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Thinning operations and their impact on biomass production in stands of Norway spruce and Scots pine

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Abstract

Forests and forestry can make substantial contributions to attempts to reduce the amount of CO_2 in the atmosphere. However, management regimes differ in their effects on CO_2 dynamics, so this study was undertaken to assess the effects of various thinning strategies on the following variables: the amount of biofuel produced that could replace fossil fuels; mean annual increment of biomass; the standing biomass. In the present study, 50 blocks of Scots pine (*Pinus sylvestris* L.) and 21 of Norway spruce (*Picea abies* (L.) Karst.), established in young stands in Sweden between 1966 and 1984, were examined. Five different thinning regimes were considered: 'low thinning', 'one heavy thinning', 'thinning from above', 'low thinning + fertilization' and 'unthinned'. In the spruce blocks, there was no significant difference in mean annual increment between the thinning regimes, suggesting that fertilization did not have a positive affect on the aboveground biomass. In the pine blocks, 'low thinning + fertilization' was the most suitable thinning regime, since it led to a significantly larger mean annual increment than the other regimes and the quantity of biofuel produced was also large. 'Unthinned' had the largest standing biomass for both species, which resulted in that 'unthinned' is preferred if the objective is to maximize the standing biomass and thereby the carbon pool.

Keywords: Biofuel; Biomass; Carbon storage; Fertilization; Forest management; MAI; Norway spruce; Scots pine; Thinning

1. Introduction

Forest thinning has been practised in Sweden since the 19th century. Its main purpose 150 years ago was to prevent self-thinning. The harvesting then was light, with about 10% of the standing volume removed, and had little impact on the growth of the stands [1]. However, at the beginning of the 20th century, the market for smaller trees increased, due to the establishment of pulp industries. This led to an increased interest in thinning strategies and their impact on stands [1]. During this period, several field experiments, involving particular stands of Norway spruce (*Picea abies* (L.) Karst.) and Scots pine (*Pinus sylvestris* L.), were established. The main results from these studies showed that thinning operations could increase forestry revenue [1]. In the 1960s, new long-term experiments were established to provide information required for new forest management strategies arising from the mechanisation of forestry [2].

In Sweden, thinning operations provide an important source of wood for the forest industry. About $2 \times 10^7\,m^3$ of pulpwood is harvested annually in thinning operations, which is about 30% of the total annual harvested volume [3]. Furthermore, thinning increases the growth and economic value of the remaining trees [4], as well as providing important revenue for forest owners. Research relating to thinning activities has been dominated by consideration of their effects on forest yield [5–10] and financial returns [11–14]. During recent decades there has also been some interest in other aspects, such as snow and wind damage in thinned stands [15] and biodiversity [16,17]. Another aspect of interest now is the impact that different thinning regimes may have on reductions in atmospheric levels of CO_2, since forest management strategies form part of the Kyoto Protocol [18].

Forests and forestry can contribute to reductions in the amount of CO_2 in the atmosphere in several ways: via the

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accumulation and storage of carbon in biomass, soil and wood products; the substitution of biomass and waste wood products for fossil fuel; and the use of wood products rather than energy-intensive materials, such as cement, plastics and aluminium [19,20]. Several reports have described relationships between forest management and carbon storage. For instance, Cooper [21] demonstrated that the carbon store is reduced when forests are managed for maximum biomass yield, and Johnson [22] reviewed the effects of different forest management strategies on soil carbon storage. Furthermore, a study by Thornley and Cannell [23] demonstrated the effects on stored carbon of managing forests to maximise biomass yield and carbon storage. These studies considered the effects of management on carbon storage in biomass or soil, but they did not consider the effects of the amount of harvest residues produced. In addition to the cited studies, there has been some research on the effects of thinning strategies on carbon accumulation and carbon storage. For instance, Vesterdal et al. [24] studied the effects of different thinning strategies on carbon accumulation in the forest floor, and Sievänen et al. [25] investigated the impact of different thinning strategies on the amounts of carbon in the soil and trees in a single pine stand.

The objective of this study was to investigate how different thinning strategies affect the mean annual increment of biomass; the standing biomass; and the annual production of biofuel that could replace fossil fuel, and thereby studying the quantity of carbon accumulated and stored during different thinning strategies.

2. Materials and methods

The study considered experimental plots in a randomised block design, with 21 blocks of Norway spruce and 50 blocks of Scots pine, established between 1966 and 1984 in young stands with a top height of 12–15 m [2]. The 71 stands are a part of a large scale thinning trial, which is still running, and measurements are taken every five to ten years. The blocks of Norway spruce are mainly located in southern and central Sweden, ranging in latitude from 56° to 61°N (Fig. 1). The blocks of Scots pine are spread across Sweden, ranging in latitude from 56° to 67°N (Fig. 1). In each block, six to 10 subplots, with different thinning and fertilization regimes, were established. Each subplot had an area of 0.1 ha. The data from the Scots pine blocks were divided into four regions: the northern interior (A), the northern coastal area (B), central Sweden (C) and southern Sweden (D) (Fig. 1). The blocks of Norway spruce were situated in regions C and D and the results from these blocks were analysed together. In this study, five thinning regimes were examined: Unthinned, low thinning, thinning from above, low thinning + fertilization with nitrogen, one heavy thinning.

The intensity of the first thinning for each regime is outlined in Table 1. For subsequent thinning operations in the 'low thinning' regime, the intensity was determined by the development of the basal area. The basal area following each thinning, in the 'low thinning' regime, was intended to increase slightly over time. For the 'thinning from above' and 'low thinning + fertilization' regimes, the objective was to keep the mean basal area the same as in the 'low thinning' treatment. The first thinning was performed when the top height was between 12 and 15 m and the interval between the thinning operations depended on the top height [2].

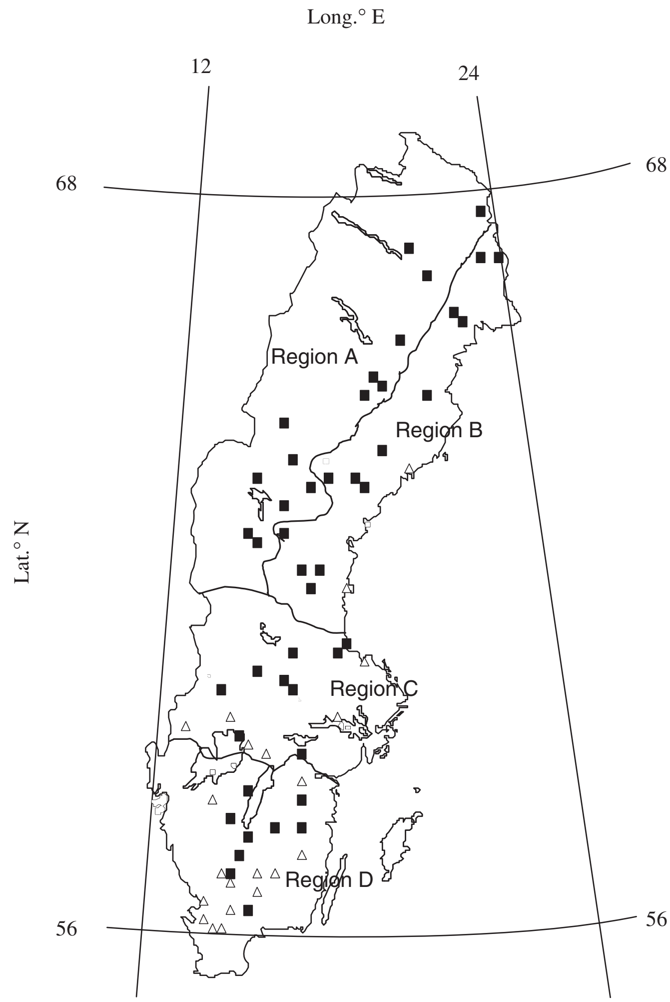

Fig. 1. Location of the Scots pine (*P. sylvestris* L.) (■) and Norway spruce (*P. abies* (L.) Karst.) blocks (△). (After Eriksson and Karlsson [2]).

In the 'unthinned', there was no harvesting of trees, i.e. self-thinning occurred. In the 'one heavy thinning' regime, the subplots were thinned at the start of the experiment and the thinning grade was 60–70% of basal area (Table 1). In the 'low thinning' regime, trees from all size classes were harvested, but the mean basal area diameter of the harvested trees (d) was lower than the corresponding diameter of the trees left on-site (D). This resulted in a thinning ratio, d/D, of 0.7–0.9. In the 'thinning from above' regime, larger trees were mainly harvested, and the objective was to obtain a thinning ratio (d/D)$>$1.15 at the first thinning. In the 'low thinning + fertilization' regime, the first fertilizer application was in the spring, two years