Forest Ecology and Management 386 (2017) 86–91

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Correspondence

Comment on "A simple way to incorporate uncertainty and risk into forest harvest scheduling"

Kyle Eyvindson [a,*], Annika Kangas [b]

[a] University of Jyväskylä, Department of Biological and Environmental Science, P.O. Box 35, 40014 Jyväskylä, Finland
[b] Economics and Society, Natural Resources Institute Finland (Luke), P.O. Box 68, 80101 Joensuu, Finland

ARTICLE INFO

Article history:
Received 11 March 2016
Accepted 14 March 2016

Keywords:
Stochastic programming
Risk
Uncertainty
Conditional Value at Risk

ABSTRACT

In a recent research article, Robinson et al. (2016) described a method of estimating uncertainty of harvesting outcomes by analyzing the historical yield to the associated prediction for a large number of harvest operations. We agree with this analysis, and consider it a useful tool to integrate estimates of uncertainty into the optimization process. The authors attempt to manage the risk using two different methods, based on deterministic integer linear programming. The first method focused on maximizing the 10th quantile of the distribution of predicted volume subject to area constraint, while the second method focused on minimizing the variation of total quantity of volume harvested subject to a harvest constraint. The authors suggest that minimizing the total variation of the harvest could be a useful tool to manage risk. Managing risks requires trade-offs, however, typically less risk involves higher costs. The authors only superficially stated the costs and did not consider if these costs are reasonable for the management of risk. In this comment, we specifically develop the models used in their article, and demonstrate a method of managing the downside risk by utilizing the Conditional Value at Risk.

1. Introduction

Being able to incorporate uncertainty, and the management of risks associated with harvesting decisions are important questions for both small scale and large scale forest owners (Pasalodos-Tato et al., 2013). This topic has been recently explored in a research article published by this journal (Robinson et al., 2016) (hereafter RMM), which demonstrated a method of incorporating uncertainty through utilizing historical information about harvesting quantities, linking to the predicted values. The authors then demonstrated a method that minimized the variance while achieving a specified harvest target. While the paper demonstrated a useful method of integrating uncertainty through empirical data, the method which they strove to minimize the risk (measured as variance) did not assess the required trade-off to manage the risk.

In order to manage risk, it is important to really understand the meaning behind what risk is. In an application to manage the risk of an investment portfolio, Markowitz (1952) defined risk as the variation of the distribution and that a risk-averse individual would want to minimize the variation with a specific decision. More recently, the ISO has defined risk in a slightly more general fashion as the "effect of uncertainty on objectives" (ISO Guide 73:2009). For both of these definitions, both unexpected losses and gains are treated as undesired.

Other definitions of risk can be more context specific, such as downside risk measures. Some examples are the downside mean semideviation (Krzemienowski and Ogryczak, 2005), the Value at Risk (VaR: a given quantile of the distribution, Duffie and Pan, 1997) and the Conditional Value at Risk (CVaR: expected shortfall, Rockafellar and Uryasev, 2000) (Fig. 1). The key feature of downside risk measures is that only losses below the target set are of importance. Even though RMM have identified a context specific preference towards risk (specifically "the loss associated with under-prediction is held to be less than the loss associated with over-prediction"), the authors have decided to ignore this preferential information, and utilize the more general definition of risk, rather than utilize a downside risk measure. An example of managing downside losses for a multi-period forest harvest scheduling problem is found in Eyvindson and Kangas (2015).

By focusing solely on the minimization of the variation of the total harvest quantity, RMM did not analyze the increasing costs required to minimize the variation. By focusing on minimizing the variation, the authors seemed to be willing to accept a cost of doubling the area harvested (from 997 ha to 1983 ha) for a modest improvement in the variation. The implicit meaning behind such a large increase of harvested area is that lower volume and

* Corresponding author.
E-mail address: kyle.j.eyvindson@jyu.fi (K. Eyvindson).

http://dx.doi.org/10.1016/j.foreco.2016.03.038
0378-1127/

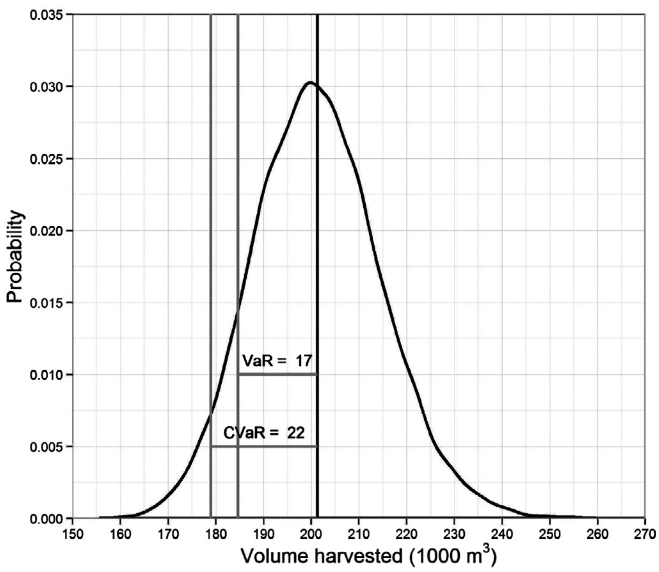

Fig. 1. A representation of the possible harvest distribution for the simulated forest. The black vertical line is the expected harvest (which is used as the target for evaluating the downside risk measures), while the VaR and CVaR when $\alpha = 0.1$ are identified for losses exceeding 5000 m^3 from the mean result are in grey.

possible less productive stands will be harvested. This is a very large cost. To aid in the decision making process, those individuals tasked with making the decision may wish to see the trade-off between increased harvesting area and decreased harvesting variation.

As the authors have identified, managing risk requires a balance of trade-offs. For the investment portfolio problem of Markowitz (1952), this trade-off occurs between the expected mean return of the investment, and the variation of the expected return of the investment. A choice must be made by the investor, a risk-averse investor would like to minimize the variation, while a risk-seeking investor would solely be interested in maximizing the mean return. For the case described by RMM, the trade-off occurs between the variance of the total volume harvested at a specific target and the total area harvested. To represent the trade-off more accurately, an analysis could be done as the trade-off between the total harvest variation and the total cost of conducting the harvest.

In this comment, we clarify the trade-offs that are occurring as the decision maker shifts from being risk-averse to risk-seeking. Additionally we suggest an alternative approach to managing the risk associated with determining the appropriate harvest schedule. Rather than minimizing variation, the objective should be to minimize the total area harvested which provides a specific target volume, while ensuring that a specific downside risk measure is met. This is done by including the CVaR, a coherent risk measure (Artzner et al., 1999; Krokhmal et al., 2011), as a constraint to the optimization model. In this way, the key constraint is placed in the objective function, and the associated downside risk is set as a constraint. We believe that this kind of optimization process better reflects the intent of area constraint, and focuses harvest on only a limited forest area.

2. Materials and methods

2.1. Methods

To ensure clarity for the models, we will mathematically describe the models used by RMM (both based on the written description and the supplementary R file). From there, we will emphasize the (probably unintended and most likely unwanted) effects of the optimization models on the forest structure and harvesting costs. We then suggest an alternative way to achieving a specific target with a specified level of risk. While we are not utilizing the same data used by RMM, we are using the simulated data which they suggest is realistic, and we expect is a reflection of the real dataset that they used. As the result that we obtained from the simulated data has the same properties as described in the article, we believe that an appropriate comparison can be made.

The first model used by RMM was a simple integer linear programming model, which maximized the expected harvest, subject to an area constraint (and in the R code a constraint limiting the number of stands harvested). We identify this model as Model 1:

$$\max \sum_{j \in N} \mathbb{E}(c_j) x_j \tag{1}$$

subject to:

$$\sum_{j \in N} a_j x_j \leqslant t_a \tag{2}$$

$$x_j \in \{0, 1\}, \forall j \in N \tag{3}$$

where $\mathbb{E}(c_j)$ is the expected timber harvested for stand j, N is the set of stands under consideration, x_j is the decision variable defining if stand j is to be harvested or not, a_j is the area of stand j, and t_a is the limit to the area harvested. This is a simple integer linear programming model, where the objective is to maximize the quantity of timber harvested, subject to: an area constraint (2). A note: in the R model provided as a supplement to RMM, there is a constraint limiting the total number of stands harvested ((4) where t_s is the limit to the stands harvested), while in the paper there is no mention of this constraint. For this comment, we will not include an additional constraint limiting the total number of stands harvested.

$$\sum_{j \in N} x_j \leqslant t_s \tag{4}$$

The second model presented by RMM is one which maximizes the 10th quantile of the timber harvest predictions, rather than the expected timber harvest. The only change is in the objective function. We identify this model as Model 2:

$$\max \sum_{j \in N} c_j^q x_j \tag{5}$$

subject to (2) and (3), where c_j^q is the qth (in this case $q = 10$) quantile of the distribution of predicted timber harvested for stand j.

The third model is one which minimizes the variation of the total timber harvested, subject to a targeted harvest constraint. We identify this model as Model 3:

$$\min \sum_{j \in N} v_j x_j \tag{6}$$

subject to:

$$\sum_{j \in N} \mathbb{E}(c_j) x_j \geqslant b \tag{7}$$

and (3), where v_j is the variation of the timber harvested from stand j, and b is the target for the total harvested volume. From the description provided by Robinson et al. (2016) they indicate that the area constraint was replaced by the volume constraint. However, in the R script from the supplementary material, this model also has an area constraint (2). In the R code the maximum area was set to 2000 ha, which can explain the reason why this model has nearly 2× the area harvested than the models one and two of RMM.

While this model does manage the risk (positive and negative gains), it does so indiscriminately. The authors of this paper have