



GEOGRAPHIC DISTRIBUTION OF PROTECTED SEDGE SPECIES *Carex Pilosa* Scop. IN LATVIA WITH REFERENCE TO FOREST ECOSYSTEMS

Edgars Iliško, Juris Soms

Daugavpils University, Faculty of Nature Sciences and Mathematics

Parādes st.1, Daugavpils, LV 5401, Latvia

Ph.: +371 28663100, e-mail: edgars_ilisko@inbox.lv; juris.soms@du.lv

Abstract. *The results of field studies, laboratory research and desk-based GIS geospatial analysis of ecological factors which determine geographic distribution of hairy sedge (Carex Pilosa Scop.) in Latvia with reference to forest ecosystems are presented in this article. Hitherto such a complex studying of chorology and ecology of this protected forest herb has not been performed before in Latvia, nor has it been attempted in the other Baltic states. The obtained results demonstrate that this protected plant species ecologically is quite plastic regarding its growing conditions and can be found in different forest ecosystems, however the most vital and largest cenopopulations of Carex pilosa are associated with the old deciduous forests, particularly those growing within erosion landforms on the slopes of the southern or south-eastern aspect. This research is important both from the scientific and practical view point, allowing to work out recommendations for the protection and conservation of this rare species in Latvia.*

Keywords: *Carex pilosa, chorology, ecological factors, forest ecosystems.*

Introduction

Hairy sedge *Carex pilosa* Scop. ranges in the temperate climate zone of Eurasia, and occurrence of this herb in the northern part of the continent in general corresponds to the biogeographic regions of oak distribution. Although hairy sedge is rather widespread in Central Europe, where in Oak-Hornbeam woods this species can form large, even square-kilometres stands within which any other herbaceous plants can grow [1, 2], in Latvia it is very rare, because the north-western edge of this plant growing areal crosses the south-eastern part of Latvia. This species of sedge belonging to the family *Cyperaceae* is included in the 1st category of the Red Data Book of Latvia [3], as well as in the list of protected plant species of Latvia [4]. According to Ellenberg [5], *Carex pilosa* is hemicryptophyte species of the thermophilic – close to partially thermophilic group, with moderate demands on nutrients. At a distance this forest herb looks similar to other sedges. However, with a closer look, this species can be distinguished easily from other common sedges by evergreen leaves, which are the best indicators of this species - in contradistinction to other *Carex* species growing in Latvia it has hairs alongside the central string and margin of the narrow leaf blade. This species is early flowering plant, which in Latvia usually flowers in the end of April – beginning of May. During flowering flower stalk usually carries one male inflorescence spike on the top and one or two female spike lower down; the female spike has more subtle white stigmas.

Carex pilosa for the first time was recorded in south-eastern part of Latvia in 1939 [6], within one of the gullies which dissect the right slope of the Daugava valley near the Juzefova village and for a long time had been regarded as rarity of Latvia flora. However, since 2002, when inventory of species of EU Habitat Directive (Annex I and II) [7] was performed in Latvia, six new records of this sedge were found in south-eastern part of country. In recent years complex research programme is undertaken at Daugavpils University to study chorology and ecology of this forest plant, and since 2008 authors found two more records [8]. Thus at the present moment 10 records of this protected plant species are documented in

Latvia [8, 9]. Although documenting of all known *Carex pilosa* records in Latvia for botanical data bases and herbariums is completed, the extent to which ecological factors controlling the distribution of this species and regularities of its chorology are currently studied is insufficient.

In order to get insight into these issues and to elucidate the regularities of geographic location of hairy sedge with reference to forest ecosystems, detailed studies of all records were performed *in situ*. The specific objectives of the study presented in this article were (1) to aggregate information stored in data bases about precise geographic location of *Carex pilosa* records in Latvia; (2) to carry out reconnaissance and survey of all cenopopulations of sedge by precise delineation and mapping of them by high-accuracy GPS; (3) to obtain data on the physiogeographic, ecological and habitat characteristics of all *Carex pilosa* populations during the field expeditions; (4) to perform laboratory analysis of soil samples from *Carex pilosa* records in order to estimate nutrient content and pH; (5) to process GPS survey data and to digitize GIS thematic layers with subsequent preparing of large-scale maps of hairy sedge records, including maps of digital elevation models and slope aspects; (6) to carry out complex mathematical and geospatial analyses of the obtained data by GIS tools in order to elucidate ecogeomorphological aspects and abiotic factors controlling spatial distribution of this perennial evergreen sedge in respect of landforms type, slope aspect and gradient, and forest habitat.

Hitherto such a complex studying of factors controlling geographic distribution of this protected forest herb has not been performed before in Latvia, nor has it been attempted in the other Baltic countries. Consequently, the obtained data contribute to a better understanding of the ecology of *Carex pilosa* in Northern Europe and enhance our knowledge about chorology of this species with reference to forest ecosystems.

Materials and methods

The results presented in the article are based on original data obtained in course of 33 expeditions and the research programme carried out in 2008 – 2010. Various methods and techniques were applied in order to achieve the objectives stated in Introduction of this article. In general, research was done in four main directions, i.e. aggregation and analysis of the data, field studies, laboratory research and desk-based studies by GIS tools.

Aggregating and analysing of the data about records of *Carex pilosa* in Latvia was carried out by searching through data bases of the Ministry of Environment of Latvia and Latvian Botanical Society, as well as by examination of herbariums of University of Latvia (LATV) and Daugavpils University (DAU). It allows to get precise geographic location of hairy sedge records within the study area for further field research.

Thereafter field studies of the identified *Carex pilosa* records were carried out including reconnaissance all cenopopulations, survey and precise delineation of them by THALES MobileMapperCE GPS (a maximum error up to several meters), description of tree and plant species composition of forest, soil sampling and identification of topographic characteristics of records (e.g. aspect of slope, its gradient and profile, type and morphometry of landforms etc). The last tasks were done with the help of standard geomorphological techniques [10, 11]. Slope profiles with location of *Carex pilosa* records on them were generated by AutoCAD 2008 LT software from the data collected during measurement of slope gradients along the sampling line. In turn these measurements were performed by precise oil damped AngleLevel clinometer (error $\pm 0.5^\circ$) placed on the rod of 1 m length, hence reducing impact of microtopography. The description of tree and plant species composition recognized in records further was used to identify the type of forest habitats.

Field studies of the sedge *Carex pilosa* was performed in ten records situated in the south-eastern part of Latvia (Fig 1.). Three of these records are located in the Daugava spillway

valley within the Nature Park “Daugavas Loki”, one in the river Lazdukalna valley (left tributary of the Daugava in the Nature Park “Daugavas Loki”), one in the river Puņiška valley (right tributary of the Daugava in the Nature Park “Daugavas Loki”), another two in the Rubeņu brooklet and the Dubezers tunnel valley within the Nature Reserve “Pilskalnes Siguldiņa”, large record consisting of many smaller patches located in the Nature Reserve “Raudas Meži”, one on the Lakstīgalu island in the Nature Reserve “Zvirgzdenes ezera salas”, and the last one near Dūdeļi village on the southern edge of the Latgale upland.

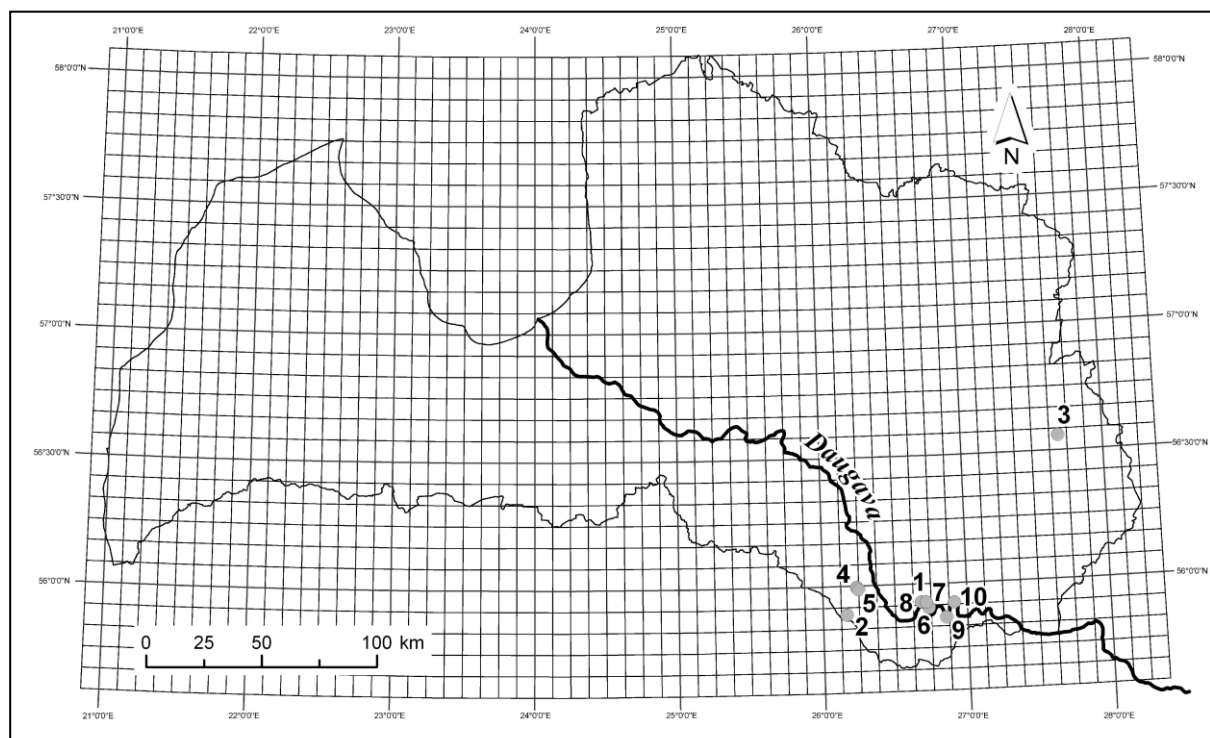


Fig 1. Location of all records of the hairy sedge *Carex pilosa* Scop. in the south-eastern part of Latvia.

Number of record in the map in chronological sequence of finding: 1 – the gully Baznīcas grāvis (the Nature Park “Daugavas loki”); 2 – the river Ilūkste valley (the Nature Reserve “Raudas Meži”); 3 – the Lakstīgalu island (the Nature Reserve “Zvirgzdenes ezera salas”); 4 – the Dubezers tunnel valley (the Nature Reserve “Pilskalnes Siguldiņa”); 5 – the Rubeņu brooklet (the Nature Reserve “Pilskalnes Siguldiņa”); 6 – the gully Peščanij ručej (the Nature Park “Daugavas loki”); 7 – the park Juzefova (the Nature Park “Daugavas loki”); 8 – village Dūdeļi (the edge of the Latgale upland); 9 – the river Lazdukalna valley (the Nature Park “Daugavas loki”); 10 – the river Puņiška valley (the Nature Park “Daugavas loki”)

During field expeditions ten soil samples were taken from O-horizon of each *Carex pilosa* record. These samples subsequently were analysed according to standard methods (LVS ISO 10390:2006) in the Laboratory of Environmental Chemistry, Daugavpils University, in order to identify chemical parameters of soil, pH_{KCl} and $\text{pH}_{\text{H}_2\text{O}}$ in particular.

Finally, mathematical and geospatial analyses of the obtained data were carried out by GIS tools. For these purposes as data processing platform was used ESRI ArcGIS software, which was applied for procedures of digitizing, for converting and integrating GPS data into GIS thematic layers, for creating digital elevation models and preparing of maps, as well as for calculation of topographic parameters and geospatial analysis of ecogeomorphological aspects and abiotic factors controlling spatial distribution of *Carex pilosa*.

Results and discussion

Obtained results, first of all, show direct interconnection between location of *Carex pilosa* records and landforms, in particular negative erosion forms. In fact the largest part, i.e. seven from ten known records of hairy sedge are located exactly within river valleys, gullies, tunnel valleys and spillway valleys. Secondly, data obtained during direct reconnaissance *in situ* and large scale analysis of information derived by overlaying of GIS thematic layers show, that large stands of this plant spatially is associated with forest ecosystems, i.e. forest habitats of different types (Table 1.).

Canopy vegetation in the records under study mainly is represented by broad-leaved or deciduous forests. The main stand-forming tree species in the Daugava spillway valley, the river Lazdukalna valley, the Lakstīgalu island and the Rubeņu brooklet study sites are wych elm (*Ulmus glabra* Huds.), linden (*Tilia cordata* Mill.) and oak (*Quercus robur*), hazel (*Corylus avellana* L.) occur only in undergrowth, whilst in the river Ilūkste valley record within the Nature Reserve “Raudas meži” and the Dubezers tunnel valley prevails aspen (*Populus tremula* L.) with admixture of ash (*Fraxinus excelsior* L.) and oak (*Quercus robur* L.). In such broad-leaved or deciduous forests during the sedge flowering and development in spring sunlight can penetrate through the open structure of the tree layer right to the ground where the xero-thermophilous *Carex pilosa*, which is dominating in the herb layer, can find acceptable conditions.

Considering such combination of abiotic geomorphological factors and composition of forest habitats, it is possible to assume that recognized geographic distribution of *Carex pilosa* had formed as result of human activities, when broad-leaved forests on nutrient-rich soils were cut off in order to establish fields of arable land. In this case remnant patches of broad leaved forest on the steep slopes unsuitable for soil cultivation and other agricultural needs became as a kind of refuge for hairy sedge. Partially this assumption was proved by the desk-based studies of historical topographic maps published in 1917, 1928, 1936 and 1972, and comparison of them with aerial photographs flown in 2005. Cartographic analysis of this information sources reveal the long-term presence of woodlands in majority of localities, where records of *Carex pilosa* had been found. However, to get better understanding about ecological factors controlling geographic distribution of this species, detailed analysis of topographic characteristics were performed by GIS.

The GIS analysis of digital elevation models of the study sites show that to a great extent distribution of the sedge is related to the sunniest and warmest forest habitats on southern, south-eastern and south-western slopes of river valleys and gullies in the region under study (Fig 2.). The influence of dryness and warmth can be well observed by comparing similar canopy vegetation with that of the slopes of north-, north-western- or north-eastern-spacing where *Carex pilosa* occurs sporadically and does not form large stands. Simultaneously it is necessary to highlight, that inclination of slopes within records, where the sedge was found, varies from 5° to 20°, however, in majority of sites it exceeds 15° (Table 1.).

In this case topographic features, i.e. aspect and gradient of slope determine the spatial distribution of *Carex pilosa* within landforms, because steeper slopes of S, SE or SW aspect receive more solar energy and thus warm up faster and to higher degree than gentler slopes of other exposure.

Laboratory analysis of soil samples demonstrates that soil type in records is mainly presented by luvisol, developed on stony and gravelly sandy loam of glacial origin (moraine). These relatively dry soils have pH_{KCl} and pH_{H₂O} values, which ranges from 5.36 to 7.58 and 5.83 to 8.0 respectively.

Table 1.

The characteristics of main records of hairy sedge in south-eastern part of Latvia

Geographical location of record	Location with reference to land form	The average slope (in record)	The dominant slope aspect	Habitat
The gully Baznīcas grāvis (The Nature Park "Daugavas loki")	Slope of the gully	23°	S; SE	Wych elm-oak rich broad-leaved forest
The gully Peščanij ručej (The Nature Park "Daugavas loki")	Slope of the gully	31°	SW	Mixed deciduous forest
The river Puņiška valley, record No 1 (The Nature Park "Daugavas loki")	The left slope of the river Puņiška valley	20°	S; SE	Grey alder forest
The river Lazdukalna valley (Daugava spillway valley)	Slope of the river valley	18°	SW	Wych elm-lime rich broad-leaved forest
The Rubeņu brooklet (The Nature Reserve "Pīlskalnes Siguldiņa")	Slope of the gully	26°	SE	Mixed deciduous forest
The Dubezers tunnel valley (The Nature Reserve "Pīlskalnes Siguldiņa")	Slope of the tunnel valley	16°	SW	Mixed deciduous forest
The river Ilūkste valley, patch No 1 (The Nature Reserve "Raudas Meži")	The right slope of the Ilūkste valley	12°	SW	Aspen rich deciduous forest
The river Ilūkste valley, patch No 2 (The Nature Reserve "Raudas Meži")	The right slope of the Ilūkste valley	15°	SW	Aspen rich deciduous forest
The river Ilūkste valley, patch No 5 (The Nature Reserve "Raudas Meži")	The slope of the gully within Ilūkste valley	21°	S; SE	Mixed deciduous forest
The river Puņiška valley, record No 2 (The Nature Park "Daugavas loki")	The right slope of the river Puņiška valley	5°	SW	Grey alder forest
The Lakstīgalu island (The Nature Reserve "Zvirgzdenes ezera salas")	The middle part of the SE slope of the island	4°	SE	Lime rich broad-leaved forest

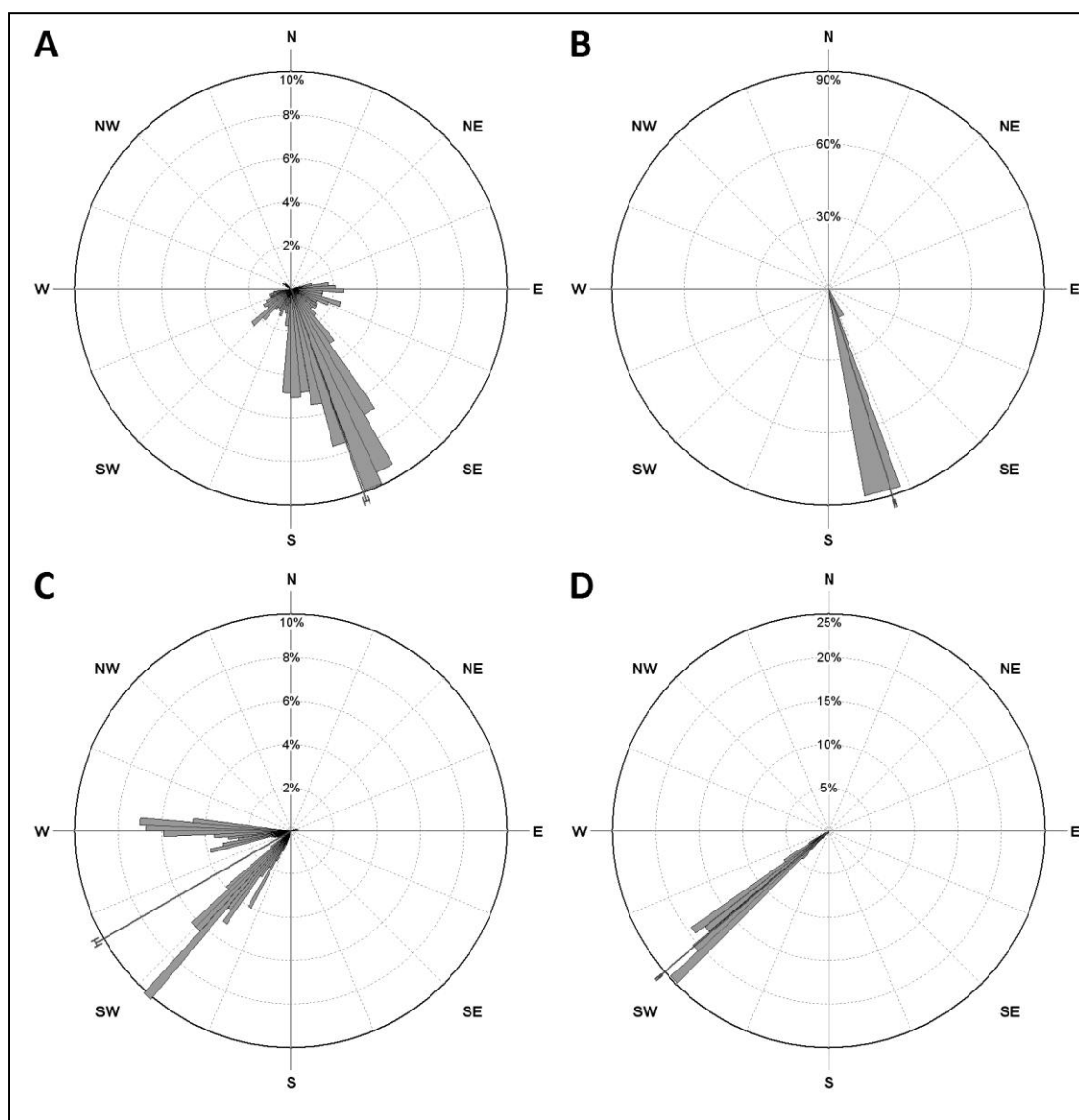


Fig 1. Rose diagrams of hairy sedge *Carex pilosa* relative distribution (in percents from total area of record) on the slopes of different aspect within selected records: A – the gully Baznīcas grāvis (the Nature Park “Daugavas loki”); B – the Rubeņu brooklet (the Nature Reserve “Pilskalnes Siguldiņa”); C – the river Lazdukalna valley (the Nature Park “Daugavas loki”); D – the Dubezers tunnel valley (the Nature Reserve “Pilskalnes Siguldiņa”)

Conclusions

The results of the given research permit to draw several important conclusions about the factors controlling geographic distribution of *Carex pilosa* with reference to forest ecosystems in south-eastern Latvia.

1. Alongside topography and soil type, forest habitat of the record is the principal one that affects spatial distribution of *Carex pilosa*, because the ecology of this species determine the presence of forest ecosystem as prerequisite for its favourable growing, in contrary the decreasing of *Carex pilosa* cenopopulations was observed in places, where former woodlands had been transformed into clearings after forest cut-off.
2. The spatial distribution of *Carex pilosa* can be explained as result of interaction of indirect and direct controlling factors. On the one hand, growing of the sedge within erosion forms is a result of preservation of forest habitats due to steep slopes. On the

other hand, development of erosion landforms within landscape causes formation of environment favourable for existence of *Carex pilosa* due to slope aspect, slope gradient, soil properties and amount of solar radiation. Hence results highlight the positive role of geomorphological factors in formation of different habitats and increasing of biodiversity.

3. *Carex pilosa* is growing mainly on the steeper sunlit slopes of south, south-eastern or south-western aspect under broad leaved or deciduous vegetation where solar radiation can reach the ground through the tree layer.
4. The hairy sedge grows in relatively dry places with soil pH values near to neutral, or slightly alkaline or acid, where in spring, before formation of leaves, soil surface are warmed up by direct sunlight.
5. Further findings of this species can be expected in similar habitats in neighbouring areas of Latvia and Lithuania, particularly in V-shaped deep river valleys and gullies within uplands of Baltic morainic ridge, e.g. the Augšzeme Upland and the Aukštaitijos Upland.

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Anotācija. Rakstā ir izklāstīti lauka, laboratorisko un kamerālo pētījumu un GIS ģeotelpiskās analīzes rezultāti par ekoloģiskajiem faktoriem, kuri nosaka augu sugas - matainā grīšļa (*Carex pilosa* Scop.) ģeogrāfisko izvietojumu Latvijā saistībā ar meža ekosistēmām. Līdz šim padziļināti kompleksa rakstura šīs aizsargājamās augu sugas horoloģijas un ekoloģijas pētījumi nedz Latvijā, nedz citās Baltijas valstīs nav veikti. Iegūtie rezultāti parāda, ka suga ekoloģiski ir diezgan plastiska augšanas apstākļu ziņā un ir sastopama dažāda tipa mežu ekosistēmās, tomēr vitālākās un lielākās matainā grīšļa audzes ir saistītas ar veciem platlapju mežiem, it sevišķi tiem, kas aug erozijas reljefa formās uz dienvidu-dienvidaustrumu ekspozīcijas nogāzēm. Veiktie pētījumi ir nozīmīgi gan no zinātniskā, gan no praktiskā viedokļa, jo ļauj izstrādāt ieteikumus šīs retās sugas saglabāšanai un aizsardzībai Latvijā.