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Ground Cover Vegetation Diversity of Riparian Forests in Salaca Basin

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***Abstract*—Riparian forests serve as ecotones, marking the transition between terrestrial and aquatic ecosystems and differing from the surrounding landscapes. Managing these forests has been identified as a means to enhance various ecological functions, which play a key role in erosion control, as their vegetation stabilizes soil and reduces nutrient and carbon runoff into rivers. Additionally, riverbank vegetation helps mitigate flooding and improves water quality. Currently in Latvia, the Life project "LIFE IS SALACA" encompasses riverine habitat restoration and management, which demands an assessment of the initial conditions within the study region, necessary for characterising future dynamics of rivers and streams, as well as riparian forests and ground cover vegetation development. Therefore, the aim of this study was to describe and specify the current situation regarding ground cover vegetation diversity in riparian forest habitats in Salaca basin. To assess vegetation composition and structure, permanent 20×20 m (400 m²) sample plot was established in each study area. Vegetation surveys were conducted using the Braun-Banquet method, recording all vascular plant and moss species. The total projected cover (%) was estimated for four vegetation layers: tree layer (E3, trees >7 m), shrub layer (E2, shrubs and young trees 0.5–7 m), herb layer (E1, herbaceous plants, dwarf shrubs, and juvenile trees/shrubs <0.5 m), and moss layer (E0). Additionally, within these layers, the projected cover of each species was determined. The collected data will become an essential basis for monitoring riparian management processes, as well as provide valuable insight into the current vegetation diversity in the Salaca basin.**

Keywords*— *Herbs, Moss, Shrubs, riparian ecotones

I. INTRODUCTION

Riparian zones are essential ecological ecotones that play a crucial role in maintaining water quality, filtering excess nutrients, stabilizing streambanks, and trapping sediments [1]-[3]. These ecosystems support diverse plant and animal communities, provide habitat through deadwood, and contribute organic matter, such as leaf litter and invertebrates, to aquatic ecosystems [4], [5]. Additionally, they regulate light and temperature, influencing primary productivity in both terrestrial and aquatic environments [6], [7]. Positioned at the land-water interface, riparian zones are shaped by river dynamics, such as flooding, while also being highly sensitive to terrestrial disturbances like windthrow [8].

Riparian forests are particularly important for maintaining biodiversity, acting as habitat corridors and influencing key ecological processes such as nutrient cycling, temperature regulation, and organic matter input into aquatic ecosystems [9]-[11]. Riparian vegetation influences soil microbial communities by creating distinct niches that shape fungal and bacterial composition [12]. Riparian vegetation communities form the structural and productive foundation for many other organisms, with high species richness enhancing regional biodiversity [13], [14]. Furthermore, riparian vegetation contributes to ecosystem stability, preventing erosion through extensive root systems [15] and responding dynamically to environmental changes, such as drought or forest management interventions.

Ground cover vegetation, particularly bryophytes, is highly sensitive to alterations in microclimatic conditions

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and forest structure [16]. Silvicultural treatments, including drainage, fertilization, thinning, and harvesting, can significantly impact species composition and distribution [17], [18]. Expanding large-scale activities, including in-stream interventions like damming and upland practices such as forestry, are having growing impacts on ecological processes at both local and regional scales [19], [20]. Therefore, an assessment of ground cover vegetation composition provides valuable insights into ecosystem health and long-term forest dynamics.

In Latvia, the LIFE project "LIFE IS SALACA" focuses on riverine habitat restoration and management, requiring a thorough assessment of the initial vegetation conditions to monitor future changes. Therefore, this study aims to describe and characterize the current diversity of ground cover vegetation in riparian forest habitats of the Salaca basin, providing a baseline for evaluating ecological shifts following restoration efforts.

II. MATERIALS AND METHODS

The study was conducted in the hemi-boreal forest zone, in the Northern part of Latvia (56°0'–58°0'N and 24°0'–26°0'E), in the river basin area of river Salaca. The mean monthly temperature of the study region ranged from – 4.28 ± 2.8 °C in January to 18.1 ± 1.7 °C in July [21], with the 30-year mean annual temperature of 6.5 ± 0.7 °C and annual precipitation of 687.6 ± 80.4 mm.

The study area encompassed riverine coastal mixed species forests, as well as grey alder *Alnus Incana* and birch *Betula pendula* dominated riparian forest stands, growing alongside Korģe and Sētupe rivers. The study area is characterised by lowland conditions which varied from flat to slope-type topography. Soil conditions varied from mesotrophic mineral soils to eutrophic and drained peat soils.

For vegetation assessment, a total of 85 plots across 24 cadastral units along the banks of the Korģe and Svētupe rivers were established (Fig. 1).

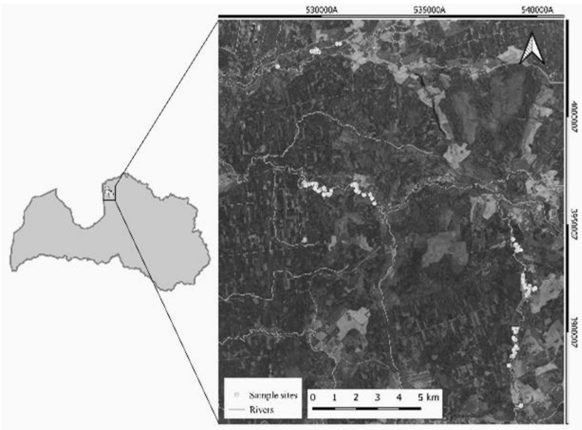

Fig. 1. Location of the study plots.

Each study plot consisted of a single permanent sampling area, measuring 20×20m (400m²), with GPS coordinates recorded for each plot. The plots were identified using cadastral numbers, compartment designations, and distance markers (e.g., 66720050275-5-1). Vegetation surveys followed the Braun-Blanquet method [22], recording all vascular plant and bryophyte species. The percentage cover of each species and vegetation layer was estimated. The vegetation was classified into four layers:

- Tree layer (E3) – trees taller than 7m;
- shrub layer (E2) – shrubs and saplings between 0.5–7m;
- herb layer (E1) – herbs, small shrubs, and young trees/shrubs under 0.5m;
- moss layer (E0) – bryophytes.

To assess vegetation diversity, the total species count and the number of species within each vegetation layer were determined. The average species richness per layer and overall was also calculated. Additionally, the most frequently occurring species and their frequency across plots were identified. To analyse the ground cover vegetation species' abundance in relation to environmental gradients, Detrended Correspondence Analysis (DCA) was applied, generating ordination graphs of species and sample plots. All statistical analysis were performed in the program R Studio version 4.4.1. [23].

III. RESULTS AND DISSCUSION

A total of 238 unique vegetation species were recorded across all plots (one species could have been recorded on several vegetation layers, depending on individual's height). The highest diversity was found in the herb layer (E1) with 200 species, followed by the moss (E0) and shrub (E2) layers, each containing 31 species, which is lower than in other studies from the Baltics, particularly regarding the moss layer [24]. The tree layer (E3) had the lowest diversity, with only 18 species of trees and shrubs taller than 7m. These trends were reflected in the average species count per vegetation layer (Fig. 2): the herb layer had 26.9 ± 8.7 species on average, the shrub layer 6.9 ± 2.6, the tree layer 4.9 ± 1.9, and the moss layer 4.0 ± 1.9 species.

When assessing vegetation cover (Fig. 3), the herb (67.2 ± 40.5%) and tree layers (65.1 ± 27.4%) had the largest coverage, while the shrub layer (43.5 ± 26.8%) and moss layer (22.6 ± 27.4%) were less dominant. The high species diversity in the herb layer can be attributed to the varied environmental conditions present in riparian ecosystems, such as moisture gradients, light availability, and nutrient distribution, which provide a wide range of niches for different plant species. The high standard deviation in the moss layer (Fig. 3) suggests significant variation in its coverage across plots, possibly due to soil conditions (pH) and variation in substrate variability [25]. These findings highlight the complexity of vegetation structure in riparian forests, where each layer contributes differently to biodiversity and ecosystem function [14].

Analysis of the most common species in each vegetation layer (Table 1) revealed that in the moss layer (E0), two species were more frequent: *Eurhynchium angustirete* (Broth.) T. J. Kop. (76.7% of plots) and *Plagiomnium undulatum* (Hedw.) T. J. Kop. (65.1%), species common in riparian forests growing adjacent to streams [26]. Other frequently found species included *Plagiomnium affine* (Blandow ex Funck) T. J. Kop. (38.4%), *Climacium dendroides* (Hedw.) (29.1%), and *Plagiomnium cuspidatum* (Hedw.) T. J. Kop. (24.4%). In the shrub layer (E2), the dominant species largely overlapped with tree and shrub species found in the herb layer (E1), suggesting a dense understory. The most common species in the shrub layer were *Prunus padus* L. (68%), *Corylus avellana* L. (77.9%), *Sorbus aucuparia* L. (69.8%), and *Acer platanoides* L. (61.6%). In the tree layer (E3), the most frequent species were *Betula pendula* Roth. (67.4%), *Alnus incana* (L.) Moench. (64.0%), *Picea abies* (L.) H. Karst. (62.8%), and *Ulmus glabra* Huds. (54.7%).

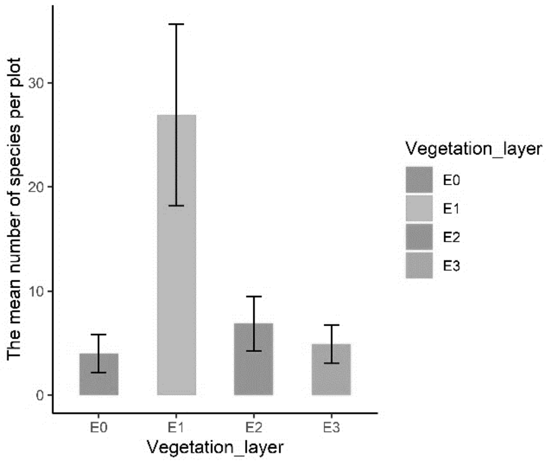

Fig. 2. The mean number of species per sample plot in each vegetation layer. Errorbars represent standard deviation.

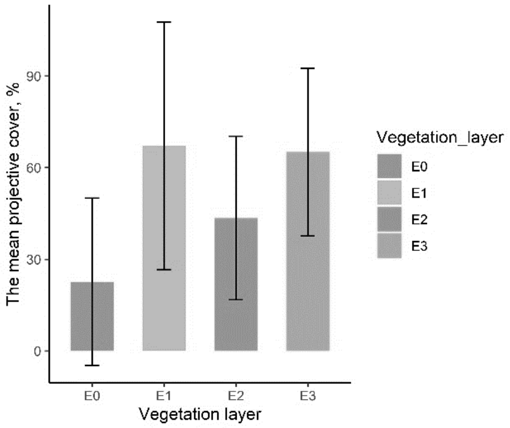

Fig. 3. The mean projective cover of species (%) per sample plot in each vegetation layer. Errorbars represent standard deviation.

Due to the high species count, detrended correspondence analysis (DCA) ordination plots were created separately for species and plots (Fig. 4). The first and second axis gradients were similar in length (DCA1 = 5.7831, DCA2 = 5.3325), with eigenvalues of 0.6543 (DCA1) and 0.4940 (DCA2). The ordination plot showed that most plots formed a single group with two subgroups, indicating a relatively pronounced heterogeneity in composition of species and environmental conditions. Moreover, some outliers had distinct species compositions, particularly in the herb and moss layers. For example, a strongly deviating plot (upper part of Fig. 4., A, B) was characterized by species typical of dry grasslands, such as *Achillea millefolium* L., *Agrostis tenuis* Sibth., *Trifolium repens* L., *Hieracium umbellatum* L., and *Dactylis glomerata* L. (Fig. 4., B).

TABLE 1 THE MOST COMMON VEGETATION SPECIES (NUMBER OF PLOTS WHERE THE SPECIES WAS RECORDED RELATIVE TO THE TOTAL NUMBER OF PLOTS) IN EACH IDENTIFIED VEGETATION LAYER. E0 – MOSS LAYER, E1 – HERB LAYER (≤ 0.5M), E2 – SHRUB LAYER (0.5-7M), E3 – TREE LAYER (≥ 7M)

E0		E1		E2		E3	
Species	***Frequency, %***	***Species***	***Frequency, %***	***Species***	***Frequency, %***	***Species***	***Frequency, %***
Eurhynchium angustirete	76.7	*Paris quadrifolia*	79.1	*Padus avium*	86.0	*Betula pendula*	67.4
Plagiomnium undulatum	65.1	*Acer platanoides*	74.4	*Corylus avellana*	77.9	*Alnus incana*	64.0
Plagiomnium affine	38.4	*Oxalis acetosella*	73.3	*Sorbus aucuparia*	69.8	*Picea abies*	62.8
Climacium dendroides	29.1	*Padus avium*	73.3	*Acer platanoides*	61.6	*Ulmus glabra*	54.7
Plagiomnium cuspidatum	24.4	*Quercus robur*	68.6	*Ulmus glabra*	55.8	*Acer platanoides*	46.5
Hylocomium splendens	22.1	*Athyrium filix-femina*	67.4	*Alnus incana*	52.3	*Tilia cordata*	41.9
Atrichum undulatum	19.8	*Sorbus aucuparia*	60.5	*Picea abies*	46.5	*Padus avium*	29.1
Pleurozium schreberi	17.4	*Dryopteris carthusiana*	53.5	*Tilia cordata*	45.3	*Corylus avellana*	24.4
Rhytidiadelphus triquetrus	15.1	*Geum rivale*	53.5	*Quercus robur*	30.2	*Sorbus aucuparia*	23.3
Dicranum scoparium	9.3	*Alnus incana*	52.3	*Fraxinus excelsior*	27.9	*Quercus robor*	17.4

The variation along the first axis (DCA1) likely reflects a gradient in soil fertility – higher axis values correspond to lower soil fertility. This is supported by species concentrated on the right side of the ordination plot, such as *Vaccinium myrtillus* L., *Vaccinium vitis-idea* L., *Ledum palustre* L., *Calluna vulgaris* (L.) Hull., *Pinus sylvestris* L., and *Hylocomnium splendens* (Hedw.) Schimp., which indicate less nutrient rich soils. Conversely, species associated with more fertile conditions, such as *Urtica dioica* L., *Geum rivale* L., *Lythrum salicaria* L., and *Cirsium oleraceum* (L.) Scop., appeared on the left side of the plot.

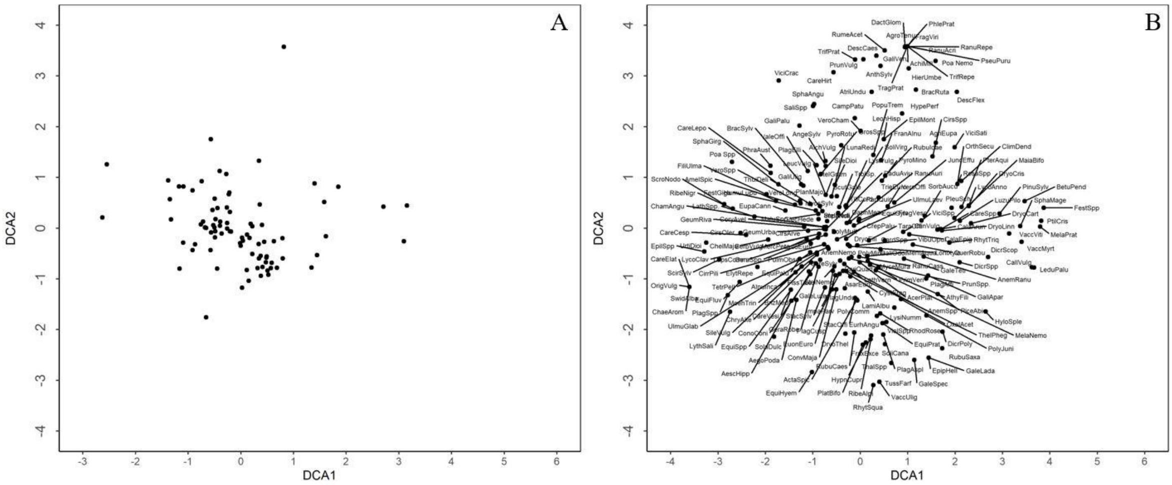

Fig. 4. Distribution of sample plots (A) and herbaceous and moss species (B) in the ordination space of detrended correspondence analysis (DCA).

The second axis gradient was hard to interpret due to the presence of outliers (Fig. 4., B). The vegetation composition in riparian forests can be highly heterogeneous, varying with the distance from the river or stream at which it is characterized, a pattern driven by the distinct physicochemical properties of riparian soils, which tend to differ from the upland soils that dominate the landscape [27]. Moreover, as riparian zones are shaped by river dynamics and terrestrial disturbances [9], river basin forests provide varying conditions suitable for different species communities. Other studies have underscored the importance of considering both climatic gradients and local hydrological conditions when assessing riparian forest responses [28]. Future research should include stand and soil properties for more precise characterisation of vegetation composition and local growing conditions.

IV. CONCLUSIONS

The riparian forests surveyed within the project support a relativly rich diversity of ground vegetation and species communities adapted to various conditions. The study identified 238 plant species, with the highest diversity in the herb layer, suggesting that ground vegetation, particularly herbs, plays a crucial role in overall plant species richness in the riparian forests of the Salaca basin.

The collected data will be useful for monitoring and characterizing the dynamics of riparian forest ecosystems following forestry restoration measures. Additionally, future research practices should focus on expanding the spatial scope to include a wider range of riparian zones with varying hydrological regimes could provide insight into broader-scale patterns and potential climate-related shifts in species composition. Finally, the role of disturbance (natural or anthropogenic) and land-use history should be more closely examined to understand how legacy effects shape current plant community structures.

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