolations were computed in all forest sites considered. Indices of aridity (De Martonne) and continentality (Gams) were also calculated.

Indirect (correspondence analysis - CA) and direct (canonical correspondence analysis - CCA) ordinations were employed to reveal the relationship between species composition and environmental variables. ANOVA and linear regressions were used to compare and explore the relationships of the ordination scores.

The continental and aridity indices were both well correlated with the CA axis 1, confirming the climatic differences between the external and inner Alps. The spruce and fir stands were separated along the CA axis 2, which was well related with the temperatures in January. The regression of the understory layer CA scores by altitude and transformed aspect was significant only for the inner sector. No significant differences were detected between the two forest types in terms of understory ordination scores, except on sunny aspects in the inner Alps, where the association between the vegetation layers was stronger in spruce than in fir stands. The aridity differentiation between contrasting aspects (sunny *versus* shaded) was significant only in the pre-alpine sector. The habitats of the two forest types were not distinguishable in terms of soil moisture in the inner Alps, contrary to what observed in the external Alps. A higher in beta-diversity was estimated in the inner sector than in its counterpart. The CCA revealed similar relationships but in addition, the third axis discriminated between the fir stands on shaded slopes and the spruce stands on sunny slopes.

The ecological response of species from different strata (with respect to soil moisture) is in contradiction with the increasing habitat differentiation along the rainshadow gradient. The understory species composition does not differ significantly between spruce and fir stands under favourable soil moisture conditions (in external Alps), despite the two forest habitat types are well differentiated in terms of water input from rainfall. The only exception is the significant floristic divergence between sprucewood and firwood understories observed on sunny slopes of the inner Alps, even though here, the spruce and fir forests occur in similar climatic conditions. The most xerophilous understory species occur under spruce canopies, although the spruce has higher requirements than the fir with respect to soil moisture. The stronger association between forest overstory and understory is in part due to differences in summer soil moisture between southern and northern aspects in the inner Alps. The species association between strata is also higher in the spruce than in the fir forests located on the sunny slopes of the inner Alps, which suggests a major importance of positive biotic interactions (facilitation) over habitat differentiation under abiotic stress. Whereas tree canopies buffer the difference in soil moisture between spruce and fir forest in the external Alps, the spruce canopy seems to exert stronger effects than fir canopy upon the understory in the inner Alps. Unlike at the wet ends of moisture gradients where species distribution may be continuous, relatively discrete species assemblages appear to develop at dry ends of moisture gradients.

3. Soil fertility and stand evergreenness as main drivers of the interplay between herb and tree sapling in southern Appalachian forests

Several reports demonstrated that the understory herbs can play an important role in canopy tree composition and age structure. The herb layer can act as a filter by either favouring or inhibiting the tree seedlings/saplings. However, not all herb species are functionally equivalent, as those tall, cespitose and/or broad-leaved being more competitive. The dominance between herbs and tree saplings in temperate forests can be partly understood on the basis of the theory of carbon- nutrient balance.The herbs are more efficient than seedlings, as the former allocate most of the acquired carbon to leaf growth, whereas the latter must invest a lot in stem growth. Over 1.5-2 m height, the saplings are more efficient than herbs, as the former must not rebuilt their stems every year and so, can allocate most carbon to leaves. Consequently, the tree saplings could be in advantage over herbs in low fertility sites (high carbon/cations ratio) and vice-versa. Nevertheless, the herb - tree saplings relationship could be mediated by the evergreen shrubs, which occur mostly on acidic soils and are known to affect the tree regeneration. The objective of the present study was to test the following hypotheses: a) the herb cover increases monotonically with soil fertility, expressed by the content in base cations; b) the tree regeneration can be reduced by evergreen shrubs on oligotrophic soils; c) the herbs can limit the tree sapling abundance, proportionally with the soil fertility.

A number of 610 forest plots of 1000 m^2 each in southern Appalachians were fully inventoried in terms of vascular species relative cover, tree density (over 1.4 m height) and site conditions. Soil sampled were drawn from each site to determine the texture, bulk density and chemical parameters. The plant species were classified in various functional groups based on (among others) height, leaf width and persistence, growth form and the ability to fix nitrogen. To remove the strong effect of the evergreen shrubs, a subset of 150 plots free of such plants were considered separately.

Linear and non-linear regression were employed to examine the shape of relationships. The fitted parabola arcs were compared on the basis of an asymmetry index (inedit). The probability of observing rich understory in both components (herbs and tree saplings) over certain levels, a Monte Carlo test was run on 100000 permutations. Linear multiple regression was used to model the abundance of herbs and tree saplings as a function of site and tree stand variables. The outcomes were employed to build systems of linear equations to be subsequently involved in path analysis for validation.

The herb cover, and especially the tall herb cover, decreased significantly with evergreen shrub and tree density, but increased with manganese and woody plant density. Tree sapling density decreased significantly with increasing evergreen shrub cover and the reduction in deciduous, nitrogen non-fixing tree cover. The parabola fitting the density of tree saplings by herb cover displayed a large positive asymmetry. A positive covariance between herb and tree saplings abundances was suggested by the distribution of tree counts by diameter class and herb cover class. However, the probability of observing large tree sapling density (over 1000 per ha) in forest stands covered more than 75% with herbs was only 1.79%. When only tall herb cover was considered, the parabola fitting the tree sapling density displayed a very slight negative asymmetry. The distribution of the median density of trees by diameters class was unimodal in the stands featuring low herb cover (<2%) but negative exponential-like in the stands with medium-high herb cover (>25%). The evergreen shrub cover was negatively related with the base cations (Mn, Ca), but positively related with the evergreen tree cover. In the inferred path diagram, the evergreen shrubs exerted the strongest negative effects on both herbs and tree saplings, which resulted in their positive covariance.

When only forest stands free of evergreen shrubs were considered, the herb cover (but not tall herb cover) became almost independent of soil cations and displayed a regression line by woody plant density with a much milder slope. The sapling density became negatively correlated with calcium and the nitrogen-fixing tree cover. The corresponding path diagram showed a strong negative effect of evergreen tree cover on herb cover and no significant relationship between herbs and tree saplings. When only tall herb cover is considered, the new built path diagram revealed a strong negative effect of the tall herbs on tree saplings.

Soil fertility and the evergreen shrub and tree cover are the main determinants of the forest understory in the studied forests. The complex relation between the evergreen shrubs and the soil manganese is a key element for the structure of herbaceous layer. Even in the absence of the evergreen shrubs, the herb cover is suppressed by the evergreen trees, the eastern hemlock (*Tsuga canadensis*) being a well-know example. The positive covariance between herb cover and tree saplings is very likely a consequence of the suppressive effect of the evergreen shrubs. In site with basic-neutral soils the herb cover is high and tree sapling density low, that is in accordance with the theory of carbon - nutrient balance. This relation is especially evident if referring to tall herbs only, which are able to drastically reduced the tree regeneration through asymmetric competition for light and soil resources (i.e., water). The decline of tree sapling density under high cover of N-fixing trees may be due to the inferior competitivity of the former compared to that of some nitrophilous, fast growing herbs.

The positive association of the evergreen woody species from all layers (dwarf sub-shrubs to trees) suggests a strategy of resource usage and allocation that is different from that adopted by herbs. The high abundance of evergreen woody species on poor soils is undoubtedly linked to soil persistence, which is a biological adaptation through which the loss of nutrients is minimised. Evergreenness represents a key factor in the complex ecological determination of the understory composition and structure in the southern Appalachian forests, as the interference of herbs on tree saplings is much released by the suppressive effect of evergreen shrubs and trees on herbaceous layer vegetation

4. The beech as promoter of tree species diversity in an old-growth, mixed beech-conifer stand in eastern Carpathians

In temperate forest composed of shade-tolerant tree species a spatial dissociation of conspecific individuals coupled with the ontogenetic reciprocal replacement of species has been observed. That can be determined by the interspecific direct or indirect facilitation and intraspecific inhibition. The negative distance-dependence of conspecific trees, which has been explained by different theories (e.g., escape or herd immunity theories), seems to be a common pattern behind the tree species coexistence in mixed forests. The interactions between neighbouring trees may lead to local maxima or minima of species richness that reveal the taxonomic identity of diversity accumulators or repellers. These can indicate the preponderance of positive and respectively, negative interactions. The spatial segregation hypothesis, which implies low interspecific competition due to limited seed dispersal and subsequent negative association of the heterospecific trees, can also be invoked as an avoidance mechanism promoting local tree diversity. The sustainable coexistence of tree species at small scales can be also reached through positive complementary effects determined by a strong differentiation of their ecological niches.

The main goal of this study was to search for non-random spatial patterns between conspecific/heterospecific trees and between tree size classes, in order to test various hypotheses regarding the autogenic coexistence of tree species at relatively small scales, that is: a) the distribution of conspecific saplings to test the spatial segregation theory; b) the distribution of saplings with respect to their conspecific/heterospecific trees to test the species alternation theory; c) the individual species - area relationship and the tree species interspersion to test the theory of accumulator/repeller species and respectively, the occurrence of positive complementary effects.

A 40 x 60 m plot, placed in a mixed (beech-fir-spruce), old-growth, uneven-aged stand within the Slătioara forest reserve, was completely inventoried in terms of trunk diameter and height, except for tree seedlings and saplings lower than 1.50 m height. The beech - *Fagus sylvatica* was dominant (67%), followed by spruce - *Picea abies* (24%) and fir - *Abies alba* (9%). The individuals with a stem girth lower than 10 cm were considered saplings.

The spatial distribution of trees and saplings was examined through univariate and bivariate point pattern analyses by employing the pair-correlation function g(*r*). The individual species-area relationship (ISAR) and the mingling index (M) were computed for each tree species separately and for neighbourhood radii from 0 to 20 m. The statistical significance of the observed distributions or values was assessed through 999 simulations of null models of either spatial independence based on heterogeneous Poisson processes or random (taxonomic) labelling. The interference of the nearest conspecific/heterospecific tree on target saplings was estimated by species through the Weiner index. Generalised linear mixed models (GLMMs) were employed to estimate the effect size of the nearest tree interference on the saplings height by accounting for spatial autocorrelation. Except for the latter analysis, in which only live individuals were considered, in all the other models the dead, standing individuals were also included. Because of the very low number of fir saplings, some results were either biased or incomplete, and consequently were not reported.

The tree saplings of any species were randomly distributed both among themselves and with respect to the conspecific/heterospecific trees. Only around beech saplings (within 4 m) a significantly higher sapling richness than expected by chance was detected. When there trees and saplings were considered as reference and respectively, target, the empirical ISARs built were not significantly different from the null models in any species. A significant positive and negative association was observed around the beech trees (over 10 m radius) and respectively, spruce trees (4 to 17 m radius). The height of beech and spruce saplings is negatively affected and positively influenced, respectively by their nearest conspecific tree.

The monospecific distribution of either beech or spruce saplings did not support the spatial segregation hypothesis. There was no evidence of conspecific negative distance dependence, as no spatial segregation was detected between the saplings and trees of any species. Other studies conducted in similar forests in southern and western Carpathians revealed a significant spatial dissociation between beech trees and saplings. The beech saplings may favour the fir/spruce saplings from the neighbourhood through a mechanism of indirect facilitation, e.g. the one behind the herd-immunity theory. The fact that, none of the three species showed either accumulator or repeller patterns at tree stage, may be explained by: the different response of single species individuals to habitat microheterogeneity; contrasting biotic interactions that overrule each other; demographic stochasticity induced by local disturbance.

The highly interspersed pattern observed around beech trees (probably linked to the accumulator status of beech saplings) is in accordance with the hypothesis of positive complementary effects, whereas the poorly intermingled pattern detected around spruce trees is probably linked to their unexpected, positive neighbouring effect on the stem growth of their conspecific saplings. Such a self-favouring process might be due to a facilitative below-ground mechanism. As reported in other European mixed forests, the beech trees act as a strong self-competitor, which is probably related with its best growth performance in mixed forests. The beech appears to be the key promoter of tree species coexistence in the study forest stand, in contrast to the low interspersion of spruce in the overstory leading to lower local tree diversity.

5. Particular topoclimatic conditions as drivers of strong compositional contrast between proximal forest communities in southern Alps

The geographic and macroclimatic factors are generally responsible for the distribution of the terrestrial zonal vegetation, which develops in widely distributed ecotopes named climatopes or '*placor*' habitats. Nevertheless, particular topographic and geomorphologic conditions may induce the occurrence of patches of extrazonal forest vegetation embedded within the zonal vegetation, given the strong contrast between the topoclimate and the regional climate. The most common extrazonal habitats are encountered in mountain areas because of the frequent inversion of the thermal lapse rate. A more striking case is represented by cooler air accumulates in the concave landforms located at the base of coarse screes composed of rocks with low thermal conductivity. The descending cool air goes between rocks in the upper part of the scree (avoiding this way the mixture with the warmer air) and exits downhill within a closed, microvalley. Such a phenomenon causes the development of extrazonal biotopes (called 'ice holes' in the Alps) that include plant species adapted to harsher climatic conditions of the high altitudes. Apart from the temperature measurements and vegetation inventories performed in the Appiano biotope (southern Italian Alps), no information is available for other similar habitats.

The aim of the study was to reveal the magnitude of hygro-thermal and forest compositional differences between the Lases extrazonal biotope (at 730 m of elevation, in the Cembra Valley, Italian Alps) and the adjacent zonal one with identical site conditions, apart from the concave landform. The latter (control) biotope is occupied by mixed *Quercus petraea*-*Tilia cordata*-*Ostrya carpinifolia* forest stands. Two independent loggers were placed at 1.50 m above the ground in special wooden, holed shelters under similar site conditions (elevation, slope, aspect) in each of the two biotopes. The loggers were setup to register the air temperature and humidity each three hours starting at 2:00 a.m. from June to August 1994. Cloud cover was estimated daily at 14:00 p.m. using an ordinal scale: sunny (<20%), partly cloudy (20-80%) and cloudy (>80%). Floristic releves were performed in each forest type (including the mixed stand in the control biotope) along a transect running from the ice hole biotope to the peak of the Costalta mountain. The plot size was constrained by the small extension of forest patches (maximum 25 m^2), except for the mixed sessile oak stands. The statistical significance of mean climatic data between biotopes (at the same time) and measurement hours (within the same biotope) was estimated by mixed, repeated-measures ANOVA. When all the terms in the model were significant, *post-hoc*, sequential, paired multiple comparisons were made. The daily temperature range was employed as an indicator of continentality in each biotope. The mean daily temperatures over +6°C were cumulated in order to estimate roughly the heat divergence between the two contrasted biotopes. The thermal lapse rate regarding the mean of minimum temperatures in the warmest month (July) was assessed by linear regression of temperature data from central-southern Alps. The thermal level in each vegetation plot was estimated indirectly by calculating the mean of the analogous indicator values of the recorded plant species. The Steinhaus similarity index along with the average linkage was employed in building the dendrogram of the floristic releves.

The monthly mean temperatures were significantly lower in the ice holes biotope at any day time (but especially in the night) and during the whole summer of 1994. The differences were somewhat lower only in the afternoon. The monthly mean relative humidity was not significantly different between the two contrasting habitats. The cloudiness had little effect on the mean of maximum temperatures (larger differences between biotopes in cloudy days) and no effect on the mean of minimum relative humidity. In the ice hole biotope the topoclimate is more continental than in the control (zonal) biotope. The difference between the cumulated daily temperatures during the three 1994 summer months was 242°C. The distribution of the mean indicator values showed a positive relationship between temperature and altitude on the northwestern slope of the cold valley. The lower part of the ice hole biotope is thermically equivalent to a zonal habitat located at 1424 m of elevation.

The forest stand fragments occupying the lower part of the extrazonal habitat were assigned to *Homogyno alpinae-Piceetum abietis*, which represents the zonal vegetation in the upper montane belt (over 1600 m) and contrasts strikingly with the mixed oak forests (*Luzulo niveae-Quercetum petraeae*) of the neighbouring zonal biotopes. The dendrogram of releves also showed a high compositional similarities between the base of the ice hole biotope and the spruce stand located at 1650 m.

The heat divergence between the two contrasting habitats would have been much larger, if the whole growing season had been considered. The small differences in terms of air humidity are unlikely to have induced noticeable vegetational dissimilarities. The estimated elevation corresponding to the ice hole biotope seems to have been underestimated on the sole basis of the minimum temperatures in July. The extrazonal spruce stands may actually represent a the former potential vegetation (post-climax), the global warming and the impact of the local anthropic activities being probably responsible for presumed topoclimatic changes that has caused the loss of some subalpine herbaceous species since the first floristic investigation in 1933. Given their high beta-diversity and the persistence of some subalpine plant populations much lower than their natural distribution area, the ice hole biotopes are worth preserving, but their management represents a big challenge.

6. Elevation, terrain slope and soil nitrofication as drivers of the species composition of aspen woodlands in the central-southern Apennines

Like elsewhere, the cultural landscapes of the Apennines mountains include specific vegetation patterns and are useful models for the study of vegetation successions. The extensive abandonment of crops and meadows in the last century has induced important changes in the vegetation landscape and has led (among others) to aspen (*Populus tremula*) woodland development in most of Europe. These stands play an important role in the recovery of the potential forest vegetation by facilitating the establishment of late successional tree species. On the positive side, this process contributes to carbon sequestration, reducing the soil erosion and increasing connectivity between forest patches. On the negative side, the shrub encroachment in the abandoned meadows and pastures constitutes a matter of concern in terms of reduction of biodiversity. The aspen woodlands display a fine-grained, fragmented distribution throughout the Apennines. Their herbaceous layer is usually abundant and composed of a series of ubiquitous species, some of which were components of the former semi-natural or synanthropic vegetation but persisting in the understory due to the loosely aspen foliage. However, the overall species composition varies from one ecoregion to another and between habitats, given the variability of site conditions in the central-southern Apennines.

To date there is no synthesis on syntaxonomy and synecology of the aspen forests occurring in the study area. That was the main objective of the study, along with the identification of the most important ecological factors and site conditions related to their species composition.

The vegetation inventory was conducted on the doline bottoms scattered over the Gargano Plateau (Apulia, Italy), where ten inedit floristic releves were conducted. Elevation and slope were measured in the field, whereas the other abiotic variables were indirectly estimated through the species indicator values for light, air temperature, soil moisture, reaction and nitrofication. These stands were analysed in the context of other 35 similar releves carried out previously in distant locations throughout the central-southern Apennines and assigned to four community types (HP: *Holco mollis-Populetum tremulae*; MP: *Melico uniflorae-Populetum tremulae*; FP: *Fraxino orni-Populetum tremulae*; GP: *Geranio versicoloris-Populetum tremulae*). The floristic pairwise dissimilarity was assessed through the Sørensen index and the resulting matrix was used in combination with the beta-flexible linkage in the clustering of releves and in their indirect ordination through non-metric multidimensional scaling (NMDS). The optimal number and stability of clusters were estimated by means of a single internal criterion and respectively, bootstrapping the mean similarity within groups. The relationships between each species occurrence and the releves groups/ordination scores were assessed through the point biserial correlation by accounting for different group size. The importance of each abiotic variable in explaining the floristic variation was estimated by non-parametric linear fitting on each NMDS axis. Those variables, displaying only marginal effects on the ordination scores, were involved in generalised additive models with the aim of fitting isolines by thin-plate splines.

The optimal classification distinguished five clusters of releves, each one corresponding to one known syntaxon, apart from the group of releves from Gargano that was assigned to a new community type, *Stellario holosteae-Populetum tremulae* (SP), which is an Adriatic synvicariant of HP that is distributed in similar habitats but in the Tyrrhenian catchment area. At higher hierarchical levels, the classification of aspen stands in two clusters matches their phytogeographical distinction in the central (MP and FP) and southern Apennines (SP, HP and GP) perfectly, which is determined by floristic differences in the regional species pool. The dominant species in the understory of SP stands are *Pteridium aquilinum* and *Rubus caesius*., whereas the most discriminant species - in the context of all similar forest types from the central-meridional Apennines - are *Stellaria holostea*, *Carex depauperata* and *Allium pendulinum*. The ordination scores of aspen stands displayed good correlation with terrain slope and elevation (measured directly) as well as with soil nitrogen, air temperature and light availability (estimated through species indicator values). Although non-linear, the relationships between the NMDS axes 1 and 2, on one side and soil reaction and moisture, on the other side, were significant.

The FP stands are the most acidophilous (by the preferential occurrence of *Genista tinctoria* and *Juniperus communis*), whereas the MP and GP stands are the most mesophilous, as indicated by the massive presence of typical beech forest herbs (e.g., *Melica uniflora*). The HP stands are the driest and lightest because of their open canopy that allows the persistence of shade-intolerant, thermophilous understory species (e.g., *Asphodeline liburnica*). The SP and MP stands display the highest occurrence of nitrophilous species, as remnants of the former manured crops and pastures (e.g., *Poa trivialis*). In the absence of major disturbance, the stands of SP and

HP should be replaced successionally by mixed *Quercus cerris* forests. Similarly, the MP and GP stands evolve towards beech forests, whereas the FP stands should be substituted by *Castanea sativa*-dominated forests.

The current outcomes are based on relatively low number of releves (especially those circumscribed to HP) and consequently, the list of differential species and the floristic distinction of the syntaxa may slightly change once new data will become available. The typological assignment of aspen woodlands is rendered difficult by the numerous ubiquitous species occurring in the herb layer. The aspen stands have little economic value, given their soft and low density wood and therefore, but rather high conservative value for their important role in the recovery of the nemoral species diversity with the successional advancement toward hardwoods. To prevent the decline of biodiversity in the protected areas of the Apennines, a minimal fraction of meadows and pastures should be maintained through traditional use.

(C) Evolution and development plans for the career development

During one year (1998-1999) I worked as a post-doctoral scholar at the University of North Carolina at Chapel Hill (USA) under the supervision of prof. Robert Peet. I also attended three doctoral courses on Biostatistics, Plant Ecology and Introduction to GIS.

After my return to Bucharest in 1994 I was involved in two research projects regarding the experimental forest plantations in Bărăgan and the forest ecosystem map of Romania. On May 1995 I was promoted as a researcher of the third grade. In the following years I continued to work on nine different research projects in Italy. All the results were inedit at the time of publication; for instance, nine new forest syntaxa were described for the first time. I was part of an international team that studied a population of *Polylepis tarapacana* on the Nevado Sajama volcano in the Andes.

For three years I worked in a project funded by the World Bank to conduct an environmental study on the peri-urban forest of Cluj-Napoca city. I was also one of the team members who were involved in the Alpnet project aimed at estimating the alpine biodiversity in Europe. Along with some French colleagues I performed complete inventories in the natural old-growth forests of Letea (Danube Delta) and Slătioara (Eastern Carpathians). A similar approach was adopted for studying the residual ash-maple forest stands in the Vaser valley.

I was an active co-worker of my colleagues from Cluj-Napoca in carrying out different projects on rare, endemic or threatened plant species in Romania. In 2006 I was responsible with the inventory and description of the Natura 2000 forest habitats in the Sighișoara - Târnava Mare SCI. Between 2007 and 2008 I acted as national coordinator (for the distinction and description of Natura 2000 habitats) within the framework of an international PHARE project. Along with bryologists and lichenologists I conducted studies on cryptogamic communities developed on live of dead wood. Another topic addressed was the choronosequence of vegetation patches installed on mining waste heaps from Roșia Montană.

I have been carried out a continuous editorial activity for the production of some scientific books and two journals. I have been also acted as an appointed reviewer for two journals indexed in Web of Science. In 1994 I was awarded the Grigore Antipa prize of the Romanian Academy.

Most of my papers were scientifically acknowledged through 152 citations in Web of Science and 308 citations in other international reference databases (self-citations excluded).

In September 1995 I got the position of lecturer at the Faculty of Biology and Geology (Babeș-Bolyai University) for teaching Biogeography (at undergraduate level), Biocoenology and Landscape Ecology (at master level). Later I was assigned the course in Biostatistics (undergraduate) and a seminar in Numerical Analysis in Ecology at the Doctoral School of Integrative Biology.

In 1995-1997 I was involved in a TEMPUS projects joining universities from Brussels and Alicante, beside my own university. From 1999 I have been involved in the elaboration and accreditation of the master curricula in Biocoenology and the Management of Protected Areas. To date I have supervised, alone or in collaboration, over 25 graduate/master theses and have been appointed as member in 12 doctoral commissions. Along with prof. Vasile Cristea and prof. Franco Pedrotti I published in 2004 a Romanian textbook of Phytosociology and an updated, Italian edition in 2015. In 2004, 2009 and 2014 I was the the promoter and organiser of three international symposia held at my university.

During the academic year 1994-1995 I was appointed as visiting professor at the Faculty of Biological and Natural Sciences of Camerino University (Italy). In 1995 and 2005 I was invited to give a lecture at the Academy of Forest Sciences in Florence (Italy) and respectively, at the Botanical Institute of the Chinese Academy of Sciences in Beijing.

I am going to continue to work on fundamental research, which is more suitable for my skills and expertise, and allows for testing logical hypotheses through the deduction method. I will work much less on forest typology but more on topics of great interest, given the threats related to massive deforestation and biodiversity loss. I will focus on structural and functional patterns in forest communities as signals of ongoing ecological processes. In my papers I will make use of quantitative methods and statistical modelling to detect the patterns mentioned before. I intend to enlarge my research team as much as possible by involving not only young Romanian researchers, but also foreign colleagues.

The courses and seminars will be all interactive and based on rational, analogies and examples, so that students can understand and use correctly the concepts presented. I will focus on the application of theoretical notions in practice and their use in new contexts. I will never ask my students to learn formulae and definitions by heart.

Before starting the seminars, I always make a summary of the most important aspects taught during the previous course. At undergraduate level I will organise small groups of students, in order to stimulate the team working, whereas at master/doctoral level the students will have to develop independent working skills. All seminars are heavily practice-oriented. I will emphasize the use of digital technologies and electronic resources in both teaching and assignments. Within the limits of possibilities, I will keep the software used by students updated on the lab computers. The syllabus of each taught disciplines will be updated annually. Whenever possible, I will invite renowned specialists to give some classes to my students, who will also be stimulated to get involved in research projects. As a personal goal, I am going to conceive a very short guide of good practice for the master and PhD students preparing and writing their theses.