SYNTAXONOMY, DISTRIBUTION AND CHARACTERISTICS OF SOME PLANT COMMUNITIES DEVELOPED AT THE EDGE OF FORESTS

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Introduction

Vegetation classification is a critical tool not only for understanding and managing plant communities but also for providing a globally relevant framework for biodiversity studies, conservation efforts, and long-term ecological research. Forest fringes vegetation (mainly class Trifolio-Geranietea) thrives in sunny edges of deciduous forests, clearings, roadsides, and abandoned fields bordering woodlands. These plant communities occur mainly in warm and dry climates with well-drained, low-nutrient soils. The affiliation of this type of vegetation to higher syntaxa may vary significantly among different authors.

Some of the typical dominant species are: *Laserpitium latifolium*, *Geranium sanguineum*, *Peucedanum cervaria*, *Agrimonia eupatoria*, *Inula ensifolia*, etc. The diagnostic species for these plant assemblages are numerous transgressive species from the plant communities in their vicinity. Some communities are species-poor but other are characterized by high species diversity. This paper investigates the distribution patterns and characteristics of forest fringes plant communities across Bulgaria and Romania. These results can be important for understanding and managing regional biodiversity patterns, improving ecosystem services, and guiding conservation efforts.

Material and methods

Vegetation classification - dataset of 351 relevés stored in Romanian (EU-RO-008) and Bulgarian Grasslands Databases (EU-BG-001).
Nomenclature of plant species - Euro+Med PlantBase (2006-) and of higher syntaxa - Mucina et al. (2016).
Hierarchical agglomerative clustering - ß-flexible algorithm (ß = −0.25), and Bray-Curtis dissimilarity.
The optimum number of clusters - corrected Rand index and the mean Silhouette index.
Diagnostic species – fidelity phi coefficient and Fisher's exact test.
Vegetation – environment relationship - Detrended Correspondence (DCA) and Canonical Correspondence Analyses (CCA).
Significant correlation of mean EIVs with scores of samples with the ordination axes - modified permutation Zelený test.
Differences in environmental preferences - non-parametric Kruskal-Wallis and Mann-Whitney post-hoc test.

Results and discussion

SYNTAXONOMIC SCHEME

Cl. TRIFOLIO-GERANIETEA SANGUINEI T. Müller 1962
Ord. Origanetalia vulgaris T. Müller 1962
Al. Geranion sanguinei Tx. in T. Müller 1962
As. *Geranio - Trifolietum alpestris* T. Müller 1962
- subass. typicum
- subass. dictamnetosum albi (Wendelberger 1954) Sanda et Popescu 1999
As. *Festuco pseudodalmaticae - Geranietum sanguinei* ass. nova hoc loco
As. *Inulo ensifoliae - Peucedanetum cervariae* (Kozlowska 1925) van Gils et Kovács 1977
As. *Trollio-Clematidetum recti* Täuber et Weber 1976
Al. Trifolion medii T. Müller 1962
As. *Stachyo officinalis - Melampyretum biharіense* Coldea et Pop 1992
As. *Trifolio medii - Agrimonietum* T. Müller 1962

Cl. EPILOBIETEA ANGUSTIFOLII Tx. et Preising ex von Rochow 1951
Ord. Galeopsio-Senecionetalia sylvatici Passarge 1981
Al. Epilobion angustifolii Oberd. 1957
As. *Clinopodio-Pteridietum aquilini* Dihoru ex Drăgulescu 1995

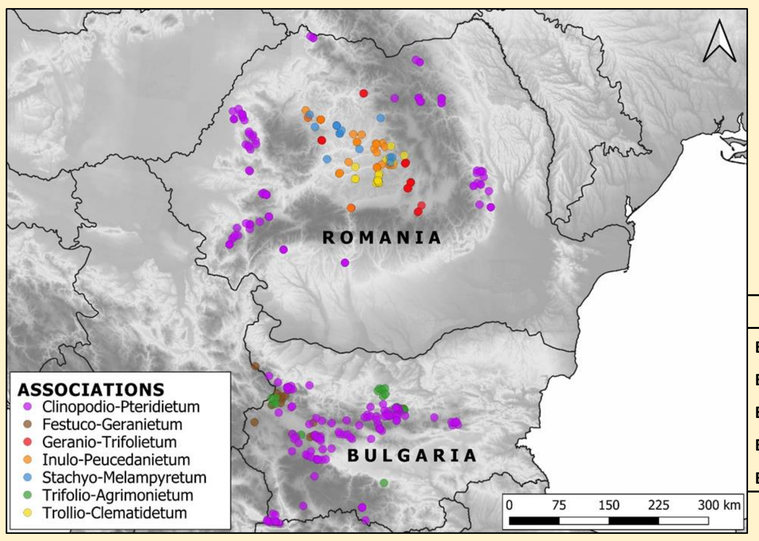

Fig. 1. Map of distution for associations classified in class Trifolio-Geranietea sanguinei T. Müller 1962 as well as of Pteridium aquilinum vegetation classified in class Epilobietea angustifolii Tx. et Preising ex von Rochow 1951 in Bulgaria and Romania

Table 2 Characteristics of the six plant associations within class Trifolio-Geranietea and Pteridium aquilinum vegetation in Romania and Bulgaria (means and standard deviations). With different letters were highlighted the significant differences (α = 0.05) among groups (clusters) according to Mann-Whitney post-hoc test while the p-values were derived from the non-parametric Kruskal-Wallis test.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	*p*
Eiv - L	7.22±0.12^{a}	7.29±0.19^{b}	7.41±0.17^{b}	7.09±0.12^{c}	7.02±0.22^{c}	7.45±0.18^{b}	6.98±0.26^{c}	<0.001
Eiv - T	5.94±0.14^{a}	5.63±0.41^{b}	6.10±0.14^{c}	5.67±0.09^{b}	5.69±0.26^{ab}	5.85±0.41^{ac}	5.37±0.50 ^{b}	<0.001
Eiv - M	3.67±0.16^{a}	4.08±0.39^{b}	3.60±0.17^{a}	4.08±0.25^{b}	4.30±0.25^{b}	3.98±0.32^{b}	4.82±0.52^{c}	<0.001
Eiv - R	7.08±0.23^{a}	6.64±0.57^{ab}	7.29±0.23^{c}	7.01±0.23^{ab}	6.65±0.30^{b}	6.69±0.31^{b}	6.02±0.45^{d}	<0.001
Eiv - N	2.98±0.17^{a}	3.12±0.33^{ab}	2.89±0.20^{a}	3.13±0.21^{a}	3.65±0.41^{c}	3.56±0.50^{bc}	4.26±0.91^{c}	<0.001

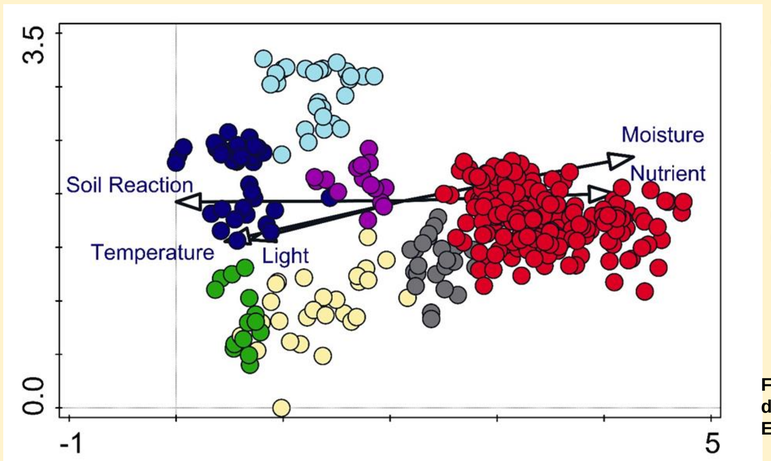

Fig. 2. DCA ordination diagram (first two axes presented) of analyzed vegetation plots performed on square-root transformed data with down-weighting rare species and detrending by segments: dark blue circles – *Inulo ensifoliae-Peucedanetum cervariae*; light blue circles – *Trollio-Clematidetum recti*; green circles – *Festuco pseudodalmaticae - Geranietum sanguinei*; yellow circles – *Geranio-Trifolietum alpestris*; violet circles – *Stachyo officinalis-Melampyretum biharіense*; grey circles – *Trifolio medii-Agrimonietum*; red circles – *Clinopodio-Pteridietum aquilini*. Eigenvalues: 1st axis: 0.589; 2nd axis: 0.296. Gradient lenght along 1st axis: 4.74. Correlations with axes (according to modified permutation test): Axis 1: Light -0.619 n.s., Temperature -0.357 n.s., Moisture 0.763, Soil reaction -0.811**, Nutrients 0.701**; Axis 2: Light 0.209 n.s., Temperature 0.460**, Moisture -0.245**, Soil reaction 0.272 n.s., Nutrients -0.231 n.s. (** p<0.01, n.s. - non significant).**

Fig. 3. Dendrogram of numerical classification of forest fringe vegetation highlighting six well-defined communities within class Trifolio-Geranietea sanguinei T. Müller 1962 and one in class Epilobietea angustifolii Tx. et Preising ex von Rochow 1951.

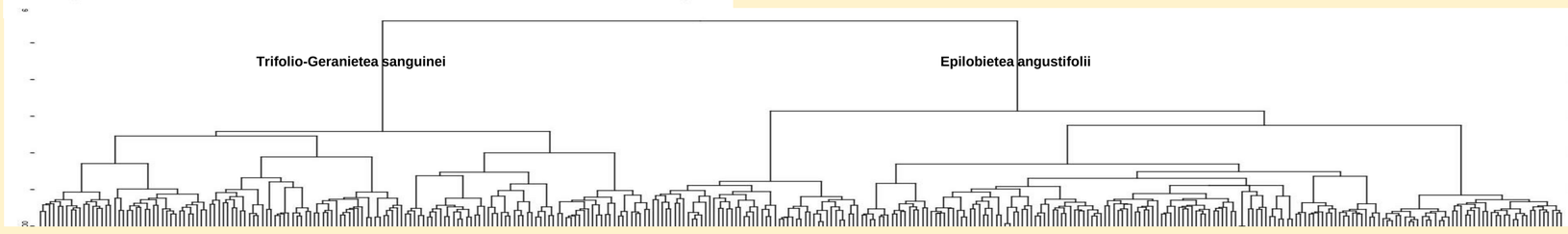

Table 1. Shortened synoptic table with the percentage frequencies of plant species in the communities within class Trifolio-Geranietea and *Pteridium aquilinum* vegetation in Romania and Bulgaria – class Epilobietea angustifolii. The associations are: 1 - *Geranio-Trifolietum alpestris*, 2 - *Festuco pseudodalmaticae - Geranietum sanguinei*, 3 - *Inulo ensifoliae-Peucedanetum cervariae*, 4 - *Trollio-Clematidetum recti*, 5 - *Stachyo officinalis-Melampyretum biharіense*, 6 - *Trifolio medii-Agrimonietum*, 7 - *Clinopodio-Pteridietum aquilini*. Only species registered in at least 40% from the relevés of a cluster are displayed.

Group No.	1	2	3	4	5	6	7
No. of relevés	26	19	34	27	15	21	209
Geranium sanguineum	100	100	26	19	.	10	1
Stachys recta	92	.	59	26	.	.	.
Teucrium chamaedrys	81	37	79	7	13	5	14
Trifolium alpestre	73	32	32	67	40	14	4
Hylotelephium maximum	69	.	9	.	.	.	.
Galium album	54	16	9	4	.	52	7
Fragaria vesca	54	.	15	11	40	.	22
Cytisus hirsutus	50	.	9	7	7	.	1
Origanum vulgare	50	11	35	11	47	5	14
Rhamnus cathartica	46	.	12	.	.	.	.
Festuca pseudodalmatica	.	53	.	.	.	24	2
Knautia arvensis	4	47	26	19	40	24	9
Rumex acetosa	.	42	.	37	.	5	7
Hypericum perforatum	42	42	15	7	27	29	20
Inula ensifolia	12	.	94	4	13	.	.
Galium glaucum	46	.	82	7	.	.	1
Dorycnium pentaphyllum subsp. herbaceum	8	21	82	26	40	62	10
Elytrigia intermedia	35	.	79	56	27	.	.
Peucedanum cervaria	8	.	79	11	33	.	1
Euphorbia cyparissias	62	26	74	11	20	19	30
Carex humilis	15	5	71	30	.	.	.
Anthericum ramosum	38	.	65	63	.	.	.
Bupleurum falcatum	31	5	65	33	27	.	.
Coronilla varia	58	16	59	22	47	10	10
Festuca stricta subsp. sulcata	27	.	56	41	.	.	2
Onobrychis viciifolia	12	.	56	41	40	.	.
Campanula sibirica	35	.	50	7	.	.	.
Medicago falcata	27	26	50	22	13	14	5
Centaurea stoebe	12	5	50	11	.	.	2
Bothriochloa ischaemum	.	5	50	.	.	38	2
Jurinea mollis	.	.	50	19	.	.	.
Aster amellus	12	.	47	.	.	.	.
Salvia verticillata	8	.	47	4	13	14	5
Phleum phleoides	8	11	47	11	7	.	.
Potentilla incana	.	.	44	.	.	.	.
Inula hirta	19	11	44	7	.	5	.
Verbascum lychnitis	35	.	41	7	.	.	1
Veronica austriaca	27	5	41	22	20	.	3
Lembotropis nigricans	23	.	41	11	27	.	4
Artemisia campestris	.	.	41	.	.	.	.
Thalictrum minus	8	26	41	15	.	.	1
Clematis recta	12	.	21	93	7	.	.
Laserpitium latifolium	8	.	6	93	40	.	.
Briza media	.	68	29	89	27	14	9
Dactylis glomerata	.	47	3	74	67	43	29
Thesium linophyllon	4	11	32	67	7	.	.
Trifolium montanum	12	26	15	63	20	5	1
Ranunculus polyanthemos	.	11	3	63	.	14	11
Primula veris	12	32	3	63	20	5	2
Polygonatum odoratum	31	.	32	63	47	.	4
Brachypodium pinnatum	27	47	50	59	33	43	20
Euphorbia angulata	.	.	.	59	.	.	.
Plantago media	.	11	.	56	13	.	.
Festuca pratensis	.	37	.	56	13	19	8
Helleborus purpurascens	.	.	.	56	27	.	.
Anthoxanthum odoratum	.	26	.	52	.	5	14
Asperula cynanchica	4	21	50	52	13	10	3
Centaurea scabiosa	12	5	38	52	13	5	.
Peucedanum oreoselinum	38	.	41	52	40	.	6
Festuca rubra	8	21	.	52	.	.	29
Leucanthemum vulgare	.	21	.	52	20	.	16
Salvia pratensis	27	16	32	48	.	.	1
Linum catharticum	.	.	.	48	.	.	4
Tanacetum corymbosum	31	5	38	44	.	.	2
Carex montana	15	.	3	41	.	.	.
Pilosella cymosa	.	.	.	41	.	.	.
Melampyrum biharіense	12	.	3	15	100	.	.
Stachys officinalis	12	37	21	37	100	10	6
Vincetoxicum hirundinaria	58	11	62	30	73	5	.
Veronica chamaedrys	15	26	3	11	67	10	24
Achillea millefolium	8	53	29	22	67	48	32
Cyanus segetum	.	.	6	26	67	5	6
Trifolium medium	12	32	26	11	60	14	12
Brachypodium sylvaticum	.	11	3	7	47	.	15
Cruciata glabra	8	37	18	33	40	.	19
Ligustrum vulgare	15	5	6	.	40	.	1
Hieracium umbellatum	4	.	3	15	40	.	.
Agrimonia eupatoria	4	42	44	19	60	100	31
Galium verum	4	58	38	70	20	86	30
Daucus carota	.	5	3	.	.	81	6
Poa angustifolia	42	26	32	4	.	76	9
Clinopodium vulgare	58	47	26	15	67	76	60
Filipendula vulgaris	12	63	44	63	40	67	21
Fragaria viridis	4	42	47	4	20	67	25
Crataegus monogyna	27	37	24	.	33	62	26
Elytrigia repens	.	37	.	19	.	57	10
Rosa canina	.	32	.	.	20	52	21
Potentilla argentea	.	5	.	.	.	43	13
Pteridium aquilinum	.	5	6	7	.	.	100
Agrostis capillaris	.	53	.	48	33	48	58
Holcus lanatus	.	.	.	.	.	.	44

Conclusion

- The study presents an analysis of the some forest fringes vegetation with focus on their floristic variability, their environmental characteristics and on the main ecological factors influencing their floristic composition.
- Numerical classification highlighted six well-defined communities within class Trifolio-Geranietea sanguinei T. Müller 1962. while the association Clinopodio - Pteridietum aquilini Dihoru ex Drăgulescu 1995 formed an distinct group and was classified in class Epilobietea angustifolii Tx. et Preising ex von Rochow 1951.
- Soil reaction, soil nutrients and light were identified as a significant drivers of species composition distinguishing, along the first ordination axis, the tall-herb semi-natural, species-poor, acidophytic phytocoenoses dominated by *Pteridium aquilinum* from the rest of analyzed vegetation with richer floristic composition, while secondly, differentiating the communities of alliances *Geranion sanguinei* from those classified in *Trifolion medii*.

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