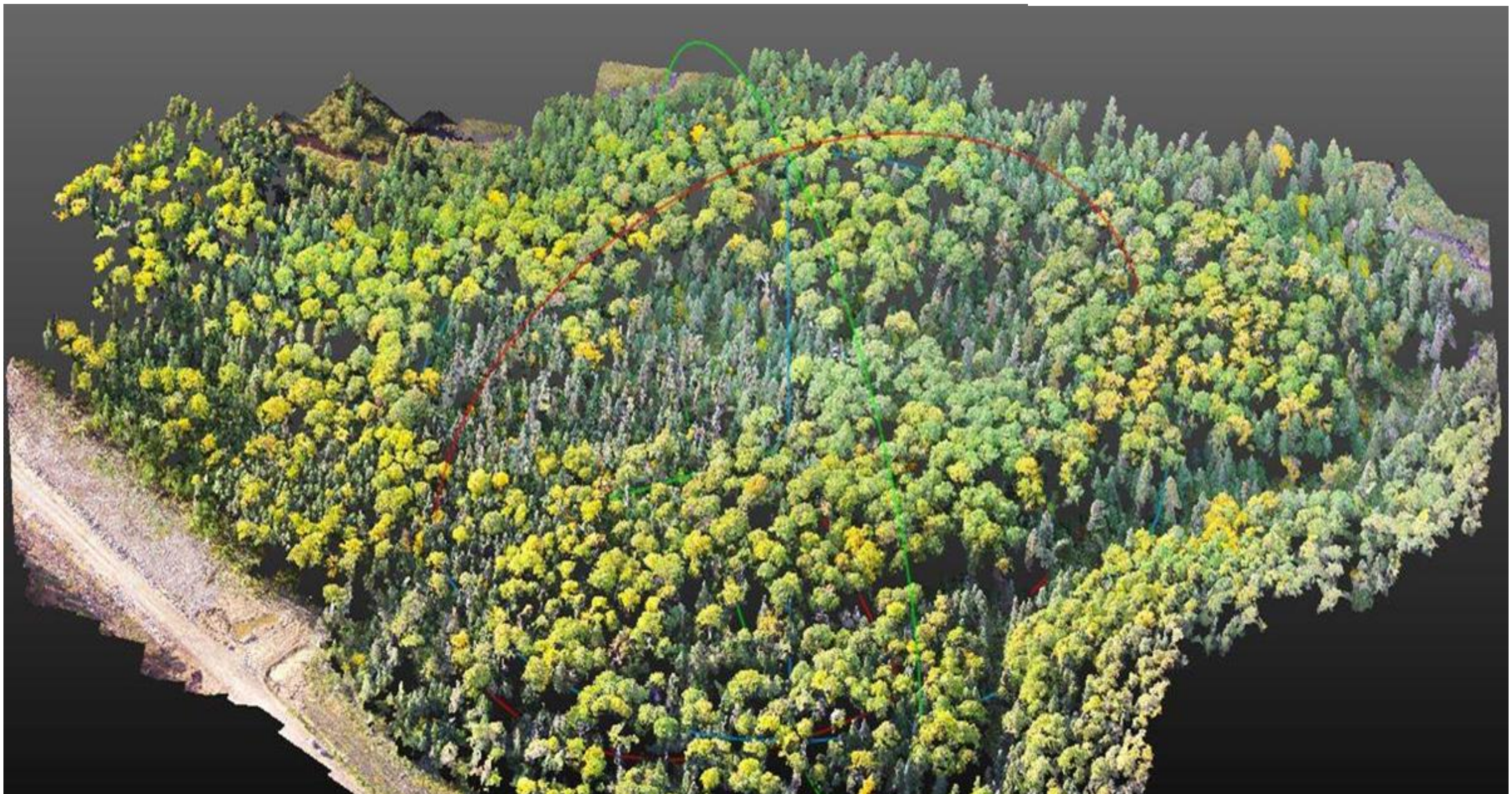

Forest Geomatics Gap Analysis for the Province of Alberta

Date: April 2016

By:

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1. BACKGROUND

The geomatics industry provides products and services related to the collection, integration, analysis, and management of geographic data. The data can be sourced from satellites, ground-based instruments, on-board data loggers and/or airborne sensors. Geomatics products can then be created to provide resource managers accurate, detailed information to make management decisions. The forest industry is already using many geomatics products and services, but some of their needs for information are still not filled. Considering also that the industry is dealing with millions of hectares of forested lands that need to be monitored periodically, data management and integration remain a huge issue.

Recent technology advancements like LiDAR for enhanced forest inventory, high-resolution satellite imagery, on-board computer capabilities of forest machinery, communication technology for remote areas, field data acquisition systems and unmanned aerial systems are offering a great potential for making better decisions and improving the competitiveness of the forest industry. However, gaps in technology and third party services are still slowing the full uptake of the recent science advancements.

In partnership and co-funding with TECTERRA, FPInnovations through an interview and survey process identified the geomatics tools and technologies currently being used in the forest industry and also the issues and needs facing the forestry industry within the province of Alberta. A workshop was organized with the cooperation of TECTERRA to bring together the forest industry and the geomatics industry to identify potential solutions.

Objective

The objective of this gap analysis is to identify issues and challenges facing the forest industry from a geomatics perspective and increase awareness of current and future technology for the forest industry and create awareness for solution providers.

Interviews

To ensure representation from the entire forestry sector, interviews were completed across the range of representatives, including:

- Face-to-face interviews with planning and operations foresters for all the major forest companies in Alberta to determine current use of geomatics technology and data, and to determine gaps and anticipated needs;
- Face-to-face interviews with government representatives, specifically within Alberta Agriculture and Forestry (AF); and
- Telephone interviews with technology and value-added service providers (e.g., geomatics companies) based in Alberta and others regions of Canada that provide services in the province of Alberta.

GeoForest 2016

GeoForest 2016 was held on March 1, 2016 at the Alberta Innovates Technology Future auditorium in Edmonton, Alberta. Over 100 participants from the forest industry, government agencies, technology developers and service providers attended. The geomatics technology gaps identified by the forest companies through the interviews were used to develop the program for the workshop that provided an opportunity for the geomatics industry in Alberta to engage with the forest industry in Alberta to discuss issues and challenges from a geomatics perspective. The presentations, discussions and the panel session were used to solicit and collect further challenges facing the forest companies and discuss potential solutions from the geomatics community.

A summary on the number of participants by industry sector, engaged during the interview stage and the workshop is provided in Table 1.

Table 1 Number of interview and workshop participants

	Interviews	GeoForest 2016
Government (Federal)	**1**	**9**
Government (Provincial)	2	19
Academia and Research	2	11
Forest Industry	14	15
Geomatics Service Industry	21	45
Data and Technology Industry	11	13

2. TECHNOLOGY OVERVIEW – TRENDS AND DEVELOPMENT

The technologies used in, and advancing the geomatics industry are wide ranging consisting of many specialised fields. Once considered niche and highly specialized, the evolution of geomatics has radically changed the way we create, manage, and use geo-spatial information from information technology and telecommunication to machine learning and data access. As such, a comprehensive review of all advances in technology is beyond the scope of this report. Rather, this document aims to highlight five broad categories to provide an overview of existing technologies, their application, their level of adoption across the forest and other sectors, and new developments and trends.

Remote Sensing Imagery

The practice of gathering information of the Earth's surface from above can be traced back to the mid-1800s, when pictures were taken from cameras attached to air balloons. The first full image of Earth from space was captured by the Apollo 17 mission in 1972. The same year the first civilian Earth observing satellite, Earth Resources Technology Satellite (i.e., Landsat-1) was launched. Since then astronomical advances in remote sensing technology have provided unprecedented views of the Earth surface, atmosphere, and oceans using the various portions of the electromagnetic spectrum. There are many remote sensing technologies able to collect data at various spatial and temporal scales that often involve technical and financial trade-offs such as spatial and temporal resolution, coverage, viewing geometry, collection and data processing costs. The following provides a description of four general categories that are being, or soon to be, used in the forest sector in Alberta.

Aerial Photography

Aerial photography collected from a fixed-wing aircraft is a well-established technology used extensively within government and private operations, including the forest sector in Alberta. True colour, colour infra-red, and/or hyperspectral data, along with photogrammetric techniques provide detailed information for various applications ranging from terrain analysis to vegetation and landscape studies. In Alberta, aerial photographs were used to support the creation of provincial Alberta Vegetation Inventory (AVI) and Forest Inventory data sets. Stereo ortho-photos also supported production of province-wide digital elevation data.

Current advances in digital cameras are leading to more compact digital imaging systems with higher resolution sensors as well as additional imaging capabilities. Hyperspectral imaging systems and thermal sensors are available for use in aircrafts providing additional advances in vegetation and mineral mapping. A relatively recent advancement or technique in aerial photography is Pictometry, an aerial image capture process to obtain images from multiple perspectives via low-altitude flight paths. Digital images consist of views from various perspectives including vertical and oblique angles allowing the side of ground objects to be collected and information obtained. These images represent up to 12 oblique perspectives and can be stitched or joined together to create a composite image that a can be used to estimate surface object size and position.

Requirements for specialized software and the cost of data collection has focused the use of this technology to non-forestry applications, such as urban planning, insurance, defense, construction, and utility assessments.

Unmanned Aerial Systems (UAS)

With advancements in robotics, engineering, global positioning and computer platforms, unmanned aerial systems (UAS), unmanned aerial vehicle (UAV), or “drones” are now used for civilian applications. Similar to aerial photography, imaging units range from true colour to hyperspectral sensors and laser scanning sensors allowing UAS to service a wide range of applications and sectors. However, its portability, easy logistics, flexibility in payload capacity, and relatively low-cost provides an advantage over traditional aerial photography when covering smaller areas. Due to its relative recent entry into commercial use, UAS are still in the development and evaluation phase for most forest applications and are not in operational use in the province of Alberta, however UAS technology are used in other sectors such as civil engineering, search and rescue, construction, real estate, and film industry. Several Albertan oil sands operators have begun testing with UAV technology for land surveying, pipeline monitoring, and land reclamation mapping.

Although the potential applications are numerous, regulatory requirements established by Transport Canada currently impede wide-spread adoption of UAS technology. The need for constant visual line of sight (VLOS) between the pilot and UAS is a key regulatory restriction limiting additional beyond visual line of sight (BVLOS) applications and use in the forest sector. Some technology development is still needed to address the "sense and avoid" capability to fully allow BVLOS operation but recent clarification by Transport Canada allows the use of visual observers to effectively extend the operational area. Visual observers maintain VLOS and direct the pilot as to when and where to maneuver the aircraft and provide the "sense and avoid" function.

UAS can provide timely, cost effective, and safely acquired data sets for analysis and information management. They have the capability to fill various roles in forestry at different price points. However regulatory limitations by Transport Canada, and the need for expertise in data acquisition, processing, and analysis, limit operational use to date, such as chip pile volumetric estimation and live monitoring applications.

Current trends and development in UAS technology link to advances in many other fields such as robotics, computer engineering, and software engineering. Trends include:

- Development of smaller and lighter instruments with additional imaging capabilities, e.g., Light Detection and Ranging (LiDAR), hyperspectral;
- New more stable hybrid platforms with higher payload carrying capacity and longer flying times such as the hybrid Vertical take-off and Landing (VTOL) and the fixed- winged Wingcopter[1];
- Onboard real-time data processing and cloud-based integrated workflows, e.g. Hexagon Geospatial GeoApp.UAS or Airware's platform;
- New computer vision algorithms to predict and avoid collisions, i.e., avoidance collision controls allowing for BVLOS; and
- UAV swarms to quickly cover more ground with a single pilot. Swarms can also be used as a distributed network to assist for communications in remote area.

Potential applications of UAV technology are promising and include:

- Area-based calculations: inventory, cut areas, or burned area information;
- Species Identification: area-based and single-tree based recognition;
- Tree height extraction: through scanning laser, photogrammetric (stereo) data collection, or Semi-Global Matching (SGM) techniques;
- Single stem identification and stocking densities: automated processing;
- Disease detection and identification: defoliator characteristics;
- Route, road, watercourse mapping: terrain analysis using GIS and remote sensing;
- Forest fire information and asset management: thermal image collection and GIS analysis;
- Hot spot detection: monitoring road side pile burning for situation awareness;

[1] http://www.wingcopter.com/

- Near real-time data processing: quick turn-around to assess post-harvest conditions;
- Accurate volumetric analysis: mill inventory such as log pile volumes; and
- Realistic 3D visualization and structural information for hazard detection and safety.

Air-borne Laser Scanning – LiDAR

The application and use of airborne laser scanning, or LiDAR, technology in measuring forests is rooted in over 50 years of science and engineering (Nelson 2013)[2]. Today's technology provides researchers and natural resource managers the ability to look at and measure individual trees and collect stand level and regional wall-to-wall forest mensuration data, as well as terrain features, at sub-metre detail for forest management, forest inventory, and wet area mapping (White et al. 2013)[3]. Accurate information obtained from LiDAR data, in the form of digital elevation models (DEM), digital surface models (DSM), and point cloud data, has prompted early adoption of this technology within the private sector and government organizations. Notably, the Government of Alberta has acquired widespread LiDAR data for 33 million hectares of the province, equating to most of the "Green Area".

LiDAR is an active remote sensing technology that determines the range or distance of an object based on the time-of-flight measurement principle. Coupled with highly accurate position information from kinematic global positioning systems (GPS) and an inertial measurement unit (IMU), emitted laser pulses returned by an object can be accurately located. LiDAR technology can be characterized as either full waveform or discrete return. Full waveform systems record the energy from each laser pulse as a continuous signal while discrete return systems convert the waveform data into individual separated return targets referenced in time and space.

Derived from LiDAR point clouds, various metrics are obtained and used in area-based measurements of forest attributes. Some of these attributes include: basal area, timber volume, stem density, above-ground biomass, average tree height, etc. LiDAR derived data are also used to aid in harvest block layout, resource road design and maintenance, enhanced forest inventories (EFIs), and sensitive habitat and ecosystem mapping.

As with other technologies, collecting LiDAR data for forest applications involves many trade-offs with regard to pulse density, flight altitude, swath overlap, scan angle, etc. Furthermore, since many of the LiDAR-derived forest inventory attributes and predictive models rely on plot-level data, design of the ground plot data is crucial. The sampled ground plots must represent the full range of variability in all variables, and the sample size and sample design must be carefully planned (White et al. 2013).

Current development and advances in LiDAR technology involve more powerful sensors allowing for higher number of returns. Longer range full waveform sensors are providing more information over larger areas. Development of mobile laser scanning and terrestrial laser scanning is also advancing the application of highly detailed 3D data.

[2] Nelson, R. 2013. How did we get here? An early history of forestry lidar1. *Canadian Journal of Remote Sensing*, *39*(sup1), S6-S17.

[3] White, J.C.; Wulder, M.A.; Varhola, A.; Vastaranta, M.; Coops, N.C.; Cook, B.D.; Pitt, D.; Woods, M. 2013. A best practices guide for generating forest inventory attributes from airborne laser scanning data using an area-based approach. The Forestry Chronicle. 89(6):722-3.

Due to different behaviours in reflectance and attenuation for various features (e.g., vegetation, soil, water, etc.), there is current development in multi-wavelength LiDAR data for spectral separation of tree species and application in land cover classification. The fusion of LiDAR and hyperspectral data for species classification is also being investigated.

Space-borne Satellite Data

Designed to provide synoptic views of Earth's features and its natural resources, images collected by Earth observation (EO) satellites are now common-place through direct access to true colour images of the world using Google Earth. With over sixty satellites currently in orbit dedicated to Earth observation, numerous sensors are available to provide forest measurements including multi-spectral, hyperspectral, Radar, and LiDAR sensors. Advances in technology allow for increased spatial resolution down to 30 cm, revisit frequency up to daily, and increases in spectral resolution to identify finer detail.

The use of EO data within forestry has a long history within Canada with pioneering research in monitoring forest cover and health, species composition, tracking disturbances, and many other factors. EO data is currently used to provide better information of forests over larger areas enabling better-informed decision making, primarily at the regional scale for strategic or tactical purposes. Due to cost and level of detail obtained, use of satellite EO data operationally to provide information throughout the forest supply chain is not widespread.

In addition to the suite of medium to high-resolution satellite sensors (e.g. Landsat, SPOT, RapidEye) several new platforms are available now, or soon to be, with improved potential to provide operational information. The new spectral capabilities of the WorldView-3 satellite (total of 28 spectral bands) has the potential for species recognition. Constellation of micro-satellites or nano-satellites, like the ones planned for TerraBella[4] (formerly Skybox Imaging) and Planet Labs[5], will have the ability to acquire data at high resolution every one to three days, opening new potential for operational monitoring of forests.

Over the next decade, more than 50 new satellites[6] are planned to study various earth system processes and forest applications. These new satellite platforms will carry on-board hyperspectral, radar, and laser sensors with increase spectral and spatial resolution. For example the European Space Agency is considering launching a P-band Synthetic Aperture Radar (SAR) able to obtain forest biomass at regional scales. Commercial satellites such as WorldView-4 are also planned able to collect data with a spatial resolution better than 0.25 m.

Software and Computer Systems

Over the last 30 years, computer systems have revolutionized our world and affected every aspect of our day-to-day lives. The continued reduction in costs of computer technology has facilitated this exponential growth. In addition, advances in micro-processors and graphical processing capability, and the pervasiveness of computing, software applications that allow us to interact with computers are also changing.

[4] https://terrabella.google.com/
[5] https://www.planet.com/
[6] https://www.wmo-sat.info/oscar/satellites

Cloud Computing

In 2002, Amazon launched the first cloud computing web service allowing clients to access memory, software, and processing ability through the internet. This was further developed in 2006, when Amazon released the Elastic Compute Cloud (EC2) allowing clients to pay for space on Amazon's computers' infrastructure to store and run their own software applications. Since then an explosion of mainstream technology providers (e.g., Google, Microsoft, Oracle, etc.) are now offering cloud computing in one form or another. The idea of accessing software as a service (SaaS) or infrastructure as a service (IaaS) will increasingly be a more popular alternative to purchasing proprietary software or maintaining costly IT infrastructure.

Cloud based solutions offer forest companies the potential to reduce costs in maintaining a spatial data infrastructure and select pre-built software or platform services that fit their needs. However, the current lack of cloud computing standards, interoperability issues, and privacy and security issues in public clouds has limited the adoption of this technology.

Development of cloud–based workflows will also provide forest companies with immediate, and eventually, real-time access to information for better informed decision making. Combined with other technologies such as UAV or mobile laser scanning data collection, tree attribute data can be collected and processed in real-time and delivered to a feller-buncher operator, via augmented reality to make harvesting operations more efficient.

Open Source Software

Another revolution occurring in the technology sector that has potential to benefit the forest industry is the increased interest in open source software. Access to freely available software and applications is gaining popularity, particularly within organizations that want to reduce costs or are facing budget constraints. Organizations like the Open Source Geospatial Foundation (OSGeo) whose mission is to foster global adoption of open geospatial technology, is helping remove the perceived barriers of open source software and increasing their use by providing a platform to improve usability of the open source software. Regardless of proprietary or open source, software application must be compatible with multiple platforms, interoperable, easy to use and simple.

Information Access and Wireless Communication

Given the nature of the forest industry, information access and communication in remote field locations is important. Improvements in mobile and cellular network capacity (e.g., 3G or 4G), along with improved positioning, are key in capitalizing on geomatics technology within the forestry sector. Compared to other national digital programs, such as those in the United States and Britain, Canada's commitment to building digital high-speed broadband networks lags far behind, especially for 'under-served regions'. This limits the full potential of a distributed spatial data infrastructure and constrains the ability to access large volumes of information in real-time (NRCan 2016)[7].

[7] Canadian Geospatial Data Infrastructure, Information Product 47e, 2016; 287 pages, doi:10.4095/297709. Accessed online at:
http://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=297709

The full potential of mobile application and tools (e.g., data collection) is currently not being serviced due to this lack of broadband access in remote areas. Typically data using mobile device and applications are collected offline and uploaded back to a central data repository once the user returns to the office or returns to wireless connectivity. Real-time data access and information sharing would allow the forest sector to operate more effectively by making better informed decisions.

The idea of sensor-webs which are essentially a network of sensors or data loggers connected by standard interfaces and communication protocols would greatly benefit from wide-spread availability of wireless connectivity.

Navigation and Positioning

Accurate positioning and navigation systems are necessary for many applications including many of the technologies summarized in this section. The global navigation satellite system (GNSS) provides the necessary technology for accurate positioning, navigation and guidance systems, automation, tracking, location-based services and much more. Within forest operations GNSS technology aids in positioning of equipment, determining position of field plots and control points for remote sensing studies. Ubiquitous and common within all industries, navigation and positioning technology is well adopted within the forest sector to some degree.

The most used and common GNSS is the United States' Global Positioning System (GPS), with a constellation of 29 satellites. A second system in operation is the Russian Federation's Global Orbiting Navigation Satellite System (GLONASS) with a constellation of 24 satellites. Two more GNSSs are in development and will be operational by the end of the decade; the European Galileo GNSS and the Chinese BeiDou Navigation Satellite System. With these two GNSSs coming online by the end of the decade, positioning accuracy and precision will be unprecedented. Multi-GNSS brings significant improvement to satellite visibility allowing greater applicability in more environments as well as improved geometrical dilution of precision (GDOP) (Li et al. 2015)[8].

Currently, positioning and navigation technology is limited under forest canopy, particularly under dense canopy, and require ground-based transmitters to enable coverage of a larger area. This increases time and cost for certain applications. For these signal-challenged environments such as forested areas or indoor applications, research is focussing on changing the transmitted signal power or selecting a different frequency that is better suited for reduced line-of-sight locations.

3. STATE OF TECHNOLOGY IN ALBERTA'S FOREST INDUSTRY

Forest companies have been using a wide variety of geomatics tools and techniques in the collection, integration and analysis of geographic data to manage the resources on the landbase. Land managers are managing a large landbase and need geospatial tools to support the decision making process and meet forest certification requirements. Remote sensing plays an important role in both strategic and operational planning. Some companies are completing up to 85% of the block development process in the office before going to the field.

[8] Li, X.; Zhang, X.; Ren, X.; Fritsche, M.; Wickert, J.; Schuh, H. 2015. Precise positioning with current multi-constellation global navigation satellite systems: GPS, GLONASS, Galileo and BeiDou. Scientific reports. 9(5).

Imagery

Many remote sensing technologies are being used by the forest sector to collect data. Imagery is being collected by fixed-wing aircraft, space-borne satellites and UAVs. Aerial photography from fixed wings is the most established method, but more recently companies are using satellite imagery although cost and resolution is still a limiting factor. The airborne LiDAR data recently acquired by the provincial government has been employed by all the companies for many planning purposes, but to varying degrees. Many useful products can be created from the data (contours, hill shade, bare earth and slopes) that has assisted in mapping and planning activities on the landbase. A valuable planning tool, the wet area mapping layer, was created from the LiDAR data and has been widely adopted for operational planning including wetland mapping for site plans and culvert placement, block layout, road layout, silviculture planning and scheduling harvest blocks by season (winter or summer). Ground-based or terrestrial LiDAR is being also used to collect growth and yield data during reassessment of permanent sample plots. UAVs are starting to be used more in the forest industry. Interest level is high and many operational applications are being considered, but companies are waiting until some of the uncertainties are worked out before getting too involved.

Software and computing systems

Field personnel are using a variety of mobile applications for geo-located data collection and field operations (phones, tablets, on-board computers, and data loggers). Some of these are commercially available and “field-ready” while others are being modified, either in-house or by consultants. In cases when a suitable program does not exist, custom software is being developed. Larger forest companies tend to have in-house expertise that can modify or design custom software for their needs, while smaller companies are relying on consultants to provide this service. Field crews prefer devices that are easy to use and have a short learning curve (i.e. they are ready to use right out of the box).

With increased availability of GPS functionality in mobile devices now, field crews are able to use them for data collection with spatial information attached or photos with geo-tags that can be annotated. This increases the value of the data collected. Aerial surveys are being conducted from helicopters by crew with a tablet, allowing them to annotate the files as they go and not having to transfer the information from the paper map into their corporate GIS back at the office.

The most common use for mobile devices (phones, tablets, on-board computers, and data loggers) in the field is for mapping and navigation by crews and contractors. Contractors and machine operators are using mobile devices for navigation during operations and producing treated area maps and productivity summaries (e.g. feller-bunchers, herbicide application and mechanical site preparation). On-board computers in harvesting equipment or logging trucks are tracking productivity, or haul cycle times with the ability of producing a summary quickly. Some companies are relying on feller-bunchers to use a map on a tablet for navigation in the cutblock for ribbon-less layout. This significantly reduces the planning costs of laying out a block.

Maps on a hand-held device can be used for locating wetland or stream crossings, culvert placement and for in-field inspections. The location can be confirmed in the field, photos can be added and data can be uploaded or synchronized with the office records when the crew return to the office or when they are within cell range.

Several safety systems that use a hand-held device (InReach or Spot) are in use in forest operations for safety checks. This allows crew to safely work in remote locations.

Analytics

The data analysis and interpretation is a major component of the remote sensing program. Companies are using different approaches to managing the GIS systems across the companies surveyed. Some systems are managed by individuals or small groups and other companies had large, organized and coordinated teams working across divisions. Others relied on consultants or service providers to provide all GIS services. The remaining companies had a blended system with some activities being completed in-house and others done by consultants.

Data was handled differently at several companies. Depending on the level of integration between field data collection procedures and data management needs, some companies have to manually delineate block boundaries for planning and submission purposes. In some cases, there are 3 steps to convert files to a format specified by the Alberta Government for submission into their systems. In other circumstances, it leads to re-keying information collected in the field.

Information Access

Access to wireless communication is not consistent across the province of Alberta, built up areas tend to have better coverage than some of the more remote areas. In some areas, the oil and gas industry has cell towers that the forest companies can use. Satellites and satellite phones can be used to transfer data, but at a higher cost. Most companies are waiting until their crews are back in camp, in cell range, or back in the office to update office files.

Data submissions (ARIS) to the government are still tabular, not spatial, but this is scheduled to change in May 2016. This will increase the efficiencies and value of the data.

During consultations with public or First Nations, companies have traditionally used paper maps. Some companies are now providing digital maps and using web based systems to share data depending on the sophistication of the public or band requesting the information. Some service providers are using a web based system that can be updated as new information is made available.

Level of Adoption

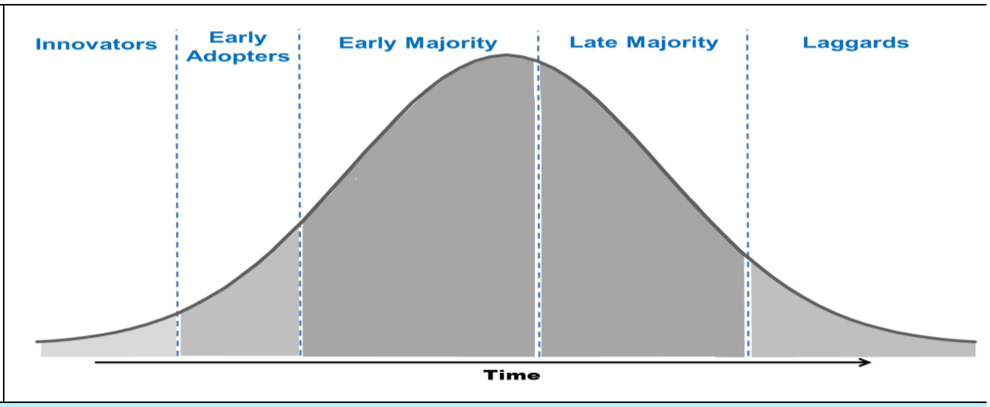
The adoption or acceptance of new technology or innovation can be described by the technology adoption life cycle model (Rogers 2003)[9]. The life cycle describes the traits and customer segments and their typical approach to disruptive ideas and technologies. Pioneers in the use of new technology or innovations are known as "Innovators" and are the group that is most willing to accept risk and have the capability to absorb or mitigate financial failures associated to new technologies. The next group are the "Early Adopters" or "Visionaries" and are not only the early users of the technology but also the key group to provide constructive feedback to innovators and technology developers to help refine the product or innovation. The largest group described by the model are the "Early Majority" and represent group that are pragmatists. This group adopts or accepts a new technology after a varying degree of time to allow the technology to mature and be proven. A more skeptical group are the "Late Majority" or

[9] Rogers, E. 2003. Diffusion of Innovations, 5th Edition. Simon and Schuster. ISBN 978-0-7432-5823-4

"Conservatives" and adopt new technology only after the majority of people have already adopted the innovation. The last group are the "Laggards" or "Skeptics" that have typically an aversion of change.

Figure 1 illustrates the adoption life cycle of key technology sectors within geomatics and their acceptance in the forest industry based on findings from interviews and workshop.

Technology Adoption Life Cycle



Technologies					
Aerial Photography		X			
Space-borne Satellite Imagery			X		
Air-borne LiDAR		X			
Terrestrial LiDAR		X			
UAV		X			
Wireless Devices				X	
Spatial (geo-located) Data Collection			X		
Machine Navigation			X		
Mobile Computing				X	
GIS	X				
Web-based systems				X	

Figure 1 Adoption life cycle of geomatics technology within the forest industry.

4. GAP ANALYSIS

Needs of Forest Industry

The forest industry needs geospatial tools and techniques that can increase efficiency, in the daily work flows of the staff for managing the resource on the landbase. With more demands on the landbase by other resource users, managers are having to manage for many more goods and services than previously while maintaining an economic viable forest industry. With a shrinking workforce this task is left to fewer and fewer people. A reasonable solution is to replace people with technology where feasible and provide tools and technology to streamline procedures and increase efficiencies. Processes need to be re-aligned to make the job easier and speed up the procedures. The biggest gain in efficiency will be with automation, so any procedure that can be automated will save time and reduce human error, while freeing up resources to address other issues.

Adding any new technology or tool into the work flow increases the need for all processes to integrate seamlessly with existing technology and be compatible. Moving information or data between the office and the field and between devices creates an opportunity for incompatibilities that need to be reduced or eliminated.

Imagery

Everyone we contacted wanted more powerful imagery, but at a reasonable cost as resources are limited and budgets are tight. Companies want high resolution aerial and satellite images, LiDAR, infra-red, and multi-spectral data. Better information will lead to better decision making. Companies want to reduce the restrictions on accessing data and want to be able to collect imagery on demand, especially through smoke and clouds.

Software and computing systems

One message that was repeated by everyone was the need to be more efficient. There are more demands on time and resources. With the shortage of workers, that is predicted to increase over time, companies are replacing people with technology. People have to do the same amount of work (or even more) with less support staff. They need to re-align processes to make the job easier and speed up the procedures. Workflows need to be effortless and to work seamlessly in the background. The biggest gain in efficiency will be with automation. Any procedure that can be automated will save time and reduce human error. Staff are looking for automation in the data uploading and downloading processes

Analytics

With all the new imagery becoming available, more data and images are being collected. This leads to larger data sets that require more handling and storage space. Computers need to be more powerful to manipulate and manage the data, while companies need the capacity (people and computers) to deal with large data sets. Managers need to decide what data they actually need versus what is available. Many of the service providers are able to address these needs for the companies.

A new area of interest with the companies was change detection. Managers want to know when the landbase has changed from a disturbance (e.g. wildfire or insects). The sooner they are notified, the sooner they can react and schedule salvage operations if necessary.

Information Access

Field crews need timely access to the same information while they are away from the office as when they are in the office. They want access to the GIS layers in the field with the ability to upload and download information in real-time. This will lead to better decision making, more timely data management and more current information. This could be coordinated in-house or by a service provider using a web based portal or cloud based solutions.

Managers want real time tracking for equipment and personnel. This would provide access to productivity numbers continuously and provide a safety system for staff. Tracking personnel can be used for daily safety checks or real time for high risk situations (e.g. wildfires).

There needs to be consistency across the company and across jurisdictions for data standards and submission requirements. Many companies have divisions in different provinces that have different needs. This leads to having two different data systems or having to re-work data to meet the regulatory agency's requirements. Even within government, different departments have different requirements (frequency of updates and details required). Information from other sectors and other resource users is not always accurate (i.e. infrastructure planned by the oil and gas sector may not be built on the landscape but will be on the maps). This leads to more time spent confirming accuracy of the information in the data base with what is on the land.

Tools and mobile applications

Field crews want access to more applications for their mobile devices (tablets and phones). They want to be able to use them for multiple activities (data collection, inspections, and navigation) without requiring more than one device. Field crews are being asked to do more tasks but are not experts in every field, may be more of a generalist, so they need applications that will assist them to do some of the tasks. Not all field crews are GIS experts, so need simple, user-friendly mapping tools with user-friendly interfaces that will integrate seamlessly with their GIS systems in office. Field crews want programs to run in the background without their input. Data collection will be easier, quicker, and more accurate. Field crews will be more efficient.

Moving data and images between devices and between office and field and back to the office requires all systems to be compatible regardless if they are physically connected in the office, or linked in remotely. Within the office, data has to be in a format that is compatible with office systems and still meet the submission requirements of the agency.

Although most of the companies are not using UAVs yet, they are aware of them and very interested in their potential. There are many applications where UAVs could provide better, more timely images than those collected by the more traditional fixed-wing or helicopter, but they have not all been tested yet in the forestry. This is a huge opportunity and will be a game changer for the forest industry.

Currently, there are limitations with the battery life in a UAV, and operators would like a battery with longer life. This also applies to tablets, with the demand for smaller and lighter batteries. Want to reduce current problems with cold weather, and flight length which affects productivity. Operators also want smaller, but more powerful sensors for UAVs (better resolutions), and LiDAR for UAVs at low cost. Also want Transport Canada to reduce the restrictions on flying within line of sight, flight heights, training requirement, and ease of use.

Gaps and Opportunities

The following “Gap Cards” are perceived challenges and information requirements currently not addressed by the geomatics industry. These “gaps” represent the greatest opportunities where the geomatics and technology industry can fulfill.

Mobile apps for tablets and phones	
Description	Field crews want access to simple, multiple applications (Apps) for their mobile devices (tablets and phones) for navigation, data collection and inspections.
Background	Field crews are using tablets more and more for data collection. Want to be able to do multiple activities while in the field. Field crews are generalists and need apps to help them take on more specialized tasks without having to be an expert in the subject.
Expected results	Data collection will be easier, quicker, and more accurate.
Potential users	Forest industry and government, other resource sectors
Value of technology	Incremental to disruptive

Monitoring and change detection	
Description	Automatic detection of change in the natural resource on the landscape.
Background	Managers need to react to change on the landbase. With automatic monitoring the resource and the ability to detect a disturbance (e.g. wildfire or insects) sooner, will allow them to react quickly and schedule salvage operations if necessary.
Expected results	Ability to detect changes on the landbase automatically and provide notification to the managers. Quicker response time, better decisions, and capacity to realize maximum value from resource.
Potential users	Forest industry, government and other resource sectors
Value of technology	Incremental

eConnected Forests	
Description	Access to GIS information in real time.
Background	Field crews need timely access to the same information while they are away from the office as when they are in the office. They want access to the GIS layers in the field with the ability to upload and download information in real-time.

Expected results	This will lead to better decision making, more timely data management and more current information
Potential users	Forest industry and other resource sectors
Value of technology	Incremental

Real-time Tracking (vehicle and personnel)	
Description	Live tracking of equipment and personnel
Background	Managers want real-time tracking for equipment and personnel. This would provide a safety system for staff working remote or dangerous situations (wildfires). Tracking equipment can provide productivity data on operations, and assist in locating equipment in case of theft.
Expected results	Increased safety of personnel, ability to determine operational productivity and increased security of equipment (theft prevention).
Potential users	Forest industry, government
Value of technology	Incremental

Geo-spatial Data Standards for Forestry	
Description	Standards are required for geo-spatial data
Background	There needs to be consistency across the company and across jurisdictions for data standards and submission requirements. Companies may have divisions in different provinces each with different standards. It may lead to two different data systems or having to re-work data to meet the regulatory agency's requirements. Different departments within governments often have different requirements (frequency of updates and details required). Information from other sectors and other resource users is not always accurate (i.e. infrastructure planned by the oil and gas sector may not be built on the landscape but will be on the maps). This leads to more time spent confirming accuracy of the information in the data base with what is on the land.
Expected results	Higher accuracy in data records and submissions, more efficiency in data management
Potential users	Forest industry, government, service providers
Value of technology	Incremental

Applications of Unmanned Aerial Vehicles (UAVs)	
Description	Use of UAVs for forestry applications
Background	There are many applications where UAVs could provide better, more timely images than those collected by the more traditional fixed-wing or helicopter, but they have not all been tested yet in the forestry. Currently, there are limitations with the battery life in a UAV, and operators would like smaller, lighter batteries with longer life. Want to reduce current problems with cold weather, and flight length which affects productivity. Operators also want smaller, but more powerful sensors for UAVs (better resolutions), and LiDAR for UAVs at low cost.
Expected results	More applications for UAVs at less cost. UAVs with smaller and lighter batteries and more powerful sensors.
Potential users	Forest industry, government, service providers and other resource sectors
Value of technology	Disruptive

Data Integration (e.g., Sensor Web Enablement)	
Description	Enable integration of data from many disparate sources, many file formats, and across locations within a company or site
Background	Field staff are collecting data from a variety of sources and for multiple reasons using various equipment. Managers need to integrate data, manipulate, store and export it. Data needs to meet requirements of many systems (e.g., fibre supply, accounting) within the company. Also, data collected from a network of sensors or devices require a common platform for integration.
Expected results	Greater interoperability and flexibility in data sharing and co-operation between people and departments. Greater amount of information at higher frequency to better support decision making.
Potential users	Forest industry, government, and other resource sectors
Value of technology	Disruptive

Other opportunities

Although there are many technologies and tools from the geomatics industry available to assist natural resource managers in managing the landbase, there are still opportunities for more development in many areas. With the shortage of workers expected in the forest industry and other resource sectors over the next few decades the opportunity to fill the need and relieve the pressure on limited resources with technology is huge. Technology can be used to simplify workflows to increase efficiencies and improve accuracy and decision making.

Forest companies need standardized procedures that meet audit requirements for certification and for chain of custody and traceability of forest products along the value chain. New technology including UAVs, are being tested during health and safety audits to simplify data collection in a safe manner. Standards are needed for data submissions to ensure they meet provincial standards.

Automation of processes is a critical area that needs to be addressed wherever possible to improve efficiencies throughout the sector. Recent science advancements in the field of robotics are new to forestry, but also have the potential to make big changes in the industry. Other innovations or technology being explored that could have major impacts on the forest industry is augmented reality and machine vision. Real-time visualization can be used for planning and decision making.

The new Federal government is favouring clean technology and greenhouse gas (GHG) and climate change monitoring. This is a large opportunity for the forest industry to take the lead using new and existing technology.

Recent technology advancements like LiDAR for enhanced forest inventory, high-resolution satellite imagery, on-board computer capabilities of forest machinery, communication technology for remote areas, field data acquisition systems and unmanned aerial systems are offering a great potential for making better decisions and improving the competitiveness of the forest industry. From operational planning for product sorts to high-level decisions, there are many opportunities for geomatics tools and technology.

5. CONCLUSIONS

Overall, the forest industry has embraced geomatics tools and technology, but there are many areas for improvement and a need to better integrate geomatics/geospatial tools and technology into operational activities. Each company had different needs and even between divisions within the same company there was discrepancy on what was needed. But, overall there were many comments that came up repeatedly.

- Automation:, Ability to process and analyse information will little or no human input to support decision making, e.g., change detection notification
- Efficiency: Data standards are needed for data uploads and downloads (e.g., submissions to regulatory agencies), inventory updates.
- Portability: Staff are looking for ways to be more efficient in their jobs. Companies are replacing the shrinking workforce with technology as there is a shortage of workers that will increase with an aging workforce. Companies are looking for more efficient processes that will either reduce the number of steps involved or automate the procedures. Field crews want to have access to the same information in the field on their mobile devices as they do in the office, and they want to be able to do updates in real time. Field crews want to be able to do more tasks on their mobile devices without being experts in all fields.
- Compatibility: Any new systems introduced, must be compatible with existing company systems to avoid causing more problems and nullifying any of the gains.

- Accuracy: Companies want a higher level of data accuracy for inventory purposes, and management of the landbase. This will provide better information for decision making.

Some of the gaps identified by the companies can be addressed quickly with technology already available, while other will need more development. The technologies with the greatest potential to have an immediate impact are mobile apps, satellite imagery, and geospatial awareness. The technologies for mobile devices (phone or tablets) are currently mature enough that mobile applications can now be built for immediate use in data collection. For example ESRI's Collector App allows users the ability to customize the complexity of the application and provide a simple mobile data collection platform that is easy to use. The new series of space-borne satellites have the ability to provide very high resolution information at unprecedented frequency allowing for change detection and monitoring. Forests now are connected and can be represented to some degree digitally. Providing geospatial information is something that should be and immediately exploited.

Real-time tracking, application of UAVs, and data integration are longer term developments that require further technological or regulatory advancements in order to provide the greatest impact. Wireless connectivity and infrastructure need to improve to facilitate affordable real-time tracking of vehicles and personnel. UAV regulations addressing BVLOS need to be resolved before wide-spread adoption of UAV technology. Government consensus on geo-spatial data standards for forestry would also be required to facilitate potential automation of regulatory submissions and increase operational efficiencies.

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