Extended abstract No. 26

BIOMASS PRODUCTION OF 10 YEARS OLD DOWNY BIRCH (*Betula pubescens* Ehrh.) STAND IN AN ASH-FERTILIZED CUT-AWAY PEATLAND

Noora Huotari[1], Jyrki Hytönen[2], Eila Tillman-Sutela[1], Jorma Issakainen[1] and Eero Kubin[1]
[1]Finnish Forest Research Institute, Oulu Unit, PL 413 (Rakentajantie 3), FI-90014 University of Oulu, Finland
[2]Finnish Forest Research Institute, Kannus Research Unit, Silmäjärventie 2, 69100 Kannus, Finland
N. Huotari, tel.: +358 40 801 5066, e-mail: noora.huotari@metla.fi

SUMMARY

We studied the effects of fertilization on the biomass production and density of downy birch stands in a cut-away peatland. Six treatments of peat-ash, wood-ash, biotite, or PK-fertilizer were used in different mixtures. The biomass and the stem quantity were measured 10 years after fertilization. Ash fertilization increased the stand density more than 2-fold compared to the PK-fertilized areas, and 6-fold compared to the unfertilized area. The leafless above-ground biomass was greatest, 22-23 t ha^{-1}, in the areas where wood-ash, mixed-ash or peat-ash + biotite was applied. Areas fertilized with peat-ash or Forest PK-fertilizer resulted in biomass of 17 t ha^{-1}, whereas the biomass in the unfertilized area was 5 t ha^{-1}. Downy birch comprised the major part of the tree biomass in all the fertilized areas, whereas in the unfertilized areas the biomass was mainly formed by Scots pines.

KEYWORDS: wood-ash, peat-ash, biotite, PK-fertilizer, Scots pine

INTRODUCTION

The demand for bioenergy has increased recently due to the EU's target to reduce greenhouse gas emissions. The national target set for Finland is to produce 38 % of the final energy consumption from renewable sources by 2020 (Ministry of Employment and the Economy 2010). In 2010, 22 % of the Finland's total energy consumption was produced by wood-based fuels (Official Statistics of Finland, 2010). Consequently, wood plays a leading role in attempting to reach the EU's target. At the moment the largest share of domestic forest biomass in Finland originates from logging residues of final fellings (Röser *et al*., 2008). Recently also interest in the establishment of dense energy wood plantations in short rotations have increased.

In addition to wood, also peat is an important domestic fuel in Finland. In 2010 about 7 % of the Finland's total energy consumption was produced by peat (Official Statistics of Finland 2010). At present, peat is harvested on an area of about 60 000 ha and it is estimated that 3 000 ha of cut-away peatlands are abandoned by the peat industry annually (Turveteollisuusliitto). Without active measures these cut-away areas may remain non-vegetated even for decades after the peat harvesting has expired (Lavoie *et al*., 2005; Huotari *et al*., 2007). One alternative for further land use of these areas is to produce bioenergy with dense tree stands. However, since the residual peat layer on cut-away areas is typically rich in organic nitrogen (N), but poor in mineral nutrients, especially increasing soil stores of phosphorus (P) and potassium (K) (Paavilainen and Päivänen, 1995), are needed.

It is estimated that in Finland 500 000-600 000 tons of wood- and peat-ash are produced annually as a by-product of energy production. Ash contains all the essential plant nutrients except N, which is vaporized in the combustion. In our earlier studies we found that wood- and peat-ash fertilizers are required for the establishment of full cover of ground vegetation and downy birch seedlings on a cut-away peatland (Huotari *et al*., 2007; 2008; 2009). Both wood- and peat-ash ensured an adequate level of nutrients for the early growth of birch seedlings (Huotari *et al*., 2011). However, the effect of wood- and peat-ash fertilization on the long-term growth and biomass production of dense stands is not well known. In this study we monitored the effects of wood- and peat-ash application on the density and woody biomass production of a downy birch stand in a cut-away peatland ten years after the ash application.

MATERIALS AND METHODS

The experimental field was established in 2000 on a cut-away peatland located in Northern Ostrobothnia (64°44´N, 25°16´E, 45 m a.s.l.), in Finland. Detailed experimental design is previously published (Huotari et al. 2007, 2008, 2009 and 2011). In May 2001 the following six fertilization treatments were applied: 1) unfertilized, 2) wood-ash 7.9 t ha^{-1}, 3) mixed-ash 6.3 t ha^{-1} (wood-ash 3.9 t ha^{-1} + peat-ash 2.4 t ha^{-1}), 4) peat-ash 4.8 t ha^{-1}, 5) peat-ash 4.8 t ha^{-1} + biotite 1.5 t ha^{-1} and 6) Forest PK-fertilizer 0.5 t $ha-^{1}$. The doses of the fertilizers were adjusted corresponding to 50 kg ha^{-1} of phosphorus, as recommended for peatland forests (Paavilainen and Päivänen, 1995).

On each trial plot 6 circular (a 12.6 m^2) sub-sample plots were established. All trees higher than 1.3 m were measured and the quantity of trees over 0.5 m was counted 10 years after fertilization in October 2010. Biomass of the birches over 1.3 m in height was calculated using earlier biomass equations (Hytönen and Kaunisto, 1999). For smaller trees new biomass equations based on local sample tree data were calculated.

RESULTS

Stand density

Downy birch was the dominant tree species and comprised about 70 % of the total stem quantity in all the six treatments (Fig. 1). The quantity of birches varied between 83 000 and 99 000 stems ha^{-1} in the ash-fertilized areas, whereas the corresponding density in the Forest PK-fertilized area was about 44 500 stems ha^{-1} and in the unfertilized area 14 000 stems ha^{-1}. Since there was no major difference in the birch quantities between the sown and naturally regenerated areas, the results presented here concern only the effect of fertilization.

In addition to birch, also willows (*Salix* spp.) and some Scots pines (*Pinus sylvestris* L.) had regenerated on the experimental area (Fig. 1). The quantity of willows in the ash-fertilized areas varied from 26 000 to 34 000 stems ha^{-1}, whereas the quantities in the PK-fertilized and unfertilized areas were about 15 000 and 3 000 stems ha^{-1}, respectively. At the same time, the number of Scots pines was largest, 4 900 stems ha^{-1}, in the Forest PK-fertilized area and smallest, 1 900 stems ha^{-1}, in the peat-ash fertilized area.

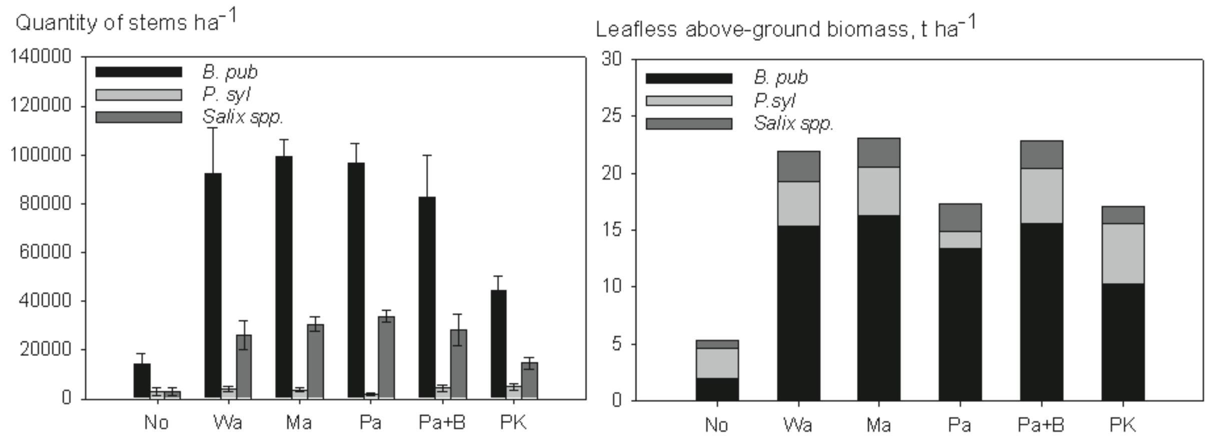

Fig. 1. The quantities of stems (left) and the leafless above-ground biomass (right) by tree species in 10 years old energy-wood stand in a cut-away peatland. Treatments: No = unfertilized, Wa = wood-ash, Ma = mixed-ash, Pa = Peat-ash, Pa+B = Peat-ash +biotite, PK = Forest PK-fertilizer. The data of the two afforestation methods, broadcast seeding and natural regeneration, is combined (n=6).

Biomass

The leafless above-ground woody biomass of the 10 years old birch-dominated energy-wood stand was greatest, 22-23 t ha^{-1}, in the areas where wood-ash, mixed-ash or peat-ash + biotite was applied (Fig. 1). Consequently, the annual woody biomass production was on an average 2.2-2.3 t ha^{-1}. In the areas fertilized with peat-ash or Forest PK-fertilizer, the leafless above-ground woody biomass was on an average 17 t ha^{-1} and in the unfertilized area 5 t ha^{-1}. Downy birch comprised the major part, 61-78 %, of the tree biomass in all the fertilized areas, whereas majority of the biomass in the unfertilized areas was formed by sporadic Scots pines.

DISCUSSION

Our results showed that fertilization increased the density of the 10-year old stands considerably. The quantity of birches in all the ash-fertilized areas was about 2-fold compared to the Forest PK-fertilized areas and 6-fold compared to the unfertilized area. About half of the birch seedlings established in 2001 (Huotari *et al*., 2008) had survived for 10 years on the fertilized areas. At the same time the low stand density in the unfertilized areas remained almost unchanged. Thus, the self-thinning in the fertilized areas is due to the high within-stand competition for light and nutrients.

We found also that fertilization increased the leafless above-ground biomass production. In all the fertilized areas the total leafless above-ground tree biomass was about 3-4 times greater in comparison to the unfertilized area. Fertilization increased especially the biomass of downy birch, which supports the use of ash fertilizers on birch dominated energy-wood stands on cut-away peatlands. Interestingly, Scots pine formed a major part of the biomass in the unfertilized areas, even if their stem quantity was almost 5-times lower than birches. The sporadic, large-sized Scots pines had established in the area before the experiment was started. Our result confirms the previous observations on the negative effect of ash on the germination of pine seeds (Reyes and Casal, 2004). Furthermore, also competition for light and nutrients with fast growing pioneering species, such as birch, may have complicated the early growth of pines in the fertilized areas.

The mean annual woody biomass production measured here was lower than reported earlier in dense wood stands on cut-away peatlands (Ferm, 1990; Hytönen and Saarsalmi, 2009; Hytönen and Kaunisto, 1999), however the biomass production may increase along with stand age (Hytönen and Issakainen, 2001). The previous studies reporting higher biomass production have focused mainly on the effects of planting density of seedlings or cuttings, and coppicing efficiency of various tree species on the woody biomass production. The woody biomass production of naturally established birch stand with single ash application is not fully comparable to the energy-wood plantations with repeated fertilization and weed control. In young naturally established stands, also the biomass formed by ground vegetation and below-ground parts of plants is considerable in comparison to the above-ground biomass of trees. High early biomass accumulation in ground vegetation has several environmental advantages in cut-away areas (Huotari *et al*., 2007; 2008; 2009; 2011).

ACKNOWLEDGEMENTS

We thank Mr. Seppo Vihanta and Mr. Eero Saari for the help in the field work.

REFERENCES

Ferm, A. (1990). Coppicing, aboveground woody biomass production and nutritional aspects of birch with specific reference to *Betula pubescens*. *The Finnish Forest Research Institute, Research paper* **348**, 1-35.

Huotari, N., Tillman-Sutela, E., Kauppi, A. and Kubin, E. (2007). Fertilization ensures rapid formation of ground vegetation on cut-away peatlands. *Canadian Journal of Forest Research* **37**, 874-883.

Huotari, N., Tillman-Sutela, E., Pasanen, J. and Kubin, E. (2008). Ash-fertilization improves germination and early establishment of birch (*Betula pubescens* Ehrh.) seedlings on a cut-away peatland. *Forest Ecology and Management* **255**, 2870-2875.

Huotari, N., Tillman-Sutela, E. and Kubin, E. (2009). Ground vegetation exceeds tree seedlings in early biomass production and carbon stock on an ash-fertilized cut-away peatland. *Biomass and Bioenergy* **33**, 1108-1115.

Huotari, N., Tillman-Sutela, E. and Kubin, E. (2011). Ground vegetation has a major role in element dynamics in ash-fertilized cut-away peatland. *Forest Ecology and Management* **261**, 2081-2088.

Hytönen, J. and Saarsalmi, A. (2009). Long-term biomass production and nutrient uptake of birch, alder and willow plantations on cut-away peatland. *Biomass and Bioenergy* **33**, 1197-1211.

Hytönen, J. and Kaunisto, S. (1999). Effects of fertilization on the biomass production of coppiced mixed birch and willow stands on a cut-away peatland. *Biomass and Bioenergy* **17**, 435-469.

Hytönen, J. and Issakainen, J. (2001). Effect of repeated harvesting on biomass production and sprouting of Betula pubescens. *Biomass and Bioenergy* **20(4)**, 237-245.

Lavoie, C., Saint-Louis, A. and Lachance, D. (2005). Vegetation dynamics on an abandoned vacuum-mined peatland: 5 years of monitoring. *Wetlands Ecology and Management* **13**, 621-633.

Ministry of Employment and the Economy (2010). Finland's national action plan for promoting energy from renewable sources pursuant to Directive 2009/28/EC.

Official Statistics of Finland (OSF) (2010). *Energy supply and consumption* [e-publication]. ISSN=1799-7976. Helsinki: Statistics Finland. Available at: http://www.stat.fi/til/ehk/index_en.html, cited 4.1.2012.

Paavilainen, E. and Päivänen, J. (1995). *Peatland forestry, Ecology and principles*. Ecological Studies 111. Springer-Verlag, Berlin-Heidelberg-New York.

Reyes, O. and Casal, M. (2004). Effects of forest fire ash on germination and early growth of four pinus species. *Plant Ecology* **175**, 81-89.

Röser, D., Asikainen, A., Raulund-Rasmussen, K. and Stupak, I. (eds.) (2008). *Sustainable use of forest biomass for energy. A synthesis with focus on the Baltic and Nordic region*. Managing Forest Ecosystems 12, 259 pp. ISBN 978-1-4020-5053-4.