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Climate and treeline dynamics in the Ukrainian Carpathians Mts

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Abstract

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In this paper we examine climate change and treeline dynamics of the Ukrainian Carpathians Mts during the 20th century. Changes in atmospheric circulation responsible for higher summer and winter temperatures are examined. Comparison of treeline positions in 1930s and 2000 reveals a decrease of area above the treeline and a general rise of treeline elevation, mostly in places where the treeline is formed by coniferous species. However, at locations with predominantly deciduous species there is little or no change. The magnitude of change is spatially heterogeneous. We consider warmer temperatures, among other relevant factors, to have impacted the observed treeline changes.

Key words

climate change, coniferous species, deciduous species, treeline dynamics, Ukrainian Carpathians Mts

Introduction

On a global scale, climate determines vegetation zonality, including montane vertical vegetation belts. Climate warming has been observed to raise the world's temperature by 0.6 ± 0.2 ºC in the 20th century. Atmospheric circulation is an important agent in determining global and regional climates, as well as causing extreme weather events. Temporal assessment of the variability of large-scale atmospheric circulation and its weather types for climate change analysis is a traditional task of synoptic climatology and is studied by different methods: statistical methods, classification of synoptic patterns, by Empirical Orthogonal Functions, by method of analogs, cluster analysis, Canonical Correlation Analysis, and Principal Component Analysis.

Climate change, associated with rising temperatures, has been reported to raise the treeline elevation in many places of the world; moreover, paleoclimatic investigations indicate a higher treeline position in previous warm epochs. At local scales, however, the modern treeline in Europe is influenced by other factors, both natural and anthropogenic; the latter include grazing, tourism and logging, which also change on a temporal basis (Gehrig-Fasel et al., 2007). Climatic, edaphic, wind, and anthropogenic treeline types are discriminated by various researchers in the Ukrainian Carpathians. The treeline of the Ukrainian Carpathians is mainly coniferous (main species – spruce *Picea abies*), but at some parts it is formed by beech (*Fagus sylvatica*). Its average altitude is 1,200–1,300 m, lowering to 1,000 m in regions with intense grazing and close proximity to settlements. The altitude rises from west to east, indicating an influence of continentality, and thus higher summer temperatures. Overall, the position of the modern treeline is a result of a sum of relevant factors. Evaluation of changes in treeline position provides insight on how the coupled human-induced and natural processes impact the environment.

Material and methods

Mean monthly fields of Sea Level Pressure (SLP) and geopotential fields over the North Hemisphere archive from the World Data Center, Obninsk Russia (1961–2000) and database of the Climate Research and Long-Range Weather Forecast Department, Ukrainian

Hydrometeorological Institute (1990–2005) were used (both 5 × 5° regular grid) for analysis of the large-scale atmospheric circulation. Historical data was taken from (Lamb, 1961). Change to the large-scale atmospheric circulation is studied from decade to decade during the 20th century.

Objective classification of synoptic processes in this research was made on the basis of method of analogs (Martazinova, 2005). Etalons of SLP fields were chosen. An etalon for each class of synoptic situations is a SLP field selected among others which has the greatest similarity with all the other fields in its class. SLP etalons of the most probable class characterize the pattern of atmospheric circulation which formed predominant weather conditions for each month of the 20th century.

For assessment of treeline dynamics of the Ukrainian Carpathians (47°40'–49°32' N, 22°40'–24°50' E) WIG historical maps issued by the Polish Military Institute circa 1930 (1 : 100,000) and renewed Czech maps based on the Third Military Survey of the Austro-Hungarian Monarchy issued circa 1925 (1 : 75,000) were compared with Landsat ETM images (2000–2002) and contemporary topographic maps (1 : 100,000; 2006) in ArcInfo software produced by ESRI. A Digital Elevation Model was produced based on contour heights digitized from 1 : 200,000 topographic maps. There were selected 71 mountain ridges, based on visual analysis of satellite images and maps. Two vector layers were created by manually delineating the forest-free area above the treeline – the first, "historical" one from Polish and, where their coverage was insufficient, Austrian maps (S_1), and the second, "contemporary" one from the Landsat images (S_2). The difference $\Delta S = S_1 - S_2$ was calculated. To compare spatially the measure of treeline dynamics, a treeline advance coefficient k was introduced: $k = \Delta S/L$, where L is the length of each mountain ridge (measured based on the highest points within the S_1 polygons). Thus, k represents the amount of meadow area decrease per kilometer. The average treeline altitude for each mountain ridge was calculated based on DEM values. Based on a geobotanic map (Golubets, 1968) and satellite vegetation spectral features, one of four categories (coniferous, deciduous, mixed – mainly coniferous, mixed – mainly deciduous) was assigned to each ridge based on the prevailing tree species at the treeline.

Results and discussion

Transformation of atmospheric circulation in the Atlantic-European sector during the recent decades

Changes in the global climate over the last century have been spatially and temporally heterogeneous. Three periods can be distinguished in the global temperature regime: two periods of warming (end of 19 century – 1940 and end of 1970's – end of 1990's) are separated with a period of relative temperature stability (1940–1970's) (*WMO statement on the status of the global climate in 1995,* 1996). It has been shown (Martazinova and Sverdlik, 1998) that this periodicity can be explained by changes in the large-scale atmospheric circulation. In this article we will examine changes to the atmospheric circulation over the Atlantic-European sector during the last period of global warming.

Over the North hemisphere, the maximum warming since the end of the 1970s took place in continental areas between 40º N and 70º N in winter and spring. The winter planetary atmospheric circulation of the North hemisphere in the middle layer of the troposphere in the latitudinal sector 40º and 70º N is a three-vortex system consisting of three ridges (North Atlantic, Siberian and Canadian maximums of pressure). Three vortex minimums of pressure are placed between them (European, Aleutian, and Icelandic). In winter weather of the Ukrainian Carpathians, an important role is played by the state of the European minimum and Siberian maximums of pressure. In this paper prevailing pressure fields are shown for winter and summer of the three decades of the period 1974–2005 (Fig. 1).

The area of high pressure was predominating in winter over the Ukrainian Carpathians during 1974–1983; however, cyclones also well developed in the area of Icelandic minimum and in Eastern Europe, causing cool and snowy winters in Ukraine. The summer of 1974–1983 was characterized by less intensive SLP gradients with moderately warm weather. In winter of the subsequent decades (1986–1995 and 1996–2005), the high pressure moved eastward and occupied almost all Europe including Ukraine. Such a position of high pressure creates anomalously warm winters with little or no snow. From the East, the contraction of Siberian maximum significantly reduces the opportunity for cold air to inflow to the East Europe and Ukraine.

In following decades in summer high pressure is intensified over Central Europe creating mainly hot and dry weather in Europe, including its eastern part. High temporal stability is another distinctive feature of the most probable SLP field during the recent decade that sometimes resulted in heat waves and droughty conditions in Europe.

It is widely recognized that atmospheric circulation greatly influences the climatic regime of any given territory. The role of atmospheric circulation for the climatic regime of the Ukrainian Carpathians is exemplified in Fig. 2.

The monthly average temperature of the Rahiv weather station (431 m a.s.l., see Fig. 3) during the period of 1974–1983 in January was fairly temperate, which is explained by the combination of well-developed cyclones and area of high pressure. However, in July the etalon situation caused meridional air-mass transport over the Ukrainian Carpathians, which resulted in cooler than

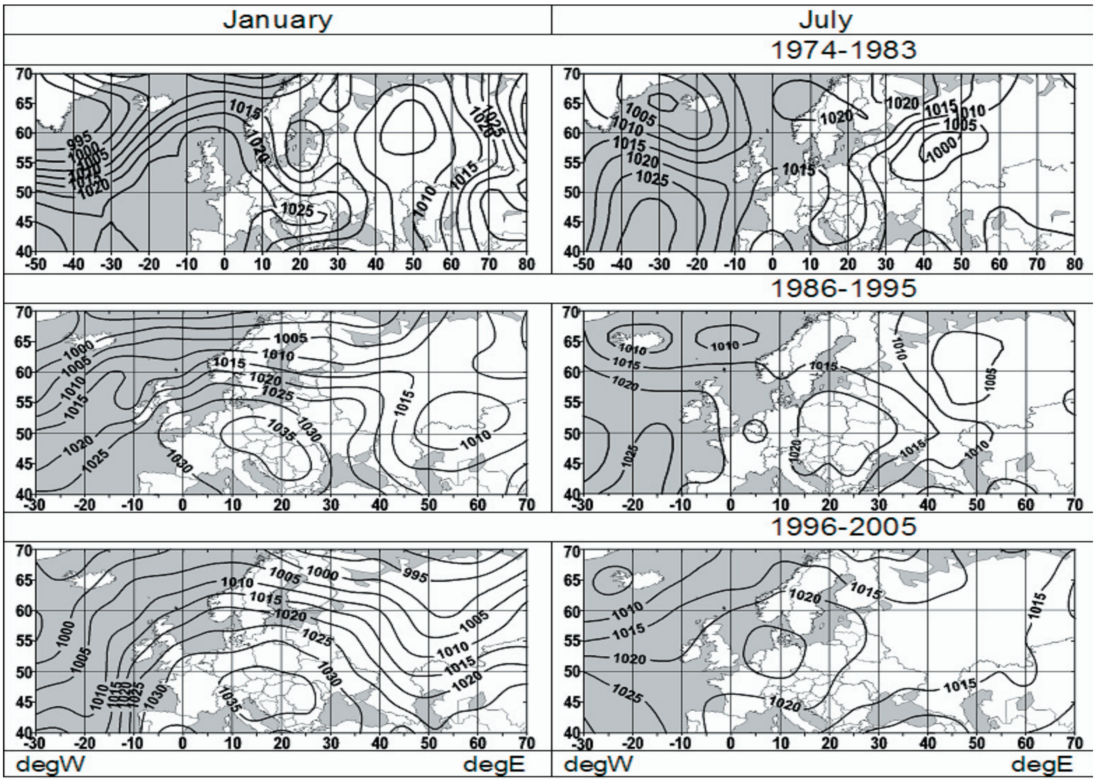

Fig. 1. Etalon SLP fields in the Atlantic-European sector in winter and summer, 1974–1983, 1985–1995, 1996–2005.

average monthly temperature. In the period of 1986–1995 the dominating field of high air pressure resulted in a general rise of monthly average air temperature both in January and July, on the other hand, short-termed but anomalously cold non-etalon atmospheric processes (not represented in Fig. 1) caused years with below-average monthly temperature both in January and July. The above-average temperature of July is especially significant for trees growing at the treeline, since their growing season is confined to the warmest months of the year.

Comparison of treeline positions (1930s to 2000)

During the study period, the total meadow area above the treeline decreased by 15,380.8 ha, which is 24% of the initial area S_1; and, consequently, the treeline position has been shifted to a higher elevation. The largest meadow area decrease was observed on ridges with coniferous species at the treeline (42%, $k = 305.3$). On the contrary, ridges with deciduous forest experienced a small increase in meadow area, and therefore a rise in treeline position (–6%, $k = -18.1$). Ridges with mainly coniferous forests have experienced decrease of meadow area, but less than in the 1st group (24%, $k = 178.7$), while the rate of meadow decrease on ridges with mainly deciduous species was quite low (32%, $k = 69.8$) (Table 1).

The high $\Delta S/S_1$ and relatively low k value in the last group of Table 1 is caused by complete afforestation of small, low-elevated ridges (mainly located in the Beskid area), which constitute a significant part of the overall number of ridges of this category. The treeline advance coefficient represents the magnitude of treeline position change more adequately than $\Delta S/S_1$ on a spatial scale.

Overall, the treeline dynamics in the Ukrainian Carpathians demonstrates regional peculiarities (Fig. 3). The largest treeline advance coefficients belong to the Gorgan, Chornogora, and Marmarosh area, followed by minimal positive values in the Beskids and negative values in the Polonina region. The changes in average treeline height for these regions are described in Table 2. As seen from the table, the changes in treeline altitude are proportional to treeline advance coefficients. The Beskid region comprises low-elevated mountains proximate to settlements. It is probable that human disturbance has impeded further treeline advance at these locations. The Gorgans, remote high elevated mountains with limited human access, have experienced the most significant treeline rise. On the contrary, the treeline of the Poloniny mountain ridge, located in the beech forest zone, was lowered during the study period. Treeline altitude

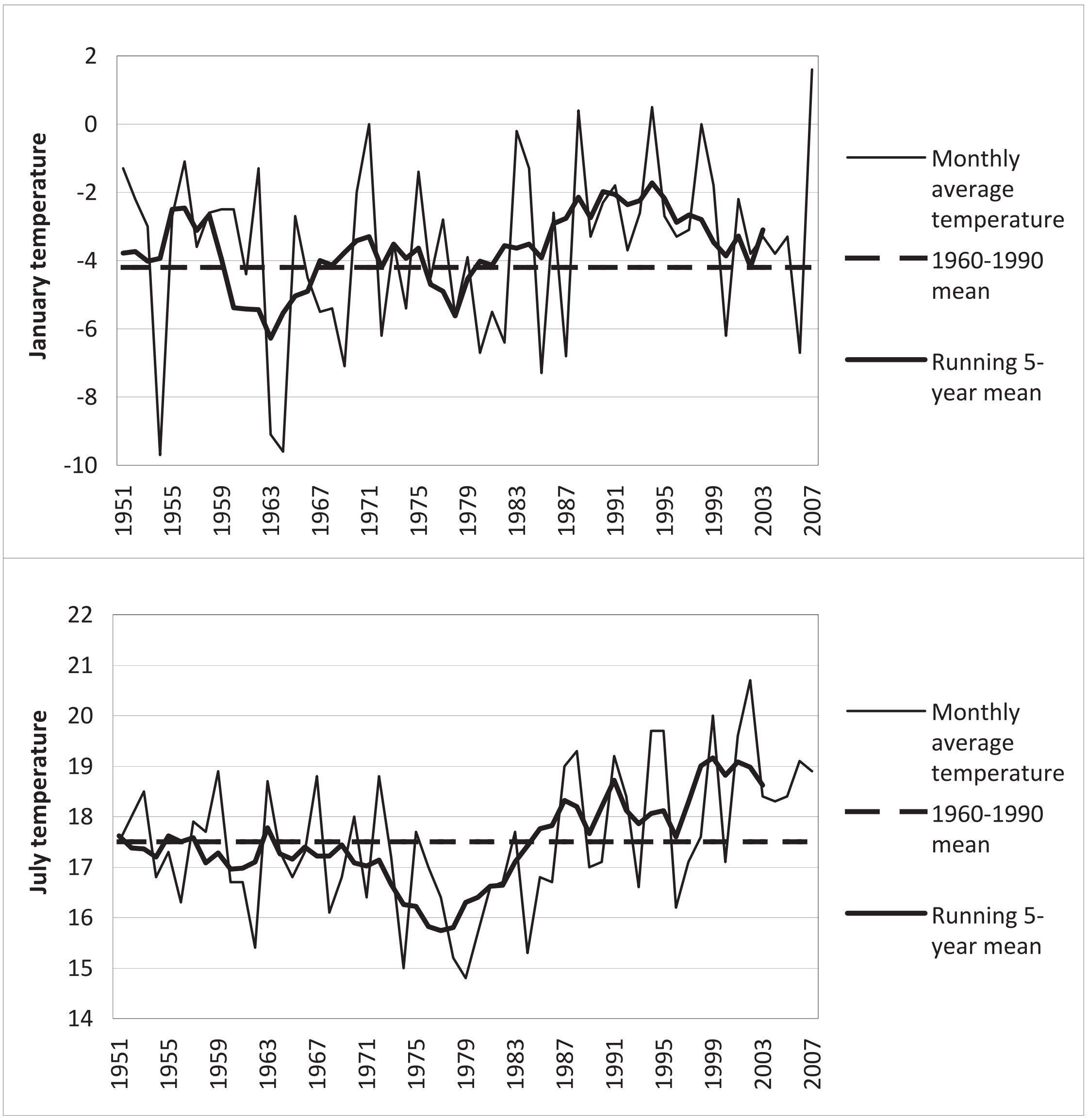

Fig. 2. Monthly average and running 5-year mean of January and July temperature at Rahiv weather station (431 m a.s.l.).

of the Chornogora and Marmarosh, the highest-elevated mountain ridges of the Ukrainian Carpathians, has risen but to a somewhat smaller extent than on the Gorgans.

At some locations, such as the Svidovets ridge from the Polonina system, the treeline on the northern slopes is constituted by coniferous trees, while on the southern slopes it is formed by beech (Fig. 4). At this location, the treeline of coniferous species demonstrated a noticeable rise in altitude while the beech treeline was stable or lowered. The influence of human presence and grazing is represented by sheds (as located on a 1 : 100,000 topographic map), which are most probably shepherd's huts. Though grazing intensiveness has generally fallen in the last decades, at some locations the presence of sheds has impeded treeline rise.

A general trend in the Carpathians forest dynamics of the last decades is a gradual replacement of coniferous forests by mixed forests (Mihai et al., 2007; personal communication). However, in this study, colonization by coniferous species was observed at some locations above the beech treeline. Given that the beech treeline in the Ukrainian Carpathians is considered by many researchers to be of secondary origin, this could indicate an ongoing process of restoration of the montane vegetation zones. With regard to the observed high rates of treeline advance in coniferous species, it must be stated that at the treeline in the Ukrainian Carpathians, coniferous tree species experienced better conditions for expansion. In general, the rate of treeline rise was positively correlated with altitude, which reflects more difficult access to elevated mountaintops and thus better conditions for tree establishment.

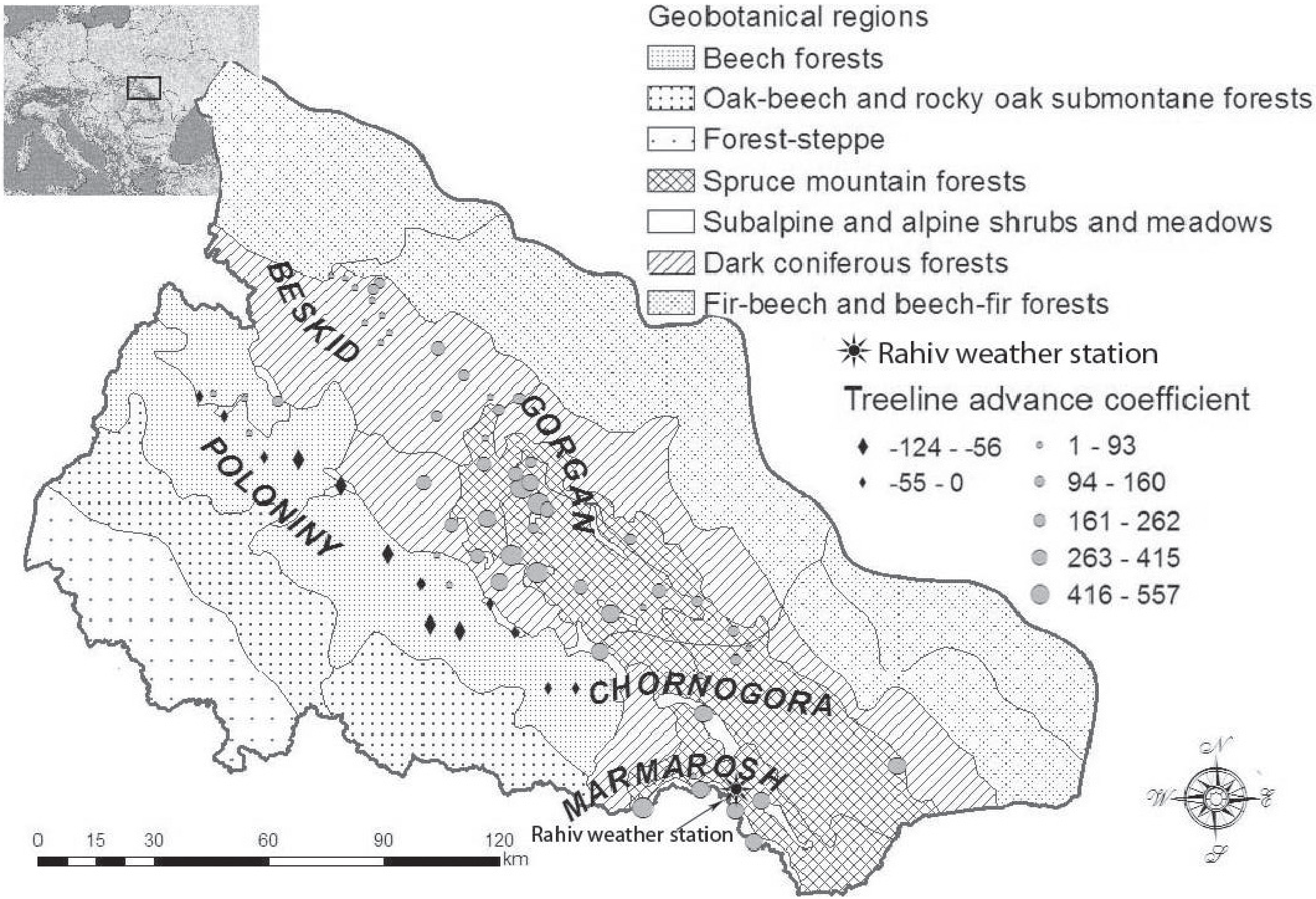

Fig. 3. Spatial distribution of treeline advance coefficients over geobotanical regions.

Table 1. Changes in mountain meadow area during the study period

Categories of mountain ridges	S_1 [ha]	S_2 [ha]	ΔS [ha]	$\Delta S/S_1$ [%]	k
All categories	62,971.4	47,590.6	15,380.8	24	147.8
1. Coniferous forest	20,575.9	12,017.3	8,558.6	42	305.3
2. Deciduous forest	11,103.4	11,736.7	–633.3	–6	–18.1
3. Mixed forest – mainly coniferous	30,150.4	23,057.9	7,092.5	24	78.7
4. Mixed forest – mainly deciduous	1,141.3	778.7	362.5	32	69.8

S_1, meadow area on historical map; S_2, meadow area on modern map; $\Delta S = S_1 - S_2$; k – coefficient of treeline advance. Area is shown in hectares.

Table 2. Changes in average treeline elevation

Region	Average h_1 [m]	Average h_2 [m]	Δh [m]
Beskid	1,105	1,096	9
Gorgan	1,393	1,347	46
Poloniny	1,169	1,183	–14
Chornogora	1,370	1,345	25
Marmarosh	1,448	1,413	35
All	1,306	1,293	13

h_1, h_2, average treeline elevation on historic maps and satellite images respectively; $\Delta h = h_1 - h_2$.

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References

Golubets, M., Malinovski, K., Stoiko, S. 1968. Geobotanical map of Ukrainian Carpathians. In *Pryroda Ukrainskuh Karpat*. Lviv: Lviv University, p.155.

Gehrig-Fasel, J., Guisan, A., Zimmermann, N.E. 2007. Tree line shifts in the European Alps: climate change or land abandonment? *J. Veget. Sci.*,18: 571–582.

Lamb, H.H. 1961. Climatic change within historical time as seen in circulation maps and diagrams. *Ann. N.Y. Acad. Sci.*, 95 (1): 124–161.

Martazinova, V., Sverdlik, T. 1998. Krupnomashtabnaya atmosfernaya tsirkulyatsiya XX stoletiya, eë izmeneniya i sovremennoye sostoyanie [Large-scale atmospheric circulation of the XX century, its changes and modern state]. *Pratsi UkrNDGMI*, 246: 21–27.

Martazinova, V.F. 2005. The classification of synoptic patterns by method of analogs. *J. Environ. Sci. Engng.*, 7: 61–65.

Mihai, B., Savulescu, I., Sandric, I. 2007. Change detection analysis (1986–2002) of vegetation cover in Romania. *Mount. Res. Dev.*, 3 (27): 250–258.

WMO statement on the status of the global climate in 1995. 1996. WMO, 838. Geneva: Secretariat of the World Meteorological Organization. 11 p.

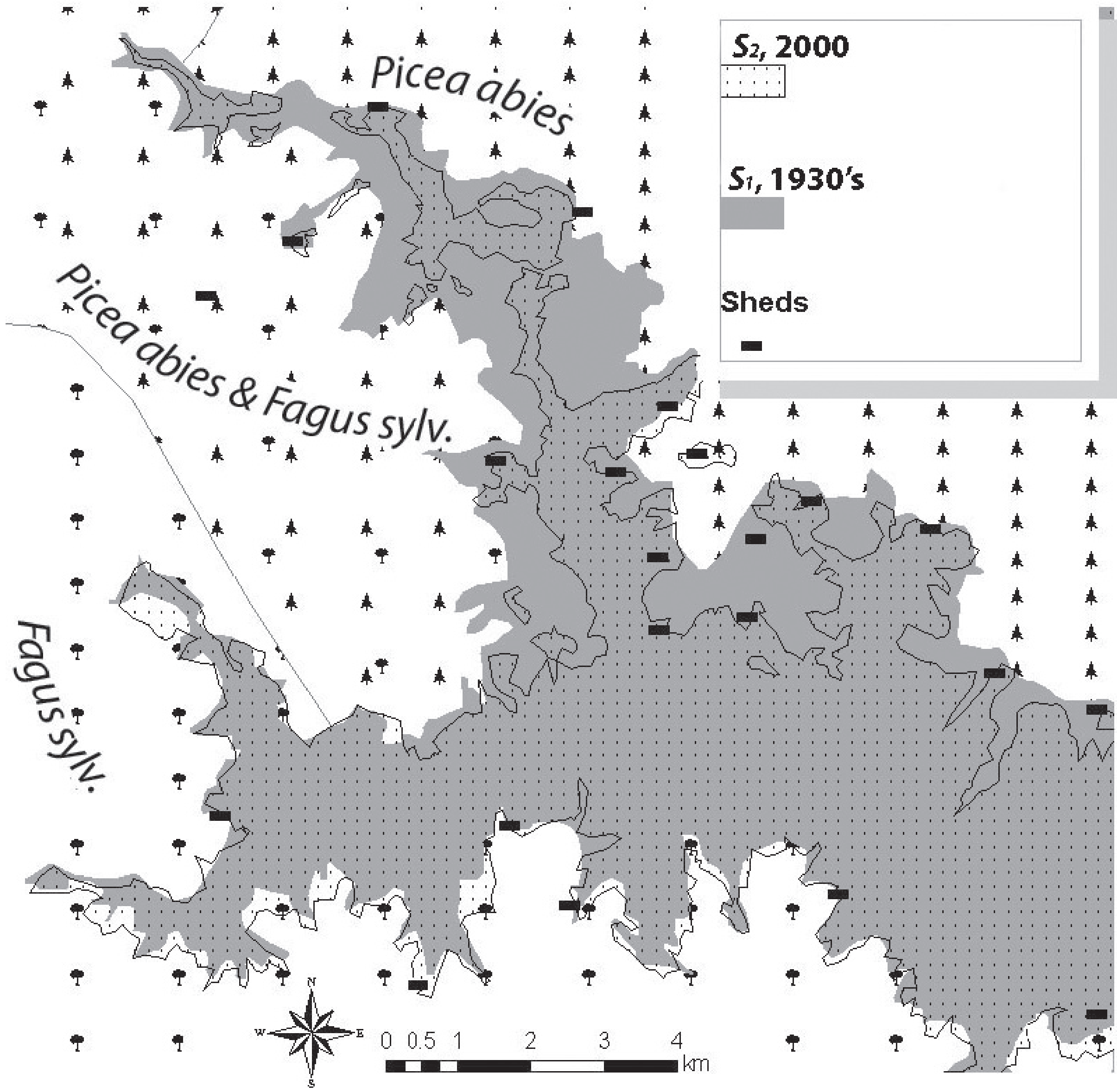

Fig. 4. Changes in treeline position on Svidovets mountain ridge. Geobotanic zones are from Golubets, 1968.

Klíma a dynamika hornej hranice lesa v Ukrajinských Karpatoch

Súhrn

Práca sa zaoberá zmenami klímy a dynamikou hornej hranice lesa v Ukrajinských Karpatoch v priebehu 20. storočia. Predmetom výskumu boli zmeny atmosférickej cirkulácie zodpovedné za nárast letných aj zimných teplôt. Porovnanie medzi hornou hranicou lesa v rokoch 1930 a 2000 ukázalo, že územie nad touto hranicou sa zmenšilo najmä v oblastiach, kde túto hranicu tvoria ihličnaté dreviny. Na druhej strane, v oblastiach s listnatými drevinami boli tieto zmeny menšie alebo žiadne. Veľkosť posunu vykazuje značnú priestorovú variabilitu. Názor autorov práce je, že príčinou posunu hornej hranice lesa bol, okrem iných faktorov, nárast teploty.

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