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NATURAL DISTURBANCE HISTORY OF THE PRISTINE *PICEA ABIES* FOREST PARANGALITSA

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Abstract

Although understanding natural disturbance regime is very important for the management of subalpine coniferous forests, studies for Southern European Mountain ecosystems are still scarce. Among the reasons are difficulties in finding unmanaged forests that could serve as reference. We studied the disturbance history of an old Norway spruce-dominated forest in the “Parangalitsa” biosphere reserve in Bulgaria. It was declared a reserve in the 1930^{s}, but was protected from human intervention before that. We used aerial photo interpretation to detect disturbance areas and dendroecological methods to date the occurrence moment of the disturbance events. Over the past 150 years windthrows have been the main type of disturbance. About 20 percent of the forested area was subjected to complete blowdown. The largest proportion of the affected territory was due to medium sized windthrows with dimensions of 1 to 10 ha. Although *Ips typhographus* populations were large enough to cause mortality of some live trees, the populations did not grow to epidemic proportions. Fire disturbance was of limited importance and only two areas (4 percent of the study area) showed evidence of fire in the 20th century. The forest ecosystem in Parangalitsa has high resilience, which is probably due to the high landscape heterogeneity of forest structures and continuous interaction between natural disturbances.

Key words: Bulgaria, natural disturbances, *Picea abies,* windthrow.

Introduction

Disturbances are among the key processes that guide forest dynamics. They affect forest structure, composition, patchiness and resource availability (Oliver and Larson 1990, Laska 2001). To enable a real understanding of forest dynamics within a given ecosystem, their role on biodiversity and thus justify adequate forest ecosystem management, thorough knowledge of local natural disturbance regime is needed (Veblen et al. 1994, Schütz

2004, Franklin et al. 2002, Kuuluvainen 2002, Kulakowski and Bebi 2004). This is especially important in cases, when restoring of forest structure and composition to a more natural state is aimed (Schütz 2004).

Norway spruce (*Picea abiest* Karst.) is one of the main species in the subalpine forests in the Southern European mountain ranges (e.g. the Alps, the Carpathians, the Pyrenees, and the Balkan Mountains) and Northern Europe. These forests are very important for timber production, but probably even more for their protective functions against avalanches, rockfall (Brang et al. 2006), soil erosion, water-holding capacity (Raev 1986) and from the landscape functions. Several big storms in the last decades that caused wide-spread damages in high mountain forests (Lassig and Schonenberger 2000, Schelhaas et al. 2003, Zielonka et al. 2009) and expectations that climate change might increase the severity of storms (IPCC 2007), raised the attention paid to the influences of natural disturbances on Norway spruce forests and their resilience (Krauchi et al. 2000, Kulakowski and Bebi 2004). Yet, information about natural dynamics and disturbance regime of Central and South European high mountain Norway spruce-dominated forests is still limited (Korpel 1995, Krauchi et al. 2000, Splechtna et al. 2005). Among the reasons for this are difficulties in finding forest that were not managed for long enough period.

Parangalitsa forest in Rila Mts., Bulgaria, is among the few well-preserved in natural state Norway spruce – dominated forests in Southern Europe. Here we present a preliminary study of the natural disturbances in this forest ecosystem. Based on interpretation of orthophotos from 1966 and 1997 we outlined clearly detectable windthrows in the last 50 yrs. and forest patches that originated after stand-replacing disturbances within the last 100–150 years.

Material and Methods

Study site

Our study site is situated in the upper parts of Bistritsa valley in the Rila Mountains in Southwestern Bulgaria (Fig. 1). The study forest (250 ha) is situated in "Parangalitsa" reserve, which is one of the first strict forest reserves on the Balkan Peninsula. In was declared in 1933 and in 1977 it was included in the "Man and biosphere" list of UNESCO. Before that the region was considered as a protected forest and human activities were limited to hunting of local governors and pasturing on the higher grass-lands above the forest (Ruskov 1934). Timber harvesting on large scale was not allowed and the lack of roads additionally hindered any possible attempts. The lower parts of the forests are famous as some of those with highest productivity in Bulgaria (Standing volume of up to 1435 $m^3.ha^{-1}$ according to the local Forest Management Plan of 1966 (Nedyalkov 1966) and are representative of the optimum growth conditions for *Picea abies* (Raev et al. 1987).

The climate in the reserve is mountainous with influence from both Atlantic and Mediterranean cyclones. The average annual temperature at 1400 m a.s.l. is 4.9°C. It ranges from a mean

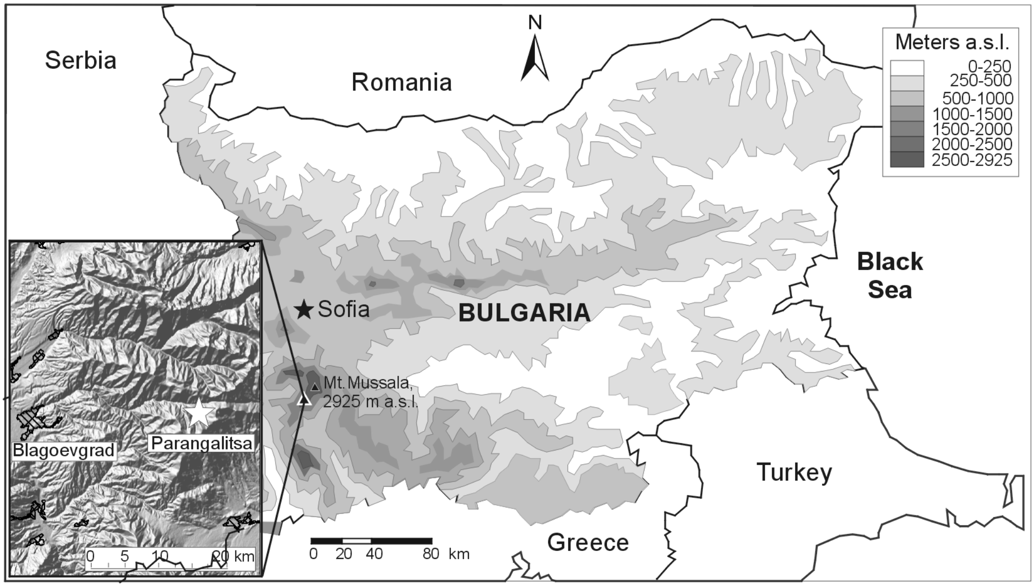

Fig. 1. Study site position.

monthly temperature of -3.7°C in January to +14.5°C in July. The annual precipitation amounts to 933 mm, with a maximum in late spring and early summer. Deep snow covers, frequently exceeding 1.5 m, are typical for the region (Raev 1986).

Data collection and analysis

The 250 ha study area was stratified by identifying internally-homogenous forest patches on aerial photos from 1966. Based on crown structure we subdivided several groups of forest patches: heterogeneous (different crown sizes, existence of empty spaces and gaps between the crowns); homogenous (densely situated crowns with similar sizes); recent disturbances (clearly visible fallen logs or cleared territories); treeline (separated trees and small groups at the treeline zone) and meadows within the forest. Because the image from 1966 reflects clearly the stand development in the previous 10–15 yrs especially in terms of disturbances, any clearly detectable blowdowns were considered as such which happened shortly before the mid 1960^s (i.e. 1950^s till 1960^s). Homogenous patches were suspected to have originated after stand-replacing disturbances in case the age of the trees was within one age class (i.e. 20–30 years) (Oliver and Larson 1990). Additional verification of this hypothesis was done by analysis of tree ring cores from surviving older trees at the borders of the patches. Additional aerial photos from 1997 were used to detect changes between these two periods and verify the first stratification. Since the images were not originally orthorectified, we performed an absolute orientation of the aerial photos in order to generate the orthophotos. Ground control points were derived from GPS field measurements, existing satellite data as well as Google Earth software. Leica Photogrammetry Suite (LPS 9.1) was used for this purpose. To enable delineation of forest patches with reasonable size that could be defined on terrain as well as on the orthophotos we chose a minimum mapping unit (MMU) of 0.5 ha.

Forest patch ages were detected by obtaining tree ring cores. In each patch we collected samples from biggest and presumably oldest trees and from such from suspected younger cohorts. We also collected cores at the borders of detectable disturbances or uniform single-cohort patches because they could contain clues for dating of the disturbance events (Veblen et al. 1994). Tree ring samples were air-dried, mounted on wooden holders, and sanded with successively finer grades of sandpaper. Annual rings were recorded with semi-automatic video equipment at the dendrochronology laboratory of the Institute of Forest Growth (IWW) in Freiburg with precision of up to 0.01 mm. Measurement and cross-dating was performed with the Woodscan software (IWW) following standard procedures.

We dated windthrows by the presence of coincident sudden increases of radial growth (releases) and/or decreases in radial growth (suppressions) in surviving trees; and the age of a younger cohort within the disturbed area. Coincident tree establishment dates (i.e. age difference of no more than 20 years) in conjunction with rapid initial growth suggest establishment under open site conditions following a variety of stand-replacing disturbance (Kipfmueller and Baker 1998).

Results and Discussion

Disturbances in the second half of the 20th century

We could identify that more than 10% (26 ha) of the forest area was affected by windthrows shortly before the images in 1966 were taken. Of them the biggest contribution had the November 1962 windthrow, which caused complete blowdown of 18 ha in several forest patches (Fig. 2). According to the forest authorities' reports (Nedyalkov 1966) in the following few years (1962–1965) bordering areas to the 1962 windthrows were affected by sporadic tree-fall and bark-beetle mortality, which increased the total disturbance area to 22 ha by 1966. The storm also caused numerous single or small group tree falls in other regions of the forest. One zone with area of 4 ha ("N17") was affected by a windthrow in 1965. Another observed and documented windthrow that was clearly detectable on our orthophotos happened in 1983. It caused complete blowdown on a territory of about 3 ha within stand "N17". The affected area was bordering to a zone that suffered windthrow in 1965.

During the last decades there were also periods with increased release reactions in tree ring cores (e.g. in the late 1970^{s} and late 1990^{s}), which cannot be attributed as a consequence of these large-scale events. They reflect high intensity of small-scale disturbances with dimensions of 0.1 to 1 ha. In the period between 1966 and 1997 (e.g. between the two sets of orthophotos) the majority of the mature trees were uprooted within small-scale disturbance patches on a total area of 9.3 ha (Fig. 2). About 30% of these new disturbance zones were bordering areas to windthrows form the period 1962–1965. In most of the cases these events were small-scale blowdowns, which later expanded. In several other patches there was continuous dieback caused by bark-beetles and single tree fall. Usually this mortality process was within small groups on the borders of recent blowdowns.

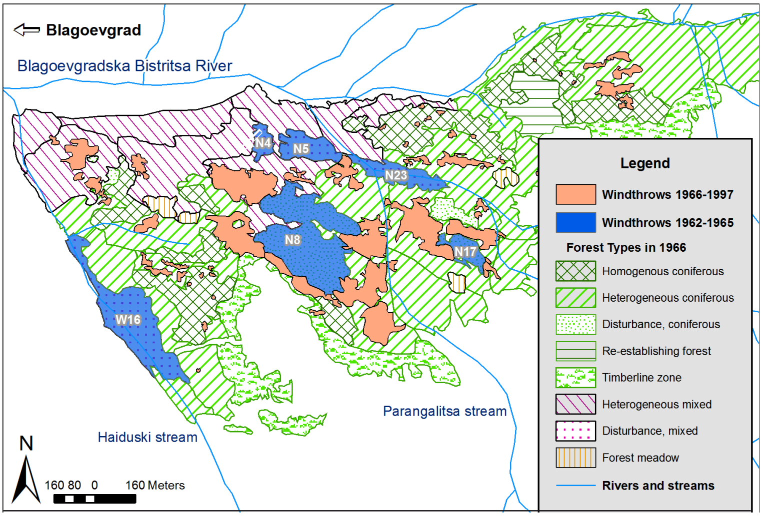

Fig. 2. Disturbances after the 1950s.

Disturbances before the 1950s

We found 4 patches composed dominantly of one cohort whose origin could be related to a dated disturbance event (Fig. 3). The patch "W18" (territory approximately 5.2 ha) is formed mainly by trees that germinated shortly after 1873. All of these have fast initial growth suggesting good light conditions and lack of canopy layer to suppress the growth of young trees (Vablen 1994). The few older trees showed signs of radial growth releases in two periods – 1865 (with only several surviving trees) and 1873. Some older trees in neighbouring areas also displayed releases shortly after 1865, but this reaction was not found in all of the older trees. We suggest that there was an event with lower severity in the 1860s which probably caused a medium scale windthrow with area of less than 5 ha within the territory of the current patch W18 and thus caused the release responses found in older trees. Later the territory expanded by additional falling of trees in 1873 thus forming the present borders of the patch. Such model of one initial disturbance event and later expansion of the territory by another event fits the most frequently observed one during the last 50 years.

The patch "N9" (territory approximately 2 ha) consists only of trees that reached coring height at the beginning of the 1870s. Yet, in the few remaining older trees in the region we found only one with abrupt growth release in 1849. Several other trees in the bordering patch "N11" originated shortly after the 1840s. While we cannot fix the date

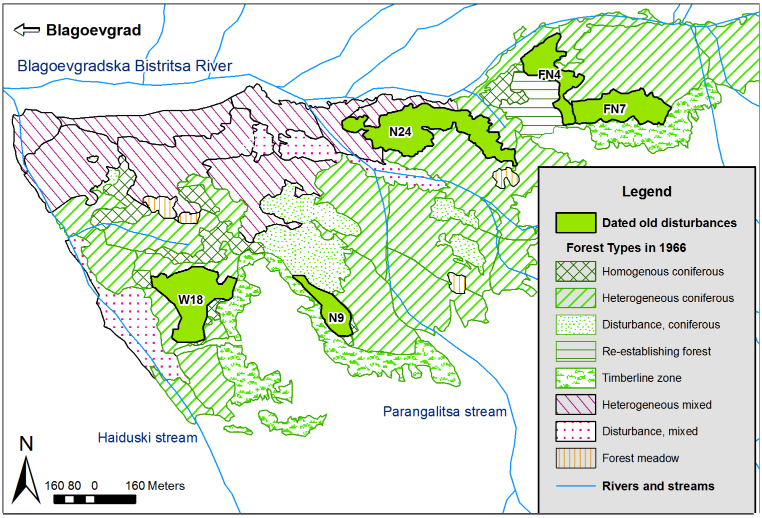

Fig. 3. Dated disturbances in "Parangalitsa" forest before 1950s.

ing older trees released at the period 1912–1914. Additionally, the first inventory reports from "Parangalitsa" forest (Georgiev 1933) mention a "fire-affected area", which according to the description matches the position of the region where our patch "FN4" is. We consider a probable explanation for the origin of patch "FN4" a combination of windthrow in 1902 followed by a low severity ground fire in 1911. Such event could explain the lack of any older trees within the patch territory since younger spruce trees would not survive even a low severity ground fire due to their thin bark and low-lying branches that easily catch fire. The other found signs also match those described as indications for fires in numerous studies of fire-driven disturbances in coniferous boreal forests (Veblen et al. 1994, Kuuluvainen 2002, Kulakowski et al. 2003).

of the event that caused the formation of this patch, the release in 1849 is a probable indicator.

Two single-cohort patches ("N24" and "FN4") were composed of younger trees that germinated at the beginning of the 20th century. Patch "FN4" (territory 3.1 ha) originated shortly after 1911. The neighbouring older trees, some of which situated at the exact borders of the patch, demonstrated abrupt growth releases after 1902. Pit-and-mound soil topography found on the territory of the patch suggests relatively recent windthrow (Ulanova 2000). Yet, there are two other findings that rise question about the character of disturbance. On one hand within the territory of the patch there are no trees that originated before 1911. There is also presence of numerous charcoal pieces straight on the surface or not fully buried by soil. Moreover, on one older tree at the border of the patch we found a fire scar, which was dated as formed in 1911. Other neighbour-

Although we could not find an older tree with fire scar, we consider the reasons for formation of patch "N24" (territory approximately 7.3 ha) similar as those of patch "FN4". All trees germinated after 1912, with majority between 1915 and 1920. Older trees in neighbouring patches show growth releases after 1898. On the territory of the patch we found numerous pits- and mounds- soil formations. These clues suggest a windthrow disturbance at the late 1890s. Yet, here again there was presence of numerous charcoal pieces on the soil surface. This, together with the very similar age of trees and the complete lack of older trees within the patch gives us the ground to consider the reasons for its origin similar as those of patch "FN4" – e.g. a windthrow followed by low-severity fire.

In two of the other patches initially classified as "homogeneous" during the stratification process we also found that most of the trees generated within a short time period ("FN7" after 1830s, "N7-1" after 1915). Yet, we could not date a disturbance with older neighbouring trees and even if such existed, we can only speculate about them based just on the age of the forest patch.

Conclusion

In Parangalitsa forest medium scale windthrows with dimensions of 4 to 10 ha were frequent during the last 150 years. Besides them small-scale damages with territory of up to 1 ha created a complex mosaic of forest patches with various ages and forest structures. Other disturbances such as bark-beetles and fires seem to have been less important. One of possible reasons is the high landscape heterogeneity of Parangalitsa, which limits the chances for fast spreading of fires or bark-beetles over vast territories. While a more complete description of the natural disturbance regime of the Southern European mountain forests requires further research in similar preserved ecosystems, our results contribute to better understanding of the natural range of variability of *Picea*-dominated ecosystems in this region and demonstrate that wind-driven disturbances with various sizes are normally expected.

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