A COMPARISON BETWEEN TRACTOR BASED AND SKYLINE BASED MECHANIZED SYSTEMS FOR TIMBER LOGGING

M. BÎRDA[1]   S.A. BORZ[1]

Abstract: *Selecting the best fit technological system for timber harvesting and logging represents a difficult task, which, on a given time, involves technical and economical decisions. In case of integral, non fragmented logging lines, differentiation between different logging-yarding means could involve economic and economic aspects. But in order to establish the differences between the applied technologies, the latter have to work in similar conditions. In this context, the presented paper describes, under technical and economic aspect the differences and the limits between two fully mechanized logging systems, one based on tractors and another based on skylines (cable-yarders).*

Key words: *logging systems, comparison, cost estimation.*

1. Introduction

Selecting the best fit technology in timber logging is a task which involves several steps regarding technical, economic, and silvicultural-ecologic problems. Technically speaking, it is quite difficult to select a logging system, especially in conditions in which, the base machine could work only in the hauling operations, the lateral skidding being realized by other means. Also, different logging means, applied in different conditions will generate different process costs.

Logging network setup is influenced by a lot of factors, such as felling area surface and shape, terrain slope and aspect, logging mean performances and their adapting to ground situation, the desired

harvesting-logging strategy. For given conditions regarding the distance between two successive logging tracks (tractor roads, skylines), the length of logging network increases by the felling area surface. In case of tractor-based setups, the terrain slope generally increases the logging network length [1], [3], by the necessity to accord the tractor road longitudinal slope with the tractor's performances and ecologic issues. Generally, the adopted longitudinal slopes for tractor roads are considered to be between 5 and 30% [1], [3], sometimes greater. On the other hand, the skyline length is technically limited by its own construction. In this case, the terrain slope has an important significance in skyline network setup, the same reduced to ground

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[1] Dept. of Forest Engineering, Forest Management and Terrestrial Measurements, *Transilvania* University of Braşov.

length, being smaller as the terrain slope increases. Terrain aspect is a condition for the logging network geometry, especially in case of tractor-based networks. Generally, in case of terrain slopes oriented to the landing sites, the logging network length is smaller. The logging network setup can be regarded as a static setup, corresponding to a certain state, or as a long term strategy [1], when it usually considers a production cycle for a management compartment. Of course, the optimization of logging network setup in the last case has to consider the scheduled interventions during a production cycle in a specific stand.

Given the above mentioned problems, it is necessary to establish in which conditions a tractor based setup or a skyline based setup for timber logging can be selected in certain conditions. For this purpose, a static approach has been considered, due to the limitation of this paper's space, in order to highlight the appropriate technologies for certain cases.

2. Technical and Economic Comparison between Fully Mechanized Tractor Based and Skyline Based Timber Logging Systems

2.1. Designing equal working conditions

In order to realize a technical and economic comparison regarding the involved costs for timber logging using the tractor (TAF Romanian concept was considered in this paper) or the skyline (FP2 Romanian concept was considered in this paper) it is necessary to provide a series of conditions which would assure approximately identical work premises for the two logging means.

For the purposes of the present paper, the following hypotheses were considered:
- the timber logging is integrally realized through one of the above mentioned means;

- lateral skidding and yarding distances are adopted by considering ergonomic aspects (up to 50 meters in tractor case) and technical-ergonomic aspects (up to 30 meters in skyline case);
- the felling area width (Figure 1) is generated by the double distance of lateral skidding in case of the mean which represents the greater distance. This way, a width of 100 meters was obtained;
- the length of the felling area is influenced by the terrain slope, the reduced to horizon length being smaller as the slope increases. Also it is influenced by the technical setup limit of the skyline (FP2 case - 2000 meters);
- on terrains with a slope of generally <25%, the tractor based logging network is developed on the great slope line [3], and in all other cases, the tractor roads are designed by a longitudinal slope of 25%;
- being just a model, no correction factors are applied for the network length or for skidding-yarding distances;
- the tractor based logging network is represented by an axial road, which begins and ends at the middle of the felling area width. Also, to cover the felling area, two skyline setups are necessary;
- the average lateral skidding-yarding distances are of 25…30 meters for tractor and 10…15 meters for skyline;
- successive slope graduation generates increased lengths for tractor logging network, whereas the skyline yarding network remains constant. The same principle applies to hauling distances;
- average terrain nature was considered for tractor network, with transversal profile elements such as: platform width of 3 meters, platform slope of 6%, and a cut side slope of 5:1. For cut volumes, an increment of 10% was granted for the cut material moved on a supplementary distance of 10 meters. The embankment works are realized by a 20 ton bulldozer, transported on a total distance of 20 km. The cost estimation

methodology was provided by the scientific literature [4], by considering current average unitary costs in case of skyline setup, regression equations for work quantity determination [3] were used, also provided by the scientific literature.
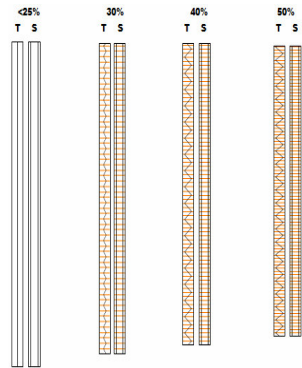

Fig. 1. *Logging-yarding setups for different slope conditions*

2.2. Materials used for economic comparison

Geometric data, as well as all the necessary input data was gathered by using AutoCAD Civil 3D 2008. Using this environment software the proper areas and distances were modelled accordingly to the slope influence over the reduced-to-horizon areas and corresponding logging-yarding distances as well as the total logging network lengths for different circumstances.

Once the geometric data became available, the cost analysis was realized by using "Evaluator Procese Tehnologice" software, by inputting the logging network geometry data as well as the unitary costs and all the associated contributions (indirect costs, profit etc.)

2.3. Analyzing and estimating process costs

For cost analysing, several scenarios regarding the felling area surface, terrain slope and stand condition were considered. Surfaces, as well as logging-yarding networks

were modelled by considering initial areas of 20, 10 and 5 hectares (for slopes smaller than 25%). In the mentioned slope scenarios, the reduced-to-horizon surfaces decrease according to the terrain slope.

For stand conditions, different scenarios regarding the extraction volume per hectare and the average tree volume were considered. In the first case, were considered volumes of 40, 50, 60, 70, 80, 90, 100, 150,
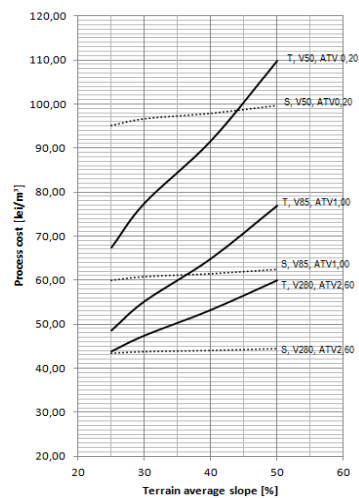

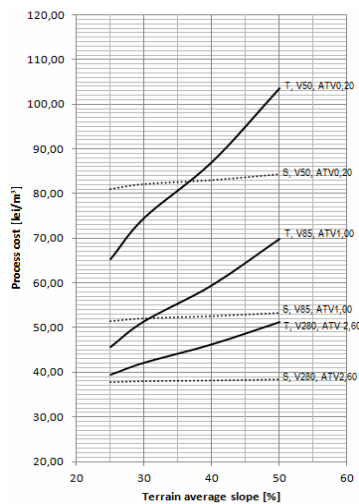Fig. 2. *Logging-yarding processes costs for a felling area surface of 20 hectares*

Fig. 3. *Logging-yarding processes costs for a felling area surface of 10 hectares*

200 and 300 m^3. In the second case the considered volumes were adopted according to different silvicultural systems scenarios, ranging from 0.05 to 3.00 m^3/piece.

Cost analysis was conducted for both, resinous and broadleaved species. Average values (96) were obtained for 192 different scenarios.

In order to highlight the overall characteristics of the modelled processes, in the following are presented the obtained costs for two situations: 20 hectares felling area and 10 hectares felling area.

In Figures 2 and 3 respectively, the symbols provided along with cost curves are the following:

- T - tractor based logging system;
- S - skyline based yarding system;
- V 50...260 - extracted volume per hectare [m^3/ha], resulted as average by grouping similar or close scenarios;
- ATV 0.20...2.60 - average tree volume [m^3/piece], resulted as average by grouping similar or close scenarios.

The presented costs are only informative because significant modifications may appear in more specific cases such as those modelled in the above mentioned, more individual scenarios.

3. Results and Discussion

3.1. Combined influence of the relevant factors over the processes costs

By analysing Figures 2 and 3 there can be obtained overall indicators regarding the involved costs in applying one of the studied logging-yarding systems. Each factor presents its influence in the process cost, but the combined action of all relevant factors generates feasible situations for one of the studied means as well as zones where, from economic point of view, any of the above mentioned means can be used. There are also zones in which none of the studied systems is adequate.

The combined influence on overall process cost is presented in the following:

- Terrain slope may be the most significant factor, because it generates higher costs, especially in case of tractor based systems. On small terrain slopes, generally smaller than 25%, where the tractor roads do not involve embankment works, being necessary only summary setups and in case of extracted volumes of less than 200 m^3/hectare, the integral logging using tractors is generally more cost effective in comparison with skyline based yarding. For greater extracted volumes, the skyline based system becomes more economic, due to reduced yarding costs reflected by significant reduced fuel consumption in comparison with the tractor. Of course, on slopes smaller than 15%, this system is technically limited by gravitational reasons [3]. On terrain slopes between 25 and 30%, where the tractor roads involve embankment works (with reduced magnitude) tractor based systems are more effective especially in case of volumes less than 150 m^3. For values of extraction volume greater than the mentioned one, the influence of the logging costs is greater, and the skyline system becomes more advantageous. In case of terrain slopes between 30 and 35%, the situation is variable, because, on the one hand, the associated logging costs do not compensate the network setup costs. This situation is evident in case of reduced distances for logging-yarding setup where the skyline system just becomes more cost effective in comparison with the tractor based system (case of extracted volumes around (90 m^3). In case of longer setups and for the same extracted volume (90 m^3), the tractor based system remains more economic for volumes less than the mentioned value. In case of terrain slopes between 35 and 45%, where the tractor based logging network involves ample

embankment works, tractor based systems can be justified (depending also on the length of the network) only for extracted volumes less than 60 m^3/hectare. In all other terrain slope cases, due to the increased embankment works, the skyline setups are more cost effective in comparison with tractor based systems.

- The setup time in case of skyline system increases with the length of the yarding network as well as with the number of successive setups. There can be observed that the longer network setup generates higher costs for the yarding process (Figures 2 and 3).

- Logging network length affects the overall process costs, especially in tractor case, and for increasing terrain slopes. This reflects negatively on process cost especially in case of reduced extraction volumes, as well as small dimension trees.

- The logging-yarding associated costs are greater in case of tractor utilization due to its increased fuel consumption in comparison with the skyline (around 3 times greater). This could change in case of using different machine generations, as well as all the associated costs. On the one hand, the older machines will consume more fuel, but on the other hand they will present lower associated costs in case of amortised ones. The present study followed the idea of two new machines.

3.2. Feasibility limits, economic zones, and systems economic overlap points

By analyzing Figures 2 and 3, feasibility limits, economic limits for one of the systems as well as economic overlap points can be identified.

In case of reduced extraction volumes, as well as in case of small size trees, both systems are not feasible due to high labor consumption in lateral skidding-yarding. In fact, this technological operation could take approximately the same amount of

time as the on-road logging operation on distances of 1000 meters. Also, the corresponding fuel consumptions are involved, being more evident in case of tractor usage.

Economic zones for one system are defined in terms of its economic feasibility in rapport with the compared one. The terrain slope and the extraction volume (implicitly the average tree volume), could be used as indicators.

Of course, there are economic overlapping points, where any of the studied system may be used. These points depend on the same factors as the above mentioned ones.

4. Conclusions

Different logging networks setups as well as fragmented logging technological lines may lead to different processes costs, the results and analyses presented in this paper being strictly informative and helpful to differentiate between the presented systems. The increment of logging-yarding associated costs may lead to different curves for cost distribution (Figures 1 and 2). For example, the fuel cost increment may have negative influences over the tractor based systems due to their increased fuel consumption. Also, realizing the logging network involves supplementary fuel consumption (bulldozer), which may increase the associated unitary cost.

Reduced extraction volumes as well as reduced volumes per tree may lead to different, more economic logging systems applications, by eventually involving non mechanized means (animal logging). These means could be and are currently employed for lateral skidding on various distances. Of course, they present their technical limits [3], especially in relation to terrain slope as well as with ecological constrains.

The dynamic approach for logging network development (by considering a production cycle for certain situations) is not currently applied in our country, maybe because the operations in a specific time slot are performed by different companies. As a forecasting matter, the forest owners should consider the best strategy for logging operations, employed in the forest's best interest.

Acknowledgments

References

1. Heinimann, H.R.: *A Computer Model to Differentiate Skidder and Cable-Yarder Based Road Network Concepts on Steep Slopes.* In: Journal of Forest Research **3** (1998) No. 1, p. 1-9.
2. Oprea, I.: *Proiectarea şi organizarea şantierelor de exploatare a lemnului* (*Timber Harvesting Sites Design and Organization*). Braşov. *Transilvania* University Press, 1986.
3. Oprea, I.: *Tehnologia Exploatării Lemnului* (*Timber Harvesting Technology*). Braşov. *Transilvania* University Press, 2008.
4. Oprea, I., Borz, S.A.: *Organizarea Şantierului de Exploatare a Lemnului* (*Timber Harvesting Site Organization*). Braşov. *Transilvania* University Press, 2007.