Current and Potential Tagging and Tracking Systems for Logs Harvested from Pacific Northwest Forests

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ABSTRACT

The forest industry is constantly changing, and technology is constantly shifting the bar for efficiency and profitability. To maintain competitiveness and control costs in a global market, an efficient log tracking method must be used by regional stakeholders in the log supply chain from stump to mill to end consumer. It is important to understand the implications of recent innovations in log tracking for stakeholders in the Pacific Northwest in the context of a global economy, and how innovations in other regions may affect the future of log tracking. In this report, we (1) discuss the importance of log tracking technology, (2) review both regional and international efforts to harness technology for tracking logs from stump to mill, (3) report on a regional survey that examines the current status of log tracking in the Pacific Northwest, and (4) identify the most promising technologies that could be implemented in the near future. The majority of regional stakeholders use paper tags or other relatively simple tagging methods. Radio frequency identification (RFID) tags and other tracer technologies were not used when marking, sorting, tracking, or paying for logs by any of the regional organizations responding to the survey. RFID tags and spray-on code marking show promise for the near future.

Keywords: log tracking, supply chain, logistics

The forest industry is continually changing, and technology is constantly shifting the bar for quality, safety, efficiency, and profitability (e.g., Rayner et al. 2001). In a global market, it is critical to maintain competitiveness by controlling costs and maximizing customer service wherever possible. Log tagging has enormous potential for improving production efficiencies in the log supply chain from stump to mill and ensuring that the right kind of timber is used for the end product for which it is best suited (Dykstra et al. 2002, Hakli et al. 2010).

Many industries believe that product tagging provides both track and trace opportunities. Track capabilities allow companies to know where a product is at any given moment within the supply chain. Manufacturers have the ability to know when a product has been delivered to trading partners. Purchasers can better manage inventories and reduce the cost of maintaining stock quantities. Trace capabilities allow companies to see exactly where a product has been throughout the entire supply chain process. Manufacturers get a perspective on how their products move through the supply chain, allowing them to determine where costly delays are taking place or where shrinkage may be occurring within the delivery process.

There is a varying degree of interest for implementing innovative log tracking technology in the international forest industry. Stakeholders in the Pacific Northwest (PNW) should be aware of what are the recent innovations in log tracking, what are their pros and cons, and how these can affect practices in regional and international markets.

In this article, we (1) discuss the importance of log tracking technology, (2) review both regional and international efforts to harness technology for tracking logs from stump to mill, (3) report on a regional survey that examines the current status of log tracking in the Pacific Northwest, and (4) identify the most promising technologies that could be implemented in the near future.

Literature Review

Importance of Log Tracking

Efficient log (and wood product) tracking is important to landowners, mill owners, and wood product suppliers for several reasons, including (but not limited to) the following:

- Improved logistics and stock control management (Evanson 1998, Dykstra et al. 2002), particularly where suppliers are preparing logs for niche markets. Knowing where logs have come from and how long they have taken to get to various intermediate points can help identify bottlenecks in the supply chain and potential sources of downgrade (e.g., loss of log freshness). Net revenue increases when logs are efficiently supplied to the most appropriate mills.
- Improved ability to identify, allocate, and track logs from stands or trees with particular wood properties (e.g., logs with high stiffness or wood density characteristics; Amishev 2008). Technology currently exists to estimate wood properties in the field. However, if this information cannot be passed along the chain of custody, timber cannot be optimally allocated between different customers. This information is lost if a log is only visually sorted and labeled by grade.

Manuscript received July 16, 2011; accepted January 5, 2012. http://dx.doi.org/10.5849/wjaf.11-027.

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- Environmental certification of forest products (such as with the Forest Stewardship Council [FSC]) requires a system for tagging individual logs with certification status (Ozanne and Vlosky 1995). Two surveys of value-added wood product manufacturers in 2002 and 2008 (Vlosky et al. 2009) identified some of the primary reasons for stakeholders to get involved in certification. The primary motivators included (1) business owner commitment to environment, (2) growing markets, and (3) increasing sales and market share. Increasing unit profit ranked very low in these surveys as a reason for certification.
- Curbing illegal logging and wood theft (Simula 2001) and loss of government taxes and revenues. Increased regulations to control illegal logging (such as the Lacey Act in the United States) have received international support.
- Facilitating comparisons between forecast and achieved grade and volume yields based on pre- and postharvest forest assessments (Dykstra et al. 2002).

Review of Efforts to Harness Technologies for Log Tracking

Several different log tracking technologies have been developed and adapted for monitoring logs from stump to mill, including paint (conventional, microtaggant, and chemical tracer); hammer branding; paper tags and barcoding; nail-based labels; radio frequency identification (RFID) tags; and biometric, genetic, or chemical fingerprinting (Dykstra et al. 2003, Hakli et al. 2010). Depending on the application, these technologies can track products at the truck level or stem (log) level.

For the stakeholder, the optimal choice will depend on several factors, and it is quite possible that different stakeholders could arrive at different choices. Tracking the movement of individual logs requires that they be cost effectively and uniquely tagged in a manner that can be easily and repeatedly read along the supply chain (from mechanized processing to loading, to trucking, and delivery to the customer).

An ideal tagging technology in the PNW would have the following characteristics:

- Easy to read and accurate.
- Able to withstand harsh climatic conditions, such as rain, freezing temperatures, and sweltering heat.
- Able to withstand difficult transportation conditions (dragged over dirty ground, wind-whipped on the back of a logging truck traveling at 50+ mph, or sitting in the bottom of a ship's cargo hold crossing tropical oceans).
- Not interfering with log processing stages. For example, if the tags are attached to logs by staples, the tags and staples should not damage sawing equipment or be detected by metal sensors. Additionally, the tags and staples should not be a problem for the pulp and paper industry.
- Lasting for long time periods (several months is not unrealistic).
- Easily applied manually or by harvesting/processing equipment.
- Reusable.

In 1992, the USDA Forest Products Identification and Tracking Group ranked the most promising asset accountability methods using criteria such as value protected, application costs, reliability, information provided, field practicality, range of tracking problems addressed, and regional coverage (Simonson 1992). At that time, the top five most promising technologies were RFID tags, unique reflector identification tags, unidirectional bar coded tags, dye, and two-directional bar coded tags.

A decade later Dykstra et al. (2002) provided a detailed description of current and potential tracking technologies along with their strengths and weaknesses. They listed four technologies that were suitable for log tracking: conventional paint, conventional tags with or without bar codes, nail-based tags with bar codes, and RFID tags.

In our review, we focus on two technologies conventional tags and barcoding and RFID tags. Conventional tags and barcoding is one of the dominant regional technologies, and RFID tags are the main contender to replace conventional tags and barcoding. We will also provide a brief commentary on other technologies that are currently being implemented in the PNW or could be implemented. The reader is referred to the reports by Dykstra et al. (2002), Uusijärvi (2003), and Timpe (2005) and to the Indisputable Key website (Indisputable Key 2011) for more detailed discussion on the advantages and disadvantages of various log tracking technologies.

Conventional Tags.—Conventional tags (treated paper or plastic) have been used for decades. They can include information about sources (company brand, harvest location), as well as index numbers. This option has appeal to the stakeholder for many reasons. It is cheap, has relatively low capital cost, is easy to understand, and requires little training. Well-designed and well-manufactured tags can be very reliable. However, numbers alone can be difficult to read. Including a unidimensional bar code that can be read by bar code scanners can improve the accuracy of data recording. Bar coded labels can be difficult to read in dusty, dirty, or wet conditions. Other paper-based technologies have been proposed, including two-dimensional tagging (similar to the Quick Response [QR] matrix codes that are becoming popular), which uses a pattern based on an algorithm that can be placed on the end of a log (Little 1991). More information can be recorded on two-dimensional bar codes than unidirectional bar codes. Weaknesses of conventional tags include that they (1) can fall off (as reported by Dykstra et al. (2002), 1–5% of these tags fall off) (2) require line-of-sight for reading, and (3) are often not designed to be reusable.

RFID Tags.—RFID tags have been developed (Nath et al. 2006) and evaluated extensively for logs throughout the world, including Europe (Korten and Kaul 2008), Asia (Friedlos 2009), Canada (Swedberg 2005), and the United States (Swedberg 2011). RFID tags work by storing electronic information on a memory chip. When an embedded antenna is activated by a magnetic field, information is read from or written to the memory chip. RFID tags can either be the repository for information written to the tag and relating to the log (such as diameter, height, log quality, ownership details) or contain only an identification number, which provides a linkage to a centralized database where log information is stored. The former are read and write (RW) tags, and the latter are read-only (RO) tags. RO tags are less costly than RW tags. RFID tags can also be classified as active or passive. An active RFID tag has an onboard battery that always broadcasts its signal, whereas a passive RFID tag does not use a battery. Battery life for active RFID tags ranges from 5 to 10 years. Most applications for log tracking are passive, which in general are smaller and cheaper but have a lower range (ODIN Labs 2010). Read times and error rates increase with distance between the reader and the tags.

Adoption of RFID technologies for log tracking varies regionally, at least in part because of the funding available for testing and

development. In Europe and Asia, government funding is being provided, whereas the funding available in North America is mostly from private sources (Edwards 2007). There is a wide gap in RFID applications in the wood supply chain when comparing the European Union and the United States—only sporadic use has been noted in the United States, and it is normally noted in tracking high-value products, such as utility poles (Swedberg 2011).

An example of a government-sponsored project to test RFID technology for log chain of custody was the Indisputable Key project. The primary goal of the Indisputable Key project was to leverage track and trace technologies to follow wood through the supply chain from stump to end user. In doing so, tags were researched, but so were other key components and peripherals, including readers, software, and application/measurement techniques. Indisputable Key was funded by the European Commission, with 29 partners (including research institutes, universities, developers, forestry firms, sawmills and others) from Estonia, Finland, France, Norway, and Sweden.

RFID can respond well to harsh operating conditions (Knehr 2005), because reading does not need a visual connection from transponder to reader (Ehrhardt et al. 2010). However, RFID tags can be adversely affected by wood moisture—according to an Indisputable Key project, it is sometimes necessary to almost touch a reader to a tag to read it properly. This limitation could be a concern for the PNW region.

Extensive research has been implemented to address the weaknesses of RFID.

- RFID antennas are composed of metals that can adversely affect manufacturing if not removed; recent development has created an antenna from paper printed on a polymer paste, which would be wrapped in a material not detrimental to wood production (Ohnimus et al. 2010).
- Reading from tags is not 100% accurate; as tags become cheaper, including multiple tags identifying a single log, truck, or deck would increase reliability (Bolotnyy and Robins 2007). The optimal number of tags would depend on the value of the products.
- There is difficulty in placing RFID tags into logs cheaply and efficiently. The Technical University of Munich has mounted a staple gun to a single-grip harvester to mount RFID tags to logs (Wessel 2005).
- UHF RFID tags specifically designed for outdoor harvesting conditions in Scandinavia have recently been developed (Hakli et al. 2010). These wedge-shaped tags are relatively small ($80 \times 10 \times 6$ mm), function well in moist wood, and can be applied automatically in the harvester when the log is cut or manually at later stages in the supply chain. Read rates of greater than 99.3% have been recorded in log sorting and sawing tests. Read ranges vary from 1.6 to 2.5 m depending on the frequency of the transponder. Hakli et al. (2010) do not report the cost of these tags.
- Read-only RFID tags can be designed to be reusable, but these are often more expensive than nonreusable tags.

Other Current and Potential Technologies.—Current (and historical) regional methods range from no monitoring of individual stems (especially for lower value material, such as biomass) to paint and log hammer branding techniques. These technologies are excellent low-tech ways to sort and track logs at a batch level, but they are more limited when identifying log characteristics, such as log stiffness, at a finer detail. Other batch level technologies include microtaggant tracers and chemical tracer paint. These impart a high level of security and are difficult to counterfeit but cannot be electronically scanned or can require expensive and time-consuming laboratory services for identification of the paint signature (Dykstra et al. 2002). Aroma tagging and sensing with an electronic nose is another technology that could be suitable for batch level tracking, but the technology is not sufficiently developed for current application (Murphy and Franich 2004).

Potential technologies for individual log identification and tracking include "fingerprinting" technologies and log code marking technologies. Fingerprinting technologies include genetic fingerprinting and chemical fingerprinting (Dykstra et al. 2002), and biometric fingerprinting based on external log characteristics such as shape and growth ring patterns (Chiorescu and Gronlund 2004, Flodin et al. 2008, Peterson 2009). These fingerprinting technologies are not sufficiently developed for current application.

Log code marking methods have recently been developed in which patterns of dots or circles are stamped or sprayed onto the ends of logs (Sorvik 2002, Moller 2011). These can be applied automatically by harvesting machines and can be subsequently interpreted by handheld devices or machine mounted readers. Similar to QR codes, they can contain a significant amount of information. The major advantages of the log code marking concept are the low marking cost (below $0.003 per log), the fact that tags cannot fall off, and the fact that no production time is lost attaching or detaching the tags.

Methods

A survey was undertaken to assess current regional industry usage and perspectives on log tracking technologies in the PNW. The aim of the survey was to determine the following:

- What tracking technologies are currently being used
- How these technologies are integrated in each organization's supply chain management system
- What information is passed on to customers
- The current attitude concerning tagging and tracking technologies

The survey included a mix of eight open-ended and closed questions. The exact wording of the questions is included as an appendix to this article. Respondents could provide multiple answers to some questions, e.g., what tracking technologies are currently being used by your organization?

A draft survey was created and distributed to a set of test respondents to check for clarity and completeness. The revised survey was sent to 91 organizations between June and September 2010. A cover letter was attached, and a self-addressed stamped envelope was provided for respondent reply. Options for fax and e-mail responses were also provided. The survey selection pool was bounded by Oregon forest products companies identified from two sources: the Oregon Forest Industries Council (Oregon Forest Industries Council 2010), a trade organization of forest landowners and forest products manufacturing companies, and the Oregon Forest Industry Directory, a service of the Oregon Wood Innovation Center at Oregon State University. Many of the organizations from these

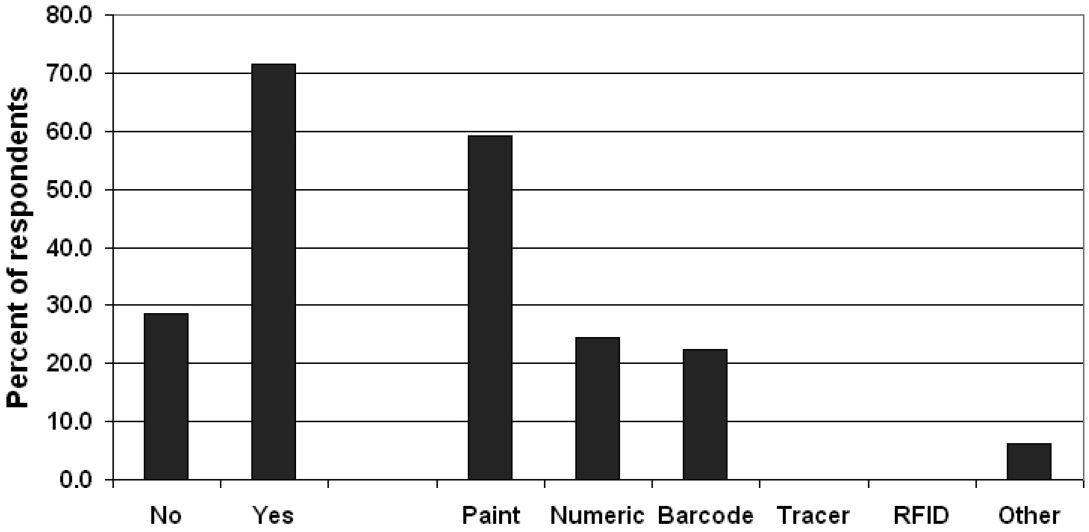

Figure 1. Survey respondent use of log marking and tracking technology for log sorting. RFID, radio frequency identification.

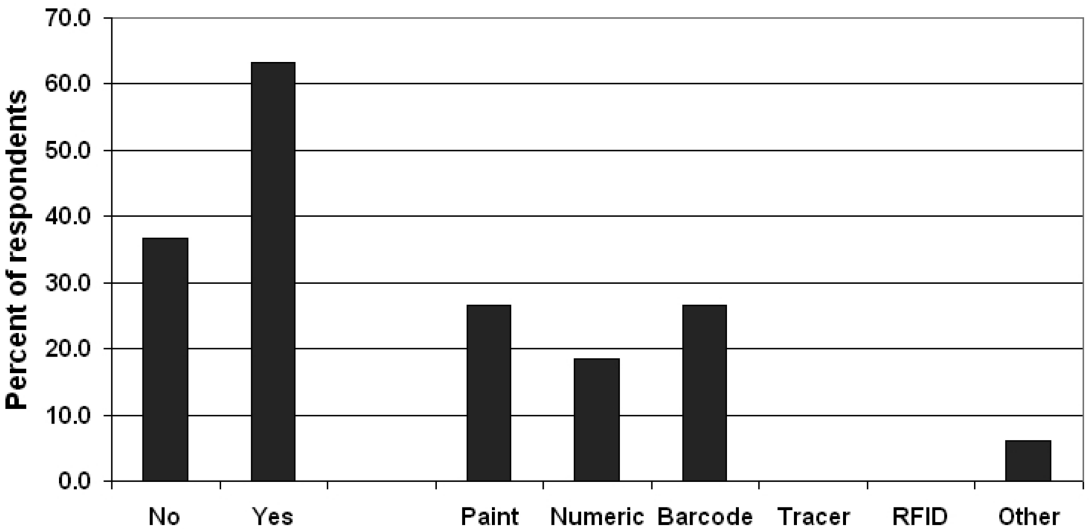

Figure 2. Survey respondent use of log marking and tracking technology for inventory control. RFID, radio frequency identification.

sources have forestland and milling facilities in the Pacific Northwest beyond Oregon (including Washington, northern California, and Idaho).

The 2010 survey was supplemented in 2011 with an interview with representatives from one of the log scaling bureaus from Oregon. The bureau was responsible for scaling and tagging significant quantities of logs destined for overseas markets.

Results

Results of the Survey

The overall response rate was 55%, with 58 of 91 surveys returned. The responding organizations included a wide range of forest landowners and processing facilities and included both large and small stakeholders.

Tracking Technologies for Sorting Logs

The first question inquired whether the organization currently uses tracking technologies to sort logs. Over 70% indicated using some form of tracking technology in their log sorts (Figure 1), and many used more than one technology simultaneously. Of those who did, paint (spray or marking crayon) was the most common marking method at 59%. Numeric and bar code paper tags were used by 24 and 22%, respectively. A distinction was made between simple numeric tags and bar code tags that typically also incorporate a visible number. Other technologies that were used included color cards and log brands. Log brands are routinely used on a few logs on each delivered truckload but are not typically used to identify individual logs. On larger, higher value products, each log on a truck may be branded, but this method was not considered in the survey.

Tracking Technologies for Inventory Control and Log Payment Tracking

The second question inquired whether the organization used marking or tracking technologies for (1) inventory control and/or (2) log payment tracking. Sixty-three percent of the responses indicated using a technology for inventory control (Figure 2), and of the affirmative responses, paint and bar codes were used 26% each. Numeric tags were used 18% of the time, reflecting the benefit of computer efficiency in use of direct read bar codes with system storage of information and subsequent transfer over the requirement

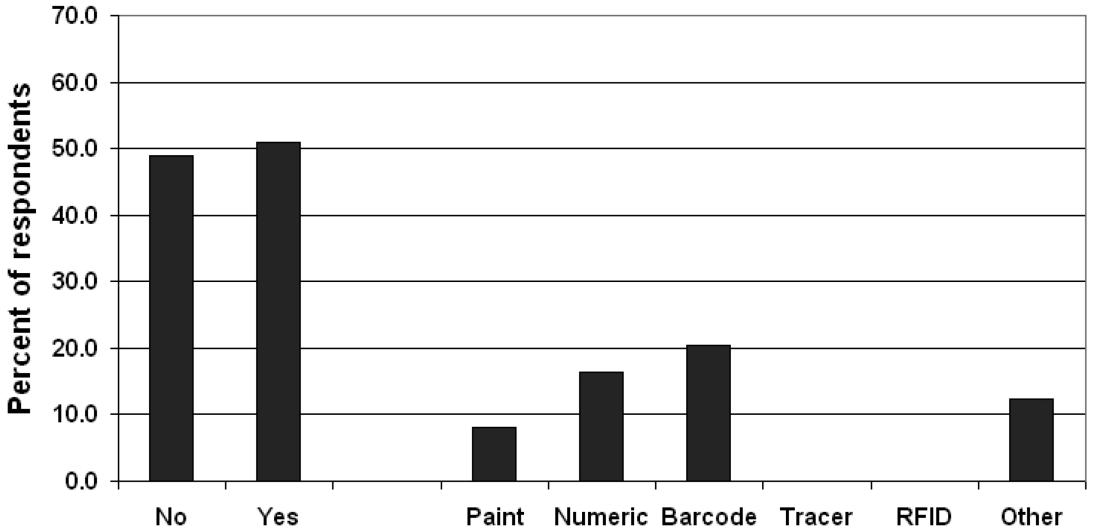

Figure 3. Survey respondent use of log marking and tracking technology for payment tracking. RFID, radio frequency identification.

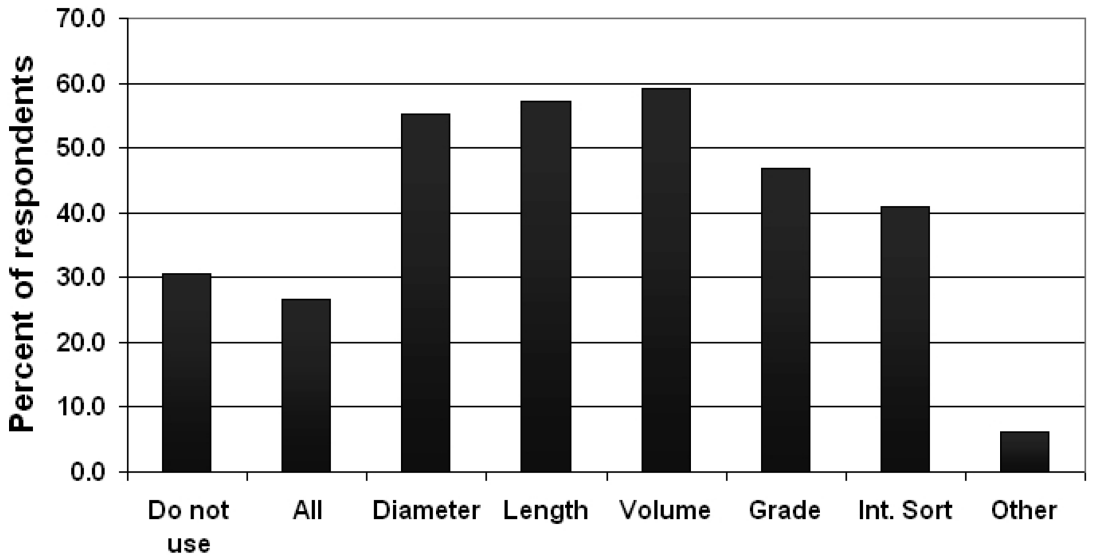

Figure 4. Log information currently linked to inventory control technology. Int. Sort, internal sort.

to manually create a hardcopy record or enter numeric values in computerized storage device. The "other" method indicated tracking inventory based on log load ticket information. It should be noted that a subset of those who noted that they used numeric or bar code tags indicated that they did so only on special logs (veneer, large diameter, high value).

The use of tracking technologies decreased from 63% to 51% for payment tracking compared with inventory control (Figure 3). Of the affirmative responses, 20% used bar codes, and 16% used numeric tags. Twelve percent responded with other technology. Other technology included scaling certificates and log load tickets. RFID tags and other tracer technologies were not used by any of the responding organizations for marking, sorting, tracking, or paying for logs.

Log Information Tracking with Inventory Control

The next three survey questions investigated the transfer of the linked and stored log data (including log diameter and volume) from forest inventory to subsequent milling operations or sale of logs. One third of the responses indicated the that data were transferred to milling operations for integrated operations, 35% indicated that data were not transferred to integrated mills, and 33% indicated this question was not applicable to their operation (i.e., their organization was not part of an integrated forestland and milling organization). Forty-seven percent of those reselling logs transferred the linked log characteristics to the buyer. Figure 4 shows that more than half of the survey respondents linked diameter, length, volume, and grade information to their inventory control system.

Technologies Used for Chain of Custody for Certification Purposes

More than 60% of the respondents did not use log tracking technologies for chain of custody certification purposes. Of the respondents who do use log tracking for this purpose, almost identical percentages did so for Sustainable Forestry Initiative (SFI) and FSC certification (Figure 5).

Organization Needs for Inventory Control Met by Current Technology

Eighty-three percent of responses indicated that current technologies meet their needs for log tracking and inventory control. Four

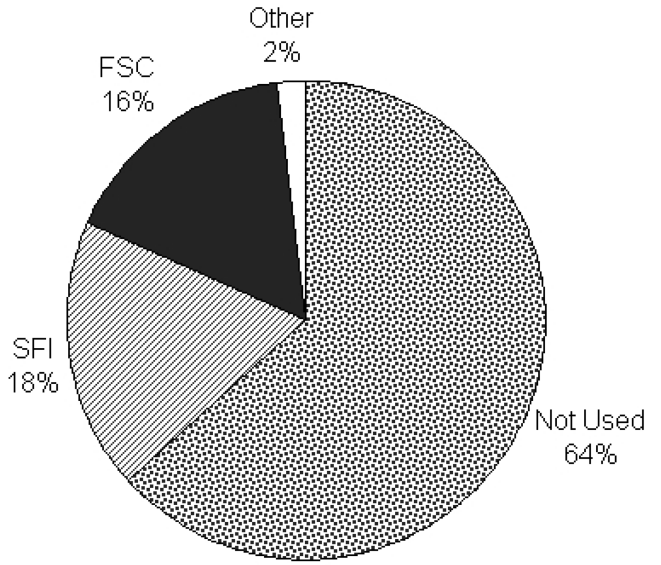

Figure 5. Stakeholder use of tracking technologies for chain of custody and certification purposes. SFI, Sustainable Forestry Initiative; FSC, Forest Stewardship Council.

responses (8%) indicated that current technology did not meet their needs. An additional four respondents indicated they were not sure whether the current technology met their needs.

Several of the survey respondents indicated what they perceived to be weaknesses of the current technologies. These included the following: mills not having kept up with technology, lost or missing tags, human error, inefficiency, and needs for computer systems.

General Comments on Log Tracking

The final written question broadly addressed any general needs in regional log tracking. Responses included that there was a need for lower cost and improved RFID technology, improved data transfer and timeliness of transfer, and improved efficiency and communication. Several respondents indicated that they had investigated RFID technologies but considered that this technology was not reliable or cost-effective at this time.

Results from the Interview

The export market in the PNW uses paper tags with bar code tracking extensively. This is a large market in the PNW; for example, the Columbia District, which includes Longview and Coos Bay ports, had approximately 87.5 million board feet exported in 2009. Assuming 140 board feet per log, this means that more than 600,000 logs were moved in a single year from this region. An interview with Yamhill Log Scaling and Grading Bureau (YLSGB) (T. St Laurent, YLSGB, pers. comm., June 2, 2011) indicated that all export logs are individually tagged with a paper tag. Types of paper tags vary, but tags tend to be colored for deck identification, and they often include multiple bar codes on the same tag so that part of the tag could be removed to validate log movement at specific steps, e.g., when placed on a barge for transport. Multiple staples are normally used to secure the tag to a log. Read errors when scanning bar codes are very low, but when errors occur, tags are manually cross-referenced to ensure accuracy. YLSGB have been attaching bar codes to logs and reading them in the field for more than 20 years.

Currently, logs are tagged in large sort yards, not in the field. Several challenges would need to be addressed to move tagging into the forest, including consistency and accuracy, and ownership of the tagging system (tagging is currently accomplished for the landowner and buyer by a third party). These challenges would need to be addressed to optimally collect information for each log and tag real-time as part of the harvest process in the field.

Discussion

Is There an Optimal Technology for All?

One of the primary results that stand out from the survey is the perception of current technology versus future innovation. The survey shows that the vast majority of regional stakeholders (~90%) consider current technology as sufficient for current operations. This may be true, but newer technologies, including RFID and spray-on code marking, are approaching costs, reliability, and ease of use that would make them competitive with current paper tags. It is certain that RFID will eventually become cost competitive, and regional stakeholders should assess benefits and barriers associated with implementing newer technology.

When selecting a tracking system, two of the first decisions to make are what type of information will be stored and when, along the chain of custody, that information will need to be accessible. Currently in the PNW, basic information can be painted on the butt end of a log (e.g., log grade, such as 2-saw, pole, special mill) in the field for easy identification and sorting at the mill or in a sort yard. However, if a mill wanted more detailed information from the field, such as log stiffness, log quality, or track and trace information for improved logistics, another technology, such as RFID or paper bar codes or spray-on codes, may be desirable.

Obviously, one of the most important parameters when choosing a technology is the relative profitability. Detailed research has been compiled in projects such as Indisputable Key that show that the profitability of the system depends on the synergistic information gathered along the chain (Talbot et al. 2010), as well as the overall price differentials for varying log qualities. Ehrhardt et al. (2010), for example, note that RFID tags on individual logs would be suitable for high grade timber, such as sawlogs or veneer logs, but not for industrial wood or energy wood.

Depending on the harvest system used (e.g., cable yarding versus cut to length system), value-added information that could be acquired at the stump and passed through the supply chain include log top diameter, log length, tree species (e.g., white fir versus Douglas-fir), general quality (e.g., rot, taper, sweep, damage), and internal properties (e.g., acoustically measured stiffness).

It is inefficient for a single stakeholder to implement a new technology that increases information within one part of the supply chain if that information is not passed on throughout the entire chain. The costs and benefits of implementation would ideally be shared by all stakeholders in the chain. Regional acceptance of any new technology would optimally have a wide scope of interest in implementation.

Regional stakeholders that include exports as a product must be able to identify and track logs as required by the customer.

What Can Happen in the Future to Affect Log Tracking Decisions?

There are several things that can affect supply chain management. As with most electronics, the price, power, and availability of RFID will improve rapidly in the future (Bhattacharyya et al. 2010). The continuing trend for certification could encourage the log supply chain to integrate further—using a common log tracking system

would favor technologies such as RFID. And finally, familiarity with new tracking technologies could lead to migration from current methods.

Of those factors, the most important is cost. Paper tags currently range from about $0.06 to about $0.13 per tag (Universal Tag 2011). In addition, there is a staple cost: assuming $46/box, 5,000 staples/box, and 3 staples per tag, staple cost is about $0.03/tag. This means that paper tags cost $0.09–0.17/tag. The cost of read-only RFID tags varies, but current estimates indicate that ~$0.25/tag is reasonable (ODIN Labs 2010). The cost differential has been closing between the two technologies, but paper tags are still cheaper. Codes sprayed on by harvesting machines cost less than $0.01/tag (Moller 2011). To these costs need to be added the full costs of attaching the tags, detaching the tags (if necessary), encapsulating and ruggedizing the tags for application and use in forestry conditions, and providing equipment and software for reading the tags.

Conclusions

The current system of log identification has historically worked well for stakeholders, as shown in the survey. However, the international market may show historical methods of tracking to be inefficient in the future.

Significant change and adoption of technology does not occur overnight, and it usually requires industry to reach a social or economic tipping point. There are several indicators that may lead to change in the Pacific Northwest in the near future.

Indicators include the following:

- The cost of the technology continues to drop as manufacturing costs decrease and adoption rates increase.
- Innovation within technology continues to address known weaknesses and improves accuracy of measurement systems in adverse environments.
- As other regions improve efficiencies and information, pressure will increase for local industry to follow suit since they have to operate within a global market place.
- Increased interest in the source of wood and certification will continue, and cost-effective techniques for obtaining/storing/relaying this information will be critical to maintain market competitiveness.

Appendix: Questions Included in the Survey

1. Does your organization use any marking or log tracking technology for sorting logs? YES or NO. If yes, what methods: (a) Crayons or paint codes, (b) Numeric tags, (c) Barcode tags, (d) Tracer paints, (e) RFID tags, (f) Other: (please specify).
2. Does your organization use any marking or log tracking technology for inventory control? YES or NO. If yes, what methods: (a) Crayons or paint codes, (b) Numeric tags, (c) Barcode tags, (d) Tracer paints, (e) RFID tags, (f) Other: (please specify).
3. Does your organization use any marking or log tracking technology for payment tracking? YES or NO. If yes, what methods: (a) Crayons or paint codes, (b) Numeric tags, (c) Barcode tags, (d) Tracer paints, (e) RFID tags, (f) Other: (please specify).
4. If your organization uses technologies for inventory control, what information is linked to the method? (a) Scaling diameter, (b) Scaling length, (c) Volume, (d) Grade, (e) Internal company sorts, (f) Other: (please specify).
5. If the technology in question 2 is used in an integrated operation, is the information transferred to mill at time of processing? YES or NO.
6. Does you organization use technology in question 2 for subsequent sale of logs? YES or NO.
7. Does your organization use any of these technologies for chain of custody tracking for purposes of SFI, FSC, or other certification processes? YES or NO. If yes, please list certification organization(s).
8. Are there any needs within your organization for log inventory control/tracking which are not being met by current technology? YES or NO. If yes, what are the weaknesses of current technologies? If yes, what are the specific needs?

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