FOREST GROWTH MODEL FOR PREDICTION OF TIMBER SUPPLY AND REQUIREMENT IN PENINSULAR MALAYSIA

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ABSTRACT

High demand of timber supply leads to a need of splendid forest management and planning for the timber harvesting operations in order to anticipate the surpluses or shortages of timber stock. It is crucial to ensure the sufficiency of high quality timber stock correspond to the cutting cycle over years. Traditional approaches of estimating and predicting the number of timber stock resources are based on the focus towards the forest inventory that has been done through the Selective Management System (SMS). In order to predict the supply and requirement of timber stock, mathematical modelling do plays an important roles. The construction of suitable mathematical model has been widely formulated by considering various practical constraints. Based on the forest harvesting operations, many researchers have produced a variety of models to solve the problems by using suitable methods. To provide support in modelling problem characteristic and in suggesting applicable algorithm, this paper put a particular focus on the forest growth model and the timber supply. In order to validate the model, small data instances have been applied. LINGO programming software has been used to conduct a numerical experiment in evaluating the performance and to obtain exact solution of the suggested model.

Keywords: growth model, timber supply

INTRODUCTION

Forest is one of the most important asset that contributes many benefits directly and indirectly to the nation. As the population grows, demand for the forestry sector also increase. Malaysia, particularly is committed in ensuring continuous timber production, maintaining the multiple functions of forests, biodiversity conservation and controlling the environmental impact (Mohd Yunos, 2000). Basically, in Peninsular Malaysia, there exists an issue on the prediction of timber supply and requirement. This is related on the timber harvesting operations where from the first cutting cycle to the next cutting cycle, there is a demand in ensuring that the stock estimations of the timber supply for the next cutting cycle to be adequate in meeting the requirements. Hence, the forest growth model through the mathematical review has been chosen in order to look into this matter.

THE GROWTH MODEL

The key to forest modelling is to accurately portray the dynamics of forests. Successful forest-management modelling finds a means to improve management through accurate representation of all parts of the systems (Twery, 2004).

As being known, management planning for forest plantation is a complex activity. In conjunction with that, linear programming model offers an optimal solution to the problem of forest plantation management. Hence, the management alternatives were formulated mathematically as a linear programming model.

On the other hand, growth model generally refers to a system of equations which can predict the growth and yield of the forest stand under a wide variety of conditions. It also provides a reliable way to examine silvicultural and harvesting options, determine the sustainable timber yield and examine the impacts of forest management and harvesting on other values of the forest (Jerome K. Vanclay, 1994).

While for the model evaluation, it plays an important role of model building, and some examination of the model should be made at every stage of model design, fitting and implementation, while thorough evaluation of a model involves several steps, including verification and validation. (Vanclay & Skovsgaard, 1997).

According to Vanclay (1994), in order to evaluate growth models, it includes the revealing of any errors and deficiencies in the model, such that by establishing those procedures:

- whether the equations used adequately represent the processes involved;
- if the equations have been combined correctly in the model;
- whether the numerical constants obtained in fitting the model are the best estimates;
- whether the model provides realistic predictions throughout the likely range of application;
- if the model satisfies specified accuracy requirements;
- how sensitive model predictions are to errors in estimated coefficients and input variables.

Aim of this study is to portray maximization of the volume yield to forestry which is economically profitable and on the other hand to forest management systems that emphasize biodiversity and other environmental aspects of forestry.

THE MATHEMATICAL FORMULATION

This section proposed sample of mathematical formulation for the growth model which concentrated on maximizing the volume yield to forestry.

Let $T_t = [T_{tij}]$

where t=0, 5, 10,…; i=1,2,…,s; j=1,2,…,n, denotes the number of trees of species i in size class j at time t.

Let $b_{tij} = [T_t]$

where t=0, 5, 10…; i=1,2,…,n, denotes the fraction of trees of species i in size class j that move to next size class at time t. This fraction depends on latitude, site type, stand density and structure.

The stand development can now be illustrated with the following equations

$$
\begin{aligned}
y_{t+5,i,1} &= d_i + a_{ti1} y_{ti1} - h_{ti1} \\
y_{t+5,i,j+1} &= b_{tij} y_{tij} - h_{t,i,j+1}, j = 1,\dots,n-2 \\
y_{t+5,i,n} &= b_{t,i,n-1} y_{t,i,n-1} + y_{t,i,n}(1 - m_{t,i,n}) - h_{t,i,n}
\end{aligned}
$$

Denoting the discount factor as $b = \dfrac{1}{1+r}$

where r is the interest rate.

h_{ijt} = Number of harvested tree of species i in size class j at time t

$m_{t,i,n}$ = Natural mortality of species i in size class n at time t

d_i = Tree density of species i

SIMPLE OPTIMIZATION PROBLEM

From the above formulation, an example of maximization problem of the volume yield that is economically profitable to forest management systems is being displayed as follows

$$\max \sum_{t=0}^{\infty} \sum_{i=1}^{s} \sum_{j=1}^{n} h_{tij} (p_{i1} v_{ij1} + p_{i2} v_{ij2}) b^t$$

where v_{j1} and v_{j2} denote the saw log and pulpwood volume respectively of a tree in size class *j*. p_1 and p_2 are corresponding species specific stumpage prices.

$$h_{tij} \geq 0, t = 0,5,10,...; i = 1,2,..., s; j = 1,2,..., n$$

Forest growth model for tree type I, tree type II and tree type III is being applied where for each species the number of size classes is 12, from 75mm to 625mm at 50mm intervals. The optimizations are made in four site types, site type A, site type B, site type C and site type D. Site type A is being least fertile while site type D is the most fertile. Mixed species stand is optimized at site type C. Saw log and pulpwood volumes are calculated using height function. The stumpage prices are calculated by taking the average from deflated stumpage prices from years 2002 to 2013 at level of 2013. Saw log and pulpwood stumpage prices are as follows.

	Saw log (RMm^{-3})	Pulpwood (RMm^{-3})
Tree type I	63.70	23.91
Tree type II	63.26	31.51
Tree type III	56.35	23.38

Solution

Both optimal volume and net present value maximization solutions converge to same species-and-site type specific steady state. The highest annual yield is obtained by applying the shortest harvesting interval for all species at all sites. When prices for saw log and pulpwood in addition to interest rate are added to the optimization and the harvesting interval extended to 15 years, the optimal solution produces 95-99% of maximum yield. The annual yield decreases with increasing interest rate.

This optimization model shows that other decision alternatives can be also solved simultaneously and become more practical with more constraints. The efficient utilization of this technical equipment allows for more treatment types and tree types besides uncertainty in parameters values also can be dealt with this optimization model.

Conclusion

This paper discussed on the forest growth model formulation through the mathematical approach where it is such an important way to model the complexity of the forest composition. This study also performed a simple optimization problem to validate the forest growth model by using LINGO 14.0. This study should enhance the understanding of integrating mathematical model into the forest growth model.

Future research looks certainly very exciting and it is expected that more researchers will dwell into this field of research. With respect to the application, we remark that the main contribution is represented by the integrated resources of the forest timber production. For future studies, a few other operational research approach will be applied to the integrated model with real life data.

Acknowledgments

The authors would like to thanks the Malaysian Ministry of Higher Education and Universiti Teknologi Malaysia for their financial funding through RUG vote number Q.J130000.2526.20H16. This support is gratefully acknowledged.

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