Can we define historical range of variability in temperate mountain spruce forests of Central Europe: Disturbance dynamics in primary montane *Picea abies* forests of the Central Carpathians, Romania

P. Janda*[1], M. Svoboda[1], R. Bace[1], T. Nagel[2], S. Fraver[3], J. Rejzek[1], M. Mikolas[1], V. Trotsiuk[1], J. Douda[1], K. Boublik[1], P. Samonil[4], M. Valtera[4], M. Theodosisus[5], I. Biris[5], O. Bouriaud[5], J. Zelenka[1], O. Sykora[1], P. Uzel[1], J. Lehejcek[1], S. Kosobud[1], V. Cada[1]

* Czech University of Agriculture in Prague, Kamýcká 129, 16521, Praha 6 – Suchdol, Czech Republic; jandap@fld.czu.cz; 1 CULS Czech Republic; 2 UL Slovenia; 3 FS USDA USA; 4 VUKOZ Czech Republic; 5 ICAS Romania

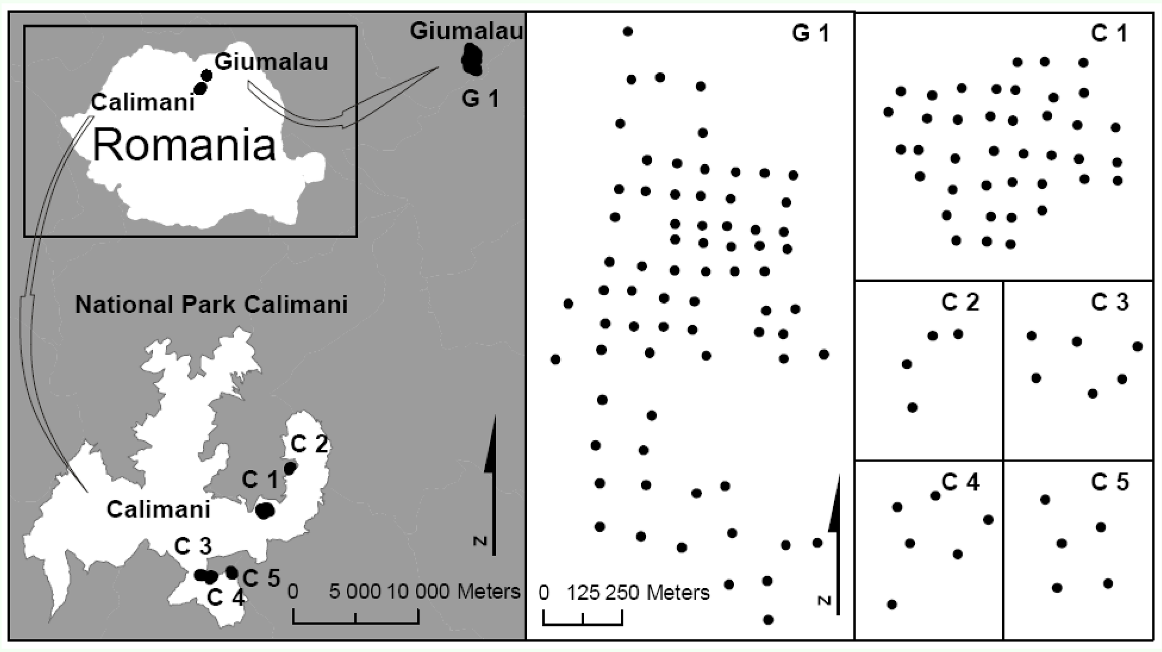
Introduction

Natural disturbances strongly influence the dynamics and succession of forest ecosystems worldwide. Understanding the spatial and temporal variability of disturbances, particularly at the landscape scale, is critical for ecological forest management, which intends to emulate the historic range of forest structure, composition, and processes that result from natural disturbances. Maintaining the historic range of variability in managed forest stands and landscapes is believed to curtail biodiversity losses simply because native species evolved under, and are adapted to, this range of conditions. Management practices that drive systems outside the historic range of variability may place native species at risk. Characterizing the historical range of variability in forest disturbances often requires retrospective studies in primary forests, that is, forests relatively uninfluenced by human activities. During the past decade, Central Europe has experienced severe blowdowns and bark beetle outbreaks. Thus, an important question is whether these events are part of the historical range of variability, or whether they are related to climate change and past management practices. Specific objectives were to: (1) quantify the temporal and spatial pattern of the disturbances at the plot and landscape level; (2) describe the gradient in disturbance severity on the plot and landscape scale and (3) use these results to make inferences regarding the disturbance agents for this region.

Methods

We conducted this study in the Calimani and Giumalau Mts. located in the northern Carpathians of Romania. Within the largest remnants of *Picea abies* primary temperate forests in Europe. Based on the initial field survey, we selected five stands in the Calimani Mts. and one stand in Giumalau Mts. (Fig. 1). Sample plots were established in each stand using a stratified random design (Fig. 1). Using GIS, a 100 x 100 or 141.4 x 141.4 m grid was overlaid on each stand. Within each grid cell, a circular inventory plot (1000 m^2) was established at a restricted random position. In each plot, we labeled all living trees ≥ 10 cm diameter at breast height (DBH). We selected randomly 25 non-suppressed trees per plot for increment core extraction. Disturbance history was reconstructed from two patterns of radial growth: (1) abrupt, sustained increases in radial growth (releases) indicating mortality of a former canopy tree and (2) rapid early growth rates (gap-recruited trees) indicating recruitment in a former canopy gap. The number of growth releases and gap recruitment events were converted to the amount of canopy area disturbed each decade and finally there were summed by decade separately for each plot to construct disturbance chronologies.

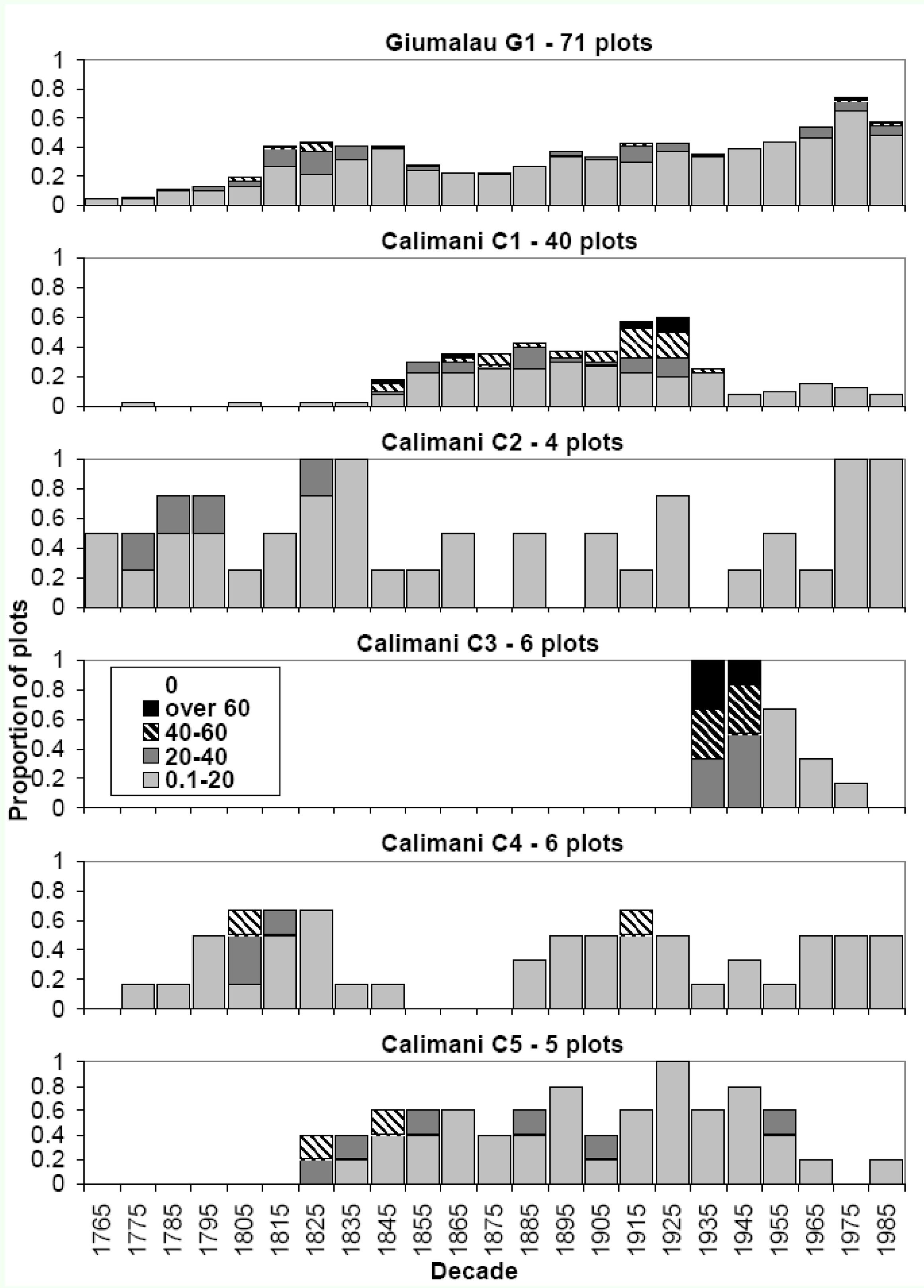
Fig. 1. Map of the study area with the location of the stands and plots.



Results

We created a set of chronologies, in which the proportion of plots, per stand, experiencing various disturbance severities is expressed for each decade (Fig. 2). These chronologies better capture the temporal variability in disturbance severity for each stand. Both Calimani C1 and C3 show extreme severity disturbance (> 60% of trees showing disturbance evidence) on a portion of plots, although at different decades for each stand (Fig. 2). In contrast, Calimani stands C2, C4, and C5 show lower disturbance rates, with most plots recording light disturbance (< 20% of trees showing evidence). The Giumalau also shows relatively low disturbance evidence, with only small number of plots showing heavy or extreme severities, respectively, in any decade. The result of summing disturbance evidence over three consecutive decades (to account for the protracted periods of gap recruitment following disturbance) revealed several periods of heavy to extreme disturbance in all stands (Tab. 1). These periods were further examined for spatial patterning (below). Assuming protracted recruitment as the explanation for these lengthy periods, we take the first decade in each period to represent the timing of the disturbance. Using this approach, in Calimani, stands C1 and C3 showed 80 and 100 % of plots with heavy and extreme disturbance over three consecutive decades, respectively (Tab. 1). On the other hand, in Calimani C2, C3, and C4 there were many plots, which show light disturbance (Tab. 1). In the Giumalau, many plots also showed light disturbance, when the proportion of plots with extreme disturbance was 36 % (Tab. 1). The periods of extreme disturbances varied from stand to stand, but several periods (1800 – 1830, 1840 – 1870, 1900 – 1930, and 1950 – 1980) were common between the stands (Tab. 1). However disturbance synchronicity among stands and landscapes was only partial. In Camilani C1 stand, the Mantel's test between Bray-Curtis distances based on disturbance history matrix and spatial distances among plots was significant (P<0.001, r=0.43), indicating synchronization of disturbance among closely located plots. On Giumalau, the Mantel's test revealed only slightly clumped pattern (P=0.002, r=0.13) of plots with similar disturbance pattern. A visual assessment of within-stand spatial patterning for the Calimani and Giumalau landscapes confirm the results of Mantel's test and show clustering of heavily disturbed plots within given time periods (Fig. 3).

Fig. 2. The disturbance chronology with expressed frequency of disturbance rates per plot and decade. The results are expressed on the plot level with five disturbance rates: 0, 0.1 – 20, 21 – 40, 41 – 60, over 60 % of disturbance rate per given plot. In every decade proportion of plots within the five levels of disturbance rate are shown. For each plot, the chronologies were truncated when the depth sample was below 20 %.



Tab. 1. Proportion of plots with disturbance rates over 60 and 80 % in three consequent decades in individual stands. For every plot, running window with sum of disturbance rate over three consequent decades was run, and plots with summary value over 60 and 80 % of disturbance rate were selected. Selected 60 and 80 % disturbance rate criteria correspond to heavy canopy removal. When the plot fulfilled for given three decades period criteria of 80 %, it was not included in the 60 % class. The periods with highest number of plots fulfilling the 60 and 80 % criteria are shown of each stand in column.

Disturbance severity	over 80 %		60.1 – 80 %	
Study sites	Percentage of plots	Important decades	Percentage of plots	Important decades
Giumalau G1	11 %	1800-1830	25 %	1800-1830
		1900-1930		1900-1930
		1950-1980		1950-1980
Calimani C1	50 %	1900-1930	30 %	1900-1930
		1840-1870		1840-1870
Calimani C2	0 %		0 %	
Calimani C3	100 %	1930-1960	0 %	
Calimani C4	0 %		50 %	1800-1830
				1900-1930
Calimani C5	0 %		60 %	1800-1830

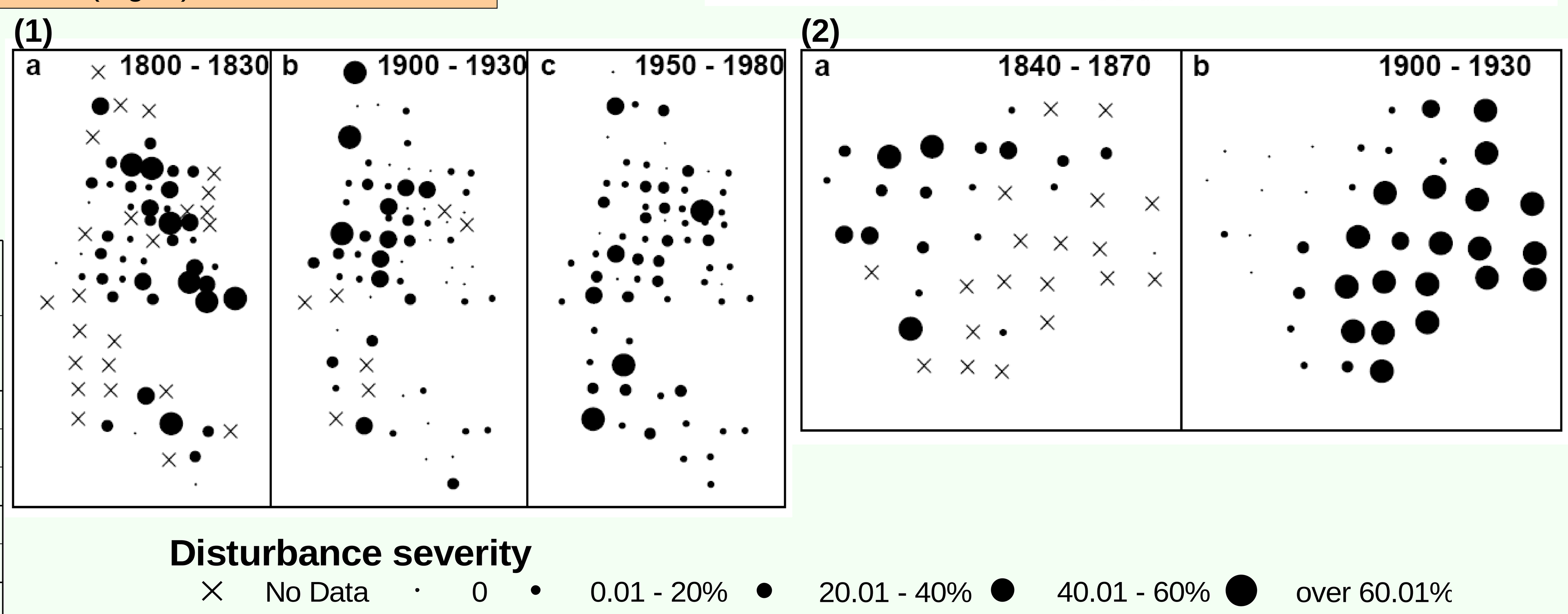


Fig. 3. Maps of disturbance rates for Giumalau (1) and stand Calimani C1 (2) for periods with the most severe disturbance events based on the Tab. 1. Disturbance rates were summed in three consequent decades for selected periods a) 1800 - 1830, b) 1900 - 1930 and c) 1950 - 1980 in Giumalau and for selected periods a) 1840 - 1870 and b) 1900 - 1930 in Calimani C1. The size of the circle show one of the defined classes of disturbance rate: 0, 0,1 – 20, 21 – 40, 41 – 60, over 60 % of disturbance rate per given plot per given period.

Conclusions

In Giumalau and Calimani, there is evidence on considerable temporal and spatial variation in the disturbance severity across studied landscape. We have found an evidence of both, periods with the heavy and extreme disturbances causing stand replacing events as well as periods with light disturbances. More than half of the studied plots experienced high severity disturbances, although they were not always spatially and temporally synchronized. Calimani landscape showed higher proportion of plots with severe disturbance compared to Giumalau. Plots with high severity disturbances showed tendency for clustering, while this tendency was less clear for moderate and low severity disturbance. We found an evidence of stand replacing disturbances on scale of 10 – 20 ha, most probably caused by windstorms. Historical evidenced showed that windstorms played probably more important role in shaping these forests, although the role of the bark beetle outbreaks remain unclear. Moderate to light disturbance played also important role on significant part of the landscape, pointing to considerable variation in disturbance severity over the landscape.

Acknowledgment:
This study was supported by the Grant Agency of the Czech Republic, project No. P504/10/1644 "Natural disturbance regimes of mountain *Norway spruce* forests: the basis for ecological forest management".