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Economic impact of enhanced forest inventory information and merchandizing yards in the forest product industry supply chain

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A B S T R A C T

Forest products industry should maximize the value of timber harvested and associated products in order to be competitive in global markets. Enhanced forest inventories and merchandizing yards can help in maximizing value recovery in the forest products supply chain. This study develops an optimization model to analyze the economic impact of enhanced forest inventory information and merchandizing yard operations in the forest products supply chain. The application of the model is demonstrated by using a case study of a hypothetical forest industry in northwestern Ontario, which obtains four log assortment grades from the surrounding eight forest management units. The model analyzes five different scenarios with 0%, 25%, 50%, 75%, and 100% certainty of tree quality in forest inventory information. The results of the study show that with full certainty of tree quality information, it is possible to gain 49% in gross profit in comparison with a scenario with no certainty. The usefulness of enhanced forest inventory and merchandizing yard in the entire supply chain of forest products industry is recognized by maximizing total value of wood fiber (by allocating right log to the right product), reducing fluctuations in raw wood fiber supply, and minimizing inventory carrying costs and lost sales.

1. Introduction

Canadian forest products industry, which has traditionally produced commodity products is facing challenges of increased production costs, shifting of input factors to other sectors of the economy, lack of coordinated and integrated supply chains, and decline in capital available to improve existing facilities or build new ones [9,17]. To be competitive in global markets, the Canadian forest products industry must maximize the value recovered from timber and other associated forest products, and supply chains need to be improved [17,29]. The integration of an enhanced forest inventory, containing information on the variability of species, stem quality attributes and fiber quality, with merchandizing yards will potentially allow for value creation along the forest products supply chain [25,27]. The forest inventory information should provide timely, accurate and consistent information on valuable fiber attributes for sustainable development of forests [8], and is expected to help in obtaining maximum value from each tree harvested [27,28]. However, as many forest inventories were not designed to optimize each link in the forest value chain, the existing tools and methods are unable to support today's needs for accuracy, spatial detail and timely updates [28].

Inaccurate inventory is often related to the problems in technology, where it is difficult to make better measurements, whereas precision in inventory information refers to certainty in tree quality (volume of different log assortments in m^3). Inaccurate and less precise inventory information can lead to incorrect harvest decisions, and affects production planning in the forest products industry [13,15,23,24,26,32]. Borders et al. [5] in their study found that timber management organizations in the southern United States having lack of precision in inventory information are experiencing losses (188 $ ha^{-1}) in net present value. Most of the studies have tried to address stochasticity in inventory information using different routing methods and direct deliveries [16,23,26]. The multifold benefits from enhanced forest inventory information have also been documented [5,12,14,19,20,34], and some forest-based companies have started using enhanced forest inventory information in their decision making [27].

Traditionally, the forest management planning decisions depend on the accuracy of stand volume, which is obtained from different data acquisition methods, each having certain limitations [19,20]. There is always an economic trade-off between using

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higher-quality data for operational planning and the cost of obtaining such data [12]. The forest industry relies on the cost plus-loss methodology, which takes into consideration the hierarchical structure and iterative nature of planning, to analyze the value and need for better data in the planning process [12]. Ståhl et al. [34] found that forest inventories are most profitable, if they were conducted well ahead of the harvest operations. A posterior distribution of the inventory can be calculated using Bayesian theory, if an inventory is carried out in advance within the forest planning framework [34].

Enhanced forest inventory captures information, which is precise enough for value chain optimization [28]. It enables forest product industries to prepare plan to access, harvest and deliver the right forest products to the right mills and markets, at the right time. It makes the forest products industry economically sustainable for the long term by reducing costs and increasing profitability [27,28]. For example, forest industries in the provinces of Ontario, Quebec, Newfoundland and Labrador, Alberta, and British Columbia have reported substantial savings by using enhanced forest inventory information [35,37,27]. Based on the enhanced forest inventory information, the forest-based companies have reported savings from (i) the construction of efficient and environmentally sound forest road systems, (ii) accurate forest maps produced by automatic mapping algorithms, (iii) substituting high-density balsam fir for black spruce, and (iv) accurate information on tree height, volume and wood properties [37,27]. However, the potential of enhanced forest inventory information is still under-estimated.

Enhanced forest inventory information containing tree quality attributes will be useful only if the right log is used to produce the right product that will ensure maximum total value through optimal product recovery [10,11,18]. This requires the use of log yards for proper log sorting and merchandizing that stabilize wood supply by playing the role of a coordinating entity for raw wood supply. These log yards, commonly known as merchandizing yards, minimize wood inventory holding costs and loss sale costs for all the mills by transferring and minimizing the risks to the mill yard. Merchandizing yards are used as a buffer for the forest industries as they supply right amounts and types of forest products in right time to the mills. Merchandizing yards also provide easy access to the desired logs for small wood-based industry in rural areas. Merchandizing yards also help in generating rural employment and have potential environmental benefits by reducing the impacts of the entire harvest operation. Merchandizing yards have been found to be most successful where the end products are diverse, for example in Western Europe, Scandinavian countries, West coast of US and Canada [22]; Wallowa Resources 1997; [4,10].

Merchandizing yards are of different types depending on the purpose of log sorting and merchandizing, and their location. These include mill yards, concentration yards, log reload yards, remote log processing yards, and log sort yard [11]. In the mill yard, logs are stored for several weeks to several months before feeding into the mill. A concentration log yard is a central point for receiving logs and supplying them to the mill yards using long-distance transport [36]. Log reload yards are transfer points between different modes of transportation, namely truck, rail or barge. Remote processing log yards are used to feed satellite chip mills. A log sort yard is a place to sort logs for short periods at a landing with low capital costs. In addition to sorting, log grading, bucking and scaling can also be done at a sort yard [4,10,11]. A typical merchandizing yard has advanced log sorting facilities with storage, equipped with modern machinery for further processing of logs and chips production [4,18,33]. The main role of the merchandizing yard is to capture the highest value of forest products depending on their availability in the forests and market demands [10,18,21]. The financial feasibility of a log sort yard mainly depends on product prices and revenues [18]. Therefore, maximizing the revenues will realize the direct benefits of these merchandising yards.

Research on merchandizing yards is still sparse, with the majority of studies focusing only on the location problem of the yard [4]. Combined log inventory and process simulation models have also been developed that can monitor and update the status of logs in the merchandizing yard [25,30,31]. A few studies have also focused on optimizing the operations and transportation costs of merchandizing yards [6,21]. Developing an optimization model by linking the combinatorial sets of merchantable tree attributes distributed over a forest area with detailed operations of merchandizing yards to produce logs and biomass for each end product is a big challenge. At present, the Canadian forest products industry seems to have minimal use of enhanced forest inventory information and merchandizing yards in the supply chains. This study, therefore, analyses the role of advanced forest inventory information system and merchandizing yards for enhancing the value chains in the forest products industry with optimization modeling techniques. In particular, we consider different levels of certainty in tree quality information (0%, 25%, 50%, 75%, and 100%) to compare gross profits from different grades of logs (high, medium and low quality logs, and fuelwood). A case study is taken in northwestern Ontario (NWO) to see the usefulness of enhanced forest inventory information in a forest products industry supply chain utilizing a merchandizing yard.

The purpose of this study is to develop an optimization model that can analyze the economic impact of enhanced forest inventory information and a merchandizing yard in the forest products industry supply chain. The specific objectives are: (i) to develop an optimization model that maximizes gross profit of a merchandizing yard, (ii) to compare gross profit from this model using five different scenarios having 0%, 25%, 50%, 75%, and 100% certainty in tree quality in forest inventory information, and (iii) to compare per unit profit from each log grade in order to understand the contribution of each product in the gross profit.

2. Research area

Fig. 1 shows a snapshot of eight forest management units (FMUs) in NWO used for this study, namely Crossroute Forest, Dryden Forest, English River Forest, Kenora Forest, Lac Seul Forest, Sapawe Forest, Wabigoon Forest and Whiskey Jack Forest, surrounding a hypothetical forest products industry in Dryden. In Ontario, the Crown forests are divided into geographic planning areas, which are known FMUs. The FMUs are under the jurisdictions of provincial governments of Canada. Under a sustainable forest licence (SFL), individual forest companies manage most of these FMUs [2]. The simplified forest products industry in Dryden uses four categories of log grade: (i) log grade A is high quality logs, (ii) log grade B is medium quality logs, (iii) log grade C is low quality logs, and (iv) log grade D is fuelwood. The four types of log assortments are collected from FMUs, sorted and stored at the merchandizing yard, which is located between the FMUs and the forest products industry in Dryden. The forest area of each of the eight FMUs is divided into forest cells of 1 km^2 size. The forest cells are further classified based on the percentage of harvested cell area (forest depletion % over the years 2002–2009) as shown in Fig. 1. Alam et al. [2] describe in detail about the research area and its classification into depleted forest cells. The depletion layer of the FMUs is prepared using ArcGIS. To prepare this depletion layer, the percent occurrence method is used [3]. Depending on the depletion percentage, a code number is assigned to the grid cell in this method (percent of the cell area harvested, where, 1 is 100%, 2 is from 80% to 100%, 3 is from 60% to 80%, 4 is from 40% to 60%, 5 is from 20% to 40%, 6 is from more than 0%–20% depletion and 7 is no