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An economic evaluation of strategies for transforming even-aged into near-natural forestry in a conifer-dominated forest in Denmark

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ABSTRACT

Schemes for transformation of even-aged monoculture forest management regimes into near-natural regimes are currently applied throughout the Atlantic region of Europe. This is mainly due to poor ecological stability, low economic performance, and decrease in biodiversity in existing forests. In this study, we analysed the simultaneous transformation of adjacent even-aged stands (a forest division) into mixed conifer/broadleaved stands. The case area is found in a conifer-dominated Danish forest and consists primarily of Norway spruce, European beech, Douglas fir and Sitka spruce. An economic evaluation of several transformation strategies was carried out by simulation. An area based combined Markov chain and Dynamic yield table model was used. Analyses were conducted under risk of wind throw.

Strategies were defined by length of the cutting cycle and the diameter class harvest volume proportions of each tree species. As a reference point, an optimal strategy was determined using strict target diameter harvesting. It was assumed that such a regime would not achieve the desired change in stand structure due to the narrow diameter distributions of the existing stands as well as the present forest structure. Two groups of harvest strategies were analysed: *passive strategies* entailing harvesting mature and over-mature trees, and *active strategies* entailing harvest of immature, mature and over-mature trees; and three lengths of cutting cycles were applied: 2, 5 and 8 years. A transformation period of 80 years was assumed for the entire forest division.

The importance of the local forest conditions was evident: for all strategies, an economically over-mature forest structure resulted in large harvest income at the beginning of transformation, leading to small differences between the strategies and thus increasing flexibility in the choice of strategy. When trees were harvested before or after economic maturity, opportunity costs depended on strategy. Such costs must be taken into account when forcing a fast transformation, e.g. for biological or recreational reasons. For the worst performing strategy, the overall loss was 34% compared with the optimal strategy in terms of total expectation value. Regarding area distribution of tree species and size classes, the differences between strategies were insignificant at the end of the transformation period. The active strategies with a 2-year cutting cycle were the least vulnerable to wind throw but had the lowest economic performances, emphasising the trade-off between vulnerability and operational costs (entry costs).

1. Introduction

Over the last decades, transformation of traditional even-aged monospecific forest management into near-natural or uneven-aged mixed species management has been initiated in large parts of the forests in the Atlantic region of Europe. Poor ecological (and thus economic) stability, low economic performance and decrease in biodiversity are the main reasons. The present study aims at investigating strategies for transformation that differ in regard to how active they are. We analyse a case of a conifer-dominated forest in Jutland, Denmark and focus on economic evaluation of different strategies through simulation.

An expected advantage of transformation is the reduction of regeneration costs due to natural regeneration instead of planting — although this may imply increased tending costs and a prolonged rotation age. The use of single-tree selection instead is expected to cause increased operational costs (Price and Price, 2006). Thus, transformation may not only change the size of costs, but also redistribute them in time. The consequences for timber quality are also debated (Knoke and Seifert, 2008). According to Larsen (2005) near-natural forest management will enhance forest stability in relation to, e.g. wind throw and insect attack. Furthermore, under risk of climate change, mixed-species stand structures might enhance flexibility (Jacobsen and Thorsen, 2003). This study focuses on how the forest manager can adjust and potentially improve the transformation, i.e. we analyse the consequences of different forest management planning strategies.

Transformation will change the preconditions of making forest planning, as the stand and age structures are changed. In the early stages of transformation classic planning tools may still be applied (Jensen et al., 2005), but for long-term planning, new tools are needed. At the same

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time, many private forest owners will demand models requiring little data input. Consequently, we develop a model which is based on present stand characteristics.

We use inventory data from a private forest for simulating transformation strategies and evaluating them economically. Different tree species and age classes are investigated simultaneously as interdependencies arise through regeneration during transformation. Results are shown on an aggregate level. The species are Norway spruce (*Picea abies* (L.) Karst.), European beech (*Fagus sylvatica* L.), Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and Douglas fir (*Pseudotsuga menziezii* Mirb. Franco). The transformation goal was chosen according to the forest development types (FDT) for Danish conditions (Larsen, 2005; Larsen and Nielsen, 2007). This case is of high relevance in Denmark; to private forest owners as well as to public forest administration.

Target diameter harvesting (Tarp et al., 2000; Sterba and Zingg, 2001; Larsen, 2005; Price and Price, 2006) is a key concept in the analysis. We assume that in order to reach an uneven-aged structure, an existing even-aged stand must be harvested gradually. Thus, strict target diameter harvesting, i.e. harvesting if and only if a pre-defined diameter is reached, may not be applied due to the narrow diameter distribution of many even-aged stands. The desired structure may be better achieved by deviating from this diameter, either by cutting trees below or above this limit — corresponding to acceleration or prolongation of the stand termination compared with the optimal rotation length for the individual tree (cf. Hanewinkel and Pretzch, 2000). We refer to this as *active* and *passive* strategy, respectively (Larsen et al., 2005a). Furthermore, the length of the cutting cycle will influence the transformation process. Thus, transformation strategies will be described by two factors: the proportion of trees harvested in each size class (harvest strategy), and the years between cuttings. By testing a range of predetermined strategies we aim at showing the economic sensitivity of making various decisions regarding the timing and frequency of cutting operations.

2. Literature overview

The economics of the transformation period have been analysed by, e.g. Tarp et al. (2000), Hanewinkel (2001), Knoke et al. (2001), Knoke and Plusczuk (2001), Jacobsen et al. (2004), Price and Price (2006), Jacobsen (2007) and Möhring and Rüping (2008), while the final state have been analysed by Nord-Larsen et al. (2003) and Jacobsen and Helles (2006). In this study, we look at the transformation period and only take the final state into account when calculating the total expectation value (EV).

Most studies investigating the economics of transformation from even-aged to uneven-aged, or uneven-sized structures operate at stand level (Buongiorno, 2001; Knoke et al., 2001; Nord-Larsen et al., 2003; Jacobsen et al., 2004). Nord-Larsen et al. (2009) argue that stand-level analyses are useful because initial forest structures will influence the economics of the transformation and consequently "may conceal an actual depletion or build-up of the forest resource" (p. 150). Nevertheless, analyses on an aggregate level are relevant to decisions at forest level, given a specific age class distribution. Many private forest owners operate with a short time horizon, and a possible capitalization on the standing timber will have a huge influence on liquidity and thus might influence the decision of doing transformation or not. We therefore choose to analyse a specific case at forest division level. An alternative is to operate with model forests and compare at forest level. Tarp et al. (2000) and Buongiorno (2001) are examples thereof. A few studies look at the economic performance of uneven-aged management compared with even-aged management when transformation has taken place (see, e.g. Jacobsen and Helles, 2006). While this is an interesting approach to goal comparison, it tells little about the economic performance during the first decades which is the focus of this study.

A crucial issue of transformation is the question of risk and uncertainty. Knoke et al. (2001) analyse the impact of cash flow distribution under price uncertainty. They find that due to a more evenly distributed harvest in the transformation regime, variation in NPV is smaller here than in an even-aged regime and, more importantly, the risk of producing a deficit is smaller. This result may to a large extent depend on the age class distribution of the forest before transformation is initiated. Jacobsen and Helles (2006) take a different approach, comparing the possibility of adapting the time of harvesting to fluctuations in prices in model forests of uneven-aged and even-aged beech management, thus in principle with equal points of departure, but with different spatial distributions. They find little difference between the management systems. In this study, we do not focus on price uncertainty but instead on the risk of wind throw. According to Schelhaas et al. (2003) storm has been the most important natural disturbance in European forest for the last 150 years. It is a major source of risk in spruce forests in Denmark; Østergaard (1988) finds an overall annual wind throw risk of 8% for Norway spruce. In a transformation period the risk may be even larger if the stand has only been thinned lightly before transformation is initiated (Larsen et al., 2005a). Nevertheless, many studies analysing the consequences of transformation do not take wind throw into account (e.g., Jacobsen et al., 2004). Some studies focus on the wind resistance of different tree species, alone or in mixture (Schütz et al., 2006) and find that a higher proportion of spruce increases the risk of wind throw — an admixture of 10–20% broadleaved species in spruce stands improved storm stability by a factor of 3.4. And that destabilization caused by thinnings decreases with increased thinning frequency. Thorsen and Helles (1998) find that the economic return of a Norway spruce stand under risk of wind throw increases with increased thinning intensity.

When to initiate transformation is crucial as shown by, e.g. Hanewinkel (2001), Knoke and Plusczuk (2001), Price and Price (2006) and Tarp et al. (2000). They all find that the later in the rotation transformation is initiated, the more favourable becomes the continuance of even-aged management (depending on the discount rate), the reason being that deviation from the optimal rotation age becomes smaller. Hanewinkel (2001) emphasises the dependency of transformation costs on the discount rate. For a specific strategy Knoke and Plusczuk (2001) find that at discount rates above 2.6% transformation is superior to continuance of even-aged management due to earlier occurrence of revenues.

Target diameter harvesting, as a means of conducting transformation, is described by, e.g. Hanewinkel and Pretzch (2000), Kenk and Guehne (2001) and Sterba and Zingg (2001). They all look at the silvicultural aspect of transformation, but not the economic consequences of are not. Zell et al. (2004) look at the financial consequences of target diameter harvest but not specifically in relation to transformation. In the present study, we focus on this tool in a transformation context.

A number of studies have used Markov chains to model forest growth in a number of studies. Hinssen (1994) developed a model to facilitate strategic forest management planning. The author emphasises that the model is used on a forest level due to the underlying assumptions of the Markov chain. Lin and Buongiorno (1998) used a Markov chain to determine optimal management strategies under multiple criteria restrictions in mixed broadleaved forests. They argue that this approach is a simple and flexible way to model complex interactions as well as being management oriented.

3. Materials and methods

A simulation approach (see Sections 3.4 and 3.6) was chosen to investigate performance of a number of predetermined strategies for transformation of a forest division — defined as a group of adjacent stands constituting a total area of about 20 hectares (ha).

3.1. The case study area: Høvild forest

Høvild Forest is situated in the western part of Denmark. The forest is 147.6 ha, mainly on sandy soils with a minor content of clay.

Main objectives of the transformation are to diversify timber production and enhance ecological stability. We only show results for