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Profitability of biomass production of downy birch on cutaway peatlands

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Introduction

Annually 2 500–3 500 hectares have been released from peat production in Finland. To meet European Union targets for reducing greenhouse gas emissions, Finland has aimed at substituting fossil fuels with wood-based fuels. The afforestation of cutaway peatlands could create carbon sinks and compensate soil carbon fluxes (Hytönen et al. 2018). High nitrogen content of the residual peat enables high biomass production, while potassium and phosphorus nutrition can be secured e.g. by ash fertilization. Cutaway peatlands could be afforested cost-efficiently with native downy birch (*Betula pubescens* Ehrh.), which is a primary successional tree species thriving on peatlands. Wood production would be based on natural seeding, early clear-cutting with whole-tree method, and coppice regeneration. This stand management system has shown potential for profitable production of energy biomass without subvention (Jylhä et al. 2015). The present study was aimed at assessing the profitability of growing downy birch on cutaway peatlands, based on empirical productivity models and a larger dataset than in the case study above.

Material and methods

The profitability calculations for the production of energy biomass were done for various stand management scenarios, in which rotation length of the mother stand varied from 15 to 30 years. Stand development was simulated using the models based on the measurements of 25 naturally regenerated downy birch stands in Finland (Fig. 1). At the stand establishment phase, wood-ash fertilization was assumed to be done immediately after the release of each site. Natural birch seeds drifted on the sites were expected to germinate in the next summer. The stands were assumed to be clear-cut at the age of 15–30 years. Coppice regeneration was applied after the second and third rotation. Due to existing root network, these sprout-originated stands were expected to reach two years earlier the same biomass production as in the case of the mother stand in the first rotation. From the fourth generation onwards, mounding and natural seeding were assumed for an infinite series of 15–30-year rotations. The cost of ash fertilization was set at 350 € ha^{-1}, while the cost of mounding was assumed to be 393 € ha^{-1} (Luke 2019).

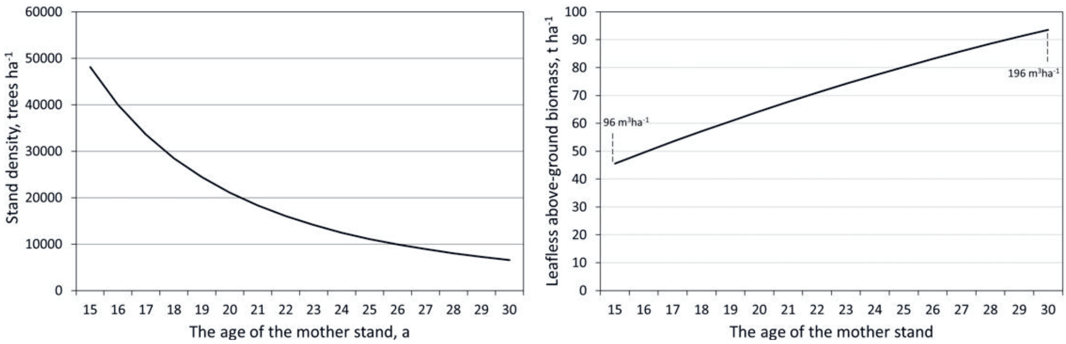

Figure 1. The development of stand density (A) and leafless above-groud biomass (B) of naturally afforested downy birch thickets based on the measurements of Hytönen et al. (2018).

When harvesting, 93% of the leafless above-ground biomass was assumed to be recovered (Jylhä and Bergstrom 2016). In the calculations associated with fuel chip production, the basic density of whole trees was set at 475 kg m^{-3} (Hakkila 1978). The effective productivity of cutting and forwarding (distance 300 m) were calculated using the models of Jylhä and Bergström (2016). The whole-tree piles were stored covered at roadside for one year, assuming a dry matter loss of 2.7 % (Routa et al. 2018). The cost of covering the piles was set at 2.60 € m^{-3} (Hassinen, Urpo, Finnish Forest Center, Pers. Comm. 18.3.2019). For the fuel chips, a moisture content of 40% (wet basis) on delivery was assumed, resulting in a heating value of 10.6 MJ kg^{-1} (Nurmi 1993, Alakangas et al. 2016).

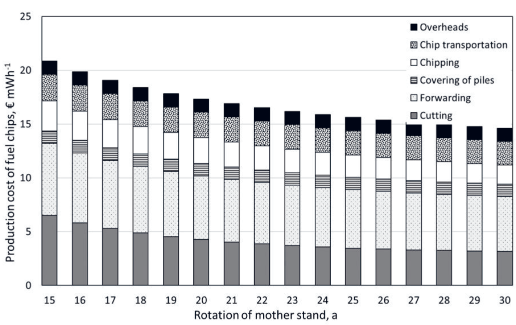

Figure 2. The production costs of fuel chips originating from naturally afforested downy birch thickets managed with varying rotation length. The rotation of the coppice-regenerated stands (2th–3th generations) was assumed to be two years shorter.

The productivity of roadside chipping of whole trees with varying size was based time study data from the stands described in Jylhä and Bergström (2016). The factors published by Jylhä et al. (2019) and Kärhä et al. (2009) were used when converting the effective productivities of cutting, forwarding and chipping into operative productivities for the cost calculations. The chips were transported to the end-use facility using a 69-ton truck and trailer with a total frame volume of 150 m^3 and bearing capacity of 45 tons. Loading and other terminal times were calculated as described by Laitila and Väätäinen (2011). For the chip loads, a solid content of 44% was used (Lindblad et al. 2014). Transportation distance was set at 60 km. The time consumption of trucking was calculated using the model of Nurminen and Heinonen (2017). The hourly operating costs of the machinery were obtained from the studies of Jylhä (2013), Laitila et al. (2015, 2016) and Väätäinen et al. (2017) and updated to the cost level of January 2019 using the forestry machine cost indexes of Statistics Finland (2019). The overhead cost of the wood procurement organization was assumed to be 2.78 € m^{-3} (Strandström 2018). The assumption above resulted in the cost structures illustrated in Figure 2.

The price of forest chips at the end-use facility was assumed to be 15, 20 or 25 € MWh^{-1}. The profitability of each stand management option with five alternative discount rates (1–5%) was evaluated based on bare land value (BLV, € ha^{-1}). The BLVs for each stand were calculated as the sum of the net present values (NPV, Santhaku-

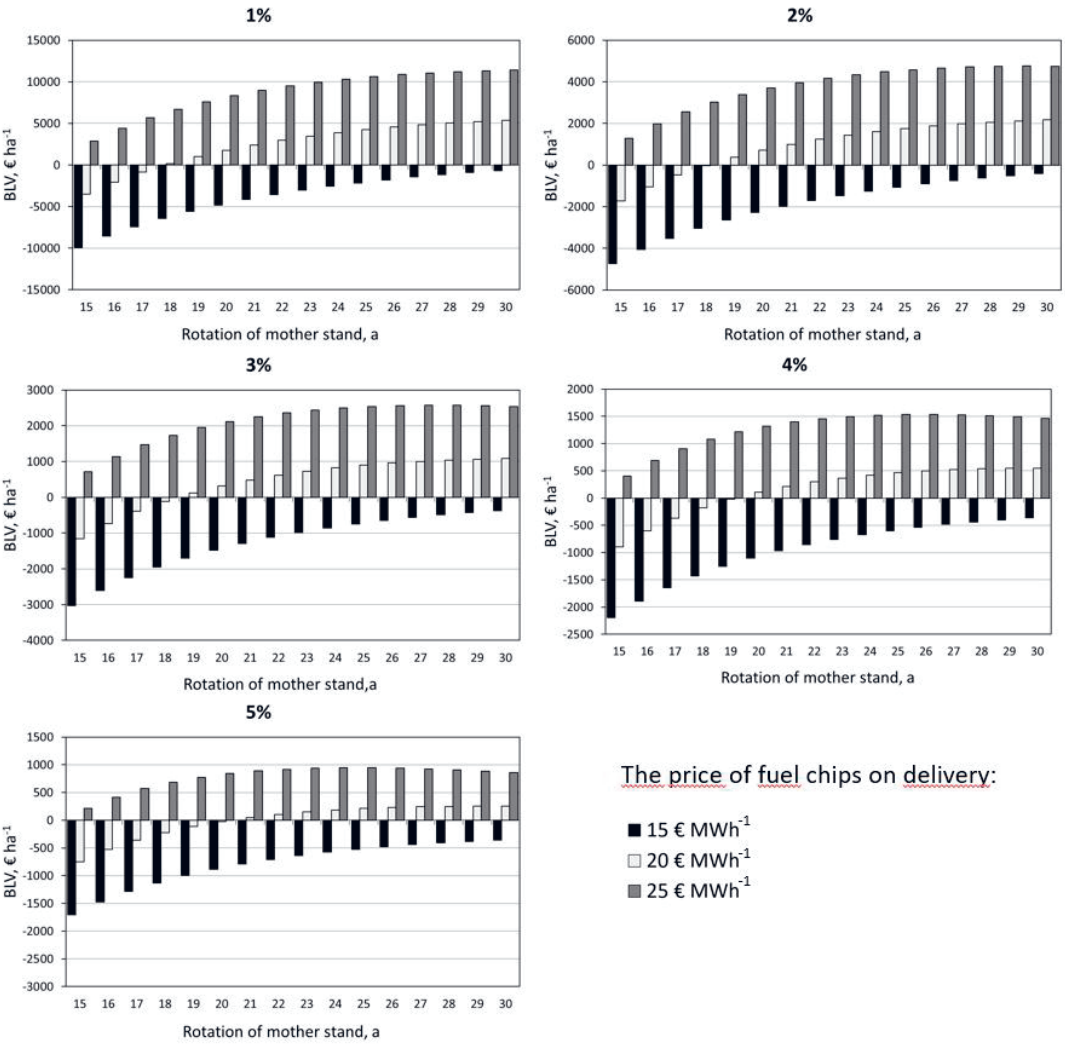

Figure 3. Bare land values (BLV) for various stand management scenarios with varying forest chip prices (15–25 € MWh-1) and interest rates (1–5%).

mar and Chakraborty 2003) associated with the first three generations and the bare land values (F, eg.Chang 2014) from the fourth generation onwards:

$$BLV = [NPV1] + [NPV2] + [NPV3] + F \qquad (1)$$

Results

With the fuel chip price of 25 € MWh^{-1}, the production of biomass was profitable in all stand management scenarios and interest rates (Fig. 3). The price of 20 € MWh^{-1} resulted in a positive BLV when rotation exceeded 18–20 years, depending on the rate of interest. With the lowest price (15 € MWh^{-1}), production remained unprofitable in all cases. Of the examined alternatives, the maximum BLV with the price of 20 € MWh^{-1} was reached within the rotation span of 15–30 years only with the highest interest rate, at the age of 29 years. With the price of 25 € MWh^{-1}, the maximum BLV was reached four years earlier.

Discussion

Dense downy birch stands can be successfully established in ash-fertilised peatlands both by broadcast seeding and by natural regeneration (Huotari et al. 2008, Hytönen et al. 2016). Following clear-cut, young birches sprout and grow well (Hytönen 2019). However, birch sprouts are vulnerable to browsing by moose and hares, which can reduce biomass production.

Cutaway peatlands show potential for profitable production of downy birch biomass without subsidies at the prevailing price level of forest chips in Finland (ca. 20 € MWh^{-1}, Statistics Finland 2021). Only minor inputs are required in comparison to other energy crops (e.g. willow or reed canary grass). Rotation period (i.e. stand age at the clear-cut) affects the profitability of downy birch biomass production. Profitability was sensitive to harvesting cost, which was dependent on tree volume and biomass removal. With the lowest price of forest chips, the production of energy biomass was unprofitable in all scenarios. A rotation exceeding 20 years is required for profitable biomass production with the current price level of fuel chips. Within the examined rotation range, the maximum BLV will be reached only with the maximum interest rate (5%) and the longest rotation (30 years). Optimal rotation is the shorter the higher price of forest chips and interest rate are used.

Based on the experiences from peatland forests, thinning response of downy birch is low (Niemistö 2017). Therefore neglecting thinnings do not affect stand development to great extent, and unmanaged stands can be converted into the production of commercial roundwood at any time, which mitigates the risks associated with the biomass production with downy birch.

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