Forest Policy and Economics 42 (2014) 30–41

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

Financially optimized management planning under risk aversion results in even-flow sustained timber yield

W. Andreas Hahn [a,*], Fabian Härtl [a], Lloyd C. Irland [b], Christoph Kohler [a], Ralf Moshammer [c], Thomas Knoke [a]

[a] Institute of Forest Management, Center of Life and Food Sciences Weihenstephan, Technische Universität München (TUM), Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany
[b] The Irland Group, 174 Lord Road, Wayne, ME 04284, USA
[c] Chair of Forest Yield Science, Center of Life and Food Sciences Weihenstephan, Technische Universität München (TUM), Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany

ARTICLE INFO

Article history:
Received 5 July 2013
Received in revised form 31 January 2014
Accepted 5 February 2014
Available online 22 February 2014

Keywords:
Portfolio optimization
Future uncertainty
Sustained yield
Sustainable resource management
Long-term strategic objectives
Surplus growing stock

ABSTRACT

The effect of explicit integration of uncertainty – determined through financial, non-linear optimization – on the distribution of timber harvests and net revenues over time was examined. A management plan for a 30 year period was developed for (1) a Bavarian municipal forest rich in standing timber, and (2) a hypothetical forest enterprise with even-aged stands which were based on actual growth data from the municipal forest. Maximization of net present value (NPV) – which implicitly accounts for uncertainty by discounting future returns – was contrasted with two alternative objective functions which explicitly account for uncertainty: maximization of the certainty equivalent (CE) and of the value-at-risk (VAR). The sources of risk considered were hazard probabilities of trees, and price volatility. Periodic harvest volumes and resulting net revenues were smoothest and increasingly more consistent when VAR was maximized, while NPV maximization encouraged sudden, unbalanced outputs. The enterprise value – measured by NPV – was reduced by 16%. The impact of risk aversion was slightly less pronounced when initial age-class structure more closely resembled a fully regulated forest. Yet, the coefficients of variation for harvests and net revenues were reduced to 14% and 21%. However, risk aversion offered a more effective hedge than age-class structure.

1. Introduction

Financial capital is scarce; consequently, it matters if money is received or spent today or in the future. Due to the potential for further monetary gain in the meantime, discounting of future costs and returns affects decisions. This 'pure' time preference is often referred to as the risk-free interest rate (Bayer, 2004; Davis et al., 2001; Klemperer, 2001), and the higher it is, the higher the preference for consumption at present rather than in the distant future will be. Defining an appropriate interest rate for discounting future consumption and environmental damages is crucial for promoting sustainable development. This became obvious in the discussion on Stern (2007) (e.g. see Ackerman et al., 2009; Howarth, 2009; Nordhaus, 2007).

High interest rates are likely to be applied if future uncertainty is integrated in investment decision making. Risk-adjusted interest rates contain a premium for uncertainty,[1] which is added on top of the risk-free interest rate (Siegel, 1992). The more uncertain a future development is, the higher the interest rate an investor will demand, because alternatives – e.g. current consumption – will appear to be more favorable. The more risk-averse he or she is, the higher the risk premium on the risk-free interest rate will be. In this context, the risk attitude of decision makers who ask for a risk premium benefit added to the expected value in the case of risky decisions is called risk aversion. Hence, in resource management harvest schedules tend to become increasingly irregular, and existing resource stocks are exploited more rapidly with rising interest rates, as more weight is shifted from future to current consumption (Ferguson, 1996; Henderson and Sutherland, 1996).

* Corresponding author at: Institute of Forest Management, Center of Life and Food Sciences Weihenstephan, Technische Universität München, Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany. Tel.: +49 8161 71 4698; fax: +49 8161 71 4545.
E-mail addresses: andreas.hahn@forst.wzw.tum.de (W.A. Hahn), haertl@forst.wzw.tum.de (F. Härtl), lcirland@gmail.com (L.C. Irland), kohlerprivate@web.de (C. Kohler), Ralf.Moshammer@lrz.tum.de (R. Moshammer), knoke@forst.wzw.tum.de (T. Knoke).

[1] Consistent with Hirshleifer and Riley (2002) and others, the terms 'uncertainty' and 'risk' are used interchangeably within this article (Drukarczyk and Schüler, 2009; queryEisenführ et al., 2010; Pannell et al., 2000). Knight (1921) defined risk as known future outcomes with known probabilities, while uncertainty was outcome combined with an unknown probability of it occurring. However, objective probabilities exist only in rare cases which are not really relevant for decision making in enterprises (e.g. for playing dice). Probabilities taken from historical data are called subjective probabilities. If they are used for decisions about future developments, their application equals a statement of belief. Thus, Hirshleifer and Riley (2002) call these situations uncertainty, while, for them, risk holds just for objective probabilities. As they challenge the existence of objective probabilities at all, finally, both terms simply express a degree of belief.

http://dx.doi.org/10.1016/j.forpol.2014.02.002
1389-9341/

Further, ecological objectives in forestry require the retention of later successional stages of forest ecosystems (e.g. for conservation of biodiversity). Thus, discounting often leads to a tradeoff between economic and ecological objectives. These tradeoffs are more obvious when the uncertainty of future management conditions is considered. They may also violate the principle of intergenerational fairness,[2] thus contravening a fundamental cornerstone of sustainable development, according to the Brundtland definition (Hahn and Knoke, 2010; WCED, 1987).

Thus, when focusing on resource management, and on forestry in particular, future uncertainty is inherent, due to the long production periods (Cooney, 2005; von Gadow, 2001; Hahn and Knoke, 2010). On the one hand, discounting of future costs and returns is needed to guarantee an efficient allocation of financial capital in conventional forest management. On the other, integration of future uncertainty by risk-adjusted interest rates hinders continuous and even harvests.

Many forest properties in Germany and Central Europe now carry high volumes of growing stock resulting from past decisions without respect to opportunity costs in most cases. Then decision making based on maximization of NPV without harvest constraints will most likely result in a sudden decrease in growing stock, the absence of older age classes, and an unbalanced harvest level over time. Constraints are often used to avoid these undesired effects. But these often contain a high level of subjectivity concerning their selection or their desired level. Consequently, if risk-adjusted interest rates and net present value maximization are applied, non-optimal conclusions may result.

It was our intent to introduce an alternative approach to the integration of uncertainty which also minimizes the conflict with sustainable development. Following Howarth (2009), discounting with a real risk-free interest rate was applied. The precautionary approach was used to account for future uncertainty instead of a risk premium, which is added to the risk-free interest rate, thus merging the concepts of sustainability and risk assessment (Krysiak, 2009a). In this context, caution was modeled by risk aversion, which was defined as a preference of decision makers for the option with the highest probability of occurring[3] among options with similar expected returns. Thus, whether it is possible to bridge the gap between economic, social, and ecological objectives was investigated. For our study, data from a small forest enterprise was used to test the following hypothesis:

The consideration of risks within the objective function supports more even harvesting volumes and net revenues than strategies that purely maximize net present value.

Thus, we aimed at the extent to which the achievement of a more or less even-flow of timber and net revenues is possible, purely by means of the specification of our objective functions. Before we analyze the functions themselves, in Section 2 we will first describe the data, introduce the techniques of linear and non-linear programming and explain their application. To test the above hypothesis, we adopted three objective functions, each of which represented an increase in risk avoidance: maximization of net present value (NPV), of the certainty equivalent (CE), and of the value-at-risk (VAR). We will then present the comparison in Section 3. Our objective with this research was to highlight the potential advantages of explicitly considering risk in resource management. This will be discussed in Section 4.

2. Material and methods

2.1. Case study characteristics

We began with the premise that harvest schedules in forest enterprises with above average growing stock volumes will most likely lead to initially high harvest levels, followed by a sudden decrease, if they are based on maximization of net present value. Thus we searched for a forest enterprise with high growing stock. The forest enterprise belonging to the municipality of Hausham in southern Bavaria (Germany; 47° 45′ 4.07″ N, + 11° 50′ 22.12″ E) met this requirement. It is used as case study forest as it holds a standing timber volume of 440 cubic meters per hectare under bark [m^3/ha], which ranks very high for managed forests. The global average in 2010 was only 131 cubic meters over bark per hectare [m^3 o.b./ha]: Only eight countries reported an average growing stock in excess of 300 m^3 o.b./ha. Among these was Germany, with 315 m^3 o.b./ha (FAO, 2010). The largest growing stocks within Germany are found along the mountain range of the Alps, in which Hausham is located. The last federal inventory in 2002 calculated a growing stock for the region around Hausham of 418 m^3 o.b./ha (region of Oberland; BMVEL, 2005), which was 30% above the average for Germany calculated by this inventory, which was 320 m^3 o.b./ha (BMVEL, 2005).

Growth conditions in this region are highly favorable for forests, with an average annual temperature ranging from 5.5 to 7.5 °C, and a mean annual rainfall of 1200 to 1800 mm, depending on elevation. Elevations in the municipal forest range from 720 to 1160 m above sea level (Keler and Bieg, 1999). Hausham forest is part of the vegetation range known as mixed mountain forest (Fischer, 2003), and contains tree species typical for this forest type. Currently those forests are dominated by Norway spruce (*Picea abies* [L.] Karst.), while their natural composition included a much higher percentage of European beech (*Fagus sylvatica* L.) — at least at lower elevations (see Table 1). This change has occurred as a result of a combination of past timber management practices and increased ungulate browsing, which destroys broadleaf regeneration.

The community forest area is nearly 130 ha, whereas the productive forest – to which our case study was limited – covers 83 ha divided into 45 stands.

The age-class structure of the Hausham forest is quite unbalanced. Around 60% of the stands are 80 years and older, and 80% of the stands are more than 60 years old (Fig. 1). In the current management plan, Keler and Bieg (1999) used an average rotation period of 120 years, without giving any justification. Financial analyses in order to check the financial consequences of this decision were not applied. Nevertheless, if this rotation period were used, just 50% of the forest area would be older than 60 years if a fully regulated age-class system were applied, which is still considered to be state of the art for the German harvest scheduling practices currently in use (Knoke et al., 2012).

To test the effect of the current age-class structure, we modified the stand areas to create a hypothetical, more balanced initial age-class distribution for an enterprise of identical size. Age classes based on twenty year intervals were then distributed across equal areas. If numerous stands were part of one age class, area was uniformly distributed over steps of five years. However, species mixture and stand density remain unchanged, and thinning was still carried out. Thus, this modified initial

Table 1
Hausham forest tree species composition at the starting point for growth simulations.

	Tree species	Area share	Volume share
Conifers	Norway spruce (*Picea abies*)	69%	73%
	Silver fir (*Abies alba*)	14%	16%
Sum conifers		83%	89%
Broadleaved	European beech (*Fagus sylvatica*)	4%	3%
	Common ash (*Fraxinus excelsior*)	5%	4%
	Mountain maple (*Acer pseudoplatanus*)	3%	1%
	Further broadleaved tree species (e.g. *Alnus* ssp., *Salix* ssp,. *Ulmus* ssp,. *Prunus* ssp.)	5%	3%
Sum broadleaved		17%	11%

[2] Depending on the assumption that future generations are worse off and proceeds were invested in less profitable or more risky investments than forestry.

[3] A detailed definition is given in Section 2.2.1 with the definition of the certainty equivalent.