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EFFECT OF WATER LEVEL CHANGE ON RADIAL INCREMENT OF SCOTS PINE IN A RESTORED PEATLAND IN ESTONIA

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SUMMARY

The study focuses on long term changes in annual radial increment of pines (*Pinus sylvestris*) at Laiuse Bog. This is an abandoned peat extraction site in East Estonia where an experiment of peatland restoration is going on since 2019. We studied effect of water regime change on tree growth along a gradient of water table from abandoned and restored peatland area to the pristine parts of the peatland. The peatland has been drained in its northern part for peat extraction. Mining activity was ceased in 1996 and the peatland was left for natural regeneration. Since 2019 water level was raised as a result of peatland restoration. Tree-ring samples were collected in autumn 2019 from five different sections of the peatland. At the former peat extraction area samples from stumps (cross sections) and living trees (by increment borer) were collected. The second sample set was collected from pines growing next to the ditch surrounding the extraction site. The third set was collected at distance of 150 m from the drainage ditch. Fourth sample set consists of cores collected from the pristine part of the peatland. An additional sample set represents a pine stand in the southern part of the peatland near the bog lake. This site was unaffected by peat extraction but should reflect a dated event of water level lowering in the lake. Tree-ring widths of pines were measured and the increment series were analysed to establish the effects of anthropogenous disturbances. The results show difference in reaction in annual increment to various kinds of manipulated water regime.

***Keywords**: Climate, dendrochronology, water regime, tree ring, peat extraction site*

INTRODUCTION

Peatlands provide many important ecosystem services such as carbon sinks, water reservoirs and habitats (de Groot et al. 2012, Taminskas et al. 2019, Edvardsson et al. 2019). It is estimated that about 22.3% of Estonia (Orru and Orru 2008) and 12.3% of the Baltics are covered with peatlands (Taminskas et al. 2019). Over the last century peatlands have been under heavy human influence, mainly by draining (Edvardsson et al. 2019). It is estimated that about 70% of peatlands in Estonia have been influenced by drainage or other activities (Vasander et al. 2003, Paal and Leibak 2011). The main activities influencing peatlands in Estonia have been forestry, agriculture and peat-harvesting (Vasander et al. 2003, Masing et al. 2010). Peat harvesting started in the 17th century. By the beginning of 19th century draining and burning mires were one of the most common agricultural practices (Vasander et al. 2003). Previous studies have shown that drainage increases tree growth and thus annual tree rings (Macdonald and Fengyou 2001, Choi et al. 2007). This study focuses on spatial and temporal relations between anthropogenic changes in water level and annual tree-ring growth in a raised bog covering full sequence from natural status to drainage and peat extraction, abandonment and restoration of the bog.

MATERIALS AND METHODS

The study area is located in Laiusevälja Village in Jõgeva County in Eastern Estonia. The area is on the northern part of the old Kivijärve peat deposit in the Laiuse Bog. Mining activity was ceased there in 1996 and the peatland was left for natural regeneration (Ramst et al. 2006). The bog area is 1066 ha and of that37.38 ha was the former milled peat extraction area (Orru et al. 2020). Since 2013 there was a raise in water level in the southern part of the abandoned extraction site due to beaver activity. Since 2019 water level was raised because of the restoration of the peatland.

On the southern border of the study area lies Lake Kivijärv. The lake had its water level lowered in the 1920s and during the 1950s the lake almost overgrew (Kalapeedia). There was also a second attempt in lowering the lake's water level in 1973 (Maaparandussüsteemide register). Nowadays the lake has an area about 20 hectares (Otsmaa 2017). Since the 19th century the lake has lost most of its volume and nowadays only the former deepest part of the lake remain (Kalapeedia).

Tree-ring samples of pine trees (*Pinus sylvestris*) were collected in October 2019 from five different sites of the Laiuse peatland (Figure 1). At the former peat extraction area samples from stumps (cross sections) and living trees (by increment borer) were collected. Only core samples were collected from other study sites. The second sample set was collected from pines growing next to the ditch surrounding the extraction site. The third set was collected at a distance of 150 m from the drainage ditch. These three study sites were assumed to be most affected by the lowering of water level in the former peat extraction site. The fourth sample set consists of cores collected from the pristine part of the peatland. An additional sample set represents a pine stand in the southern part of the peatland near the bog lake. This site was unaffected by peat extraction but presumably reflects a dated event of water level lowering in Lake Kivijärv.

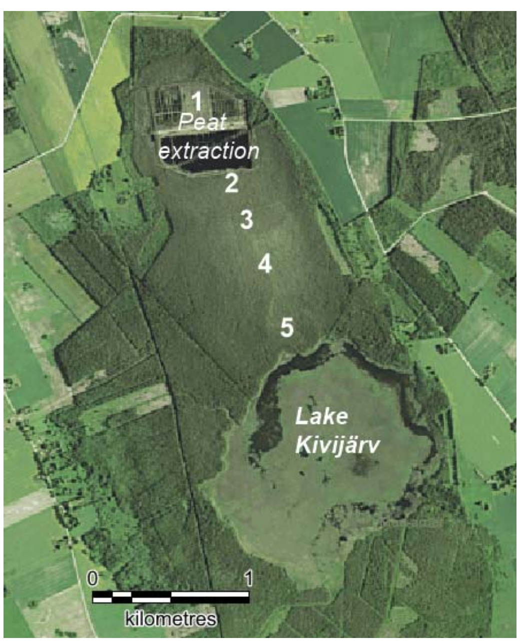

Figure 1. Study area in the Laiuse peatland and location of the sample sites (numbered).

Tree-ring widths of pines were measured and the increment series were analyzed to establish the effects of anthropogenic disturbances. Except for the tree stumps the samples were collected at about half a meter from the ground. The widths of tree rings in the samples were measured with a LINTAB measuring device and Leica S4E microscope. Each sample was measured from two opposite radii – from bark to pith. The TSAP-Win™ program was used for recording the tree-ring widths. From each site at least 12 samples were collected. For every study site a synchronized tree-ring chronology was composed with at least two trees (Figure 2). These chronologies were later compared with each other and analysed using historical records about water level manipulations in the area.

RESULTS

In the first site the seven samples collected with increment borer were up to 15 years long (Figure 2). The trees started to grow randomly in that area after the peat extraction stopped on the site in the 1990s (Figure 1). The average tree-ring width in sample site was 3.37 mm.
In the second site the chronology consists of seven increment borer samples and is 43 years long. Average tree-ring width for the samples was 2.06 mm. The average tree-ring width in the site is declining since the 1990s (Figure 2).
The tree-ring width chronology for the third study area consists of seven tree-ring width chronologies. The length of the chronology is 172 years, with the average tree-ring width of 0.61 mm. Trees from that site show an increase in tree-ring widths from the middle of 1970s till the middle of 1980s (Figure 2).
The fourth study site tree-ring chronology consists of nine samples and the length of that chronology is 157 years. The average tree-ring width for the area was 0.47 mm. An increase in tree-ring growths is visible between the years 2011-2015 (Figure 2).
The fifth site's synchronised and averaged chronology consists of eleven tree-ring chronologies. The chronology is 115 years long. The average tree-ring width for the samples was 1.31 mm. The results show an increase in tree-ring widths in 1930s and in 1970 and followed by steady decreases shortly after that. Small peaks in 1980s and 1990s are also clearly visible (Figure 2).

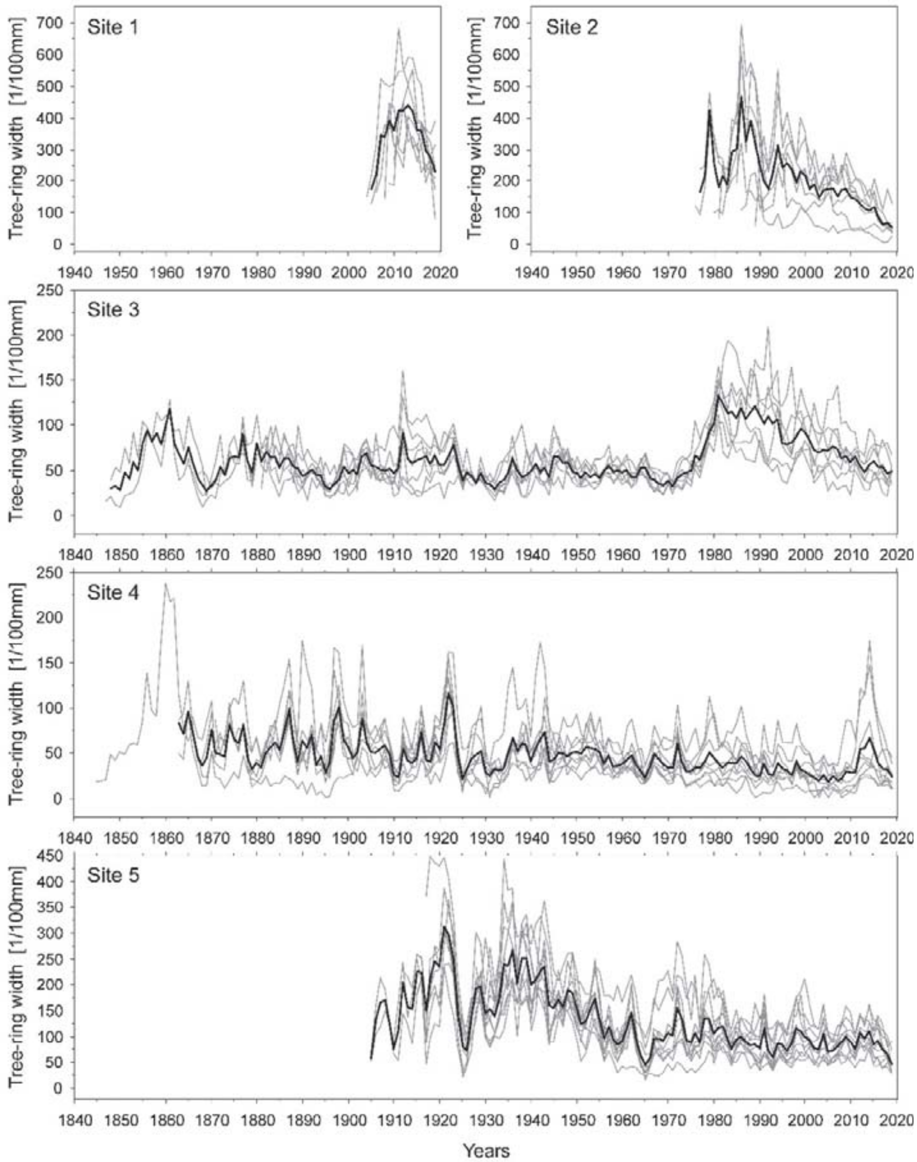

Figure 2. Tree-ring widths of pines (gray lines) and the average chronologies (black lines) in the study sites.

DISCUSSION

In the first study area there is no visible correlation between the individual samples collected in the area (Figure 2). That is because of the young age of the sample pines and differences in their individual growth sites. Because of the short age of the sample trees the study area can also not be compared with other study sites.

There is no correlation between second study site and the other sites average chronologies. The samples show a decrease in average tree-ring widths since the 1990s that coincides with the abandoning of the peat extraction site and end of the drainage system functioning. Also, the effect of flooding due to beaver activity in the area can be seen on the last tree-ring widths (Figure 2).

The third study area shows an increase in tree-ring widths from the middle of 1970s till the middle of 1980s (Figure 2). The reason for that increase is the lowering of water level for peat extraction in the nearby area (150–200 meters) (Figure 1). After that, a slow and steady decline in tree-ring widths can be seen which is consistent with raising of the water level due to leaving the former peat extraction site to recover on its own (Figure 2).

The fourth study area was located in the wettest part of the peatland and should not have been influenced by the peat extraction. Growth of pines in this study area should therefore reflect the influence of climatic variables. The tree-ring chronology from that area shows quite steady tree-ring growth. The increase in tree-ring growth in the 2011–2015 period can be explained by warmer seasons (Kotta et al. 2018) (Figure 2).

The chronology from the fifth study site shows the effects of lowering the water level in Lake Kivijärv in the 1928–1929 and the 1973. There can be seen an abrupt increase in tree-ring growth in the 1930s and after that a steady decline. That is due to the lowering of water level by one meter in nearby Lake Kivijärv (Figure 1). The short-lasting decline in growth after 1928 can be explained by the trees' shock to that change. The small peaks in the 1970 and 1980 can be explained by secondary drainage and extensive use of fertilizers and aerial fertilization in the nearby fields (Sults 2003) (Figure 2).

Comparing the site chronologies with each other shows a noticeable correlation between the chronologies of the study areas 3 and 4 (Figure 2). Nevertheless, there is a big difference starting in the middle of 1970s and coinciding with the lowering of the water level in the former peat extraction site. Lowering of the water level affected the third study area by increasing the annual tree-ring growth.

The third, fourth and fifth study area have a common increase in radial growth in the 1920s and a sharp decline shortly after that. This change is to be attributed to climatic effect while the prolonged increase of tree-ring width at fifth study area since 1928 is due to the lowering of water level in the nearby Lake Kivijärv by one meter. All five study sites showed that in the recent years annual tree-ring growth decreased (Figure 2). While decrease is common for all study sites it is more pronounced for sites affected by drainage system of former peat extraction area. The study also indicates that the pines in Laiuse peatland may have a quicker reaction to the lowering of the water level than to the rise. However, that aspect should be further investigated.

CONCLUSION

The study in Laiuse peatland shows that changes in water level influence tree growth substantially. In the first two study sites the influence of drainage from the peat extraction was the most considerable. The third study area was also influenced by drainage in the peat extraction site but with considerable delay due to larger distance. The fourth study site serves as a natural reference with minimal long-term growth variation but revealing climate induced peaks in 1920s and 2011-2015 reflected also in other chronologies. The fifth study site was mostly influenced by changes in water level in Lake Kivijärv. The biggest similarity lay between the tree-ring width patterns of the third and fourth study areas. All five study areas showed a steady decrease in tree-ring growth over the recent years.

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