FUTURE FORESTS RESEARCH

HARVESTING TECHNICAL NOTE

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A Review of Fuel Consumption in New Zealand Harvesting Operations

Summary

With continuously increasing fuel prices, operating costs for harvesting operations are likely to continue their upward trend. Moreover, energy use by the forest industry has been under increasing scrutiny because it is a significant source of greenhouse gas (GHG) emissions. A few studies have quantified the fuel used for the production of logs from radiata pine plantation forestry in New Zealand. Numbers reported range from 1.96 to 3.01 l/m^3 of harvested wood depending on the evaluated harvesting system. Several recommendations for reduction of fuel consumption and increased fuel efficiency are described.

Dzhamal Amishev, Scion

Introduction

The forestry sector in New Zealand plays a significant role in the nation's economic activity. For the year ending 31 March 2009, the log flow from plantation forests was 18.9 million m^3, and forest products exports amounted to $3.7 billion, or 8.9% of New Zealand's total exports. This makes the sector the third largest exporter (NZFOA, 2010).

The NZ wood industry has, however, been under continued pressure both in domestic and export markets. In domestic markets wood is competing with substitute building products and systems while in export markets, fluctuating freight costs, exchange rates and market prices influence industry competitiveness. With continuously increasing fuel prices, operating costs for harvesting operations are likely to continue their upward trend. For example between 2006 and 2010 daily costs for tower yarders increased by 14% and for 30 tonne loaders by almost 18% (Forme, 2010). Therefore efforts to monitor and reduce fuel consumption become increasingly important.

Moreover, as the global community develops an awareness of the implications of global climate change, a need to identify and understand the origin and quantity of greenhouse gas (GHG) emissions is emerging. Energy use by the primary industries has been monitored (Statistics NZ, 2009) because these industries represent around 9 percent of the estimated total energy consumed in New Zealand and the corresponding total national GHG emissions. Hence, energy use by the forestry sector, and especially in harvesting, given the degree of mechanisation, (Figure 1) will come under increasing scrutiny.

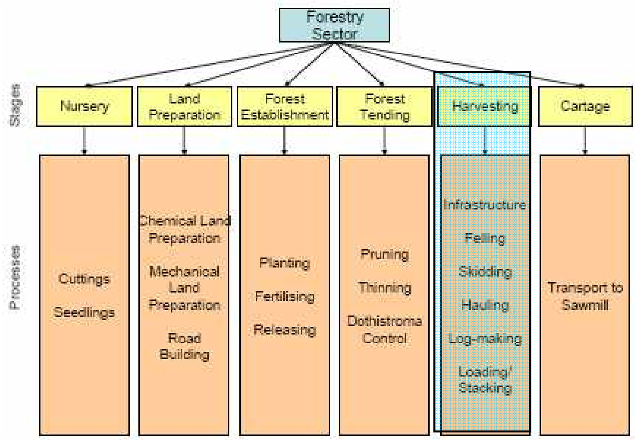

Figure 1. Stages and processes within the forestry sector (Sandilands *et al.*, 2009).

The major form of energy used by the forestry sector is fuel (diesel, petrol and oil). Some studies have aimed at identifying and discussing the GHG emissions released through the production of logs from radiata pine plantation forestry in New Zealand. One way of analysing and evaluating the greenhouse gas emissions of the forestry sector is by using Life Cycle Assessment (LCA). The LCA methodology takes a systems perspective over the whole life cycle

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of a product or process, and thus avoids problem-shifting from one life cycle stage to another, from one geographical area to another, and from one environmental medium to another (Gifford *et al*., 1998).

The objective of this report is to review, identify and discuss with various forest industry stakeholders the fuel consumption rates and suggest various fuel-saving solutions in forestry operations, more specifically related to harvesting.

Harvesting Operations Fuel Usage

Harvesting operations involve the construction of infrastructure, transport of workers to the forest and the processes of felling, skidding, hauling, log making and loading/stacking but does not include log transport (Figure 2).

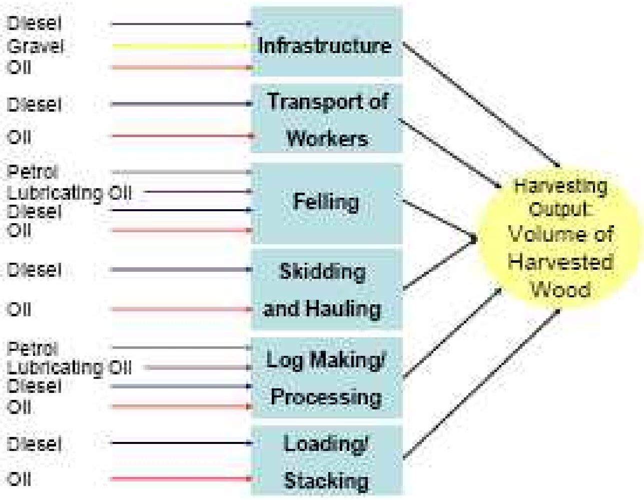

Figure 2. Fuel inputs to each harvesting stage (Sandilands *et al*., 2009).

Harvesting uses a variety of machines and techniques, depending on stand and environmental factors (tree size, terrain etc) and on the decisions made by harvesting managers (such as the road and landing layout and the most appropriate harvesting system).

It is important to describe the systems in order to outline the required input of machinery and equipment and the corresponding fuel usage in each stage of a harvesting system.

There are four commonly occurring systems:

- Ground-based manual (GMN) - manual felling, skidding, manual log making, loading/stacking;
- Ground-based mechanical (GMC) - mechanised felling, skidding, mechanised log making, loading/stacking;
- Hauler manual (HMN) - manual felling, hauling, manual log making, loading/stacking;
- Hauler mechanical (HMC) - manual felling, hauling, mechanised log making, loading/stacking.

Table 1. Harvesting fuel usage per cubic metre of harvested wood (Sandilands *et al*., 2009).

Stage	Process	Input	Quantity	Unit
Road Building	Bulldozer use	Diesel	0.38	l
		Oil	1.72E-3	l
	Gravel Truck	Diesel	5.06E-2	l
		Oil	4.40E-4	l
		Gravel	0.05	m^3
	Transport of workers	Diesel	9.30E-3	l
		Oil	9.97E-5	l
Landing infrastructure	Bulldozer use	Diesel	0.093	l
		Oil	4.26E-4	l
Harvesting	Transport of workers	Diesel	9.44E-2	l
		Oil	1.01E-3	l
	Manual Felling - Chainsaw	Petrol	0.080	l
		Lubricating Oil	0.033	l
	Mechanised Felling - Excavator	Diesel	0.073	l
		Oil	6.37E-4	l
	Skidding	Diesel	0.354	l
		Oil	0.0026	l
	Hauling	Diesel	0.665	l
		Oil	0.0078	l
	Logmaking	Petrol	0.075	l
		Lubricating Oil	0.0311	l
	Processing	Diesel	0.280	l
		Oil	0.0022	l
	Loading/ Stacking	Diesel	0.825	l
		Oil	0.0072	l

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As shown in Table 1, Sandilands *et al.* (2009) approached the problem more theoretically by using literature and statistical data regarding NZ harvesting. Based on fuel consumption rates for each of the machines used in the harvesting stages (chainsaw, excavator feller buncher, skidder, hauler, processor and excavator loader) according to their engine power, the diesel/petrol consumption per cubic metre (m^3) of harvested wood for each stage was calculated.

It was shown that the most fuel inefficient system Hauler Mechanical (HMC) used about 26% more fuel per unit of wood produced than Ground-based Manual (GMN). Hauler systems in general used around 15% more diesel per cubic metre harvested than ground-based systems (Table 2).

Table 2. Summary fuel consumption per cubic metre of harvested wood from two studies.

	Fuel consumption (litres/m^3 wood)	
System	Sandilands *et al.*, 2009	Karalus, 2010
GMN	1.96	1.98
GMC	2.16	2.76
HMN	2.26	2.76
HMC	2.47	3.01

A more recent study on the carbon footprint of Nelson Forests Ltd (Karalus, 2010) reported slightly higher values, especially for mechanical harvesting systems (Table 2). The study showed an even bigger gap between the extremes – the HMC system used more than 50% more diesel per unit production than GMN, and cable systems used 22% more than ground based systems.

These higher values may be attributed to the relatively steeper and more difficult terrain that is to be found within Nelson Forests Ltd estate (75% cable logging systems and 25% ground based) compared to an estimated national "average" of about 40% cable and 60% ground based. Visser (2009) reported 53% cable and 47% ground based for FFR Harvesting Theme member companies.

A nationwide primary industry energy use survey reported that logging, although only making up 5% of the total primary industries energy consumption, used the equivalent of more than 52 million litres of diesel (or 1998 terajoules of energy) in 2008 (Statistics NZ, 2009).

Distributed over 20.38 million cubic metres of logs produced in NZ that year (NZFOA, 2010), this results in an average fuel consumption of 2.55 l/m^3 (98 MJ/m^3). A survey of New Zealand forest managers and harvest planners resulted in reported fuel consumption between 2.0 and 2.5 litres of diesel per cubic metre of logs harvested and loaded on truck.

Internationally, researchers in Sweden have reported energy use for felling, processing and extraction ranging from 1.49 to 1.72 litres of diesel per cubic metre of wood (57 to 66 MJ/m^3) depending on the region of Sweden (Berg and Lindholm, 2001). Swedish harvesting systems consist of exclusively mechanised operations on generally flat or easy terrain, resulting in lower fuel usage. They also reported that thinnings and harvesting smaller trees resulted in increased fuel usage per cubic metre of wood.

Recommendations for Reducing Fuel Consumption

Fuel consumption differs among the different types of equipment, explained by three main factors: the design of the machine, the engine technology, and the operator's work methods.

Purchasing the wrong machine for the job can clearly have a considerable effect on fuel consumption. Operators of equipment should be trained on how to minimise fuel consumption of the machine, reaffirming the importance of regular preventative maintenance to ensure machines are running efficiently.

Karalus (2010) and the Forest Innovation Partnership (2006) have suggested several tips for reducing fuel consumption in harvesting operations:

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- Minimise engine idling – a typical excavator/loader engine can consume up to 2.5 litres of fuel per hour (l/hr) while idling.

- Keep the radiator and oil cooler clean.

- In general, the engine cooling fan should not be required to work at full speed under all working conditions. A fan that operates continuously at full speed consumes an additional 1-2 l/hr.

- Follow cold weather start-up procedures specified for each machine to shorten warm-up periods.

- Use work lights only when required (their use can increase fuel consumption by up to 0.5 l/hr).

- Keep fuel supply system components (including fuel tankers) in good shape to avoid leaks and spills.

- Install tyre chains or tracks to wheeled machines only when required (they increase rolling resistance and the weight of the machine).

- Choose tyres of adequate dimensions and keep them properly inflated to match conditions in order to minimise sinking and loss of traction.

- Optimise load size (for haulers) to ensure minimal under-loading or overloading.

- In ground-based extraction, transfer as much of the load as possible onto the skidder; by raising the load higher and closer to the cab, friction of the stems on the ground is reduced and thus fuel consumption is decreased.

- Minimise turning while travelling loaded; it is preferable to turn gradually, since this consumes less fuel than making sharp turns.

- Increase utilisation of machines by creating a buffer ahead of processing to minimise operational delays.

- Optimise positioning of machines on the skid to reduce unnecessary movement.

- Keep the saw chain and delimbing knives sharp; cutting and processing of logs requires more power, and thus more fuel, when the cutting surfaces grow dull.

Conclusions

With ever increasing energy prices worldwide and increasing awareness of GHG emissions, it is important to identify and monitor the major energy consuming links in an operational system and develop techniques and systems to improve fuel efficiency. Forest harvesting in New Zealand uses a large variety of equipment that consumes large quantities of fuel. Theoretical and empirical studies show harvesting fuel consumption of between 1.96 to 3.01 litres of diesel per cubic metre of harvested wood depending on the harvesting system employed and method of measurement.

Based on currently reported productivity rates, mechanised harvesting systems are less fuel efficient per unit of harvested wood in New Zealand than manual harvesting systems.

With increasing difficulty and steepness of terrain of New Zealand's future forest harvest, fuel consumption per unit of wood is forecast to increase as the proportion of hauler operations which have higher fuel consumption increases.

FFR has recently launched a PGP (Primary Growth Partnership) funded six-year programme, the scope of which is to focus on steep country harvesting systems, primarily the felling and extraction phases, but with the opportunity to alter current practices on the landing to allow the entire system from stump to truck to be more cost efficient.

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The primary goal is to reduce the average cost of harvesting on steep country by introducing new equipment that is more cost effective than existing technology. A secondary benefit is aimed at reduction in fuel consumption per unit of wood harvested.

Improving existing harvesting systems' productivity, machine efficiency, and work methods will potentially result in significant reduction of fuel consumption, thus improving the economics of harvesting operations.

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