FLORISTIC AND EDAPHIC PATTERNS IN TYPICAL FIR AND SPRUCE FOREST ON MOUNTAINS TREBEVIC AND ROMANIJA, IN BOSNIA AND HERZEGOVINA

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Abstract. The bi-dominant spruce and fir forests are secondary plant communities in beech-fir with spruce climax forests belt with hotspot range in Bosnia and Herzegovina (B&H) in the zone of Internal Dinarides (Central Bosnia mountains and Southeastern Bosnian area). The aim was to assess floristic composition and interaction with edaphic factors in typical sub-association of spruce-fir forests (*Abieti-Piceetum abietis typicum*) on mountains Trebević and Romanija, in south-eastern B&H. Phytocoenological and pedological data were collected from 12 sample plots. Interactions between plant communities and edaphic factors were assessed using Redundancy Analysis (RDA) in R. A high degree of floristic homogeneity was observed with 104 registered plant species in total. In spectrum of life forms the community is hemicrypto-phanerophyto-geophytic with 42%, 29% and 21% share, respectively. The statistical significance of edaphic factors is the highest for the following variables: concentration of potassium oxide (K_2O) and hygroscopic water content (HWC). Species *Picea abies* and *Festuca drymeia* showed significant response to edaphic gradients: nutrient availability and soil texture. Floristic composition corresponds to typical silver-fir community with fagetal elements and tendency to beech-fir with spruce climax forest. The research highlights the necessity for management measures that can increase the resilience of typical fir-spruce communities. These forests also need careful monitoring and assessment regarding their response to climate change.
Keywords: *beech, spruce, species composition, edaphic gradients, secondary communities, redundancy analysis (RDA)*

Introduction

Forests and forest land cover about 60% of the total area in Bosnia and Herzegovina (Lojo and Balić, 2011) positioning the country to the very top of European countries in terms of the forest ecosystems distribution and natural resource importance (Boncina, 2011). The mixed forests of beech and silver fir with Norway spruce (*Piceo-Abieti-Fagetum illyricum* Stef. et Beus 1980) represent the most abundant, vital, and economically and ecologically significant forest ecosystems in Bosnia and Herzegovina. They cover approximately 35% of the total country forest area (Matić et al., 1971) and stand out as the most prevalent and significant productive forests accounting with 42.6% and 51.8% in the volume stock and volume increment, respectively (Lojo and Balić, 2011). They also provide wide range of multiple ecosystem services.

Mixed beech-fir with spruce forests represent a primeval forest vegetation with historical significance in the development of the vegetation of the whole Balkan

Peninsula (Mišić, 1982). From Slovenia, Mountain Plješevica in Croatia to the Rhodope Mountains in Bulgaria, the vegetation belt is strongly defined and occupy large area (Gazdić et al., 2018). These forests are widespread in Bosnia and Herzegovina, as well as in northern Montenegro and western and southwestern Serbia (Jovanović, 1980; Eremija et al., 2012). The various climatic and biogeographic drivers throughout the distribution area diverge some differentiation leading to a large number of associations and sub-associations' names and descriptions of the community (Gazdić et al., 2018). General altitude ranges from 800 to 1700 m above sea level (a.s.l.) with beech-fir forests position on lower areas (800 to 1650 m a.s.l.) while stands with spruce occupy higher areas (1000 to 1550 m a.s.l.) usually above beech-fir belt (Diklić et al., 1997; Tomić, 2004; Gazdić et al., 2018). Bucalo (1994) studied this forest type on the Jadovnik mountain in western Bosnia in the altitude zone between 1200 m and 1500 m a.s.l. Comparing to beech, silver fir and, especially Norway spruce, have a much narrower elevation range and limited distribution to the subalpine zone (Horvat, 1954; Jovanović, 1980; Mišić et al., 1982). The presence of silver fir and Norway spruce in the Dinaric beech-fir forests has high importance while mixed stands are more likely to be more resistant to climate change and provide higher habitat diversity (Boncina, 2011).

In Bosnia and Herzegovina, the main distribution range of climax (climaregional) beech-fir forests with spruce spatially follows the northwest-southeast chain direction of the Dinarides, predominantly the colder central Dinaric mountain areas outside the warm climatic influences of the Pannonian or Mediterranean basins (Bucalo, 1994) in Illyrian floral province (Stefanović et al., 1983b; Beus, 1984). Within the climaregional belt of beech, fir with spruce in the entire interior area of the Dinarides, the two-dominant mixed forest of fir and spruce (*Abieti-Piceetum* Stef. 1960 = *Abieti-Piceetum Illyricum* Stef. 1960, *Abieti-Piceetum* Mat. 1978) (syn. *Piceo-Abietetum* Čolić 1965, *Piceo-Fago Abietetum* Čolić 1965, *Abieti-Piceetum abietis* Mišić & Popović 1978, *Abieti-Fagetum piceetosum* Mišić & B. Jovanović 1983) are widespread as a secondary community, representing transitional vegetation stage in the succession towards climax beech and fir (with spruce) community (Bucalo, 2002). Sintaxonomicaly they are included in the order *Vaccinio-Piceetalia* (Pawlowski in Pawlowski et al. 28) Br.-Bl. in Br.-Bl. et al. 1939. emend K. Lund 1967.) with corresponding class of frigophilous coniferous forests of mountain and alpine communities (*Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 39. Emend Zupančič (78) 1980, alliance *Vaccinio-Piceion* Pawlowski et al. 28) Br.-Bl. in Br.-Bl. et al. 1939) and suballiance *Abieti-Piceenion* Br.-Bl. in Br.-Bl. et al. 1939).

Spruce and fir forests (*Abieti-Piceetum illyricum* Stef. 1960, *Abieti-Piceetum abietis* Mišić & Popović 1978) are distributed in humid mountain habitats mainly at altitudes between 1300 and 1900 m (Eremija et al., 2012) under mountainous climate conditions throughout Bosnia starting from Grmeč in the northwest to Maglić and the plateau of Meštrovac in the southeast (especially in the area of Kupres, Vranica, Vlašić, Zvijezda, Romanija, Jahorina, Čelebić). According to Fukarek (1970), the distribution of spruce in Bosnia and Herzegovina is concentrated inland comparing to silver fir and beech, away from the Adriatic Sea and the Pannonian Basin. In central Bosnia area (Stefanović et al., 1983a), in the mountains between the Vrbas River, Bosna and Lašva, spruce occupies approximately the same area as fir, with only difference of occurring at slightly higher altitudes. The spruce distribution continues east-south with Miljacka and Prača river basin connected with the mountains Jahorina, Ravna planina and Trebević. Further

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towards the south and west it covers, mainly, only the northern slopes of the mountain Bjelašnica, Treskavica, Lelija (Mašće and Ravna gora), Zelengora, Maglić and Volujak. Regions of the Trebević, Romanija, and Jahorina mountains offer a wealth of habitat variations, making it an ideal area for researching the influence of habitat factors on shaping floral diversity. Here, natural forests are highly complex and intricate, and understanding these habitat variations is crucial for sustainable management and long-term preservation of forest ecosystems.

The current state of forests and its species composition is the result of all previous influences but also an indicator for future processes (Šercelj, 1996; Boncina et al., 2003). Studies showed that these forests are very sensitive towards climate excesses, especially rapid changes with no period for tree adaptation (Forzieri et al., 2021; Hilmers et al., 2019). Each of the dominant species has its own specific biological properties and ecological requirements that differ to a certain extent (Kvesić, 2014). Silver fir is species with high requirements towards soil and air humidity and very sensitive during youth to drought, insolation, late and excessive frost, cold and dry winds (Barbu, 2012; Teodosiu et al., 2019). There is increasing research interest in fir forests in Europe from long-term threat, caused by changes in environmental conditions and forestry practices in Central European forests (Ballian and Halilović, 2016). Klopčič et al. (2017) observed that, under various management strategies and climate change, fir may almost disappear in low elevation stands and that climate change might intensify its decline. Adding complex interactions of different environmental conditions, region characteristics, anthropogenic influences and improper management procedures may result in a disadvantageous position for one of the tree species. Simulations showed that spruce and fir presence and proportions are linked to specific ecological niche in higher elevations in the sub-alpine climatic belt as refugial zones (Klopčič et al., 2017). Additionally, forestry obligation is to recognize these areas, developmental processes in forests, species composition and understand its drivers.

Considering above mentioned, the purpose of this study is to identify the key characteristics of defined vegetation-ecological type of fir and spruce forests in south-east Bosnia region based on phytocoenological and pedological studies as determinants of forest types. Therefore, we have established two specific objectives: a) to characterize the floristic composition and structure in typical community of fir and spruce forests in Romanija and Trebević, b) to assess the interaction between the floristic composition and the ecological variables (primary edaphic) in fir and spruce forests.

This is consistent with the requirement to improve forest management, preserve their ecological and productive value, and better utilize the natural potentials of the Trebević and Romanija mountains.

Materials and methods

Study area

The research was conducted in typical mixed spruce and fir forests on the mountains Trebević and Romanija (*Abieti-Piceetum abietis* subass. *typicum*), located in southeastern part of Bosnia and Herzegovina. These mountains belong to the northeastern zone of Dinarides. Trebević (43°49′24″ N, 18°26′56″ E) is positioned between Miljacka and Kasindolska rivers canyons, Sarajevo basin and Veliki and Mali Stupanj hills. The highest peak is Sofa, 1627 m a.s.l. Romanija (43°54’20” N,

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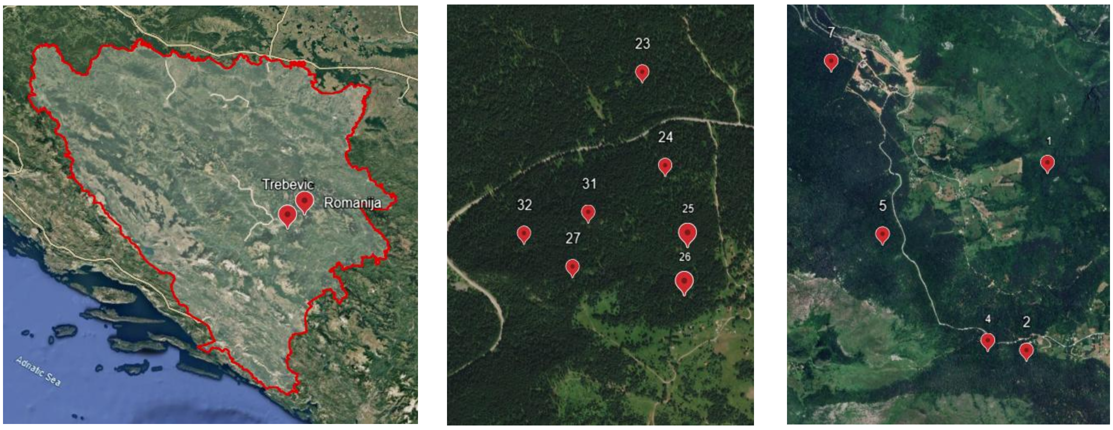
18°40’11” E) includes area among mountains Jahorina, Ozren and Kuštravica, and plateau Glasinac. The highest peak is Veliki Lupoglav, 1652 m a.s.l. Trebević and Romanija are about 18 and 31 km dinstance from Sarajevo.

The region of these mountains is characterized by a mountain type of temperate continental climate (Milosavljević, 1973) with long and snowy winters, short and cooler summers, and regular precipitation throughout the year. Elevation ranges from 700 to above 1600 m a.s.l. Average plots elevation on Romanija and Trebević is 1200 m a.s.l, with inclination up to 10° on Romanija, and 20° on Trebević.

Geologically this is a relatively homogeneous region, mostly built of limestone, with dominant series of limestone soils: calcomelanosol, calcocambisol, and luvisol. Two plots on Trebević are dystric cambisols on sandstone and chert, respectively, and one plot is ilimerised soil on sandstone. The characteristic of these soil combinations is surface rockiness. Vegetation period lasts approximately 150 days (from 120 to 190 days). About 52% of annual precipitation is in vegetation period. The average mean air temperature in the growing season is 13.8°C, the average annual amount of precipitation is 921.7 mm, late frosts occur in June, and early frosts in September. Climate data for Trebević and Romanija were taken from meteorological measurements of Republican Hydrometeorological Institute of the Republic of Srpska (RHMZ) (*Fig. 1*).



(a) (b) (c)

Figure 1. *Location of the study area Trebević and Romanija in B&H (a), with sample plots-relevés (red placemarks) on Trebević (b), Romanija (c)*

Data collecting and processing

The floristic and edaphic patterns of the studied plant communities were determined based on phytocoenological and pedological data collected on twelve plots established in 2019. After reconnaissance of the terrain, location for pedological profiles and phytocoenological relevés were determined, depending on the slope of the terrain, degree of structure, height of trees, exposure, relief conditions, vegetation, and other relevant factors. A total of 12 phytocoenological relevés were made to describe the community of which five were sampled on Trebević, and seven on Romanija. Phytocoenological relevés were taken according to the Braun-Blanquet method (Braun-Blanquet, 1964) and subsequently compiled into a phytocoenological table. The vegetation was sampled on a fixed area of 20 × 20 m for each plot. The Flora Europea I-

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V (Tutin et al., 1964-1993) and Flora Serbia I-X (Josifović, 1970-1986) are used for taxon determination. The spectrum of life forms and ecological characteristics of species (relationship of plants to humidity soil acidity, the nitrogen amount in the soil, light and heat) were made according to the method of Kojić et al. (1997). Tree height on every plot was measured using Vertex III hypsometer with a transponder (Haglöf Sweden AB), ensuring precise and accurate measurements in the field.

Twelve pedological profiles were opened on the same plots where phytocoenological relevés were taken, but eleven profiles were analyzed due to the inconvenient structure of one profile on Romanija. Soil samples were collected from the identified horizons (*Tables A2* and *A3*) in a loose (disturbed) state, ensuring that the soil structure was minimally altered while retaining the natural stratification and composition of the soil layers during the sampling process. Subsequent physical-chemical analyses (*Tables A2* and *A3*) were done on air-dry soil at the Laboratory of the Faculty of Forestry in Belgrade. The analyses included: determination of hygroscopic water content by drying in a drying oven at a temperature of 105°C for a period of 6-8 h (Black, 1965); determination of granulometric composition by treating the samples with sodium pyrophosphate while soil fractionation was carried out using a combined pipette method and elutriation method (Atterberg, 1912) with determination of the percentage content of fractions of: 2-0.2 mm, 0.2-0.06 mm, 0.06-0.02 mm, 0.02-0.006 mm, 0.006-0.002 mm and smaller than 0.002 mm (Gee and Bauder, 1986; Soil Survey Staff, 2017); determination of the active acidity of the soil - pH in H_2O; determination of substitution acidity of the soil - pH in 0.01 M $CaCl_2$, electrometrically (Thomas, 1996); determination of hydrolytic acidity, sum of adsorbed base cations (S, in $cmol*kg^{-1}$), total adsorption capacity for cations (T, in $cmol*kg^{-1}$) (Kappen, 1929); the sum of acidic cations (T-S, in $cmol*kg^{-1}$) by the calculation method; determination of the degree of soil saturation with bases (V%) (Hissink, 1924); percentage of humus and carbon (Tyurin, 1931), in the modification of Simakov (FAO, 2021); determination of total nitrogen in the soil by the Kjeldahl method and determination of the ratio of carbon to nitrogen (C:N), by the calculation method (Bremner and Mulvaney, 1982); determination of the content of easily accessible P_2O_2 and K_2O by the Al method (Egner et al., 1960). Soil classification was done according to the land classification of Yugoslavia (Škorić et al., 1985) and according to the world reference base for soil (WRB, IUSS, 2014).

Data processing and statistical analyses were performed in the R (R Core Team, 2020). Three matrix data frames related to species abundance, edaphic variables and supplementary variables (indicators) of species ecology for 11 plots were prepared. One sample plot was excluded because of lacking soil data. Also, soil variables with missing data were excluded (total nitrogen, the ratio of carbon to nitrogen and P_2O_2) so the final edaphic data set contained 20 variables. To represent soil profile characteristics on particular location where phytocoenological recording was performed, edaphic continuous variables were calculated by multiplying the variable values by horizon thickness and dividing the sum of these values by the total profile depth. For the variables expressed in percentages, horizon aggregation was performed summing multiplied percentage and horizon thickness per profile (Quick and Chadwick, 2011; NRCS, 2006). Also, Redundancy Analysis (RDA) was used to assess the importance of edaphic variables on species composition patterns in the communities on two mountains. Different univariate and multivariate methods and techniques are used in studies to examine the plant species/communities respond to environmental gradients

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(Anderson et al., 2011). RDA is a form of canonical multivariate ordination, applied in community ecology that directly compare floristic composition and a set of environmental descriptors to understand which predictor variables are most strongly associated with the response variables and to visualize the relationships between them (Anderson et al., 2011; Legendre and Legendre, 2012). RDA was performed on an initial matrix set with all explanatory variables. Initial data were transformed using Hellinger transformation to run transformation-based RDA (tb-RDA). To simplify the model and avoid misleading interpretation of the tb-RDA results due to multi-collinearity of scaled environmental variables, we optimized the tb-RDA model performing variable backward selection and checked the variance inflation factors (VIF). The analysis of variance (ANOVA) to test the significance of constrained ordination was used to evaluate the tb-RDA model, individual RDA axes and environmental variables (ter Braak and Prentice, 2004). The Hellinger-transformed plant abundance and significant environmental variables in addition to passive projection of scaled species ecology indicators are plotted on the triplot ordination diagram. The analyses were performed using “vegan” package in the R (R Core Team, 2020).

Results

Dominant plant community of studied area is beech-fir forests with spruce *(Piceo-Abieti-Fagetum*) with significantly represented secondary plant community of mountain spruce and fir forests (*Abieti-Piceetum illyricum* Stef. 1960, *Abieti-Piceetum abietis* Mišić & Popović 1978), of transitional properties, belonging to the alliance of acidophillous spruce forests (*Vaccinio-Piceion* Br.-Bl. 1939) of order *Vaccinio-Piccetalia*. The studied community on Romanija and Trebević included syntaxonomically typical subassociation of spruce and fir association (*Abieti-Piceetum abietis* subass. *typicum*) (*Fig. 2*). The following types of soil occur over mostly limestone bedrock on both locations: calcomelanosols, calcocambisols, dystric cambisols and luvisols. The dominant texture category on Trebević is loam, while on Romanija is clay.

Floristic composition and structure

The plant community is represented by twelve phytocoenological relevés with 104 plant species found and recorded in total (*Table A1*). The summary phytocoenological table (*Table A1*) shows the floristic composition and community structure for studied localities.

Fir and spruce dominate in the tree layer with a cover range from (0.6) to (0.9), tree heights of 35 to 40 m and with an average diameter of 35 to 40 cm. Rowan (*Sorbus aucuparia*) and wild pear (*Pyrus pyraster*) sporadically appear in tree layer.

The shrub layer is sparse and cover ranges from (0.1) to (0.4) with heights 2 to 4 m. In this layer dominant species are fir, spruce, with significant presence of beech (*Fagus sylvatica*), sycamore maple (*Acer pseudoplatanus*) and fly honeysuckle (*Lonicera xylosteum*).

Herb layer is floristically diverse and developed, the coverage ranges from (0.8) to (1.0) with largest presence for species: *Abies alba*, *Festuca drymeia, Lamium galeobdolon, Aremonia agrimonioides, Corylus avellana, Deshampsia flexuosa, Daphne mezereum, Dryopteris filix-mas, Euphorbia amygdaloides, Gentiana asclepiadea, Hieracium murorum, Lonicera xylosteum, Vaccinium myrtillus.*

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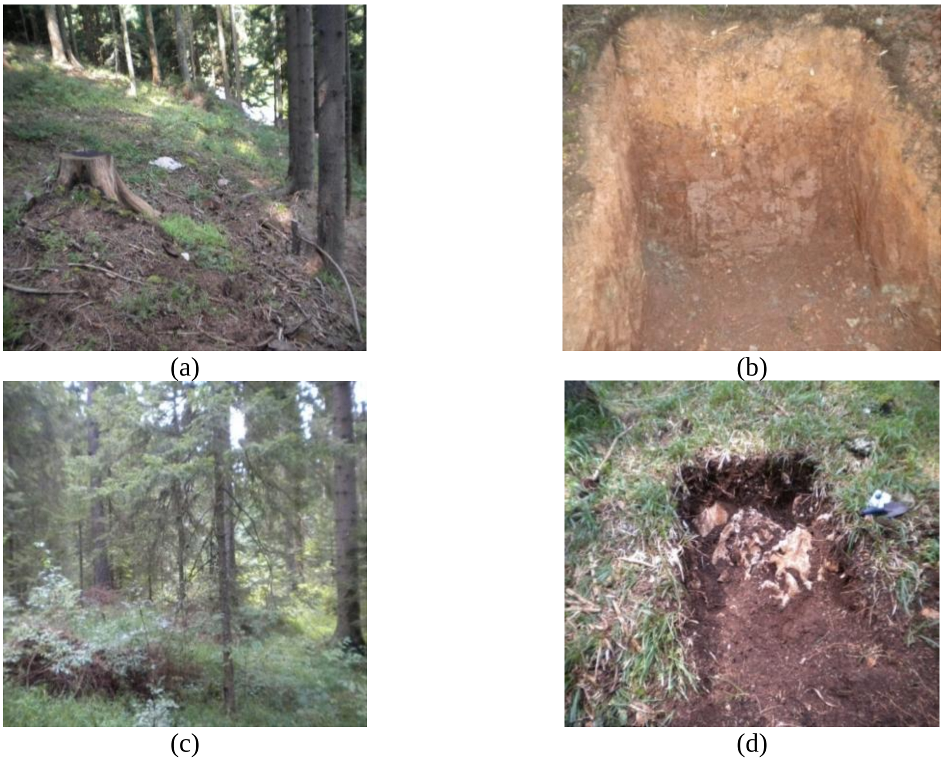

Figure 2. *Typical spruce and fir community on sample plots: (a) Trebević, (c) Romanija; associated soil profiles on plots: (b) luvisol on sandstone on Trebević, (d) calcomelanosol on limestone on Romanija*

Spectrum of life forms

The analysis of the spectrum of life forms (*Fig. 3*) shows that investigated community is dominated by hemicryptophytes with 42% followed by phanerophytes with participation of 29%. The share of geophytes is also high, accounting for 21% which indicates the mesophillous character of this community. The share of chamaephytes is 5%, while the therophytes have the smallest share of 3%. According to the spectrum of life forms, the community can be characterized as hemicrypto-phanerophyte-geophytic.

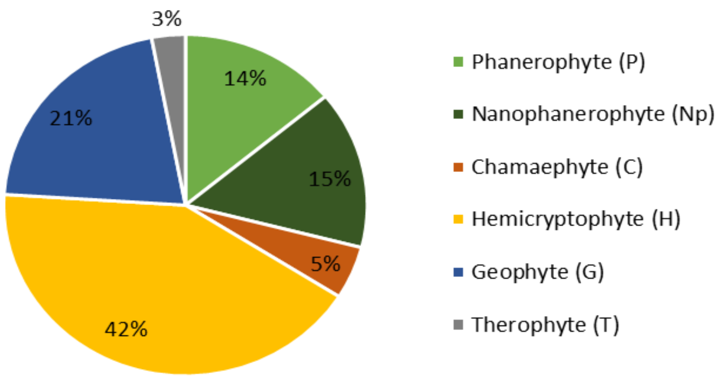

Figure 3. *The spectrum of life forms in typical subassociation of spruce and fir forest community (Abieti-Piceetum abietis subass. typicum)*

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Interaction with environment

The quantitative analysis of the vegetation and edaphic data matrix relates species in the community with edaphic, chemical and physical properties.

Applied constrained ordination connected the species community composition to the edaphic variables aiming to extract the variance of species composition under their influence. Edaphic set contained 20 variables in total, with 58 pair-wise significantly correlated variables ($p < 0.05$). To highlight the most probable relationships between species communities and edaphic variables, it was necessary to retain variables that represented sets of highly correlated variables but behaved uncorrelated in multidimensional space.

Ordination of species abundance data was constrained by available soil data and optimal model was determined using backward variable elimination. The optimal model relates species abundances with two uncorrelated soil variables: soil concentration of potassium oxide (K_2O) and hygroscopic water content (HWC) representing groups of chemical and physical properties. Both, the model and two terms were significant ($p < 0.05$).

The soil concentration of potassium oxide (K_2O) and hygroscopic water content (HWC) explain 25.5% of the variation in species community composition across sites. The first constrained axis (RDA1) explained 14.9% of the variance while the second (RDA2) explained 10.6% of the variance. Considering that the first two unconstrained axes explained about 29.5% of the variance, it seems that some other environmental variables beside K_2O and HWC affect species compositions.

The ordination plot of the Hellinger-transformed plant abundance data constrained K_2O and HWC (scaling 1) is presented in *Figure 4a*. In addition, the most abundant species and passive projection of indicators of species ecology preferences are included on triplot to analyze compositional gradients (*Fig. 4b*).

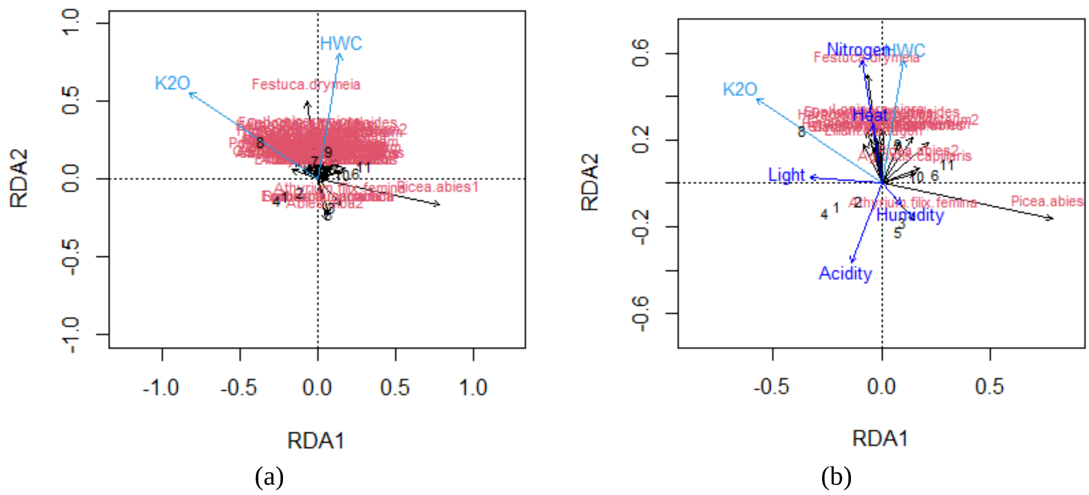

Figure 4. *RDA triplot of the Hellinger-transformed plant abundance data constrained by soil concentration of potassium oxide and hygroscopic water content (a), the most abundant species and passively projected indicators of species ecology (scaling 1) (b)*

Tree types of data are presented in *Figure 4a*: sample scores as black numbers, species scores as black arrows with red names and significant environmental variables

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as blue arrows with names. Scaling 1 present distances among sites reflect their similarities. Sample scores related to Trebević (1 to 5) are closer in multidimensional space pointing out higher similarities of species compositions compared to communities on Romanija mountain. Species scores in *Figure 4a* represent all species where the most of them are clustered together around the root of both axes. Species that are closer together occupy more sites in common. Several species with longer arrows stand out from the cluster: they did not appear on many sites sharing intermediate edaphic properties with other species then express correlations with different edaphic patterns. In *Figure 4b*, only species correlated with RDA axes are presented and species ecology indicator variables as dark blue arrows with names are added.

Related to species abundance, the negative scores of the first RDA are related to *Atropa belladonna, Polypodium vulgare, Prunus avium* and *Rubus idaeus* in the herb layer, while positive scores are related to *Picea abies* in tree layer, *Picea abies* and *Lonicera xylosteum* in the shrub layer and *Agrostis capillaris* and *Athyrium filix-femina* in the herb layer. Soil variables indicate that species on the left side are nutrient demanding, occupying nutrient's rich sites while on the opposite side appear species on oligotrophic sites. Here could be presumed nutrient availability gradient. The second RDA axe is related negative scores to the *Sorbus aucuparia* and *Picea abies* in tree layer, *Abies alba* in shrub layer and *Epilobium montanum, Euphorbia carniolica* and *Athyrium filix-femina* in the herb layer. On the axe positive side are the most important species *Lonicera xylosteum* in shrub layer and *Festuca drymeia*, *Lonicera nigra, Euphorbia amygdaloides*, *Dryopteris filix mas* and *Heracleum sphondylium* in herb layer. This axis is positively correlated with hygroscopic water content pointing out effects of physical properties. Two significant RDA axes related to significant soil variables, representing chemical and physical characteristics, indicate effects of nutrient availability and soil texture gradients (from sandy to clay soils) on species compositions. The furthest arrows are for *Picea abies* in tree layer (characteristically higher on plots 1 and 3 on Trebević) and *Festuca drymeia* across axis 2 (on some plots located on Romanija) indicating higher significance and more distinct response to the edaphic gradients. Indicator variables related to ecological characteristics of species: the nitrogen amount in the soil and heat are highly associated with high HWC indicating plant communities with *Festuca drymeia* and nutrient and light demanded species presence. Such communities are positioned on sites with increasing nutrients availability gradient and increasing HWC gradient. These sites are distributed on positive side of the second RDA and all are situated on Romanija mountain (plots six to eleven on triplot). Species communities preferring acidity and humidity are distributed on the opposite side, with indication of *Picea abies* in tree layer dominance and lower number of species adapted on oligotrophic and sandy sites as *Athyrium filix-femina*. This part of multidimensional space is related to sites on Trebević mountain (plots one to five on triplot).

Majority of species are clustered together away from species that are correlated to nutrient availability or soil texture gradients. Clustered species prevail in the studied community containing transitional categories of plants, between oligotrophic-mesotrophic to mesotrophic-eutrophic. Their presence points out diverse species community compositions occupying different edaphic patterns present on the studied typical fir and spruce forest.

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Discussion

European mixed forests of common beech (*Fagus sylvatica* L.), silver fir (*Abies alba* Mill.), and Norway spruce (*Picea abies* (L.) Karst) cover over 10 million hectares of mountainous areas of Europe and are considered one of the most valuable ecosystems with high production and biodiversity. Recently, they are very sensitive towards climate changes (Forzieri et al., 2021; Hilmers et al., 2019).

In Bosnia and Herzegovina, the beech, fir and spruce forests (*Piceo-Abieti-Fagetum illyricum* Stef. et Beus 1980) represent the most widespread and significant forest ecosystems in ecological, social and economic terms. In vegetation belt of dominant beech-fir with spruce plant communities significant presence possess secondary plant communities of transitional properties of the order *Vaccionio-Piceetalia*-mountain fir and spruce forests *(Abieti-Piceetum illyricum* Stef. 1960, *Abieti-Piceetum abietis* Mišić & Popović 1978). A detailed review of these communities and classification of primary and productive spruce-fir forest types was elaborated by Stefanović et al. (1983a). The floristic composition and ecological patterns, primarily edaphic, of typical fir and spruce community (*Abieti-Piceetum abietis* subass. *typicum*) on the limestone substrates, at 1100-1300 m a.s.l. on Romanija and Trebević mountains, were analyzed in this study.

Eremija et al. (2012) described spruce-fir community as a secondary community on Lisina in western Bosnia and Herzegovina in altitude range from 1000 to 1150 m, usually on eastern aspects in discontinuous, mosaic distribution within the community of beech-fir with spruce on limestones, dolomites and silicate substrates. Inclination ranges from 6 to 17° on the limestone surfaces. Generally deeper luvisols and dystric cambisols predominate while rendzinas on dolomite and colluvial soil are less common. Differently from our research, the terrain is not rocky on Lisina. On Lisina, a high content of humus, nitrogen and potassium was noted in the humus layer, and it decreases sharply with depth (Eremija, 2015). Also, on Javor mountain in the eastern part of BiH, this community is associated with more productive soils where dominant species reach considerable dimensions (Kapović, 2013).

Similar to Bosnia and Herzegovina, the forest of spruce and fir extends over climate-regional belt in Serbia only on Tara (Pešter plateau), while on the rest territory these forests occupy much smaller areas with disjunct areal over several mountains (Eremija, 2015). Spruce and fir community in Serbia (*Abieti-Piceetum abietis* Mišić et Popović, 1978) belongs to the association of acidophilous spruce forests *Vaccinio-Piceion* (Pawlowski et al., 1928) Br.-Bl. in Br.-Bl. etc. 1939, i.e. subseries *Abieti-Piceenion* Br.-Bl. in Br.-Bl. et al., 1939, which includes mixed spruce-fir, spruce-fir-beech forests and monodominant spruce forests at lower altitudes from 1000 to 1600 m (Tomić and Rakonjac, 2013; Šljukić, 2015). The community has been first described in the Mesian province in Kopaonik above the canyon of the Samokovska river (Mišić and Popović, 1954), Zlatar (Mišić et al., 1985; Obratov, 1992) and Stara planina in favourable ecological conditions (Mišić et al., 1978; Tomić and Rakonjac, 2013). At Zlatar, the subassociation *Abieti-Piceetum serbicum* subass. *typicum* was described (Novaković and Cvjetićanin, 2008). On Kopaonik, a typical spruce and fir forest (*Abieti-Piceetum serbicum typicum*) has been described at altitudes between 1300 and 1520 m a.s.l., on wide ridges that descend to the north and northeast, on slopes of 5-30° and on different aspects (Mišić, 1985). In Zlatar, this type of forest was recorded at altitudes of 1150-1300 m, slopes of 2-35° and predominantly northern aspects (Mišić et al., 1985), the two sub-associations are *vaccinietosum* and *muscetosum* (Mišić et al., 1978). According to Wraber (1964), a community of fir and spruce, *Abieti-Piceetum*, of the order

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Vaccinio-Piceetalia appears in the transition area between the Southeastern Alps and the Dinaric Mountains among climax communities of alliance *Fagion illyricum*. It is primarily conditioned by relief and edaphic conditions, and secondarily by microclimatic conditions. The association has high species richness because of many elements from the surrounding vegetation of beech-fir forests which give it also fagetal character. Other authors reported also about presence of fagetal floral elements along acidophilous (Tomić, 2004; Eremija, 2015), what is consistent with our results. The significant presence of beech forest elements indicates community tendency to develop towards a succession stage of climax beech and fir forest with or without spruce (Stefanović, 1977).

On Romanija and Trebević, the analysis of the spectrum of life forms showed that investigated community is dominated by hemicryptophytes with 42% followed by phanerophytes with participation of 29%. Hemicryptophytes are adapted for living in temperate and colder regions and as such represent the most abundant life forms in our region (Diklić, 1984). The share of geophytes is also high, which indicates the mesophilous character of this community and additionally favorable conditions for the development of this community, primarily a favorable soil moisture regime. High geophyte presence is influenced by denser arrangement of trees and bushes in the floor, which makes it difficult for light to reach the floor of the ground flora. The share of chamaephytes is low, which is expected, because they occur most often in unfavorable habitats indicating the presence of frigorophilous conditions and habitats where extreme colds occur. The therophytes have the smallest share of 3%, because therophytes need a lot of light and heat to develop (Diklić, 1984). According to the spectrum of life forms, the community can be characterized as hemicrypto-phanerophyte-geophytic.

The floristic similarity and the homogeneity of the floristic composition of the Romanija and Trebeveć is emphasized. The dominant species *Picea abies* and *Festuca drymeia* in herb layer indicate higher significance on Trebević and Romanija respectively, and more distinct response to the edaphic gradient, while other species have lower indicator significance. In fir-spruce forests on limestone and silicate substrate on Lisina, *Festuca drymeia* has the greatest abundance and coverage (Eremija, 2015). Comparing the floristic composition on Lisina and Kopaonik, Eremija (2015) reported about many common species in fir-spruce forests: *Galium rotundifolium, Gentiana asclepiadea, Glechoma hirsuta, Euphorbia amygdaloides, Prenanthes purpurea, Rubus idaeus, Melampyrum sylvaticum, Hieracium murorum, Dryopteris filix-mas, Daphne mezereum* and others. Also, the analysis showed that the spruce-fir forest on Kopaonik and Zlatar have 50% common species, with differences in the floristic composition due to the different geographical location (more humid climate in the west), due to the height and bulkiness of the mountains (larger massif of Kopaonik, with a continental climate).

Interrelations between ecology, vegetation and productivity in fir and spruce forests in Bosnia and Herzegovina were studied in the frame of ecological-productivity classification and typology by Stefanović et al. (1983b). Two community series of this forest type were separated: the first one relates to soil rich in alkalis and the second one relates to soil poor in alkalis. Authors addressed differences in floristic composition related to soil acidity but also the relevance of biological accumulation in top soil organic layer. Location on Romanija mountain was particularly described where interaction between limestone and silicate rocks affects dystric cambisol influencing vegetation. Then, in the frame of ecological-vegetation regionalization, Stefanović et al.

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(1983b) quoted that differences in species abundance in fir and spruce forests in herb layer were related to substrate. Community on limestone substrates are assigned as rich in herb layer, particularly with neutrophilous mesophilous species due to rich humus layer. Oppositely, communities on soils with low fertility potential (poor alkali content) on silicate substrate have less species abundance with higher participation of acidophilous species. In this study, the quantitative analysis of the vegetation and edaphic data matrix indicated homogenous species community in general with slight differentiation related to edaphic gradients: nutrients availability (from poor to moderate) and hygroscopic water content (from low to high). The nutrients availability gradient reaching moderate soil fertility, is associated to sites with favorable soil chemical properties (higher bases, humus, carbon and microelements contents) situated on Romanija mountain. Here more abundant plant communities are present, with *Festuca drymeia* dominance as well as other nutrient, light and heat demanding species. The opposite nutrients gradient side indicating low soil fertility, is associated with sites with dominance of *Picea abies* in tree and shrub layers and lower abundance of acidophilous species in herb layer. Present plant communities with acidity and humidity demanding species are located on sites on Trebević mountain. Then, second edaphic gradient related to HWC, representing physical properties, indicates sites with variable soil textures from sandy to clay soils. Higher HWC is associated to sites with favorable physical properties (more balanced silt, sand and clay contents ratio) with higher species abundance and preferable environmental condition for high plant diversity. Findings in this study are in consistence with the studies of Stefanović et al. (1983a, b). Also, recent research identified edaphic effects on floristic structure in fir and beech forests in Bosnia and Herzegovina (Ibrahimspahić, 2024). Ibrahimspahić (2024) notified changed structure of species in tree layer in typical fir and spruce forests on lime-dolomite substrate on Igman mountain. Phytocoenological analyses conducted forty years ago described those forests as fir and spruce forest on limestone (*Abiety-Piceetum illyricum* Stef.), while recent studies described this forest type as mountain beech, fir with spruce forest on lime and dolomite substrates (*Abieti-Fagetum illyricum* Treg.).

The analysis of floristic composition and edaphic factors presented here pointed out interrelation between floristic compositional and edaphic gradients in fir and spruce forests on Romanija and Trebević. Spruce–fir forests may be broadly sensitive to anticipated increase of summer temperatures and drought, especially on dry sites due to climate change that could change communities composition and development (Griesbauer et al., 2021; Begović et al., 2020). Additionally, further investigation on Trebević and Romanija, integrating other environmental factors as climate and orography and also anthropogenic impact could contribute to better understanding of floristic pattern and compositional changes through the time in typical fir and spruce forests.

Conclusions

Bi-dominant typical subassociation of spruce and fir association (*Abieti-Piceetum abietis* subass. *typicum*) has secondary origin on mountains Romanija and Trebević, with high preservation level, productivity and ecological significance. The community can be characterized as hemicrypto-phanerophyte-geophytic according to the spectrum of life forms. A high degree of homogeneity was observed regarding to species composition on Romanija and Trebević with 104 registered plant species in total.

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Species *Picea abies* in tree layer and *Festuca drymeia* in herb layer indicate higher significance and more distinct response to the edaphic gradient additionally determining the character of the community. The research shows that the floristic composition is under the influence of edaphic parameters, concentration of potassium oxide (K_2O) and hygroscopic water content (HWC). In the floristic composition, participation of species from beech forests is registered, which indicates the tendency of this community to develop towards climax beech and fir forest, with or without spruce. In addition, following the developing stages and succession process of these communities is essential.

It is necessary to protect the typical habitats of these forests because edaphic changes (changes in the soil texture and chemical composition due to forestry works such as forests opening, thinning and erosion processes) affect the composition of species. The research's outcomes are useful for forest managers in differentiation, formation of productive forest types and establishing the most adequate management measures for fir-spruce communities based on the principles of sustainable development that can increase the resilience of typical fir-spruce communities. Further research should take in consideration more plots and dispersed localities of spruce and fir forests.

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APPENDIX

Table A1. *Phytocoenological table. The floristic composition of studied association/subassociation shown per layer using phytocoenological analysis*

Association	*Abieti-Piceetum abietis* Br.-Bl. 1939												
Subassociaion	*Typicum*												
Relevé number	23	24	25	26	27	31	32	1	2	4	5	7	**Presence degree**
Menagement unit	Ro	Ro	Ro	Ro	Ro	Ro	Ro	Tr	Tr	Tr	Tr	Tr	
Coordinates	43°55' 38" N 18°39' 38" E	43°55' 27" N 18°39' 42" E	43°55' 18" N 18°39' 46" E	43°55' 12" N 18°39' 45" E	43°55' 15" N 18°39' 26" E	43°55' 21" N 18°39' 28" E	43°55' 19" N 18°39' 17" E	43°49' 28" N 18°29' 09" E	43°48' 43" N 18°29' 01" E	43°48' 45" N 18°28' 48" E	43°49' 11" N 18°28' 12" E	43°49' 53" N 18°27' 53" E	
Unit	5	3	3	3	3	3	3	Pp	14	14	15	18	
Altitude (m)	1278	1270	1288	1280	1255	1265	1294	1103	1272	1262	1214	1184	
Aspect	SW	N	N	N	N	NW	NW	NW	NW	N	NE	N	
Inclination (°)	3-5	2	5-10	10	15	2	20	15	15-25	8	15	10	
Geological substrate	Limest	Limest	Limest	Limest	Limest	Limest	Limest	Limest	Limest	Sandst	Sands	Chert	
Soil type	Ccam	Cmel	Cmel	Ccam	Ccam	Ccam	Cmel	Luv	Ccam	Dcam	Luv	Ccam	
TREE LAYER													
Canopy	0.7	0.9	0.9	0.6	0.5	1.0	0.7	0.8	0.8	0.6	0.9	0.8	
Mean hight (m)	35	30	30	30	40	40	40	18	25	30	30	35	
Mean diameter (cm)	45	35	35	40	40	40	40	30	40	30	35	30	
Mean distance (m)	7	4	4	7	8	5	5	5	6	5	5	4	
Picea abies	4.4	3.3	1.2	3.4	4.4	4.4	4.4	2.2	2.2	3.3	2.2	3.3	**V**
Abies alba	1.2	3.3	4.4	2.2	1.2	1.1	1.1	4.4	3.3	2.2	3.3	2.2	**V**
Sorbus aucuparia								+					**I**
Pyrus pyraster								+					**I**
SHRUB LAYER													
Canopy	0.3	0.2		0.4	0.3	0.4	0.3	0.4	0.2	0.3	0.1	0.1	

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Mean hight (m)	3	2		2	4	3	3	3	4	3	4	2	
Abies alba	1.2	2.2		2.2		3.3	1.2	3.2	1.2	3.3	1.1		**V**
Fagus sylvatica	+			+		+.2		1.2	+	+	+		**IV**
Picea abies	+.2	+		1.2		1.2	1.2	+.2		1.2			**IV**
Lonicera xylosteum		1.2		2.3	1.2		+						**III**
Acer pseudoplatanus				+	+							+	**II**
Lonicera nigra					+.2								**I**
Sambucus racemosa					+								**I**
Sambucus nigra											+		**I**
Sorbus aucuparia												+	**I**
Tilia cordata												+	**I**
Corylus avellana								+					**I**
Crataegus monogyna								+					**I**
Juniperus communis								+					**I**
HERB LAYER													
Coverage	1.0	0.9	0.9	1.0	1.0	0.8	0.8	0.8	0.9	0.8	0.8	0.8	
Abies alba	+.2		+.2	1.2	+	1.2		+.2	+	2.3	1.2	+.2	**V**
Oxalis acetosella	+.2	3.3	3.3	+.2	1.2	1.2	1.2	2.2	+.2	1.2			**V**
Lamium galeobdolon	+.2	1.2	1.2	+.2	1.2	+.2			+.2	1.2	1.2		**V**
Festuca drymeia	1.2	+	2.3	5.5	1.2	1.2		1.2	1.2	1.2			**V**
Galium rotundifolium		2.2	1.2	+.2	+.2	3.3	2.2	2.3	3.3	1.2	3.3	+.2	**V**
Asarum europaeum	+.2	1.2	+.2	+.2		+.2	+		+.2		+.2	+.2	**V**
Aremonia agrimonioides	+	+.2	+	+	+	+.2		+			+	+	**IV**
Vaccinium myrtillus	1.2	+.2		+	+.2	2.2	+.2	2.3			1.2		**IV**
Lonicera xylosteum	1.2	+.2	+.2	+.2	1.2	+.2		+	+				**IV**
Hieracium murorum	+	+.2	+	+	+	+	+		+	+		+	**IV**
Gentiana asclepiadea		+	+	+	+	+.2	+.2	+.2	+.2	+	+		**IV**
Euphorbia amygdaloides	+	+	+	+		+	+	+	+				**IV**
Dryopteris filix-mas		+	+	+.2	+.2	+	+				+.2		**IV**
Daphne mezereum	+	+			+	+		+	+	+			**IV**
Deshampsia flexuosa				1.2	1.2	+.2			+.2		+.2		**IV**
Corylus avellana		+	+	+	+	+					+	+	**IV**

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Athyrium filix-femina	+.2			+	+.2	+	+	+	+.2	+.2		+.2	**IV**
Acer pseudoplatanus	+	+	+			+		+		+	+	+	**III**
Viola sylvestris	+	+						+			+	+	**III**
Mycelis muralis	+	+	+	+							+		**III**
Galium sylvaticum		+		+		+	+.2	+					**III**
Sorbus aucuparia	+	+		+					+	+	+	+	**III**
Sanicula europaea				+.2		+	+	+.2	+.2				**III**
Rubus idaeus			+	+	+.2	+.2					+.2		**III**
Prenanthes purpurea	+		+		+			+	+	+	+	+	**III**
Picea abies	+.2	+.2		+			+2	+					**III**
Melampyrum sylvaticum	+.2	+	+.2	+	+							+.2	**III**
Lonicera nigra	+.2	+.2	+		+.2	+							**III**
Geranium robertianum	+	+.2	+			+	+.2			+			**III**
Fragaria vesca	+	+		+		+		+.2		+			**III**
Fagus sylvatica	+	+	+				+	+.2			+		**III**
Epilobium montanum				+	+				+	+		+	**III**
Brachypodium silvaticum					1.2						+.2	+.2	**III**
Glechoma hirsuta	+.2					+	+						**II**
Polypodium vulgare		+	+								+		**II**
Veronica urticifolia							+	+	+	+			**II**
Senecio nemorensis		+				+	+	+					**II**
Rubus hirtus		+						+.2				+.2	**II**
Rosa pendulina					+			+	+			+	**II**
Prunus avium		+	+								+		**II**
Lathyrus vernus		+				+	+						**II**
Hypericum androsaeum	+		+	+	+								**II**
Heracleum spondilium		+	+	+	+								**II**
Digitalis ambigua		+		+			+						**II**
Euphorbia carniolica				+					+	+		+	**II**
Centaurea montana					+	+	+						**II**
Ajuga reptans				+		+	+						**II**
Acer tataricum								+					**I**

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Aegopodium podagraria					+								**I**
Agrostis capillaris	2.3												**I**
Anemone nemorosa	+												**I**
Aruncus sylvestris			+.2										**I**
Asplenium trichomanes	+												**I**
Atropa belladona			+								+		**I**
Bellis perennis						+	+						**I**
Betula pendula												+	**I**
Calamintha vulgaris							+				+		**I**
Campanula patula		+					+	+		+			**I**
Cardamine enneaphyllos		+											**I**
Carex sylvatica			+			+.2							**I**
Clematis vitalba								+					**I**
Dactylis glomerata	1.2												**I**
Evonymus europaeus	+												**I**
Festuca heterophylla				+									**I**
Galium cruciata	+				+								**I**
Galium schultesii			+										**I**
Genista tinctoria	+												**I**
Geum urbanum								+			+		**I**
Helleborus odorus											+		**I**
Homogyne alpina			+					+.2					**I**
Hylocomium proliferum	1.2												**I**
Juniperus communis								+					**I**
Lathyrus venetus		+					+						**I**
Ligustrum vulgare								+					**I**
Lilium martagon	+		+										**I**
Lonicera alpigena			+.2										**I**
Lotus corniculatus					+								**I**
Luzula sylvatica						+.2	+.2						**I**
L. luzuloides											+.2		**I**
Melica uniflora		+											**I**

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Myosotis sylvatica													**I**
Paris quadrifolia		+							+				**I**
Petasites albus					+								**I**
Pirola secunda		+											**I**
Platanthera bifolia					+								**I**
Poa pratensis	+.2												**I**
Polygonatum multiflorum		+											**I**
P. verticulatum				+									**I**
Polystichum aculeatum				+									**I**
P. lonhitis				+.2									**I**
Populus tremula								+					**I**
Potentilla erecta					+								**I**
Prunella vulgaris												+.2	**I**
Pteridium aquilinum					2.3			+.2					**I**
Pulmonaria officinalis									+	+.2			**I**
Pyrus pyraster	+							+					**I**
Ribes petraeum		+											**I**
Salix caprea								+			+.2		**I**
Sambucus nigra													**I**
Saxifraga rotundifolia				+					+				**I**
Sorbus aria									+	+			**I**
Stachys silvatica			+			+							**I**
Symphytum tuberosum										+	+		**I**
Tilia cordata											+	+	**I**
Tusilago farfara						+	+						**I**
Urtica dioica					+								**I**
Veratrum album											+		**I**
Veronica officinalis											+		**I**
Viburnum lantana								+					**I**
V. opulus						+							**I**

Ro-Romanija; Tr-Trebevic; Geological suptrate: limest (limestone), sands (sandstone)
Soil type: Ccam (calcomelanosol); Ccamb (calcocambisol); Dcam (districcambisol); Luv (luvisol)

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Table A2. *Soil physical characteristics*

Profile number/ relevés	Locality	Morphological formula	Horizon*	Horizon depth (cm)	Soil depth (cm)	HWC (%)	Coarse sand 2.0-0.2 mm	Fine sand 0.2-0.06 mm	Very find sand 0.06-0.02 mm	Silt1 0.02-0.006 mm	Silt2 0.006-0.002 mm	Clay <0.002 mm	TSaC >0.02 mm	TCC <0.02 mm	Textural class	Soil type
1	T	Olfh-E-B(t)	E	0-30	30	1.97	1.4	34.6		23.1	12.7	23.3	40.9	59.1	Silty loam	Illimerized soil on limestone (Luvisol)
			Bt	30-85	55	1.86	0.4	18.5	16.1	30.9	12.6	21.5	35	65	Silty loam	
2	T	Olfh-A-B	A	0-10	10	3.55	1.6	35.7	13.3	19.3	10.8	19.3	50.6	49.4	Loam	Brown soil on limestone (Calcomelanosol)
			B	10-60	50	3.49	1.1	31	11.7	13.2	10.2	32.8	43.8	56.2	Clay loam	
3/4	T	Olfh-A-(B)	A	0-8	8	2.66	1	42.9	14.5	16.5	10.9	14.2	58.4	41.6	Loam	Dystric cambisol on sandy substrate (with shale admixture)
			(B)	8-95	87	2.1	1.6	44.8	12.2	14.1	9.3	18	58.6	41.4	Sandy clay loam	
4/5	T	Olfh-E-(B)	E	0-20	20	1.75	4.9	35.6	12.4	17.7	11.4	18	52.9	47.1	Sandy loam	Illimerized soil (Luvisol) on sandy substrate
			(B)	20-80	60	1.9	7.7	33.1	11.6	14.8	8.8	24	52.4	47.6	Sandy clay loam	
5/7	T	Olfh-(B)-B(s)	(B)	0-65	65	1.71	5.2	36.5	12.7	14.6	10.5	20.5	54.4	45.6	Sandy clay loam	Dystric cambisol on chert (with occasional fragments of andesite or zeolite)
			B(c)	65-90	25	0.16	2.4	42.3	13.6	14.2	7.8	19.7	58.3	41.7	Sandy loam	
6/23	R	Olfh-A-(B)	A	0-30	30	4.01	1.6	14	9.9	26.3	14.8	33.4	25.5	74.5	Clay loam	Calcocambisol on limestone
			(B)	30-55	25	8.58	0.2	0.7	4.2	6.8	4.8	83.3	5.1	94.9	Clay	
7/24	R	Olfh-A	A	0-20	20	7.54	1.3	10.2	13	18.5	12.2	44.8	24.5	75.5	Clay	Organogenic calcomelanosol on limestone
8/25	R	Olfh-A	A	0-20	20	9.54	0.8	13.3	13.5	20.6	11.7	40.1	27.6	72.4	Clay	Organogenic calcomelanosol on limestone
9/26	R	Olfh-A-(Bt)	A	0-20	20	4.26	0.1	9.7	12.3	31.9	16.1	29.9	22.1	77.9	Clay loam	Calcocambisol on limestone
			(B)rz	20-55	35	8.12	0.2	0.3	1.4	2.8	4.1	91.2	1.9	98.1	Clay	
10/31	R	Olfh-A-(B)	A	0-10		4.7	2	10.1	9.9	34.4	16.8	26.8	22	78	Silty loam	Calcocambisol to luvisol on limestone
			(B)	10-30		7.81	4.3	0.4	2	15.3	10.1	67.9	6.7	93.3	Clay	
11/32	R	Olfh-A	A	0-20		7.38	0.7	8.7	15.9	30.7	13.1	30.9	25.3	74.7	Clay loam	Calcomelanosol on limestone

*Soil samples taken from horizons
TSaC – Total sand content; TCC – Total clay content; Olfh - organic horizon with sublayers of organic matter; A - topsoil/humus-acumulative horizon; B - brown illuvial horizon; B(t) - clay illuvial horizon with accumulation of translocated clay; E - eluvial horizon

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Table A3. *Soil chemical characteristics*

Profile number/ relevés	Locality	Horizon*	Horizon depth (cm)	Soil depth (cm)	pH H_2O	pH $CaCl_2$	Y1 mL 0.1 M NaOH/50 g	Adsorptive complex			V (%)	Humus (%)	C (%)	K_20 mg/100 g
								(T-S) cmol/kg	S cmol/kg	T cmol/kg				
1	T	E	0-30	30	5.05	4.6	18.5	12.03	5.4	17.43	30.99	1.68	0.97	10.3
		B(t)	30-85	55	7.23	5.78	0.5	0.33	10.2	10.53	96.91	0.58	0.34	15.4
2	T	A	0-10	10	4.91	4.08	65.5	42.58	9	51.58	17.45	6.74	3.91	10.3
		B	10-60	50	6.84	5.68	14.25	9.26	21	30.26	69.39	2.45	1.42	10.7
3/4	T	A	0-8	8	5.62	4.63	31.5	20.48	11.25	31.73	35.46	4.61	2.67	11
		(B)	5-95	88	5.55	4.63	23	14.95	8.4	23.35	35.97	1.88	1.09	7
4/5	T	E	0-20	20	5.38	4.34	23.5	15.28	6.4	21.68	29.53	2.68	1.55	10.3
		(B)	20-80	60	6.44	4.88	6.5	4.23	12.4	16.63	74.59	1.43	0.83	12.5
5/7	T	(B)	0-65	65	5.09	4.27	25.5	16.58	1.9	18.48	10.28	0.97	0.56	7
		B(t)	65-90	25	5.56	4.38	20	13	2.1	15.1	13.91	0.36	0.21	7.7
6/23	R	A	0-30	0-30	5.05	4.13	52	33.8	3.6	37.4	9.63	4.6	2.67	5.75
		(B)	30-55	30-55	5.88	4.77	28.44	18.49	20.6	39.09	52.7	2.37	1.38	13.36
7/24	R	A	0-20	0-20	5.34	4.67	49.5	32.18	18.6	50.78	36.63	11.24	6.52	13.29
8/25	R	A	0-20	0-20	6.41	5.67	23.75	15.44	42.2	57.64	73.22	12.86	7.46	20.96
9/26	R	A	0-20	0-20	4.75	3.88	61	39.65	3.3	42.95	7.68	4.4	2.55	4.99
		(B)	20-55	20-55	5.58	4.54	35.83	23.29	22.8	46.09	49.47	2.54	1.47	15.64
10/31	R	A	0-10	0-10	4.84	4.04	54	35.1	4.9	40	12.25	4.99	2.9	8.41
		(B)	10-30	10-30	6.18	4.9	22.16	14.4	24.1	38.5	62.59	2.51	1.45	14.12
11/32	R	A	0-20	0-20	5.76	4.91	32	20.8	18.7	39.5	47.34	8.39	4.86	9.55

*Soil samples taken from horizons
T - Trebević; R-Romanija; Y1 - Volume of NaOH consumed (in mL); T-S - Hydrolytic acidity; S - Instantaneous sum of bases; T - Total adsorption capacity; V - degree of base saturation of the soil adsorptive complex; A - topsoil/humus-accumulative horizon; B - brown illuvial horizon; B(t) - clay illuvial horizon with accumulation of translocated clay; E - eluvial horizon

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