Research Journal of Applied Sciences, Engineering and Technology 4(2): 112-115, 2012
ISSN: 2040-7467

Submitted: September 23, 2011 Accepted: November 02 , 2011 Published: January 15, 2012

Optimization Scheduling of Timber Production Logistics with Consideration of CO_2 Emission in Heilongjiang Forest Region of China

Xiaojing Zhang and Lihai Wang
College of Engineering and Technology, Northeast Forestry University,
Harbin Hei Longjiang, 150040, China

Abstract: Timber production logistics systems differ greatly in forest regions. This study investigated multistage timber production and storage system. Based on case studies from the Heilongjiang Forest Region, northeast part of China, an optimal operation scheduling model, with considerations of forest environment, economic benefit, working safety and the disturbance to carbon emission, was established by using a multi-objective optimization method. The results of the case studies, optimizing operation schedules, show that the models are quite applicable and helpful to practical operations.

Key words: Low carbon emission, multi-objective planning, optimization, timber production logistics system

INTRODUCTION

The timber production logistics system is consisted of following three stages and two states of operations according to the operation location and operation organizations on cutting site, methods of timber transport, and operations at storage yards.

Skidding, transport and conveying are crucial stages to the overall operation system (Wang and Sun, 1994). Together with wood storage on the cutting yards and wood storage before conveying at the yards, they are the five key macro-variables reflecting the state and change of a timber production system (Yang and Wei, 2009).

Differences among operation location, environment, cost, efficiency, damage to the residual stands, damage to soil, and so on, change violently from stage to stage over a year. It is difficult to assign the amount of timber production among the four seasons for each of the stages. This is why we discuss the operational planning problem for timber production in this region.

Generally speaking we make an operational yearly timber production schedule in order to decide how to harvest and how much to harvest annually. The total amount of timber should be distributed among four seasons so that we can obtain the best results for the operations from both an economical and environmental points of view.

METHODOLOGY

Selection of criteria for comprehensive evaluation of harvesting operations: Based on the knowledge about forests, forest timber production operations, and its impact on the environment, we select the following criteria to comprehensively evaluate today plans:

- **Operation cost C1:** Organizers of timber production want to know how much profit they would gain from production based on the prediction of operation cost.
- **Ratio of input of forest resources and output of products C2:** Timber production, as a kind of system production, is composed of three parts: input, processing and output. Forest resources are more and more expensive. So the ratio of input of forest resources and output of products is the key criterion to evaluate the degree of utilization for the purpose of timber production. That is:

  Ratio = total amount of forest resources/
  total amount of timber (to be) produced

- **Degree of working safety C3:** Degree of working safety is a symbol of the development level of timber production in both social and economic aspects. It has been attracting more and more attention in recent decades, and has become one of the key criteria for evaluating production.
- **Degree of timber production damage to the residual stands on the operation sites C4:** The trees maintained on the operation sites also play an important role in regeneration after timber production. Besides supplying seeds, they can influence the density of sunlight, strength of rainfall, and microclimate in the stand area.
- **Degree of timber production damage to soil and vegetation in the operation sites C5:** Poor timber production methods often result in serious damage to soil and vegetation. High soil compaction and large

Corresponding Author: Xiaojing Zhang, College of Engineering and Technology, Northeast Forestry University, Harbin Hei Longjiang, 150040, China

amounts of productive soil runoff significantly hinder the regeneration after cutting. In the long term, it would accelerate the succession of a forest ecosystem to a lower community.

- **Degree of timber production disturbance to carbon emission C6:** The forest is a giant carbon stock, it plays an important role in carbon fixation and reducing the emission of greenhouse gas. Global warming has become a grim reality, so the development of low carbon forestry has more and more vital significance. Making reasonable timber production schedule will contribute immeasurably to reducing the emission of CO_2 and realizing the low carbon forestry.

The comprehensive optimal model for harvesting operation schedule: A forest timber production operation is theoretically restrained by the multicriteria mentioned above. How may one incorporate the multicriteria into one planning model? There are two typical approaches used in industry planning. One is to take one of the criteria as the objective of planning while taking the other criteria as constraints (Yan, 1989). Another is to use the method called multi-objective programming. Here we develop a new method, which is a combination of Analytic Hierarchy Process (AHP) (Dai, 2010) (Wang and Tao, 2009; Chen and Huang, 2010) and Linear Programming (LP) (Zeng and Tian, 2010).

We solve this optimization problem by the LP method. The objective coefficients in the LP model represent the comprehensive benefit of timber production

Table 1: Reference values of comparison

Benefit	Worst	Worse	Good	Better	Best
Value	1	3	5	7	9

Table 2: Comparison of operation benefits among the four seasons

	Season	C1	C2	C3	C4	C5	C6
Stage 1	Spring	5	4	6	4	3	3
	Summer	1	1	5	7	1	1
	Autumn	3	5	9	9	3	7
	Winter	9	9	1	1	9	9
Stage 1	Spring	3	5	6	6	3	0
	Summer	1	1	7	7	1	0
	Autumn	5	5	9	9	3	0
	Winter	9	9	1	1	9	0
Stage 2	Spring	1	5	6	7	3	3
	Summer	3	1	7	1	1	1
	Autumn	5	6	9	9	5	7
	Nintu	9	9	1	7	9	9
State 2	Spring	3	3	5	0	0	0
	Summer	1	1	5	0	0	0
	Autumn	5	7	9	0	0	0
	Winter	9	9	1	0	0	0
Stage 3	Spring	9	0	5	0	0	0
	Summer	7	0	5	0	0	0
	Autumn	7	0	9	0	0	0
	Winter	1	0	1	0	0	0

Table 3: Weight distribution

Criterion	C1	C2	C3	C4	C5	C6
Distrbution bj	0.1 96	50.18 98	0.19 52	0.16 37	0.13 64	0.11 89

Table 4: Comprehensive benefits of timber production operations among four seasons

	Winter	Spring	Summer	Autumn
SG1 cutting and skidding	6.12 88	4.3311	2.763	6.0086
STI storage at sites	5.05 87	4.09 96	3.0345	5.5683
SG2 transport	7.111	4.22 8	2.5632	6.8632
ST2 storage at yard	3.66 74	2.13 34	1.3618	4.0654
SG3 processing at yard	0.39 12	2.74	2.438	3.1288

Table 5: Optimal solution without specific constraint (%)

	Winter	Spring	Summer	Autumn
SG1 cutting and skidding	100	0	0	0
STI storage at sites		34	33	330
SG2 transport	67	0	0	33
ST2 storage at yard	67	17	16	0
SG3 processing at yard		0	50	050

Table 6: Optimal solution under the constrant of unchangeable production capacity at stage 3 (%)

	Winter	Spring	Summer	Autumn
SG1 cutting and skidding	100	0	0	0
STI storage at sites	16	16	0	
SG2 transport	84	0	0	16
ST2 storage at yard	42	25	0	0
SG3 processing at yard	42	17	25	16

Table 7: Optimal solution under the constrants of stage 3 and stage 2 (%)

	Winter	Spring	Summer	Autumn
SG1 cutting and skidding	100	0	0	0
STI storage at sites	37	37	16	0
SG2 transport	63	0	21	16
ST2 storage at yard	21	4	0	0
SG3 processing at yard	42	17	25	16

Table 8: Optimal solution under the constrants of stage 1, stage 2 and stage 3 (%)

	Winter	Spring	Summer	Autumn
SG1 cutting and skidding	75	0	22	3
STI storage at sites	12	8	13	0
SG2 transport	63	4	17	16
ST2 storage at yard	21	8	0	0
SG3 processing at yard	42	17	25	16

operations. According to the AHP (Dai, 2010), the reference values of comparison for timber production comprehensive benefits among four seasons are shown in Table1. Table 2 shows the results of this comparison, and the average comparison values of each possible operation among four seasons.

Evaluation of comprehensive benefit of timber production operations for each approach: Through matrix calculation and further processing, we have weight distribution bj ($j = 1, 2, ..., 6$) shown in Table 3.

Based on Table 2 (matrix $\{X\}$) and Table 3 (as matrix $\{C\}$), we obtain the comprehensive benefit of harvesting operation among the four seasons by matrix calculation:

$$\{E\}_{20} = \{X\}_{20\times 6}\{C\}_{6\times 1}$$

and the result is shown in Table 4.

The comprehensive optimal modle for timber production operation planning: Let Xij ($i = 1, 2, 3, 4, 5$; $j = 1, 2, 3, 4$) be the proportion of operation level of the total amount of production planned for procedure i during season j. On the basis of Table 4, we can develop the comprehensive optimal model for timber production operation planning in a linear programming form as follows:

Objective: To maximize the Comprehensive Benefits of Timber Production Operations (CBTPO in short) over a year,

MaxCBTPO =

$$\begin{aligned}
&6.1288X_{11}\ \ 4.3311X_{12}\ \ 2.763X_{13}\ \ 6.0086X_{14}+\\
&5.0587X_{21}\ \ 4.0996X_{22}\ \ 3.0345X_{23}\ \ 5.5683X_{24}+\\
&7.111X_{31}\ \ 4.228X_{32}\ \ 2.5632X_{33}\ \ 6.8632X_{34}+\\
&3.6674X_{41}\ \ 2.1334X_{42}\ \ 1.3618X_{43}\ \ 4.0654X_{44}+\\
&0.3912X_{51}\ \ 2.74X_{52}\ \ 2.438X_{53}\ \ 3.1288X_{54}
\end{aligned}$$

Constraints:

- Operation level of timber production at each stage must be equal to the total amount of timber production planned by long-term planning:

$$\begin{aligned}
&X_{11}\ \ X_{12}\ \ X_{13}\ \ X_{14} = 1\\
&X_{31}\ \ X_{32}\ \ X_{33}\ \ X_{34} = 1\\
&X_{51}\ \ X_{52}\ \ X_{53}\ \ X_{54} = 1
\end{aligned}$$

- The total amount of wood storage at each state can not exceed the total of timber production for a whole year:

$$\begin{aligned}
&X_{21}\ \ X_{22}\ \ X_{23}\ \ X_{24} \le 1\\
&X_{41}\ \ X_{42}\ \ X_{43}\ \ X_{44} \le 1
\end{aligned}$$

- Dynamic constraints of states for overall system:

$$\begin{aligned}
&X_{11}\ X_{21}\ X_{24}\ X_{31} = 0\\
&X_{31}\ X_{41}\ X_{44}\ X_{51} = 0\\
&X_{12}\ X_{21}\ X_{22}\ X_{32} = 0\\
&X_{13}\ X_{22}\ X_{23}\ X_{33} = 0\\
&X_{14}\ X_{23}\ X_{24}\ X_{34} = 0\\
&X_{32}\ X_{41}\ X_{42}\ X_{52} = 0\\
&X_{33}\ X_{42}\ X_{43}\ X_{53} = 0\\
&X_{34}\ X_{43}\ X_{44}\ X_{54} = 0\\
&(X_{24} \le S1,\ X_{44} \le S2)
\end{aligned}$$

  where, S1 and S2 are initial values of state 1 and state 2 respectively. According to the harvesting practice in the Heilongjiang Forest Region, assume: $S1 = S2 = 0$.
- Non-negative constraints
  $X_{ij} \ge 0$ ($i = 1, 2, 3, 4, 5, 6$; $j = 1, 2, 3, 4$).

RESULTS AND DISCUSSION

The constraints for the model above are general for the planning of timber production operations in Heilongjiang Forest Region. In the case study, some specific constraints, also typical and popular in that region, are considered together. So the results of the model for different constraints are as follows:

- Optimal solution without specific constraint of production capacity for each operation, shown in Table 5
- Optimal solution under a specific constraint of unchangeable production rate of stage 3, shown in Table 6
- Optimal solution under constraints of both unchangeable production rate of stage 3 and storage capacity limitation of state 2 (less than 50% of total amount of production during the same season) around a year is shown in Table 7
- Optimal solution under constraints of
  - Unchangeable production rate at stage 3
  - Storage capacity limitation (less than 50% of total production during the same season) at stage 1
  - Storage capacity limitation (less than 50% of total production during the same season) at stage 2 is shown in Table 8

It is clear from the results obtained above that winter (November-March) is the best season for timber production operations in Heilongjiang Forest Region, especially for the operation in cutting sites. It has been proved by practice that conducting logging operations during winter in that region is very helpful to both economic and environmental considerations. In other words, logging operations during that period result in high operation efficiency, low cost, less damage to forest environment and low degree of carbon emission caused by timber production. Low-temperatures cause microorganism activity and root respiration to decline, which will result in low degree of carbon emission. Frozen skidding road causes low degree of soil compaction. On the one hand it reduces the change of soil physical and chemical characters; on the other hand it makes the soil productivity balance, which makes the low degree of the disturbance to carbon emission.

Spring is the worst season for timber transport operations. This conclusion is consistent with the running results of many forest enterprises in that region. During springtime, the bearing capacity and the roughness of both standard roads and non-standard roads are much worse than those in the best season for timber transport operations. Wood storage in cutting sites and at yards certainly results in higher total operation costs. But this contributes more to the comprehensive benefits of the overall operation of timber production.

ACKNOWLEDGMENT

This study was supported by the Graduate Innovation Foundation of Northeast Forestry University and China National Public Affairs Project (201104007).

REFERENCES

Chen, Z. and G. Huang, 2010. A dynamic assessment of forest ecological security on region-scale in application of psr model and analytic hierachy process. Trop. Fore., 3(38): 42-45.

Dai, S., 2010. Research of logistics system based on system dynamic. Value Engineering, pp: 18-19.

Wang, L. and M. Sun, 1994. Environmental constraints on forest harvesting Haerbin. J. Northeast For. Univ., 22(6): 78-83.

Wang, Y. and J. Tao, 2009. Application of analytic hierachy process in evaluating water preserving capability of forest soil. For. Eng., 1(25): 4-7.

Yan, H., 1989. Principles of evaluation by experts and optimal evaluation model. Syst. Eng., 2: 19-23.

Yang, B. and X. Wei, 2009. System simula of regional logistics based on system dynamics. For. Eng., 1(25): 81-85.

Zeng, M. and D. Tian, 2010. The review to the algorithm of linear programming problems. Sci. Technol. Engi., 1(10): 152-159.