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FUEL CONSUMPTION ESTIMATES FOR TYPICAL COASTAL BRITISH COLUMBIA FOREST OPERATIONS

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Abstract

Estimates of fuel consumption were made for six harvesting systems used in typical coastal British Columbia forest operations. Five of the systems—grapple yarding, highlead yarding, skyline yarding, helicopter yarding, and loader forwarding—were in clearcuts. Another system consisted of loader forwarding in a partial cut. The proportion of wood harvested by each of these harvesting systems was also determined, based on a survey of coastal British Columbia forest companies. This study was part of a larger research effort on life-cycle analysis addressing the impact of forest operations on the environment.

Introduction

Fuel consumption is becoming an increasingly important issue as environmental concerns build. Life-cycle analysis or life-cycle assessment (LCA) (Anon. 1992) is a tool for making a comprehensive assessment of a product's (or service's) impact on the environment, throughout the life span of that product. The assessment includes the extraction of raw materials, conversion, and manufacture of the product; transport and use throughout the product's life; disposal of the product at the end of its useful life; and management of the waste produced by the product. LCA techniques have been used to assess the environmental load imposed by forest technology systems (Berg 1996).

In late 1996, the Forest Engineering Research Institute of Canada (FERIC) conducted a detailed inventory of the estimated fuel consumption for the typical forest harvesting systems used in coastal British Columbia. This study was done to assist a Pulp and Paper Research Institute of Canada (Paprican) research effort on LCA addressing the impact of forest operations on the environment. The FERIC study included only one aspect of a life cycle analysis—fuel consumption. As it is of general interest to the forest industry, FERIC has summarized the results in this Technical Note.

Objectives

The objectives of the study were to: (1) estimate the proportion of the wood harvested in coastal British Columbia by each of the six typical harvesting systems defined for this analysis, and (2) estimate fuel consumption for pre- to post-harvesting activities for each harvesting system, by phase and in total.

Methods

Survey

FERIC surveyed 23 major coastal forest operations to identify the proportion of wood harvested using six common coastal harvesting systems. The six systems were grapple yarding, highlead yarding, skyline yarding, helicopter yarding, and loader forwarding[1] in clear-cuts, as well as loader forwarding in a partial cut. The survey requested information on average cutblock area, volume harvested per hectare, annual harvest levels by operation, and one-way haul distance.

[1] Loader-forwarding is the use of hydraulic log loaders to extract stems from the falling site to the roadside. Sometimes also referred to as excavator-forwarding, hoe-forwarding, hoe-chucking, or shovel logging.

Keywords: Fuel consumption, Harvesting systems, Life-cycle analysis, Cable logging, Skyline, Highlead, Aerial logging, Helicopters, Forwarding, Loaders, Clearcutting, Partial cutting systems, Coastal British Columbia

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While the survey was being completed, spreadsheet templates were developed to quantify fuel consumption for forest operations from pre- to post-harvest. Fuel usage consumption values were assigned to each machine unit with the assistance of equipment users. Literature was reviewed to verify these fuel consumption rates. The analysis included the fuel required to transport workers and operate machinery but excluded the fuel consumed by management, supervision, and safety personnel; building heat and light; and the manufacture of equipment and supplies.

FERIC conducted interviews with personnel from four divisions of MacMillan Bloedel Limited to determine how many shifts, crews or contractors would ordinarily be required to complete the activities associated with each harvesting system. The replies were averaged and entered into a spreadsheet to calculate the amount of fuel needed to harvest a cubic metre of wood on a typical coastal cutblock.

Assumptions and Limitations

In order to allow comparison on a common basis, many assumptions and estimates were made in this study. These ranged from the volumes harvested by each harvesting system to the number of shifts required to complete the forest operations. The results are therefore most useful when viewed on a relative basis. The following assumptions were made:

- The fuel consumption for the road construction phase was based on an access road length of 1 km, except for the skyline and helicopter systems. The road construction activity included ballasting and right-of-way falling, loading and hauling.
- Less than 1 km of road was constructed for the skyline system.
- Landings in the helicopter system required construction and ballasting.
- Fallers worked 6.5 h/d (Andersson and Warren 1996).
- Two fallers were assigned to right-of-way falling and four to falling within the setting.
- All crew transport (for fallers, rigging crews and planters) was by helicopter for the helicopter system.
- Helicopter transport for fallers was used for the back half of the cutblock in the skyline system.
- All of the harvesting systems used the same amount of fuel in the sorting and barging phases.
- For the barging phase, a log barge with a 7 000 m^3 log capacity and a 1 040 kW tugboat made a round trip of 580 km.[2]

The loader forwarding systems used for partial cutting and clearcutting were similar, except that for partial cutting, the harvesting phase assumed 40% volume removal, and the planning and layout phase included tree marking. Planting was not included as an activity for partial cutting, as natural regeneration was assumed.

In the spreadsheets, a theoretical cutblock determined by the averages obtained from the survey was used to compare fuel consumption among harvesting systems. The cutblock had an average volume of 704 m^3/ha, an area of 23 ha and a one-way haul distance of 38 km. The pre- and post-harvesting activities performed in partial cutting were based on the same area as in clear-cutting, but on the net harvested volume.

Fuel Conversion

After the fuel consumption figures were determined, the fuel used for each activity was converted to a common fuel equivalency and summed to give the total amount of fuel required by harvesting phase and system. Fuel was expressed as litres of diesel equivalent per cubic metre (L d.e./m^3) of wood harvested, as a uniform measure of energy content equivalent to 38.68 MJ per cubic metre of diesel. Lubricant consumption was prorated as 0.5% of fuel consumption. The conversion factors for the various fuels were obtained from the National Energy Board (1994).

Estimated fuel use for each harvesting system was multiplied by its respective proportion of coastal harvest (from the survey) to develop the average weighted value of fuel needed to harvest one cubic metre of wood for coastal British Columbia.

Results and Discussion

Twenty out of the twenty-three operations completed the survey (87% response rate), and reported a total harvest of 10 484 000 m^3 for 1996. Table 1 presents the percentage of annual harvest attributed to each harvesting system, derived from the survey results. It also shows estimated fuel consumption per cubic metre of wood harvested for the harvesting systems.

The grapple yarding system was the most widely used harvesting system on the coast. It accounted for 52% of the total volume logged, and had an estimated fuel consumption of 6.5 L d.e./m^3.

The weighted average fuel consumption for coastal forest operations, according to this analysis, was

[2] Joe Goss, Kingcome Navigation, personal communication, Dec. 1996.

Table 1. Harvesting and Fuel Consumption Results

Harvesting system	Proportion of annual harvest (%)	Estimated fuel consumption (L d.e./m^3)[a]
Clearcutting		
Grapple yarding	52	6.5
Highlead yarding	13	7.0
Skyline yarding	4	7.4
Helicopter yarding	8	11.1
Loader forwarding	21	6.0
Partial cutting (loader forwarding)	2	7.2
Weighted average	--	6.9

[a] d.e. = diesel equivalent.

6.9 L d.e./m^3 of wood harvested. This figure factored in the ratio of harvesting systems used and the estimated fuel required for each system. Although fuel was not actually measured in this study, the results are similar to those of studies that did monitor actual fuel usage. Fuel monitoring of highlead and grapple yarding systems at Pitt Lake, B.C. showed those systems used 7.5 L d.e./m^3 (Johnston 1979). An energy survey of coastal operations performed by the Canadian Pulp and Paper Association reported fuel requirements ranging from 6.7 to 6.9 L d.e./m^3 (Ash and Knobloch 1982). The survey also reported that fuel usage can change through better operational planning, increased fuel efficiency of engines, and use of alternate fuels.

Figure 1 shows the estimated fuel consumption for the harvesting systems, by phase and in total. The helicopter yarding system consumed the most fuel of all coastal systems (11.1 L d.e./m^3). This system used a support helicopter in the planning and layout, falling, and yarding phases, as well as for planting during the post-harvest phase. As a result, the helicopter system had the highest fuel consumption of all coastal systems for these phases. The most fuel was used in the yarding phase where the helicopter, support helicopter, hydraulic log loader, front-end loader, and seven crew transportation vehicles consumed a total of 7.0 L d.e./m^3.

In the non-helicopter harvesting systems, the road construction, loading and hauling, and sorting, booming and barging phases consumed a considerable amount of fuel compared to the yarding operations. This supports an earlier claim that increased fuel usage efficiency in the transportation of logs from the forest to the mill or port will be significant to the industry as a whole (Gordon and Foran 1980). The road construction phase included right-of-way hauling, and although a smaller volume was hauled than in the setting, the productivity was lower and fuel consumption was higher. The long haul and barge distances along the coast contributed to the high fuel consumption involved in hauling and barging. Hauling distances are expected to increase as forest companies have to go farther away from their base of operations to find additional sources of wood to meet mill demands (Parker 1995).

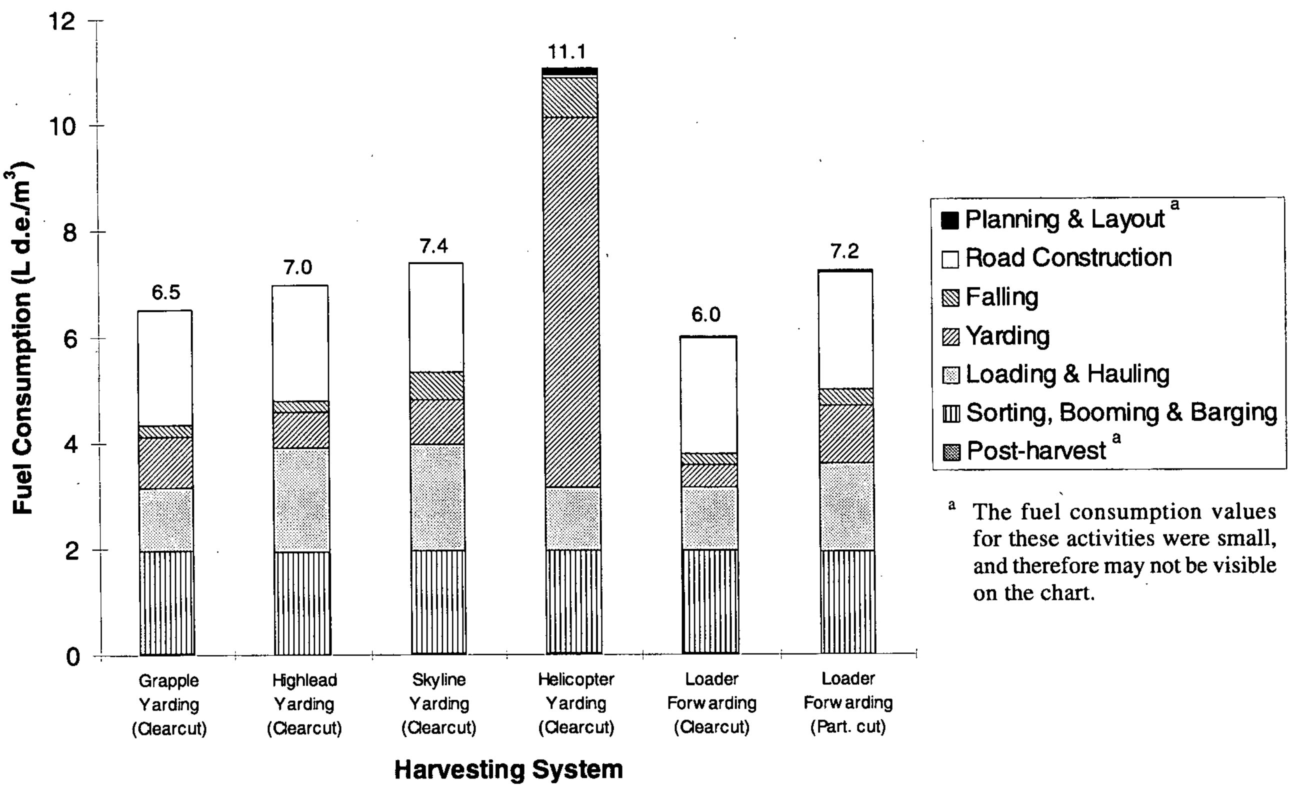

Figure 1. Estimated fuel consumption for each operating phase, by harvesting system.

In this study, fuel was used for two activities in the falling phase: falling with chainsaws, and crew transportation. The chainsaws consumed 0.3 L d.e./m^3 for partial cutting and 0.2 L d.e./m^3 for clearcutting. Falling productivity was lower for partial cutting than clearcutting, so additional fuel was required for crew transportation. Therefore, fuel consumption for falling was higher overall for partial cutting than clearcutting. A partial cutting study at Kyuquot Sound found that on similar sites, there were decreases in falling productivity in partial cuts as compared to clearcuts (Bennett 1996).

Fuel consumption for falling was higher in this analysis than in previous studies. Another coastal operation used 0.10–0.12 L d.e./m^3 (Johnston 1979), and at the Prince Albert Model Forest, 0.14 L d.e./m^3 was used for falling, delimbing and bucking (Phillips 1997).

Conclusion

The weighted average amount of fuel needed to harvest a cubic metre of wood in coastal B.C. was 6.9 L d.e./m^3, based on FERIC's survey and analysis. The grapple yarding system was the most widely utilized harvesting system on the coast, accounting for 52% of the total volume logged, and it had an estimated fuel consumption of 6.5 L d.e./m^3. Of the six systems studied, the loader forwarding system used for clearcutting consumed the least amount of fuel at 6.0 L d.e./m^3, and the helicopter system used the most at 11.1 L d.e./m^3. For most systems, the road construction, loading and hauling, and sorting, booming and barging phases consumed the greatest amount of fuel. The helicopter system was an exception, where aerial yarding consumed 7.0 L d.e./m^3.

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