# Factors that Affect Fuel Consumption in Logging Systems

Jonathan Kenney[1], Thomas Gallagher[2], Mathew Smidt[3], Dana Mitchell[4], Timothy McDonald[5]

**Abstract:**

Fuel consumption is an important aspect of the efficiency of timber harvesting. Since loggers are paid based on the weight of wood they produce, it is important to note how many gallons of fuel it takes to produce one ton of wood. An extensive literature review was conducted to evaluate different harvesting systems and the amount of fuel they consumed per unit of wood that they produced. Results showed that varying factors (such as terrain, type of system, and type of cut) led to a variety of differences in fuel consumption. For these reasons a project will be developed to find new information about the factors that affect fuel consumption such as terrain, harvesting system, and type of cut (thinning vs. clearcut). The study will involve surveying loggers to submit information about slope, tree size, type of cut, type of machines, gallons of fuel consumed, and weight (in total tons) of wood produced on a per tract basis. From this survey, new fuel consumption data will enable timber harvesters as well as mills to have a better grasp of modern in-woods harvesting systems and the factors that lead to variability in fuel consumption across a wide array of factors.

**Keywords:** fuel consumption, logging systems, fuel costs, logging efficiency, timber harvesting

## Introduction

Rising fuel costs all around the globe have contributed a great deal towards research in evaluating different ways to consume less fuel and lower fuel costs on a per unit basis. The timber products industry is an important industry that has a drastic effect on many global and local economies. In more than one way, the driving factor behind the efficiency of the forest products industry is the amount of fuel that it takes to produce these products. Many loggers have resorted to modifying their systems, minimize haul distance, reduce their workweek, reduce skid distance, cut only high value timber, and even cut their own family forest to make up for rising fuel costs (Moldenhauer and Bolding 2009). Past fuel consumption estimates are based on older machines from the 1970's and 1980's. It is assumed that newer machines have a higher productivity rate and less fuel consumption per unit of wood produced. Along with the

[1] Masters of Science, School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL. jtk0005@auburn.edu

[2] Associate Professor, School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL. gallatv@auburn.edu.

[3] Ext Spec Associate Professor, School of Forestry and Wildlife Sciences, Auburn University, Auburn, AL. smidtmf.@auburn.edu.

[4] Research Engineer, USDA Forest Service, Southern Research Station, Auburn, AL. danamitchell@fs.fed.us.

[5] Associate Professor, Biosystems Engineering, Auburn University, Auburn, AL. mcdontp@auburn.edu.

assumption that newer machines consume less fuel, it is also assumed that a variety of on-site harvesting impacts such as slope of the tract, tree size, clearcut versus thinning, type of harvesting system, as well as soil moisture conditions can greatly contribute to variability in fuel consumption. For these reasons, a study will be implemented to find the information needed to justify this hypothesis. Tests will be conducted to determine which factors have the greatest impact on fuel consumption. The study will aim to inform loggers and industry partners alike of the amount of fuel needed to produce a ton of wood across many different landscapes, harvesting systems, and harvest types.

The process in which fuel is accounted for in the forest products industry is by calculating delivered wood costs to the mill. Fuel is a major component of the total cost it takes to have wood delivered to the mill. Delivered costs to the mill is made up of multiple different rates that are combined together to form delivered price. Delivered price is made up of stumpage rate (value of the timber), timber harvest contract rate, as well as taxes. Timber harvesters are paid for what is often called a timber harvesting contract rate (Tufts et al. 1989). This rate, often deemed the "cut and haul rate", encompasses all expenses assumed from cutting the tree to having it delivered on trucks to the mill. The first component of the "cut and haul rate" deals with the in-woods machinery and the costs associated with felling, skidding, and processing the trees in order to be loaded onto the trucks. The second component of the "cut and haul rate" deals with the costs associated with the haul of the logs to the mill. The first component of the "cut and haul rate" will be the main focus of the study and used to accurately measure fuel consumption per unit of wood production. It has been found that type of equipment used and stand conditions at time of harvest have an impact on "cut and haul rates" (Tufts et al. 1989).

There are two main methods in which logging costs have been broken down. The first is called machine rate analysis. Machine-rate is a method that provides single estimations of hourly machine costs (Bilek 2009). The machine-rate method is the totaled average across all fixed, variable, and labor costs of a harvesting machine during its life time (Tufts et al. 1989). There are, however some problems associated with the machine-rate method. It does not deal with actual costs loggers assume associated with fuel consumption. The other method of costing breakdown involves using a discounting after tax cash flow model. Many of these models consider factors such as risk, overhead, and profit (Bilek 2009). With these two sources readily available, loggers are able to determine rough overall estimates of the costs associated with being in the timber harvesting sector. What they do not have however is specific information readily available as to how much fuel they are using per unit of wood produced. They need this specific information because this is the basis upon which they get paid.

We must understand how to study the variables that affect fuel consumption in typical timber harvesting systems. It has been found that fuel consumption rates for a single piece of equipment is affected by the engine size, load factor, condition of the equipment, operator's driving skill, environmental conditions, as well as the design of the equipment (Miyata 1980). The goal of this project is to evaluate the environmental factors, machine type, as well as type of harvest in order to determine variability in fuel consumption. It has been concluded that the characteristics of the forest, machine types, and intensity of the harvest operation must be balanced in order to reflect variable factors that affect equipment productivity (Akay 1998).

## Methods

In attempt to study the factors that affect fuel consumption in modern logging systems, a survey has been designed to evaluate different logging systems fuel consumption and wood production on a per tract basis. Variables that will be selected to identify possible variables that affect fuel consumption are tract acreage, type cut, tree species, tract slope, soil moisture conditions, average tree diameter, and the make and model of equipment. The fuel use will be measured on a per machine basis as well as combined to provide a total fuel use for the system. The total amount of wood produced (in tons) will also be evaluated for the tract. Once the data has been received, the information will be entered into a spreadsheet.

The data will be evaluated to find the fuel use in gallons for each ton of wood produced by each crew (gal/ton). This information will be evaluated for each crew in two ways. The fuel used for each machine type will be divided by the total amount of wood produced to determine gallons per ton used for each crew's machine. The average fuel use (gal/ton) will then be added together to find the fuel use (gal/ton) for each logging system.

To determine past fuel consumption on a gallon per ton basis, a literature review was conducted. The literature review involved searching many scientific articles that dealt with logging system productivity and fuel use. These papers were evaluated to find productive machine hours, the volume of wood produced for each productive machine hour (cubic meters), as well as the amount of fuel used (gallons) for each machine across a variety of different logging systems. The data was combined into a spreadsheet to produce a new column entitled gallons per cubic meter. When interpolating this data it was assumed that one cubic meter of wood amounts to about one ton of wood on average.

Once each logging crew's fuel use is determined, it will be presented in a way to compare fuel use across different crews and geographic regions by creating graphs that illustrate fuel use (gal/ton) for felling, skidding, loading, and the total system. The graphs will be used to show loggers how efficient their equipment is compared with other harvesting operations.

To determine if there are certain variables that have a direct effect on rate of fuel consumption in logging, the data will be evaluated using statistical software to determine significance between each variable and the rate of fuel consumption (gal/ton).

## Results

After evaluating the literature review, it was found that there was a good deal of variability noticed across each machine type and logging system. On a by machine basis it was found that there was a significant amount of dispersion from the mean in many different machine types but especially the feller buncher and skidder machine types (See Table 1).

Table 1- Literature Review Fuel Data

| Machine Type | Average of Fuel GPH | Count of Fuel GPH | Std Dev of Fuel GPH | Average of Fuel Gal/CM | Std Dev of Fuel Gal/CM |
|---|---|---|---|---|---|
| Delimber | 4.57 | 7 | 1.15 | 0.13 | 0.05 |
| Feller Buncher | 6.94 | 33 | 2.52 | 0.29 | 0.44 |
| Forwarder | 2.93 | 9 | 0.44 | 0.16 | 0.04 |
| Grapple Skidder | 6.24 | 43 | 6.10 | 0.27 | 0.35 |
| Harvester | 5.57 | 20 | 2.04 | 0.42 | 0.20 |
| Loader | 6.95 | 9 | 0.71 | 0.10 | 0.03 |
| Processor | 5.96 | 14 | 1.09 | 0.18 | 0.09 |
| **Grand Total** | **6.02** | **135** | **3.88** | **0.26** | **0.32** |

The previously mentioned survey has been issued to loggers in different states across the Southeast and up into the Lake States. Fuel data has been compiled and has been measured on a gallon/ton basis while noting all aspects of each harvesting type and tract. Graphs have been produced for felling, skidding, loading, and system totals (gal/ton) for each crew (See Figures).

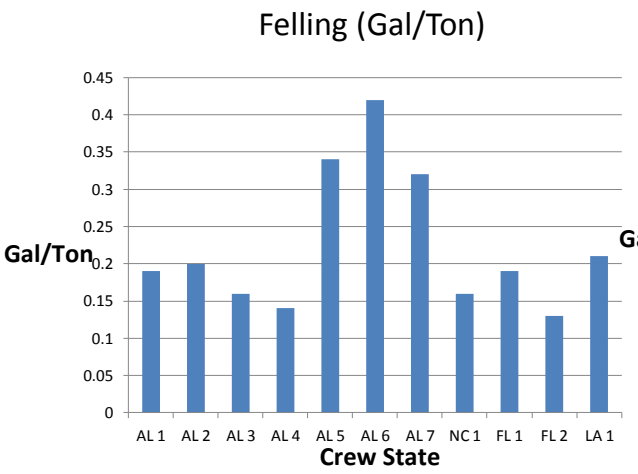


Figure 1- Felling fuel consumption

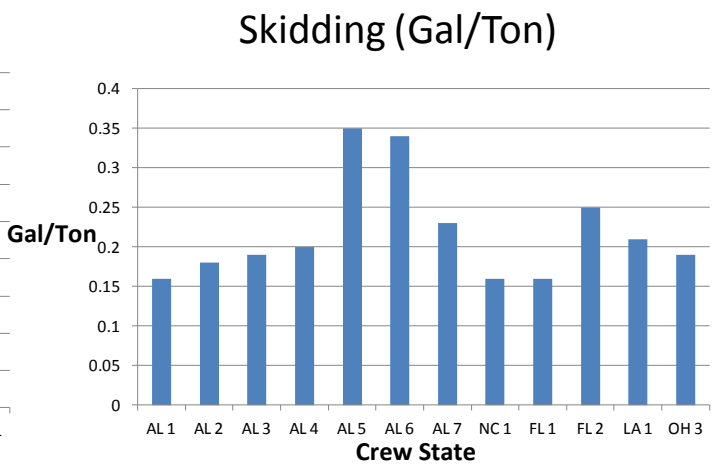


Figure 2- Skidding- fuel consumption

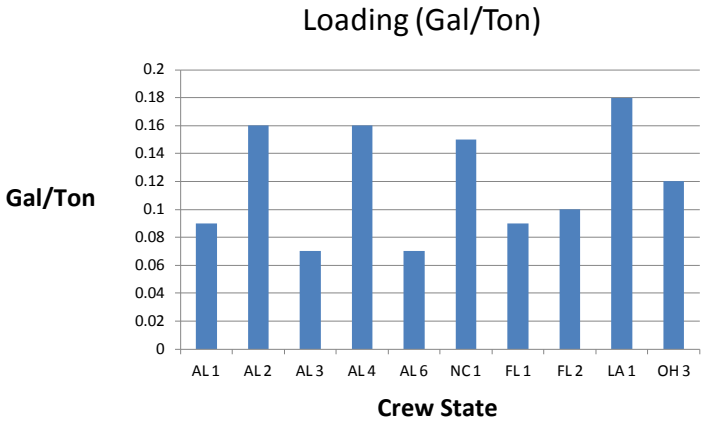


Figure 3-Loading- Fuel Consumption

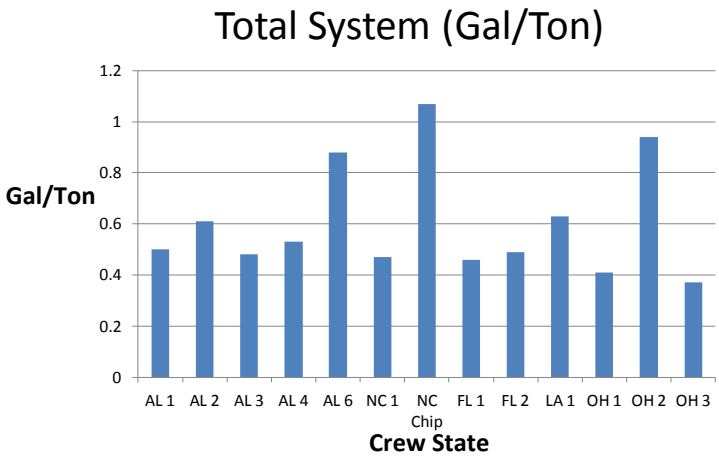


Figure 4- System- fuel consumption

## Discussion/Conclusion

The current information from both the literature review and the surveyed fuel consumption has both yielded a great deal of variability both across machine type and total system. The object of the study will be to determine what lone factor(s) contribute to this variability and whether it can be proven to be significant. Knowing what factor(s) contribute to the variability will help timber harvesters know what leads to greater fuel consumption and be able to lower their cost per unit of wood produced. Studies have shown that loggers are reducing their number of employees, downsizing their systems, as well as purchasing more fuel-efficient equipment to account for rising fuel costs (Moldenhauer and Bolding 2009). The study will address the factors that can affect fuel consumption and assist loggers with the necessary information to account for these varying factors.

## Works Cited

Akay, A. E.1998. *Estimating Machine Rates and Production for Selected Forest Harvesting Machines Operating in the Western United States and Determining the Most Economical Machine Combinations under Representative Conditions in Turkey.* M. Sc. thesis, Oregon State University, Corvallis, OR, United States. 178 p.

Bilek, Edward M. *ChargeOut!: discounted cash flow compared with traditional machine-rate analysis*. United States Department of Agriculture, Forest Service, Forest Products Laboratory, 2009.

Miyata, Edwin S. *Determining Fixed Costs and Operating Costs of Logging Equipment.* USDA For. Serv. Gen. Tech. Rep. NCFES-NC-55. 18 p.

Moldenhauer, M.C., and M.C. Bolding. 2009. Identifying loggers' reactions and priorities in an increasingly fragmented landscape. In: Proc. 32nd Annual Council on Forest Engineering Meeting; Kings Beach, CA. 5 pgs.

Tufts, R. A., J. A. Renfro, and J. P. Caulfield. "Timber harvesting contract rate calculations in the South." *Forest products journal* 39.9 (1989): 55-58.