Executive Summary

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Title: Analyzing forest biomass supply chains using agent based simulation modeling

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INTRODUCTION

Logging operations in British Columbia produce an estimated 15.5 megatonnes per year (MT/yr) (oven dry basis) of forest residues. Traditionally this logging slash has been piled and burnt on site. Due to the rising concerns around climate change and increasing demand for energy, these harvest residuals are becoming a desirable fuel source for sustainable bioenergy production. However, due to logistical complexities, high cost, and fossil fuel intensity of collection and transportation, careful planning is necessary to provide local energy facilities with these fuels in an economically feasible and environmentally benign manner.

The objective of this study was to identify the least cost operational configurations for the grinding and transportation of forest harvest residues from cutblocks to a transshipment facility. In addition, the variation and impact of fuel moisture content (MC) was investigated to determine its impact on operations.

METHOD

This work was conducted at the request of a local hog fuel supplier in Southwest British Columbia to investigate issues they had been experiencing in their forest biomass supply chain.

In order to identify biomass sources a list of all cutblocks under permit to BC Timber Sales was acquired. These cutblocks were filtered for those that had harvest residues remaining on site. Then using harvest method, terrain type, and accessibility parameters developed by FPInnovations[1], blocks which were likely inaccessible to the grinding equipment were removed. Then the amount of available biomass on each cutblock was estimated using the cutblock harvested timber volumes and biomass ratios developed by FPInnovations[1] for the BC coast. The available biomass was then proportioned into stockpiles within the block to reflect delays incurred during operations as a result of equipment movement between residue piles. These cutblocks were then treated as supply points for the development of the logistics model.

Geographic information was collected for all roads in the region as well as the relevant cutblocks. The transportation paths from each cutblock to a barging terminal were determined. Roads were then given speed classifications with gravel roads only permitting single lane traffic. The established road network and the supply and demand points were then imported into the simulation software. Operating windows, operating schedules, material MC patterns as well as trucks, grinders and loaders were instantiated and given proper attributes such as operating rates and time series values in the model. Results of the simulation model were reported across a range of spreadsheets detailing every object's behaviour on a second by second basis. These were then combined and summarized using visual basic scripts.

[1]MacDonald et al. 2012. Assessment of Forest Feedstock (Biomasss) for Campbell River. FPInnovations.

Value Chain Optimization NSERC CRSNG FPInnovations

RESULTS

Scenarios were developed to investigate least cost grinding and transportation configurations, impacts of MC on operations, and centralized versus decentralized residue grinding. Results generated through simulation modeling were then compared to those of a simple spreadsheet model using the same assumptions.

For the given set of 51 cutblocks with residue to be harvested, the least cost trucking configuration was found to be 1 equipment set (consisting of a butt-n-top loader and a grinder) active at the cutblock with a fleet of 6 trucks transporting residue. The total delivered cost for this scenario was $69.93 per Oven Dried Tonne (ODT). However the optimal number of trucks visiting a cutblock was found to vary and was dependent on the average cycle time to the given cutblock. When the fleet size was allowed to vary by cutting permit (groups of between 1 and 10 blocks) the optimal number of trucks ranged from 4 to 12, with delivered costs ranging from $48.45 to $103.99 per ODT. The average delivered cost with varying fleet sizes was found to be $68.64 per ODT.

When comparing in-block grinding of residues and the transportation of hog fuel with the direct transportation of harvest residues and centralized grinding it was found, in general, that centralized electric grinding was more cost effective from blocks with shorter cycle times. This breakeven point occurs at a cycle time of 4.7 hours with 8 block groups being more profitable utilizing diesel grinding and 10 block groups benefiting from centralized electric grinding.The linear trend line relating cost to cycle time has an R^2 of 0.38 indicating that this relationship is dependent on additional variables such as residue volume at each block group.

To investigate the impacts of material MC on operations, seasonal trends were identified in the literature and imported into the simulation model. Sensitivity analysis on these trends was then conducted. The results predictably indicated that conducting operations during the driest part of the year yielded delivered hog fuel with the lowest MC, particularly if grinding takes place in the second year after timber harvest. This trend could then be capitalized on by accelerating operations during this period (August/September). Additionally it was found that as material MC increased beyond 30% trucks would be loaded to their weight limit rather than their volume limit. This resulted in an increase in the total number of trips as well as an increase in the delivered cost per ODT. Where a 6 truck configuration delivering an average material MC of 30% would cost $67.95 per ODT, the same operations would cost $74.77 and $87.11 per ODT at a MC of 40% and 50% respectively.

In order to compare the simulation results to a simple spreadsheet model the same assumptions about road speeds, operating rates, and delays were inputted into MS Excel. The time and cost to process every cutblock was then calculated to generate an average delivered cost of $52.51 per ODT. This is significantly lower than the least cost option using variable fleet sizes of $68.64 per ODT. This phenomenon is largely due to the inability of the spreadsheet model to capture complexities of an actual operation such as equipment interactions and movement, traffic bottlenecks, or the impact of varying material density on truck load.

DISCUSSION

The use of agent based simulation modeling allows for the observation of unexpected interactions. In the case of transportation planning, the process of model development and calibration brought to light bottlenecks that would occur in reality but would be completely unobserved with more rudimentary methods. These included forestry roads where additional pullouts should be added, and constraints at reload facilities where an expansion of unloading bays may be justified.

CONCLUSION

Agent based simulation is a powerful tool, well suited to model detailed interactions that commonly occur in logistics systems. The ability to run multiple scenarios in a timely manner allows for simple and thorough sensitivity analysis. For instance, in this case study it was found that the material MC had ramifications beyond the quality of delivered product and actually had cost implications for the operations.