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Operational Research Results and Implementation Considerations for Ribbonless Harvesting Systems

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ABSTRACT

Ribbonless navigation systems offer the potential to reduce block layout costs while also improving operator productivity. We conducted a short field trial to test the accuracy of two available systems as well as identify challenges and best practices for companies looking to implement ribbonless navigation into their operation. The results highlight the importance of ongoing training and a clear set of operation wide guidelines and practices to get the maximum value out of an onboard ribbonless navigation system.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

To remain competitive in the modern commodity market, companies must continually adapt their practices to reduce costs while also meeting legislation requirements. The mechanization of harvest operations over the past 100 years has provided the greatest leap in terms of reducing fibre acquisition costs. More recently, the development of high-accuracy and relatively low-cost remote sensing data has provided companies with an opportunity to address other supply chain inefficiencies that previously relied on a “boots on the ground” approach to harvest planning and execution. The low cost and ease of use of GPS navigation equipment and productivity tracking systems, such as FPInnovations’ FPDat system, have become popular with companies and contractors looking to reduce supervision costs. Despite these systems’ potential to eliminate part of the ribboning and block layout process, the relative uncertainty of the accuracy, operator interaction, and best practices to implementation have slowed the uptake of the systems.

As part of a project aimed at improving the knowledge base surrounding ribbonless harvesting, FPInnovations conducted a study aimed at generating quantitative results regarding the accuracy with which an operator who relies exclusively on an on-board navigation system can follow a predetermined boundary. A best practices guide was developed based on interactions with member companies across Canada who have already implemented some form of ribbonless harvesting. In addition to the quantitative results recorded during the field trial, qualitative observations based on operator and harvest supervisor interactions are presented.

2. OBJECTIVES

Based on FPInnovations’ interactions with various industry partners, adopting a fully ribbonless approach to block layout and harvesting is estimated to save companies $0.50/m^3 to $0.75/m^3. Based on its current costs for block layout, Tembec, Kapuskasing, is estimating a yearly savings of approximately $300 000 once these systems are fully integrated.

This report consists of two parts: the development of an operational procedure for evaluating the accuracy of these systems as well the preliminary results for two common systems, and the implementation considerations and a best practices guide based on interactions with industry members. The two systems tested were the FPDat system and a lower cost Avenza system which uses an iPad and consumer grade GPS unit for navigation using a georeferenced PDF maps on the Avenza app. The FPDat is a more integrated system offering remote position and productivity tracking, onscreen performance indicators, as well as a ribbonless navigation system with visual and audible alerts when near boundaries.

3. OPERATIONAL ACCURACY EVALUATION

Two blocks with 100% softwood composition near Kapuskasing, Ontario, were used in this trial. Both feller buncher operators had at least three years of experience and both were, according to the harvest supervisor, familiar with the systems in their machines. In each block, three or four artificial boundaries were created using ArcGIS and a 25 m grid, and then exported as a large-scale PDF map for the iPad based Avenza system (Figure 1, left) and as a regular shapefile for the FPDat system (Figure 1, right).

The boundaries consisted of short straight lines and angled turns designed to replicate a non-linear boundary that would typically be observed around an area of concern. The strips created were parallel and spaced 20 m apart to facilitate post-trial cleanup of the block.

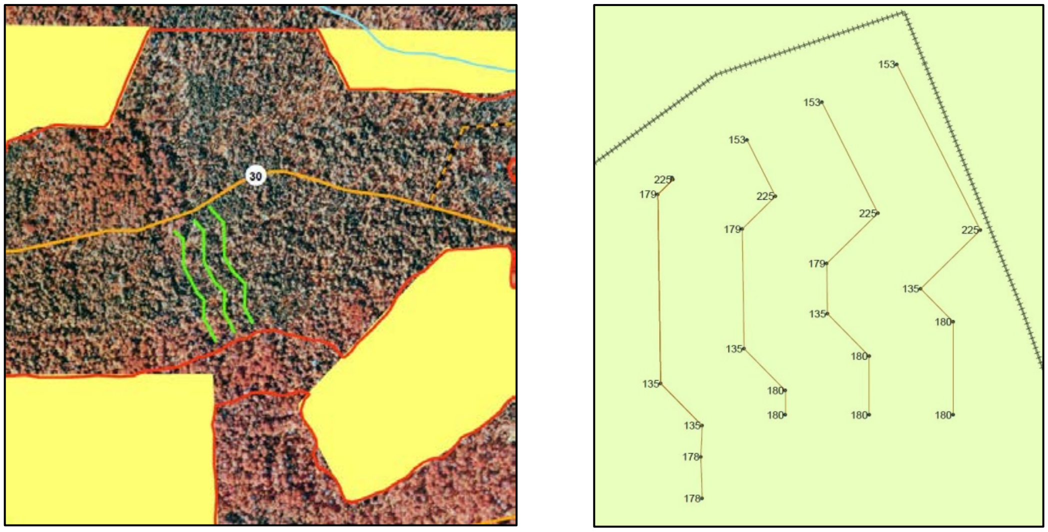

Figure 1. Maps showing artificial boundaries created for the Avenza system (left) and FPDat system (right).

The operators were instructed to cut along the edge of one side of the boundary, being sure not to remove any trees beyond the line. The trails were then cleared by the skidder operators to ensure that the stumps would not be covered by the tops of piles.

Post-harvest measurements were done using a handheld field tablet (Algiz 10x) equipped with ArcPad and paired to an SXBlue II + GPS with submeter accuracy. Each system was assessed based on 10 plots measuring 20 m in length that were randomly placed along these boundaries. Researchers would navigate as close to the vertices as possible and then collect a GPS position that averaged 300 points and had a maximum Positional Dilution of Precision (PDOP) threshold of 4 to obtain actual ground position relative to the boundary lines. Corrections from this point were done using a surveyor’s tape measure and compass based on measurements calculated using ArcPad. From the corrected point, the surveyor’s tape and compass were used to lay out the transect (Figure 2) based on angle and length measurements calculated in ArcGIS (Figure 1, right).

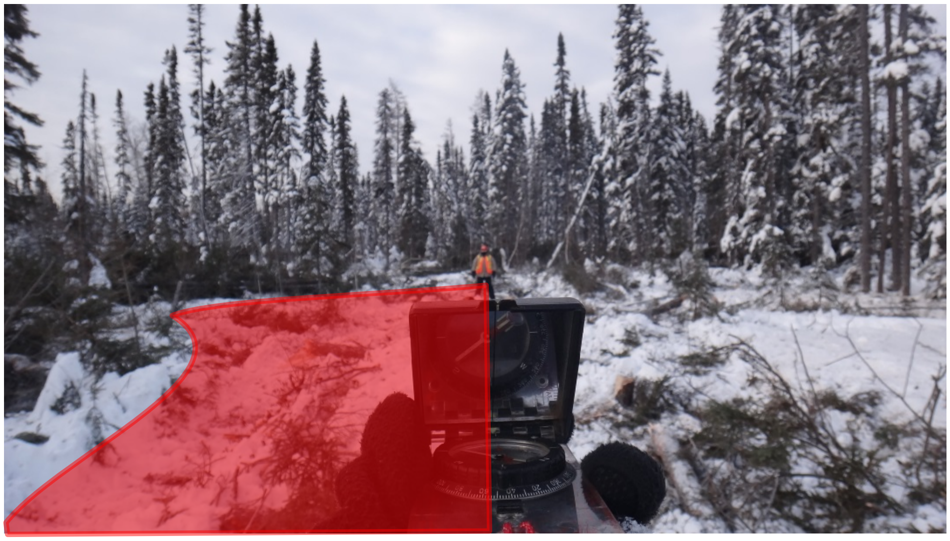

Figure 2. Post-harvest plot layout. The bearing from the compass to the researcher represents the boundary. The red polygon represents the area that was cut beyond the boundary.

Researchers then measured the distance from this transect for all stumps that were wrongfully cut beyond the line, as well as the diameter of each. Any residual trees on the other side of the line that fell between the buncher's trail and the line were measured the same way as the stumps. These distances were used to calculate the maximum distance by which trees were cut or left in error based on the operator's position along the line.

Due to the depth of fresh snow and a very high degree of variation in the Avenza trial, in which the buncher was sometimes completely over the line (Figure 3), the post-harvest assessment method was adjusted to assess the maximum distance within which machine disturbances were observed. Doing so removed the need for locating stumps, which were either buried in fresh snow or packed below skid trails.

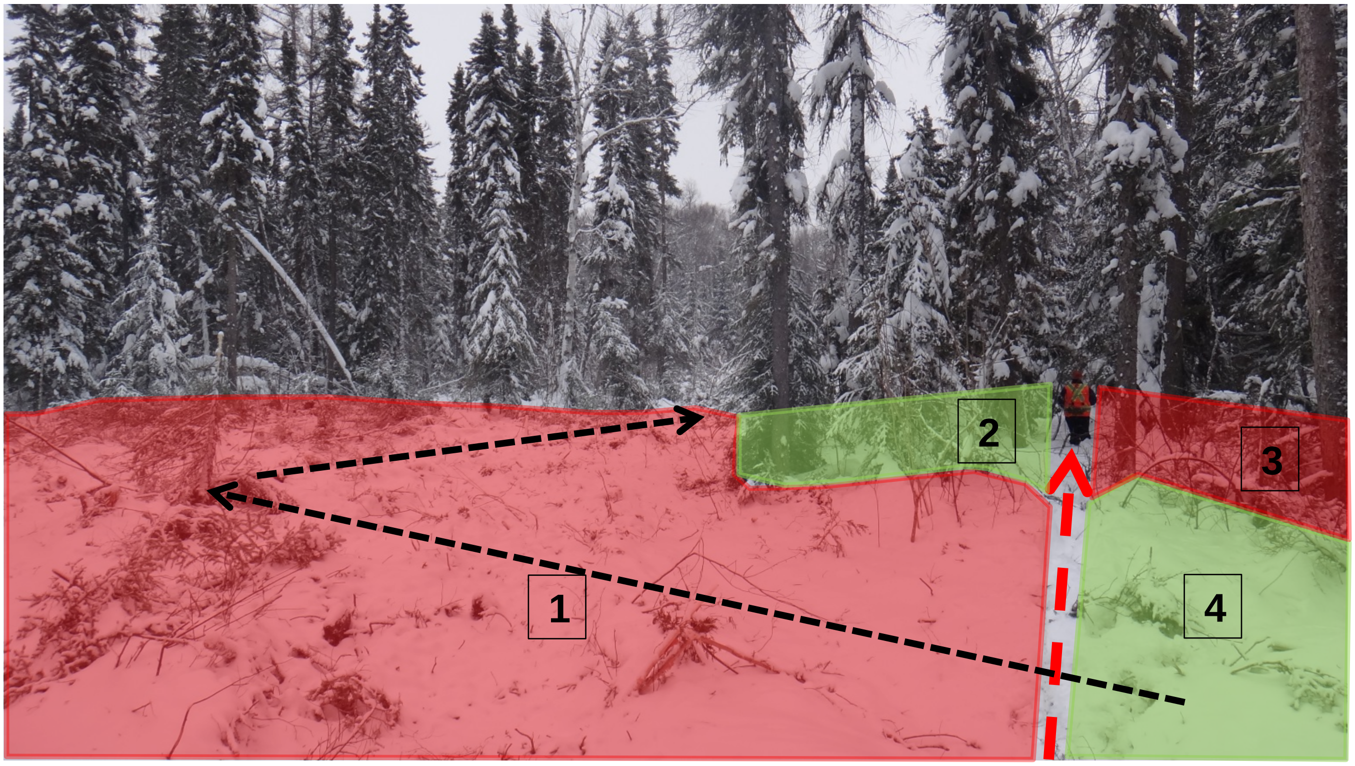

Figure 3. Example of variability observed with the Avenza system. The red arrow shows the actual boundary and intended direction, and the black arrow represents the approximate angle of travel and correction done by the operator. The red area to the left of the line (*1*) is trespass area that was overcut. The green polygons were correctly cut (*4*) or left (*2*), and the red polygon to the right (*3*) is the area that was wrongfully uncut.

4. RESULTS

The FPDat unit performed better than the Avenza system in maintaining a consistent distance from the boundary. The FPDat had a maximum boundary crossing of 6.4 m (Figure 4), whereas the Avenza crossed the boundary by 23.3 m at its farthest point (Figure 5). Both systems undercut the boundary on at least one occasion, with the FPDat system undercutting the boundary by 1.85 m (Figure 4), while the Avenza missed the boundary by at least 15 m (Figure 5) on one of the plots. The FPDat results show that the operator consistently overcut by approximately 3.5 m, which suggests that there was a bias, either in the operator's interaction with the display or the placement of the antenna relative to the machine's centre of rotation.

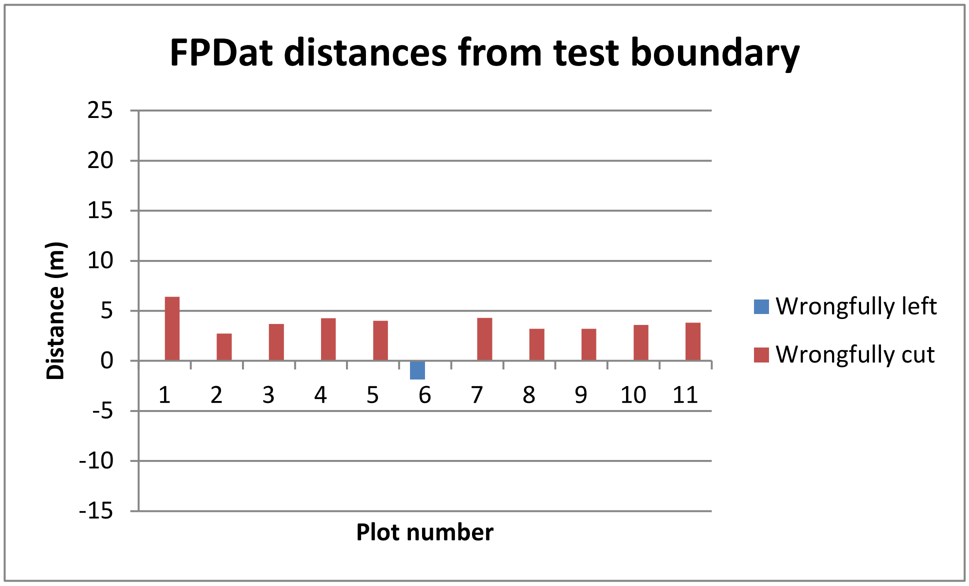

Figure 4. Observed maximum distances from boundary for FPDat trial.

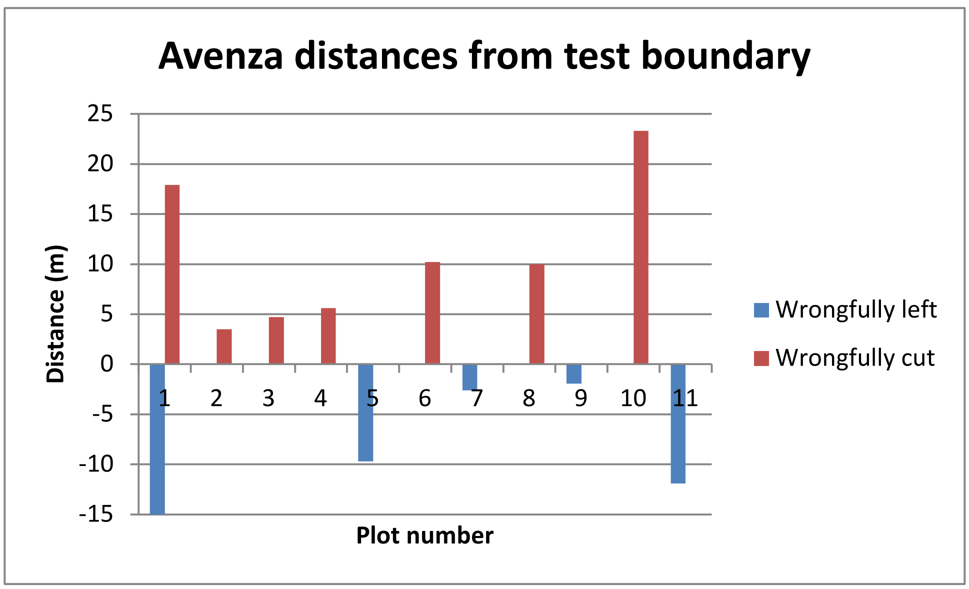

Figure 5. Observed maximum distances from boundary for Avenza trial.

5. TEMBEC-SPECIFIC OBSERVATIONS

In addition to the empirical results presented above, it is important to highlight the system and/or setup limitations or features that were not being used by operators and harvest personnel. Future tests should re-examine these systems' accuracies using optimized setups.

Antenna selection and placement

- The Avenza unit's GPS was a consumer-grade Bluetooth GPS device (Dual XGPS150A) not designed for use outside the machine and was therefore mounted inside the cab, which likely reduced the accuracy due to interference from the thick metal surrounding it. Pairing the iPad to a higher-end GPS receiver with a rugged roof mounted antenna would improve the accuracy of the system.
- The Avenza system's GPS unit had an advertised accuracy presented as ±2.5 m, but the standard that is used, the circular error probable (CEP), implies a 50% chance of the actual position falling within a 2.5 m radius circle. Using a 95% confidence interval standard (2DRMS) used in higher-end GPS units, such as in the FPDat, this equates to an accuracy of ±6.0 m.
- The FPDat antenna was on top and outside the machine cab, which offered greater line of sight compared with the Avenza system. The antenna/receiver used by the FPDat also has a much higher accuracy, of ±0.6 m (2DRMS 95% confidence), or <25 cm when expressed as CEP (Circular Area Probable).

Map configuration

- The FPDat uses a standard line shapefile to guide operators through a block. These shapefiles can be configured to change the frequency at which points are logged when an operator is close to a boundary, and they can provide a visual or auditory alert when the operator is approaching a boundary. These settings were not used during the trial since the operators and harvest supervisors who are responsible for setting up the operators' systems were not aware of these features.
- The Avenza system relied on easily generated, georeferenced PDF maps loaded onto an iPad. Zooming in enlarged the image, but it also enlarged the width of the boundary line, which created an additional unwanted buffer of 2.35 m. A two-colour system that shows the actual boundary when working at a small scale would eliminate this issue.

Tracking

- The tracking in each block allowed operators to see their progress. The FPDat stores over a year's worth of points, which was useful when moving between blocks or when resuming work after a long shutdown period.
- The Avenza system's track log needed to be cleared every three to four weeks to prevent the program from becoming slow or unresponsive, which was a negative for the operators.
- The FPDat tracking could be adjusted to help the operator by decreasing the interval at which a point is recorded around selected boundaries, such as a water boundary, or around property line shapefiles. Proximity alerts could be set up to reduce the time spent looking at the screen rather than at the block ahead.

6. DISCUSSION

The FPDat system was shown to be significantly more accurate than the Avenza system. The results also showed a clear bias in the FPDat results, which suggests that there were improper interactions or understandings of the visual cues being seen on the screen by the operator. Accuracy improvements can be made through better operator training, system setup, and instruction before implementation, as well as ongoing operator training.

The Avenza system was most affected by the poor satellite connectivity caused by a lower-grade GPS receiver and suboptimal placement. Operators complained of the Avenza icon jumping around as a position was corrected, yet the system does not have a means of indicating low connectivity. Operators frequently found themselves in error by glancing at their screen while the system was experiencing low connectivity and assuming their position to be true. This resulted in crooked paths (Figure 3), as the operator not being aware of the actual position until reception improved, at which point it was too late. Upgrading the GPS receiver or the position of the current receiver would improve accuracy, although the system still suffers from a lack of onscreen cues to indicate poor accuracy.

To protect against trespasses when relying on these systems, buffers of 23.3 m and 6.4 m for the Avenza and FPDat systems, respectively, would need to be applied based on these initial results. The accuracy of these systems could be improved through proper setup and operator training. The FPDat's navigation function is only one part of the system; utilization rate tracking, wireless progress communication with supervisors, and boundary alert systems around areas of concern (Castonguay & Gingras, 2014) should be considered when evaluating the needs of the user and the value of these features. In cases with "hard" boundaries, compliance issues, or where inaccuracies can lead to huge downstream costs, such as with poorly cut roads, investing in a higher-end system would be worthwhile. The best return on investment would be experienced through increased operator and harvest supervisor training as it pertains to the use and limitations of each system through the development of a standard operating procedure.

7. BEST PRACTICES FOR IMPLEMENTATION

Planning

A set of standard operating procedures should be developed to ensure uniformity across an entire operation. Training and refreshers need to be offered at least annually to ensure that the tools and methods are not forgotten by operators after extended shutdowns, which are common in harvest operations. This is an opportunity for harvest supervisors to also refresh their knowledge and train new foremen and operators regarding:

- The minimum threshold needed for cutting along boundaries.
- What threshold is considered "poor", and how to troubleshoot common problems.
- How to set up "halos" properly, both for work inside blocks and along boundaries. Fixed radius (typically boom reach) and variable radius (based on GPS accuracy) are most common.

    - Fixed radius is an easier visual representation to understand and work with, but additional buffers need to be added to boundary shapefiles.
    - With a variable radius, shapefiles alone are adequate since the variance in accuracy is captured in the halo radius.
- Determining a scale standard (zoom) and operating procedure when working along boundaries with a system that does not offer geofencing or a halo representing machine reach.
    - 1:500 is recommended along boundaries, and 1:2000 is recommended for working within a block.
- Buffering around boundaries based on system accuracy to avoid trespass.
- Standardized colour-coding based on the boundary type (water feature, machine reach only, non-reach, etc.).

Field validation, implementation, and support

- PDF guides or physical copies of common troubleshooting problems should be prepared to reduce downtime in case of a malfunction.
- Standardized equipment across the entire operation reduces the need to learn multiple systems and requires fewer spare parts on hand in the event of a faulty or damaged piece.
- A process for checking for water features should be determined. Most companies still require their harvest supervisors to conduct field reconnaissance to identify unknown water features ahead of harvesting; it also provides an idea of the block and layout.
    - Light detection and ranging (LiDAR) data can help to identify likely water features and prioritize their field reconnaissance based on likelihood of existence.
- Field reconnaissance should be done with high-accuracy GPS to create any necessary shapefiles to update the block shapefiles that were based on unknown features. An additional 2 m buffer is recommended as a safety margin to cover GPS inaccuracies and provide operators room for error.
- Reports of severe weather negatively affecting GPS accuracy are rare, but operators should move to cut inside the block when they experience lower connectivity.
- Satellite orientation varies by time of day and based on latitude/longitude. Reception projections can be found online through services such as John Deere's NavCom Satellite Predictor.[1] Maintenance or work inside the block should be scheduled to coincide with periods of lower accuracy.

[1] The prediction tool can be found here: http://satpredictor2.deere.com/

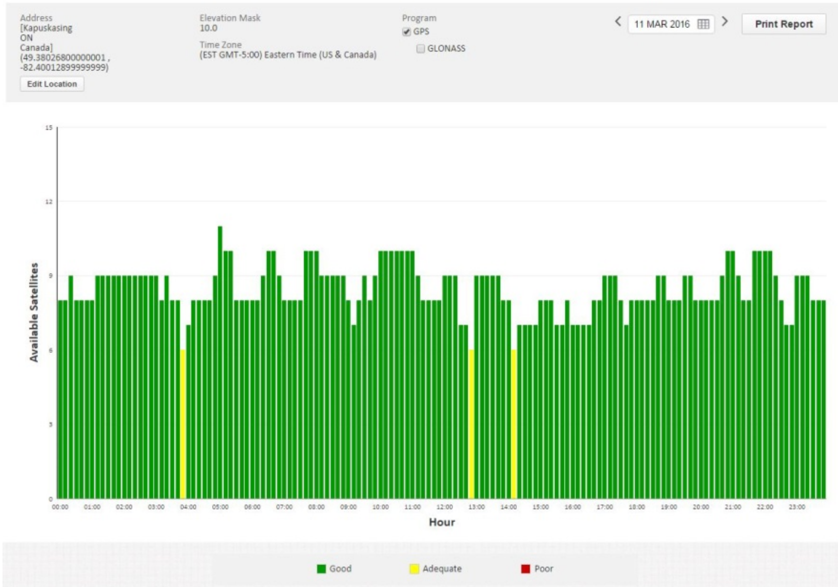

Figure 6. Predicted satellite reception for Kapuskasing on March 11, 2016. Yellow bars represent 10-minute periods when satellite reception is predicted to be lowest.

Expected benefits

- One West Coast consulting firm that does block planning and layout contracting indicated that half of its ground staff could be cut as ribbonless systems become more integrated. They warn that “boots on the ground” will always be needed where the risks and penalties of non-compliance are high; however, maintaining a reliable workforce has become increasingly challenging for companies.
- Systems offering geofencing alerts can improve productivity by reducing the time spent looking at the screen and by changing harvest processes, such as cutting the boundaries first as a means of avoiding trespass.
- Productivity gains of 10% to 20% were reported around boundaries resulting from operators not spending time looking for ribbons, especially during periods of low visibility.
- Wireless transmission of tracking files between machines and supervisors improves machine productivity when working in systems with more machines.
- Productivity on undulating terrain can be augmented using LiDAR data and accurate digital elevation models to display rough terrain (Figure 7) to allow contractors and supervisors to plan their harvests more efficiently.

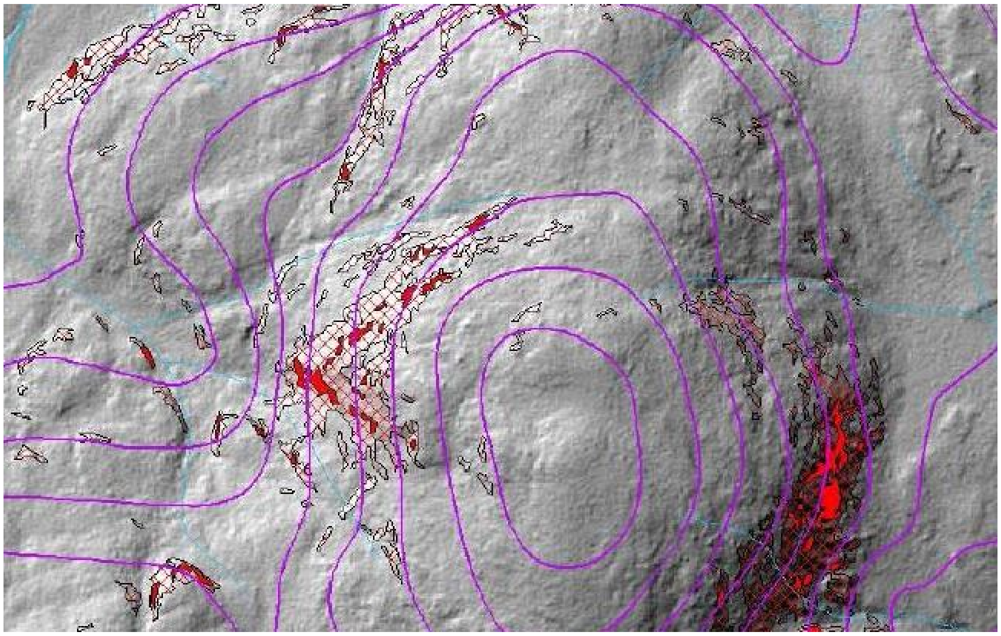

Figure 7. LiDAR-generated map in rough terrain. Red areas represent slopes of 45% or more, and hatched areas represent a slope of 30% to 45%.

8. CONCLUSION

In addition to providing financial savings by foregoing manual block layout, ribbonless systems alleviate problems with subcontractors who may not be conscientious, or challenges maintaining reliable field personnel. To achieve a maximum return on investment, the implementation and training around the hardware must be properly implemented and regularly scheduled. The potential savings associated with ribbonless harvesting must be weighed against the potential costs from loss of volume caused by conservative buffers being used around areas of concern, or, conversely, the potential penalties of non-compliance. When a ribbonless system is properly implemented, productivity gains of 10% to 20% around block boundaries can be expected. Providing operators with better on-screen information, such as slope, rough terrain, or water features, ahead of time will permit better planning and improve productivity. Finally, choosing an integrated system such as the FPDat that offers ribbonless navigation, remote progress tracking, and performance indicators will allow contractors and companies to more effectively model and manage their harvesting operations in real time.

9. REFERENCES

Castonguay, M., Gingras, J.F. (2014). *FPSuite™: An integrated monitoring platform for forest operations: Overview of the technology and benefits* (Advantage Report, Vol. 15, No. 7). Pointe-Claire, Québec: FPInnovations.

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