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Short communication

Is the impact of loggings in the last primeval lowland forest in Europe underestimated? The conservation issues of Białowieża Forest

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ABSTRACT

Loggings in biodiversity hot-spots are perceived as very serious threat to forest species and habitats of high conservation interest. In this paper we scrutinize the spatial impacts of recent loggings in the Polish part of the renowned Białowieża Forest being the last remaining area of lowland temperate forest with a primeval character in Europe with the status of World Heritage and Natura 2000 site. The loggings have been applied in order to cope with the outbreak of the spruce bark beetle *Ips typographus*. We used satellite images to perform cover change detection analysis that delineated areas being logged in Białowieża Forest between July 2015 and June 2018. Next, we assessed the extent of forest loss in areas with different management regimes as well as landscape-scale impacts. The total area of detected clear-cuts amounted to at least 675 ha, including 229 ha of old-growth stands. Assuming a buffer of 100 m from the edge of cleared forest patches, the cumulative direct and indirect impact of recent logging activities was estimated to amount to at least 4073 ha of affected forest. Logging activities resulted in a 26% increase in fragmentation in the entire Natura 2000 area. We argue that the ecological impact of logging extends beyond the logged areas by modifying the landscape structure and affecting ecosystem functioning on a landscape scale. As such, the recent salvage loggings in the Białowieża Forest clearly damaged the conservation value of this precious area, not in the least by increasing its fragmentation. To avoid further degradation, we strongly argue for allowing natural tree regeneration on clear cuts and also for the extension of Białowieża National Park to cover the entire forested area.

1. Introduction

International reporting concerning an immediate threat to forest biodiversity through logging activities usually relates to primary tropical or subtropical forests in developing countries (Lindenmayer, 2010). The value of primary forests relative to degraded forests is superior in terms of biodiversity, carbon sequestration and storage, water provision and the maintenance of human health (Watson et al., 2018). In areas that have already lost most primary forests due to long history of human exploitation, the conservation focus is on securing the protection of the last remaining patches and on restoration of diverse old-growth forests (Chazdon, 2008). This is crucial since these remaining forests of high conservation value are subjects to increasing impact of various disturbance events related to global climate change (e.g. fire, pathogens, insect outbreaks) posing a new conservation challenge (Müller et al., 2018). Therefore, disturbing them even further by human activities is highly unfavorable for biodiversity conservation (Lindenmayer et al., 2017).

In Europe, conservation of the remaining valuable old-growth forests has been attempted by national forms of nature protection (e.g. national parks, nature reserves) as well as by supranational activities like the Natura 2000 network (Winkel et al., 2015). Moreover, the efforts to integrate forest biodiversity conservation and its restoration in the European Union by Green Infrastructure approach largely based on forest habitats, is currently under implementation (Snäll et al., 2016). In spite of all these efforts, the maintenance and restoration of forest biodiversity in this wealthy region of the Global North is often not secured due to conflicts of interest among different stakeholders (Niemelä

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et al., 2005), ongoing climate change, and especially by the generally low forest cover in comparison to pre-industrial era and the extreme shortage of forests with a primary character (Hannah et al., 1995). Therefore any form of active management of such forests should be performed with extreme caution.

In this paper we scrutinize the most recent developments in the Polish part of the renowned Białowieża Forest (BF) focusing on the spatial extent of direct and indirect impacts of recent salvage loggings in this last remaining area of lowland temperate forest with a primeval character in Europe. Although the conflict concerning the conservation of this area has been going on for several decennia (Wesołowski, 2005; Niedziałkowski et al., 2014), the present stage of the conflict has an unpreceded amplitude that engage the Polish political scene, European Union, the international scientific community and nature interested public worldwide (e.g. Schiermeier, 2016; Nelsen, 2017). The trigger for the current conservation conflict was the recent outbreak of spruce bark beetle *Ips typographus* that killed a considerable proportion of Norway spruce *Picea abies* in the Polish part of BF (Stockland, 2017). The State Forests Holding that manages the BF outside of the Białowieża National Park (BNP), decided to remove dead and dying trees by means of modern technology (harvesters, forwarders), hence creating sizable clear-cuts. Based on analyses of high-resolution satellite images, our study is the objective estimate of the extent of logging (since 2015) in zones with different UNESCO protective status, and a quantification of the potential landscape-scale impact beyond the spatial extent of the actual loggings. We discuss the possible direct and indirect ecological effects of the recent salvage logging in this unique area, and provide recommendations for future management of Białowieża Forest to mitigate these human-induced impacts.

2. Material and methods

2.1. Study area

The Białowieża Forest is a contiguous forest complex (150,582 ha) bordering Poland and Belarus. It is perceived as the best preserved fragment of lowland temperate forest that once covered the European Plains. The Polish part of BF (41% of surface area) consists of: a national park (17%), nature reserves (20%) and managed stands (63%). The entire BF is a UNESCO World Heritage Site, whereas the Polish part is also Natura 2000 site (Puszcza Białowieska, PLC200004), a protected landscape area and a Biosphere Reserve. The BF is characterized by many well-preserved tree stands with characteristics of primeval forest: multi-species, uneven-aged, with a high proportion of dead wood and the occurrence of natural gap formation (Jędrzejewska and Jędrzejewski, 1998). It is treated as a forest biodiversity hot-spot with virtually complete sets of ungulate species, predators and old-growth specialists (e.g. woodpeckers or saproxylic insects) representative for temperate lowland forests.

Across this UNESCO World Heritage Site (http://whc.unesco.org/uploads/nominations/33ter.pdf) different protective regimes occur, from the strict protection (UNESCO zone 1), through the partial protection of part of BNP, the nature reserves (zone 2) and the most valuable forest stands outside the reserves (zone 3), to the active protection of the remaining area managed by the State Forests Holding (zone 4). According to the agreement with UNESCO, cutting is only allowed in zone 4. For our analyses, we quantified the impact of logging in these different protective zones (i.e. in total Natura 2000 area and UNESCO zones 1–4). Additionally, we looked at the logging impact in old-growth stands (defined as stands with at least 10% of trees of one species being 100 years old or more), which overlap with the different protective zones, as they are the most valuable tree stands occurring outside the strictly protected area (zone 1).

2.2. Data sources

To perform a three-year (2015.07–2018.06) forest cover change detection analysis we used Sentinel-2 (S2) data which is an innovative wide-swath, high-resolution (10–60 m), multi-spectral satellite with 13 spectral bands launched in June 2015 by the European Space Agency (ESA). Two best, least cloudy S2 scenes (2015.07.25 and 2018.06.09) were selected and downloaded from the Copernicus Open Access Hub (https://scihub.copernicus.eu/). We focused our change detection exercise on forest stands, excluding all open areas and non-forest vegetation. To develop a high resolution forest mask we performed a supervised classification of S2 image from 2015 using the Support Vector Machine (SVM) classifier (see the online Appendix).

2.3. Forest cover change detection

For a change detection analysis we used the iteratively re-weighted Multivariate Alteration Detection method (iMAD), followed by the Maximum Autocorrelation Factors (MAF) post-processing (Canty, 2014). The first three MAF variates were used in the supervised classification (SVM) of the observed types of forest cover change. We distinguished two classes of forest cover change; 1) resulting from logging (both clear-cuts and selective logging) or natural gap formation, 2) resulting from forest stand defoliation caused, in the case of BF, primarily by bark beetle attack of spruce trees. The third class consisted of the areas where no significant changes had occurred.

In order to map all logging activities in the study area during the observed period it was necessary to distinguish between real logging (clear-cuts and selective logging) and other forest losses resulting from the natural canopy gaps dynamics. A parameter helpful in separating these two types of events is the size of each forest loss polygon. To find an objective threshold value for this parameter we compiled the histogram of the sizes of all forest loss polygons detected within the protected zones (zones 1 & 2, Fig. A5). This reference area includes the nature reserves and BNP, all by definition excluded from the logging activity. As we were aware of safety logging activity along the road in one nature reserve ("Szafer's Reserve") we excluded it from our consideration. Finally, we chose a 0.95 quantile of the compiled reference distribution of forest loss areas (Fig. A5).

We have to note that our threshold-based method to identify forest loss areas caused by logging does not account for new, relatively large windthrow areas that emerged during the study period. We identified one extreme storm event during the study period (2017.08.27) that locally affected the south-western part of the study area. However, based on data provided by the State Forest Holding and photo-interpretation of pre- and post-event satellite images we estimated the total area of windthrow areas classified as forest loss and larger than the estimated threshold (i.e. 0.2449 ha) to be 5.48 ha which corresponds to only 0.8% of all forest loss areas included in our landscape analysis. The rest of identified windthrow areas were smaller than the threshold or were classified by our change detection algorithm (1 year after the disturbance) as defoliated forest stands (dead trees), likely because of a large amount of dead wood accumulated on the ground.

2.4. Landscape analysis

Based on the results of change detection analysis we estimated the direct area loss of forest due to recent loggings (see an example on Fig. 1) and indirectly affected forests according to different ranges of (cumulative) impact zone, assuming buffers around the logged areas of radius 10, 50, 100 and 500 m. We use those measurements to provide opportunity to discuss the impact of loggings exceeding the actual clear-cuts including the disturbance effects of forestry machines used to perform current felling and removal of trees and future silvicultural measures (e.g. soil scarification, planting, thinning), negative edge effects and the loss of core areas with forest interior conditions. Although