The Prediction of Labor Productivity in Yarder Type Logging Systems

J. Tobioka and T. Yamazaki
Faculty of Bioresources
Mie University
Tsu, Japan

INTRODUCTION

With the purpose of designing an operational system aimed at the optimization of yarder-type logging operations in steep mountain forests, the records of yarder type logging operations in a typical private forest in Japan were studied. The quantification theory (1,2) was applied to the data for factor analysis to analyze, in numerical terms, an interrelationship between labor productivity in the yarder type logging system and conditional factors of operation. Based on the results of analysis, a prediction model, needed for the formulation of yarder-type logging operation plans or for the evaluation of operations, was designed to estimate labor productivity for given conditions of operation. In addition, an attempt was made to examine the possible optimization of operational conditions in the yarder type logging system.

ANALYTICAL DATA AND METHODS

For analysis, the data on labor productivity in yarder type logging operations and on conditional factors of operation having quantitative and qualitative relevance were obtained from records of logging operations conducted in the four year period from 1985 through 1988 at a company owned forest (planted forest) of Niihama Forest Division, Sumitomo Forestry Co., regarded as one of the typical Japanese private forests.

The items as shown in Table 1 were selected as conditional factors of operation and the quantification theory was applied to the data on 36 blocks surveyed, in an attempt to find an interrelationship between labor productivity in this type of logging operation and conditional factors of operation determined by factor analysis.

RESULTS AND DISCUSSION

1. The prediction of labor productivity.

Table 2 shows a prediction model for labor productivity in the yarder type logging system designed from the results of factor analysis. This prediction model comprises two steps. Step 1 includes all the conditional factors of operation as selected in the item of factors, while Step 2 involves only those with a significance level of 1% from among the conditional factors of operationin Step 1. In designing the model, with labor productivity as an index and conditional factors of operation as factors involved, the item of factors was arranged in order of higher values of partial correlation coefficient, so that the order and degree of intensity in correlations between labor productivity and given conditional factors of operation can be identified in definite terms. The model makes it possible to predict labor productivity that corresponds to given conditions of operation. Namely, a group of values found in the column "Normalized score" in the model are considered to represent the values given to the category of factors, denoting a labor productivity for given conditions of operation. An estimated value for labor productivity in the block can be computed by summing up normalized scores given to each category of factors for the block, to which the mean value of outside criterion (labor productivity) of 1.53 is added.

When a multiple correlation coefficient shown in the prediction model is a measure of the estimated accuracy for labor productivity, then the multiple correlation coefficient is considered significant at a 1% level both in Step 1 and Step 2. This indicates that the item of factors as designated in the prediction model are combined to jointly act upon labor productivity, and that the estimated accuracy for labor productivity in each Step can be measured with a multiple correlation coefficient. A ratio of contribution is a measure employed to identify the degree with which the item of factors combined contributes to labor productivity.

In summary, operational characteristics in the yarder type logging system are numerically identified in terms of a relationship between labor productivity and conditional factors of operation, whereby the effect of conditional factors of operation on labor productivity, and the degree of contribution can be evaluated in numerical measures. Also it is verified that with the application of the prediction model to study the related conditional factors of operation in

Table 1. Results of a Study on Labor Productivity and Conditions of Operation (Characteristic Values and Explanatory Characteristics)

Labor Productivity (m^3/manday)	Cutting classification (No. of blocks)	Average grade of forest ground in block(%)	Area in one block(ha)	Production log volume in one block (m^3)
1.53		61	8.99	971
	Clear cutting 15			
0.74		23	1.00	60
	Selective " 12			
3.35		88	29.39	3,920
	Thinning 9			
0.68		16	6.19	956

Average stumpage volume per log (m^3)	Yarding system (No. of blocks)	Average area per yarding line (ha)	Average yarding distance to landing (m)
0.39		1.99	497
	Double endless 22		
0.08		0.66	80
	Endless tyler 10		
1.83		7.00	1,042
	Others 4		
0.35		1.27	278

Note: The four values in each column represent a mean value, a minimum, a maximum and a standard deviation, respectively.

Table 2. Prediction for Labor Productivity

Item of factors	Category of factors	Step 1 Normalized score	Step 1 Partial correlation coefficient	Step 2 Normalized score	Step 2 Partial correlation coefficient
Cutting classification X_1	Clear cutting	0.71517		0.69850	
	Selective c.	-0.44387	0.900**	-0.44614	0.956**
	Thinning	-0.60012		-0.56932	
Average stumpage volume per log X_2	- 0.20(m^3)	-0.01159		-0.05137	
	0.21 - 0.57	-0.08924	0.816**	-0.08201	0.817**
	0.58 -	0.80049		0.83063	
Average yarding distance X_3	- 357 (m)	0.13214		0.07603	
	358 - 636	0.03278	0.521**	0.03765	0.412*
	637 -	-0.17264		-0.11090	
Area in one block X_4	- 5.88(ha)	-0.00843			
	5.89 -12.09	-0.05541	0.283		
	12.10 -	0.07829			
Yarding system X_5	Double endless	-0.03193			
	Endless tyler	0.09855	0.224		
	Other	-0.07077			
Production log volume in one block X_6	- 492(m^3)	0.06278			
	493 -1,449	-0.01124	0.194		
	1,450 -	-0.07949			
Average area per yarding line X_7	- 1.34(ha)	-0.03790			
	1.35 - 2.63	0.02439	0.140		
	2.64 -	0.02354			
Average grade of forest ground X_8	- 52 (%)	0.01057			
	53 - 69	-0.00150	0.056		
	70 -	-0.01195			
Multiple correlation coefficient		0.975**		0.971**	
Ratio of contribution (%)		95.1		94.3	

Note: A value marked with ** is significant at a 1% level and the one with * at a 5% level.

a block, a labor productivity for given conditions of operation can be predicted with high accuracy.

2. The optimization of operational conditions.

To optimize conditions for yarder type logging operations in a planned block, an attempt was made to examine the conditions of operation that will maximize labor productivity with the use of the prediction model. In the prediction model, where Step 1 and Step 2 are given normalized scores respectively, and using the estimation method for labor productivity previously discussed, a maximum estimated value for labor productivity can be obtained by adding maximum values given to each category of factors in either step. This shows that any category having a maximum value in the item of factors should represent an optimum condition of operation. Thus, if optimum conditional factors of operation were combined in this manner in Step 1, the maximum estimated value for labor productivity would come to 3.45 m^3 / manday, which is the anticipated result, 2.26 times higher than 1.53 m^3 / manday.

Therefore, it should be noted that for the optimization of operational conditions in any block, careful examination is necessary to approximate the operational conditions by the combination of optimum conditional factors of operation, in spite of some given conditions involved being beyond artificial control, for example, an average grade of forest ground in the block.

CONCLUSIONS

To summarize, there is an interrelationship between labor productivity in yarder type logging operations in a geographically-steep man-made forest, and quantitative and qualitive conditional factors of operation identified numerically through the application of the quantification theory for factor analysis. Further, with the prediction model designed on the basis of analysis for labor productivity, given conditions of operation can be predicted and optimum conditions can be examined. A similar conclusion has been reached also with the tractor, yarder and helicopter logging systems, as a result of applying the same concept to the study and analysis on these operations in the Japanese National Forests (3, 4, 5).

The findings, as obtained here, are deemed to have important significance as fundamental information needed for rational planning and evaluation of logging operations.

ACKNOWLEDGEMENT

We would like to show our deepest appreciation to the staff of Niihama Forest Division, Sumitomo Forestry Co., for their assistance extended to us in gathering data and information for our study.

REFERENCES

[1] HAYASHI, C., HIGUCHI, I. and KOMAZAWA, T., 1974: (Information science and statistical mathematics.) Sangyotosho, Tokyo, pp. 223-238.

[2] HAYASHI, C. and KOMAZAWA, T., 1984: (Quantification theory and data processing.) Asakurashoten, Tokyo, pp. 10-48*.

[3] TOBIOKA, J., 1984: Studies on the systematization of the logging operation in forest management by the non-clear cutting method (II) On the relationship between labor productivity and conditions of operation in the tractor logging system. Trans. 95th Annu. Meet. Jpn. For. Soc., pp. 659-662**.

[4] TOBIOKA, J., 1987: A study on the prediction of labor productivity in the yarder type logging system for forest management by the non-clear-cutting method. The 18th IUFRO World Congress Proceedings S:3:04, pp. 197-203.

[5] TOBIOKA, J., 1988: A study on the prediction of productivity in the helicopter yarding system. International Symposium on Developments on Work Studies in Forestry IUFRO S:3:04:02, Thessaloniki.

* Only in Japanese

** In Japanese with English titles.

The titles in parentheses are tentative translation from the original Japanese titles by the author of this paper.