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Clearcuts and related secondary dieback undermine the ecological effectiveness of FSC certification in a boreal forest

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Abstract

Background: Over the last 25 years, the prominent forest certification system established by the Forest Stewardship Council (FSC) has been used by many companies worldwide for claiming responsible forest management. The objectives of the Russian National FSC standard to decrease the size of clearcuts and the retention of forest elements such as residual seed trees need on-site validation to prove the effectiveness of FSC. To assess the ecological impacts of harvesting practices and benefits of FSC certification, we geospatially compared logging activities with and without FSC certification. Within a sample area covering approximately 3,000 km² in the east of the Russian Arkhangelsk Region, we used available data on tree cover loss and satellite images to assess secondary impacts of clearcuttings on adjacent remnant forests and to quantify the logging intensity. Additionally, the size and structure as well as the density of skidding trails of ten specific clearcuttings located within the sample area were surveyed using satellite images and in the field observation to delineate the boundaries of clearcuts and forested remnants within the clearcuts.

Results: We found a significant increase of small-scale tree cover loss in the proximity of the clearcuts. Patchy dieback is possibly linked to the scale and intensity of logging in the surroundings. On the investigated clearcuts, FSC failed to reduce the size, to increase the retention of forest remnants including seed trees on logged areas, and to maintain larger tracts of undisturbed ground and soil compared to clearcuts that were logged before they received FSC-certification.

Conclusions: Trees and forest remnants remaining inside an increasingly stressed forest ecosystem matrix may not resist further harvesting-related and climate change-induced stresses and disturbances. Large-scale clearcuttings seem to have negative impacts even in adjacent forests and undermine the ecological effectiveness of FSC certification in the study area. The Russian FSC standard is not clearly setting effective guidelines that induce a change in clearcutting practices in order to reduce ecological risks.

Keywords: Ecological effectiveness, Impact assessment, Forest certification, Sustainable forestry

Background

Commercial timber extraction has profound impacts on forest ecosystems by causing a deterioration in structure and function, which inevitably affect the provision of other ecosystem services (Thompson et al. 2011; Miura et al. 2015). Biodiversity and especially the number of

forest-dependent species decline as intact forests are lost (Hanski and Haila 1988; Hanski and Ovaskainen 2000; Schmiegelow and Mönkkönen 2002). Forest fragmentation, habitat loss, and deteriorated forest functionality change soil nutrient status and its ability to support plant growth and food supply for animals along the food chain (Bradshaw et al. 2009). Currently, intact boreal forest landscapes cover about one third of the world's remaining forests and are characterized by vast areas with least human-induced disturbances and immense

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carbon sequestration (Bradshaw et al. 2009; Gauthier et al. 2015). The Russian Federation holds a large part of intact forest landscapes on its territory but at the same time suffers from rapid loss of such valuable forests due to economic activities as well as anthropogenic forest fires (Potapov et al. 2008, 2017). Efforts towards proactively preventing the loss of and prioritizing the conservation and restoration of intact forests are of global concern for biodiversity, climate, and sustainable development (Watson et al. 2014).

Forest certification systems were developed since the 1990s to safeguard biodiversity and ecosystem functions and have operated as market-based and voluntary schemes to promote and label more sustainable forest exploitation and at the same time tried to reconcile economic interests and social responsibility (Rametsteiner and Simula 2003; Auld et al. 2008). Over the last 25 years, the Forest Stewardship Council (FSC) established internationally a prominent certification system used by many companies in the timber business for claiming timber and woody products as responsibly produced. The FSC has gained global recognition and was approved as a measure for accomplishing at least 11 goals and 35 targets within the framework of the Sustainable Development Goals (SDG) (FSC 2016a; Ugarte et al. 2017). Despite considerable public, political, and scientific interest to understand and evaluate the effective impact of FSC around the globe, there are only few findings to show the benefits it provides for forest ecosystems (Blackman and Rivera 2010; Marx and Cuypers 2010; Blackman et al. 2015; Burivalova et al. 2017). The effectiveness of forest certification can be defined as the success of changing and mitigating negative environmental and socio-economic impacts caused by forestry (Gulbrandsen 2005).

Almost 200 million ha of the world's forest distributed across 83 countries are FSC-certified, and the Russian Federation boasts greatest coverage with more than 45 million hectares (FSC 2019). In the north west of the Russian Federation, in the Arkhangelsk Region, extensive areas of boreal forest are under certification that goes back many years encompassing almost all big companies (Lukashovich et al. 2016). The extent of forest brought under FSC certification has steadily increased since the scheme was first introduced to the region in 2004 (Blumroeder et al. 2018). Typically, forest in the Arkhangelsk Region is harvested under a clearcut regime and involves clearcuts of up to 50 ha in production forests (McDermott et al. 2010). Large areas of forest clear-felled in adjacent squares give rise to large "chequerboard patterns" clearly visible in satellite images (Blumroeder et al. 2018; Potapov et al. 2017; Potapov et al. 2009; Naumov and Angelstam 2014). The practice of clearcutting is endorsed by Russian forest legislation, and it can include primary forest. In the

Arkhangelsk Region, private enterprises conduct clearcuttings in pristine boreal forest ecosystems (Achard et al. 2006). Forest cover in Russia has changed rapidly and extensively over the last decades as a consequence of commercial timber extraction especially in European Russia (Achard et al. 2006), and future projections are for further tree cover loss (Hewson et al. 2019).

Clearcuttings are typically conducted using modern harvesters and skidding machinery to cut and extract timber. Mechanical disturbance due to tree harvesting operations alters the physical structure and chemical composition of forest soils to the extent that it can take more than 100 years to recover (Dymov 2017). Heavy machinery impacts the soil morphology and causes soil compaction and loss of porosity; under these conditions, aeration, water absorption, and retention are diminished, which can reduce forest function and productivity (Startsev and McNabb 2009; Cambi et al. 2015). Increased water runoff can contribute to soil erosion while exposed soils show higher temperature and are more likely to emit carbon (Tan et al. 2005). Forestry, and clearcutting in particular, reduces microbial and fungal biomass in soil (Tan et al. 2008; Holden and Treseder 2013). The root system and growth of plants is disrupted by soil compaction with associated changes in ion uptake (Nawaz et al. 2012).

The Russian National FSC Standard advises reducing the size of clearcuts to maintain ecosystem functioning, but clear and binding thresholds are not given in the set of Principles, Criteria, and Indicators (Blumroeder et al. 2018). Tree cover loss is a suitable indicator for quantifying timber harvesting activities, but was shown not to be influenced by FSC in the Russian Far East (Nikolaeva et al. 2019). Almost 1 million hectare of the Arkhangelsk Region was affected by tree cover loss by 2014, of which more than half was recorded within concessions that had been FSC-certified at least once up to 2016, including logging prior and during FSC certification, while least tree cover loss was found in non-certified areas, in contrast to losses in certified forests (Blumroeder et al. 2018).

The present study was carried out to test the postulated outcomes and underlying assumptions of a *Theoretical Plausibility Analysis* (Blumroeder et al. 2018), and to complement an *Empirical Plausibility Analysis* (Blumroeder et al. 2019), which was undertaken earlier to assess the ecological effectiveness of FSC certification in a case study located in the Arkhangelsk Region. For example, the FSC-Indicator 6.3.7 invites the hypothesis that clearcuts are smaller in size when harvesting is operated under FSC and reads as "The organization shall have a program to switch over from large-scale clearcuts to narrow clear-strip clearcuts and/or small-size clearcuts (up to several hectares), shelterwood (multistage) cuts and/or selection cuts in forest types where it is feasible" (FSC 2012). Concretely, this

study spatially assesses the impact of FSC certification by comparing tree cover loss and logging activities in certified areas with non-certified forest operations at two different spatial scales: (1) analyzing secondary impacts of clearcuttings on adjacent remnant forests and quantifying logging intensity in a sample area and (2) assessing the size and exhaustiveness of clearcuttings as well as the density of skidding trails within clearcuts.

Methods

The Arkhangelsk Region is located in the northwest of the Russian Federation and covered by a complex network of rivers and mires surrounded by an extensive forest area (Yaroshenko et al. 2001). The forest is of primary origin with large areas remaining intact and dominated by native spruce and pine species (Yaroshenko et al. 2001). Forestry is the main source of the economy in the region, and most of the activities are carried out in primary forests (Kobyakov and Jakovlev 2013; Angelstam et al. 2017). Timber harvesting is mainly conducted as clearcuts of up to 50 ha in compliance with the Russian forest legislation, also in primary forests, with severe negative ecological impacts (Blumroeder et al. 2018; Potapov et al. 2017; Potapov et al. 2009). In this study, clearcut is defined according to FSC as “harvesting in a designated area with retention of individual trees and shrubs (groups of trees and shrubs) to ensure forest regeneration” (FSC 2012).

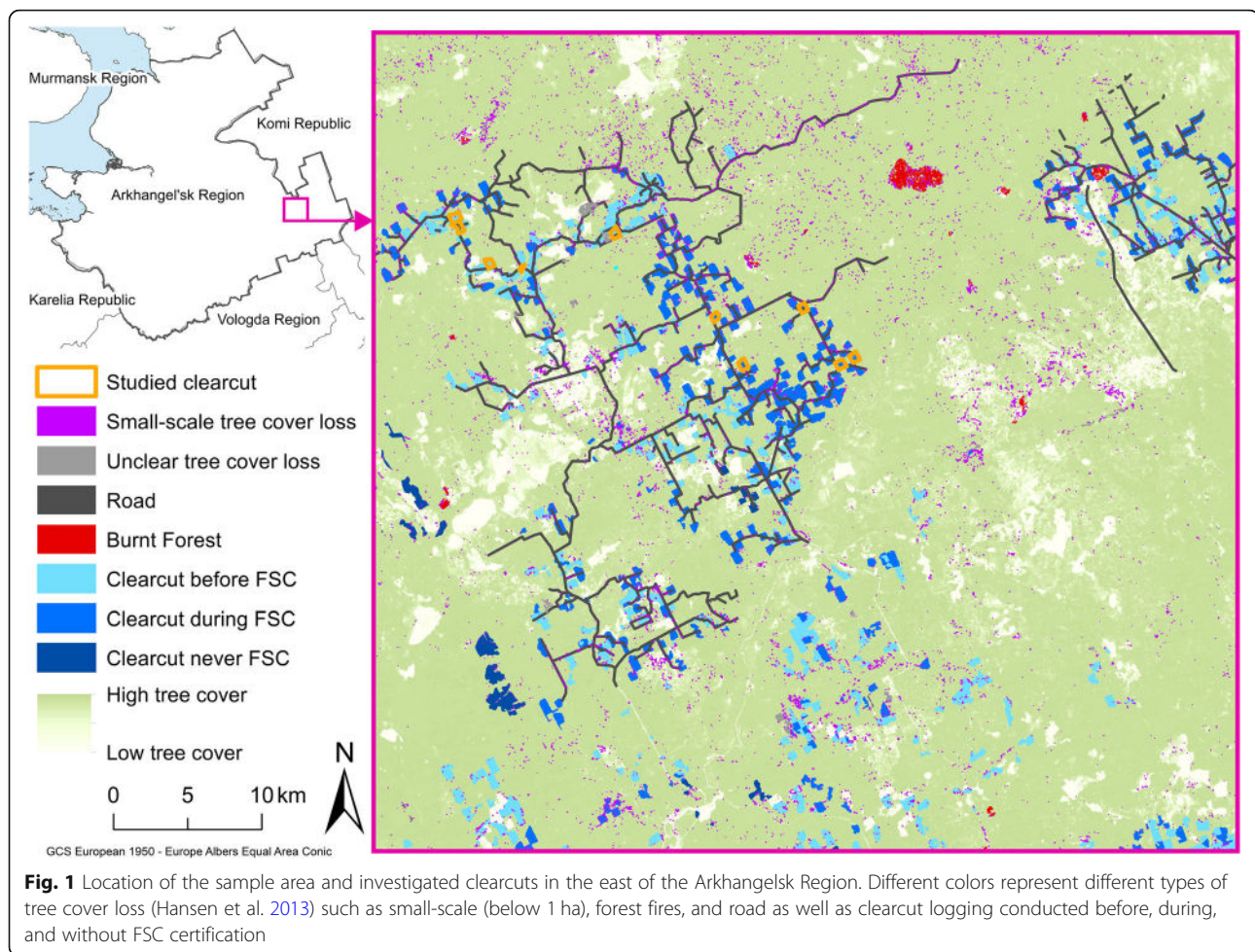
In this study, information on the spatio-temporal distribution of FSC-certified forests in the Arkhangelsk Region as of May 2016 (FSC Russia and Transparent World 2016) was processed after revising issue dates of each certificate holder according to publicly available certificates (FSC 2016b). FSC-certificates are valid for a period of 5 years and terminated if renewal was not requested by the concession holder. Non-compliance with the standard requirements detected during annual surveillance audits can result in certificate suspension. In the Arkhangelsk Region, FSC-certification started in 2004 with two concession holders and proceeded to 41 certified concession holders in 2016. Due to termination or suspension of FSC-certificates, some logging companies were not certified permanently and constantly (Blumroeder et al. 2018).

In this analysis, we distinguished between areas with no history of certification (*non-FSC* in the following) and forests that had been managed before they became certified (*before-FSC* in the following) and subsequently under FSC (*during-FSC* in the following). Within a sample area delineating approximately 3000 km² in the east of the Arkhangelsk Region, data generated by Hansen et al. (2013) on changes in global forest cover between 2001 and 2014 was used to calculate annual tree cover loss and the size of clearcuts in relation to the

certification status. Previous studies showed that the sample area and clearcutting is typical for the region's forestry operations (Karvinen et al. 2006, 2011; Greenpeace International 2014, 2017; Blumroeder et al. 2018, 2019). Within the sample area, tree cover loss was classified manually from high-resolution (between 41 cm and 100 cm resolution) observation of Google Earth Pro satellite images (Google Earth Pro 2018) into five different categories according to their shape, structure, and size as follows: (1) clearcut logging (geometric quadrangle of cleared forest with visible signs of logging operations such as tree stumps and skidding trails), (2) forest fires (irregular burnt patches), (3) roads (straight lines), (4) diffuse small-scale canopy loss (covering less than 1 ha), and (5) undisturbed forest (no apparent canopy disturbance) (Fig. 1).

All logging activities within the sample area were conducted as clearcuts by three different concession holders. During the period of study, one company was never FSC-certified (*non-FSC*), while another two became certified and comprise clearcuts that were logged prior to certification (*before-FSC*) and while they were FSC-certified (*during-FSC*). The mean area logged was calculated as the annual mean area of clearcut in relation to the area covered by the concession and compared with the status of certification at the time of logging. Records of tree cover loss during the initial and final year of certification were excluded from the analysis to reduce uncertainty, as definite assignment to *before-FSC* or *during-FSC* seemed impossible. Furthermore, within the range of 1 km around each clearcut ($n = 1096$), the spatial distance to neighboring small-scale tree cover loss polygons that occurred in the subsequent years ($n = 4641$) was determined. Spearman correlation coefficient was calculated to test the spatial interrelation between the clearcuts and the patches smaller than 1 ha.

In addition, a total of ten clearcuts which were also object of a previous study (compare a related study conducted on the same clearcuts Blumroeder et al. 2019) were scrutinized more specifically. The studied clearcuts were randomly selected within two neighboring logging concession holders who were cooperative in providing study plots but wished to remain anonymous. Clearcut harvesting was carried out between 2009 and 2011, while one company was applying FSC (certified since 2006 and thus cut during-FSC) and the other was operating without FSC (certified since 2013 and therefore logged before FSC was implemented). The edges of each clearcut, the alignment of skidding trails, and the configuration of forest remnants (defined as different types of forested patches within a clearcut, including the so-called seed trees, group of trees, key biotopes, and immature forests) were mapped and delineated using data on tree cover loss (Hansen et al. 2013), satellite images



(Google Earth Pro 2018), and obtainable forest management plans. Results for remote spatial analysis were subsequently followed-up with in-field verification in July 2017 using GPS tracking. To calculate the mean distance between skidding trails, a point matrix was created with points set at equidistance along the skidding trails. The distance between the skidding trails was calculated as mean distance between two points of neighboring trails.

All data processing and statistical analyses were performed in ArcGIS (ESRI 2011) and RStudio Version 1.1.456 (R Development Core Team 2018). Non-parametric statistical Kruskal-Wallis and subsequent Conover post hoc test were applied as alternative to ANOVA using the package PMCMR to test for differences between groups (Pohlert 2014).

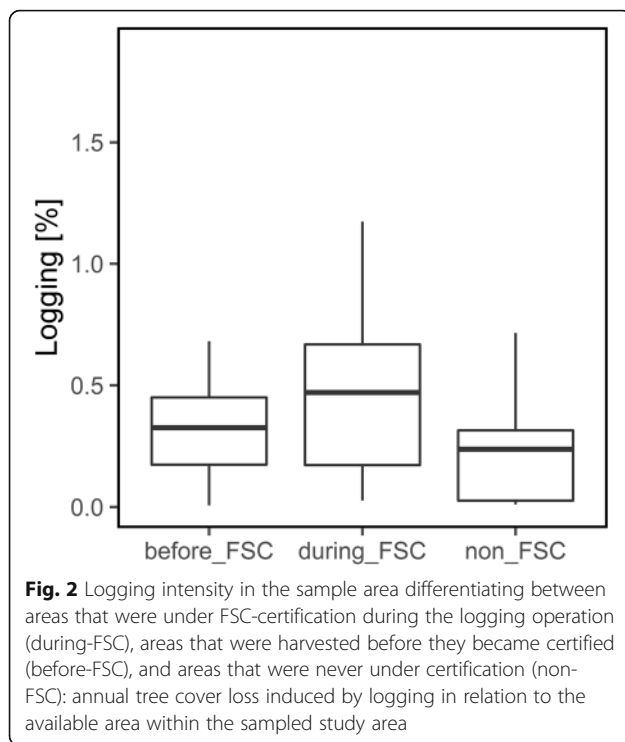
Results

A comparison between FSC-certified and uncertified forest using data on the proportion of annually logged to untouched areas within the concessions revealed no significant difference (p value = 0.30) (Fig. 2).

Within the sample area, a significant, strong, and negative correlation between large-scale clearcuts and small-scale tree cover loss of less than 1 ha was detected, meaning that in the vicinity of large-scale patches of tree cover loss (including clearcuts), additional diffuse small-scale tree cover loss occurred ($r = -0.89$; p value < 0.001) (Fig. 3). Equally, the extent of the area affected by small-scale tree cover loss was higher in areas closer to the larger tree cover loss polygons ($r = -0.9$; p value < 0.001).

The spatial dimension of the ten randomly selected clearcuts was approximately 30 ha on average (before_FSC: mean = 27.74 ha, median = 32.83 ha; during_FSC: mean = 30.12; median = 32.20 ha) without significant difference between clearcuts harvested before and during FSC-certification (p value = 0.46). However, *before-FSC* clearings varied much more in size, also comprising the smallest clearcut of 7.6 ha (Fig. 4).

There was no evidence within the sampled area to indicate that the retention of forest remnants within the studied clearcuts increased in forests during-FSC (p value = 0.77). In both certified and uncertified clearcuts, up to 97% of the area was completely cleared (Fig. 5).



On two of the studied clearcuts that were cut during valid FSC-certification, 20% of tree cover was retained on logged sites covering immature forest with little economic value. In the case of one site that was logged before it was registered under FSC, more than 17% of the forest cover was spared from felling because of the presence of key biotopes and seed trees, while on other clearcuts, less than 7% of the initial tree cover was retained.

All skidding trails on the ten clearcuts were covered with felling residues as soil protection measure. The certification of forest under FSC made no significant

difference to practices of harvesting and removal of trees and across the landscape skidding tracks were spaced on average less than 20 m apart (p value = 0.5) (Fig. 6).

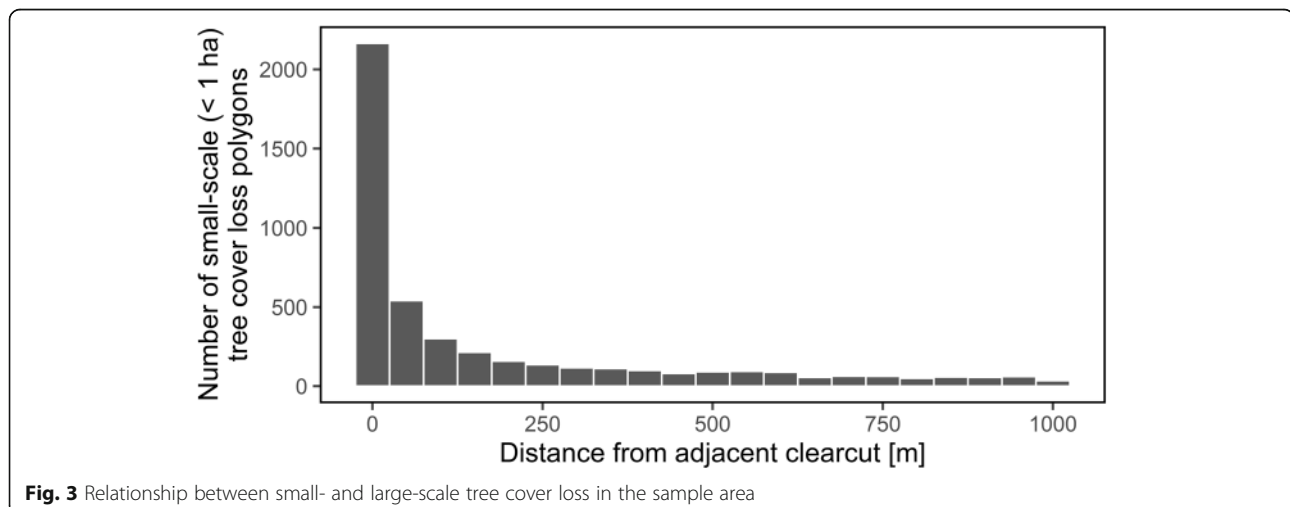
Discussion

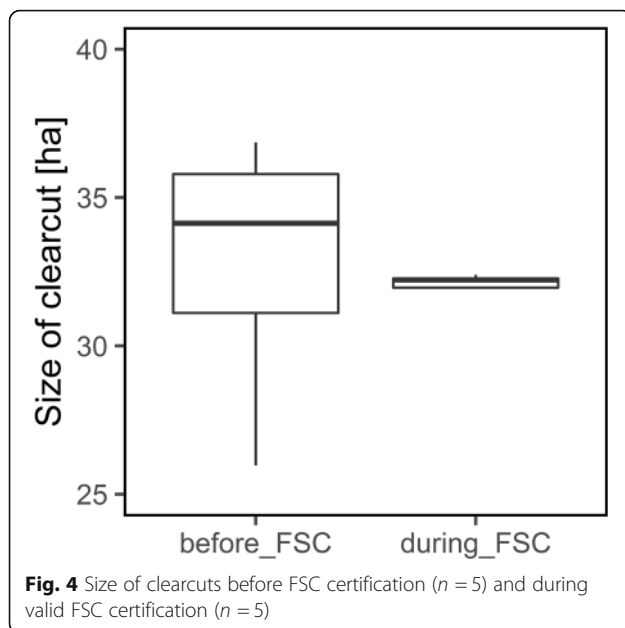
In this study, there was no evidence to indicate that FSC certification of forests leads to changes in harvesting practices in the studied clearcuts in the east of the Arkhangelsk Region. The extent of tree cover loss after the introduction of FSC remained equally high compared to as it was prior to certification or without certification within the sampled area. The results confirm the findings gained by Nikolaeva et al. (2019) showing that FSC certification did not induce changes in tree cover loss in the Russian Far East. The sixth FSC Principle, including FSC indicator 6.3.7, seems to be the most problematic in terms of non-compliance that was detected during audits (Lukashevich et al. 2016). The results are also in accordance with the findings of a previous study showing that FSC did not reduce annual tree cover loss (Blumroeder et al. 2018).

Our findings indicate that FSC failed to do the following:

- (1) Reduce the size of clearcuts significantly;
- (2) Increase the retention of seed trees on logged areas;
- (3) Maintain larger tracts of undisturbed ground and soil on the investigated study sites and clearcuts represented by less skidding trails.

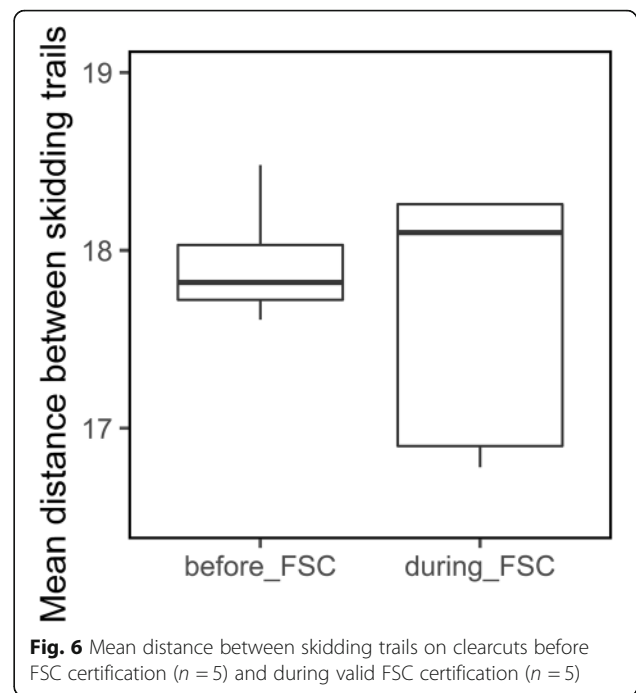
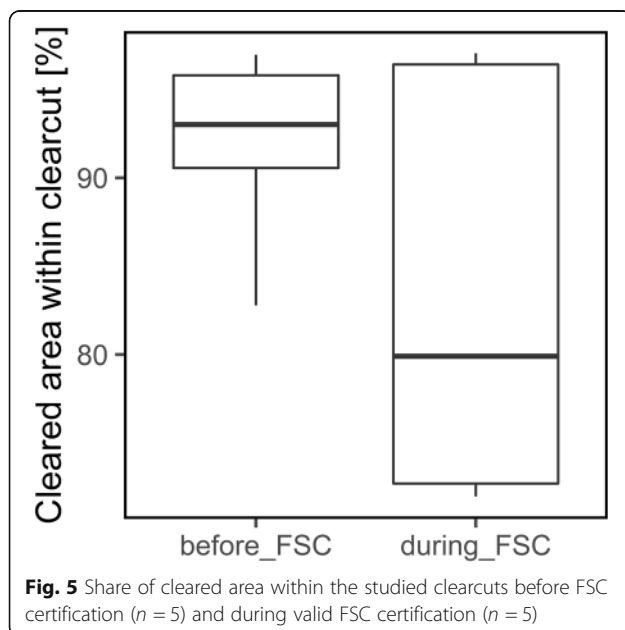
The practice of removing almost all economically profitable wood also contributes to further indirect effects of forest degradation and fragmentation, for example, an increase in edge effects as a result of opening the forest up to higher exposures of sunlight, wind, increased temperature variation, and other disturbances





(Greenpeace International 2014; Schmiegelow and Mönkkönen 2002). Dramatic changes in forest patch dynamics towards larger, geometrical patterns may contribute to tree mortality and decreased food availability along the edges (Schmiegelow and Mönkkönen 2002).

The observed diffuse small-scale tree cover loss deserves special attention. In these remote inaccessible and uninhabited areas, it is unlikely that it is related to tree felling or direct anthropogenic interventions. Rather, it is plausible that it can be attributed to dieback of desiccated, flooded, infested, or windthrown trees. Apart from obvious natural dieback and gap formation, we observed



further small-scale dieback in forest adjacent to clearcuts, which had not been included in harvesting activities. As the findings indicate, within a 1-km range around the clearcut range, a clear spatial relationship exists between diffuse dieback and larger clearcut areas. It is likely they represent secondary impacts of clearcuttings spreading into neighboring stands. There is evidence that edge effects can reach hundreds of meters inside the remaining forest ecosystem (Laurance 2000; Ries et al. 2004). Changes in both micro- and meso-climate, such as greater fluctuations in temperature and elevated maximum temperatures, possibly causing and interacting with hydrological changes, would increase vulnerability in trees already growing under extreme conditions (Blumröder et al. 2019). Not only the direct loss of tree cover within cleared forest areas, but also the catalytic losses in remaining untouched forests due to fragmentation and increased forest edges is known to threaten the maintenance of forest functions and the stability of the ecosystem (Riitters et al. 2016). So far, these indirect effects caused by the anthropogenic manipulation of the boreal forest ecosystem are insufficiently understood and can represent an enormous risk that was masked for a long time, when cuttings were smaller and less frequent and when climate was more moderate. The large-scale clearcuts could have the potential of driving irreversible changes of the mesoclimate, thus increasing the vulnerability of both uncultivated and legally protected forests. The diffuse dieback in unused areas next to clearcuttings could increase their burnability and the corresponding risk of further indirect anthropogenic degradation.

Clearcutting and concomitant mechanical disturbances by harvesting practices impact soils drastically, so much so, that scientists have classed these damaged soils as detritus turbozems (Dymov 2017). The combined effects of microclimatic and soil changes induced by the practice of large-scale and intensive “timber mining” can hamper natural forest succession and regeneration and create a long-term legacy of forest loss. In forest areas under FSC certification, the density of skidding trails within the studied clearcuts was not reduced. The initial ride on the forest floor has the most severe impact on the soil, especially on the topmost layer, while the wheel rut is impacted most (Tan et al. 2008; Cambi et al. 2015; Abdi et al. 2017). A combination of factors such as soil conditions and hydrology, as well as frequency and weight of mechanical disturbance, causes soil compaction that can take decades to recover (Cambi et al. 2015).

Tree retention can help to increase structural diversity of clearcuts to support biodiversity (Lindenmayer and Franklin 2003). Furthermore, increasing the level of retention enhances carbon storage (Santaniello et al. 2017). However, in our study, forest practices under FSC did appear to reduce the size range of forest clearings, but not the number of remaining trees or retained forest patches within the clearing. Larger volumes of remaining tree biomass would provide stronger support for biodiversity in terms of available habitats and regarding a reduction of severe threats to biota, but certain quantities of remaining biomass on clearcuts cannot substitute functions and services provided by primary forests (Gustafsson et al. 2010). The ecological effectiveness of voluntary set-asides is often poor, as mostly immature stands are spared from felling and because the structural and functional connectivity of forest ecosystems needed to maintain biodiversity are not considered (Elbakidze et al. 2016).

One of the main drivers for forestry companies in the Russian Northwest to engage with FSC is the increased access and sale to European markets (Rametsteiner and Simula 2003; Blackman and Rivera 2011; Romero et al. 2013; Henry and Tysiachniouk 2018). The attractions of lucrative markets in countries where there are strong public concerns for the environment encourages forestry companies to operate intensively under the umbrella of FSC. There is evidence to suggest FSC certification can even increase the rate and intensity of forest exploitation due to the high incentive for timber exports and sales market. This is also known from other biomes. For instance, in the Congo basin, tree cover loss in intact forest landscapes was higher in certified compared to non-certified concessions (Kleinschroth et al. 2019).

Conclusions

In order to induce quantifiable changes of the logging practices and safeguard ecosystem functionality, i.e., to

increase the ecological effectiveness of FSC, current clearcutting practices would have to be replaced. The overexploitation of provisioning services, i.e., timber extraction, diminishes the ecosystems' capacity to maintain other services of global significance. It also reduces the ecosystem functionality important to cope with and adapt to other stresses and disturbances that are increasing under rapid climate change. In combination with earlier assessments (Blumroeder et al. 2018, 2019), this study confirms doubts that the Forest Stewardship Council is an appropriate mechanism for safeguarding ecologically responsible forest use in Russian forests. The Russian National FSC Standard fails to induce ecologically friendly cutting and harvesting methods in the studied area. As reaction to our earlier papers, FSC (Germany) accepted to a certain degree this critique (e.g., in *Holz-Zentralblatt* 30, 26 July 2019), but pointed out that an environmental benefit would be the protection of 19% of the certified forests in Russia. Still, it was impossible to obtain spatial data from FSC that would confirm that such a value also applies to the Arkhangelsk Region. Furthermore, it was impossible to verify if the mentioned protected areas covered only forests, or also included (unexploitable) non-forest areas such as mires, and if the legal protection was permanent and independent from the period of certification. Fundamental questions to be raised refer to the burden of proof as well as to FSC's transparency policy. But even if long-term set-aside of forests in the vicinities of the clearcuttings was confirmed, their effectiveness has to be assessed in the light of apparent edge effects and secondary dieback potentially triggered by large-scale clearcutting practices.

Abbreviation

FSC: Forest Stewardship Council

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Authors' contributions

JSB led the methodological development, coordinated the fieldwork, conducted the data analyses and interpretation, wrote a first draft, and compiled the final manuscript. MH and OI prepared and processed the spatial data. OI and SW conducted the data collection in the field. PH revised the manuscript. PLI, SW, and JSB co-conceived the study; PLI supervised it as senior author, especially participating in the methodological development, interpretation of the results, and writing. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets analyzed in the current study are available in the Hansen/UMD/Google/USGS/NASA repository, Hansen, M.C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. a, Tyukavina, A., Thau, D., Stehman, S. V, Goetz, S.J., Loveland, T.R., Kommareddy, A., Egorov, A., Chini, L., Justice, C.O., Townshend, J.R.G., 2013. High-resolution global maps of twenty-first century forest cover change. *Science* (80-). 342, 850–853. doi:<https://doi.org/10.1126/science.1244693>. https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.5.html and FSC Russia, Transparent World <https://ru.fsc.org/download-box.1778.htm>.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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