Planning with LiDAR: How the New Brunswick Department of Natural Resources is Changing Forest Management

Each year in Canada, millions of trees are harvested for wood products, paper and pulp. In 2013 alone, 738,836 hectares of Canadian forests were harvested. Before harvesting, the forests were photographed from a plane, mapped and inventoried for forest planning. The technology used to capture these pictures—stereo imagery—dates back to WWI, when it was first used for reconnaissance missions.

But the New Brunswick Department of Natural Resources (NBDNR) has changed that. Using state-of-the-art remote sensing technology in tandem with ArcGIS, they've developed a 21st-century forest inventory system that's revolutionized conventional forest inventory methods.

The Earliest Adopter

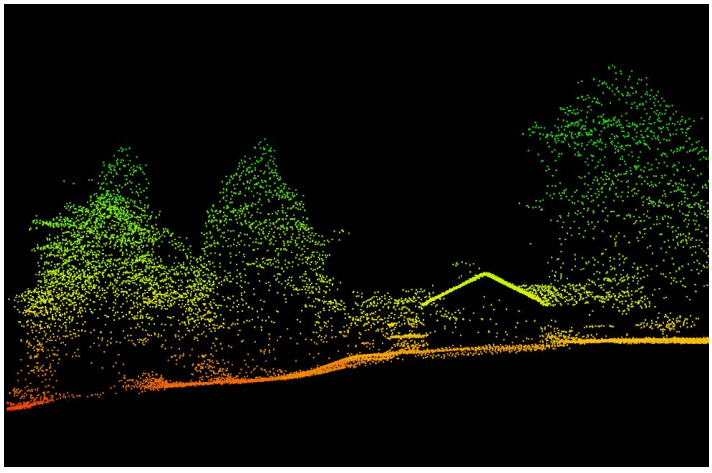
In 1982, NBDNR became Esri's first commercial user of ARC/INFO—the first iteration of ArcGIS. Running ARC/INFO on microcomputers, NBDNR used Esri's first generation GIS as a means to convert forest inventory and other land cover data from paper maps and non-spatial database files to spatial databases. But NBDNR adopted a GIS not merely as a way to digitize maps. They used it as an information system, running queries to extract information and solve complex forest management problems.

"Back then, we used a GIS to look for strategic level answers as part of our long-term planning process," said Adam Dick, Manager of Inventory Development, New Brunswick Department of Natural Resources. "We did that because we knew that there was going to be a low point in our wood supply in the future, and we've essentially reached that point now. So we need modern technology that helps us in the short-term, too. Something that can help us with every, single decision we make in the forest so we can harvest sustainably."

Forest management strategies developed by agencies such as NBDNR are crucial for the forestry industry. Over 75% of Canada's forests are managed by the provinces, and agencies such as NBDNR are responsible for identifying how many trees exist on provincial Crown land, allocating harvest volumes to private industry and balancing other values, such as wildlife habitat.

"The economics of forestry have changed dramatically over the last 30 years," said Mr. Dick. "Sawmills are run much differently today. You've got much narrower profit margins and every time you deviate from a plan it's costly. Plus, there's increased global competition and a deeper commitment to sustainably. You really have to get it right, and that starts with better planning."

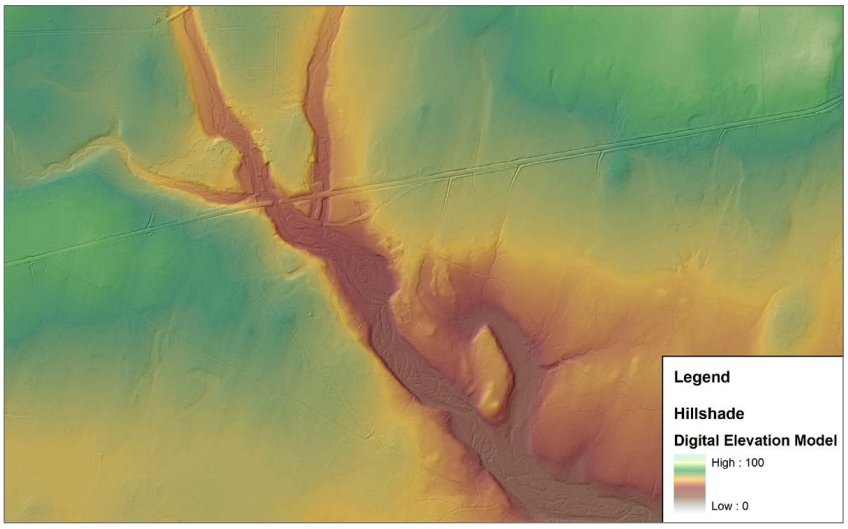
To create a system that supports operational-level decision making, NBDNR decided that transitioning away from stereo photos was a crucial first step. Although it's a tried-and-tested airborne imagery collection technique, it has limitations.



Cross-section view of LiDAR point cloud showing tree, topography and terrain details.

Beginning with the initial flight, the process of gathering, manually converting and processing stereo imagery into a final deliverable for analysis and decision making—which also requires field work to gather plot samples—can take up to 2 1/2 years. Also, stereo imagery visualizes forests at the tree stand level (a collection of trees in an area) and it can't deliver details at the tree level. This means forestry planners need to make assumptions and calculated guesses to account for variations.

"There was a lot of rework in the old process," said Mr. Dick. "You thought you had your calculations and plan right based on the imagery and data, but when you got on the ground you realized you had to rethink it."



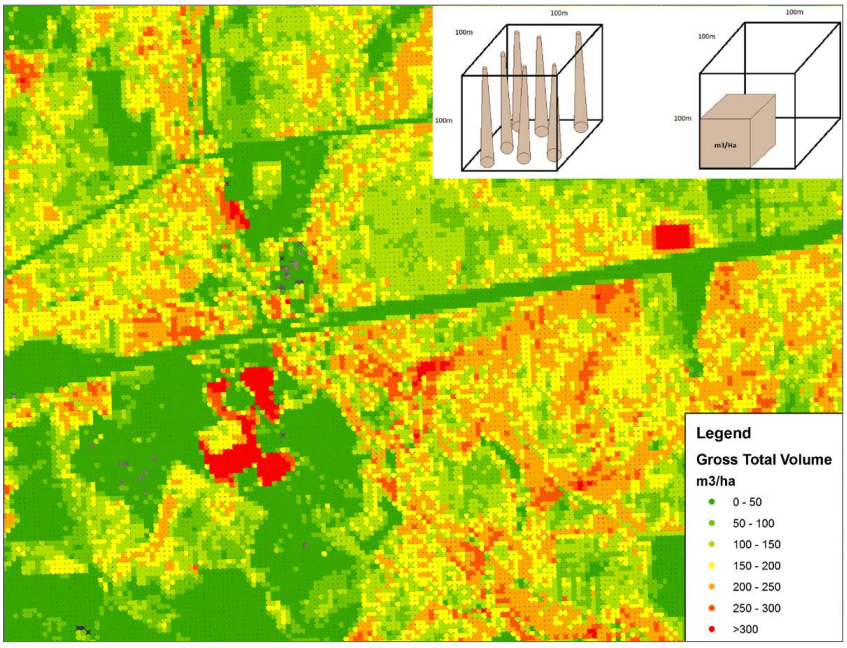
A hillshade Digital Elevation Model of a forest in New Brunswick. Dark areas represent low elevations, helping planners account for ground conditions during tree harvest operations.

Cultivating New Ideas

In 2010, NBDNR began exploring options to transition away from traditional stereo imagery towards more advanced technology. Inspired by a paper written in *The Forestry Chronicle* entitled "Operational implementation of a LiDAR inventory in Boreal Ontario"[1], NBDNR embarked on a pilot project with Leading Edge Geomatics—a Fredericton-based aerial survey and geomatics services company. NBDNR sought to replicate the paper's concepts to gauge whether they could be used for a large-scale forest inventory and transferrable to the complexity of the Acadian Forest in New Brunswick.

While LiDAR (Light Detection and Ranging) has been harnessed across many industries for different applications, it's largely flown under the radar in the Canadian forestry industry. LiDAR is an airborne remote-sensing technology that measures scattered light to find range and other information on a distant target. The technology allows you to measure three dimensional objects and terrain, extracting data that's extremely dense. One of the main advantages LiDAR offers over other optical instruments, such as digital cameras, is its ability to measure height and the distribution of structure within the canopy—a valuable metric when understanding the size and scope of a forest.

"Typically LiDAR is used to get to the ground to create a bare earth elevation model," said Bill Kidman, President, Leading Edge Geomatics. "As a by-product of that, the laser also samples the forest structure as well as the ground when it's collecting data, so we're capitalizing on that."



LiDAR's ability to detect three-dimensional objects helps planners accurately calculate timber volumes and areas of density. In the heat map above, orange and red areas indicate timber volumes greater than 200 cubic metres per hectare.

NBDNR and Leading Edge outlined the pilot project plans, then deployed multiple aircraft equipped with latest generation LiDAR scanners and cameras, and flew over a research forest near Fredericton to collect data. Next, NBDNR staff completed a field inventory to determine calibration points and performed modelling steps, resulting in a treasure trove of forest metrics, such as tree height, density and volume. Leading Edge also processed and delivered additional LiDAR derivatives to NBDNR, such as a high-resolution digital elevation model. The final step of the six-month pilot project was integrating the data into **ArcGIS** to complement, or in some cases supplant, existing datasets.

NBDNR was thrilled with the results.

"The new system allowed us to see things at an operational scale," said Mr. Dick. "Rather than describing the GIS and the forest in stands that range from 5 hectares to 70 hectares in size, the new unit we could converse in is a 400 square metre pixel. This new approach provided all the information we needed to make our operational decisions."

With LiDAR, NBDNR could visualize the streams, slopes and rocky areas that stereo imagery and field sampling (typically only 4% of an inventoried area) could not reveal. Instead of randomly encountering variations in the field, it meant foresters could pinpoint their precise locations early in the planning phase.

The success of the pilot encouraged NBDNR to put the new system into production. In 2013, Leading Edge and NBDNR joined forces again to create a LiDAR-derived forest inventory of New Brunswick's provincial Crown forests, industrial freehold and a collection of small private woodlots. According to Mr. Dick, this positions New Brunswick as the first province in Canada to adopt LiDAR to produce a forest inventory.

[1]Murray Woods, Doug Pitt, Margaret Penner, Kevin Lim, Dave Nesbitt, Dave Etheridge and Paul Treitz, "Operational implementation of a LiDAR inventory in Boreal Ontario", The Forestry Chronicle (Aug. 2011, Vol. 87), **http://pubs.cif-ifc.org/doi/abs/10.5558/tfc2011-050?src=recsys&**

Perhaps more impressive were the results. In addition to dramatic improvements in accuracy, NBDNR completed the forest inventory in just six months—a 75% time savings compared to the previous inventory. And these gains came at a budget-friendly price: the cost of the LiDAR-derived forest inventory equalled the previous inventory that employed traditional technology—dispelling the myth that LiDAR is too expensive for practical application.

Adopting a LiDAR-derived forest inventory system achieved a 75% time savings for NBDNR.

Also, the data precision virtually transports NBDNR staff right into the forest.

"Previously, we would have characterized two forest blocks that totalled 1.5 million hectares as 250,000 stands, as an example," said Mr. Dick. "Now, we characterize them as 20 square metre x 20 square metre cells which involves roughly 40 million points. So rather than making decisions on 250,000 stands, we're making decisions on 40 million points. It's as close as you get to a tree-level understanding of the forest."

To enable this enhanced decision making, NBDNR uses ArcGIS as the consistent framework to provide information to internal staff. This authoritative data is managed in a centralized, accessible geodatabase for many uses, such as analysis in ArcMap or export to NBDNR's decision support system for forestry management.

"Very few foresters need to understand all of the behind-the-scenes, technical work with data collection and GIS," said Mr. Dick. "What we're able to deliver through ArcGIS is a final information product that people can start using to analyze, plan and make decisions."

NBDNR's new system is also changing the way forestry companies approach planning.

"High precision visual data models have a tremendous impact on planning forest operations," David Young, Management Forester, JD Irving. "The resolution the LiDAR-derived forestry inventory delivers is approximately 400 times more precise than the digital elevation models we used in the past."

Because it's a relatively new system, there's room for improvement and further innovation. For example, NBDNR applies statistical models to the forest metrics gathered through LiDAR data collection. Applying these models ultimately delivers unique insights and informs decision making. Staff are constantly improving their modelling techniques, leveraging new research and innovative ideas in an effort to drive better forest management practices. NBDNR is also working with other government departments to fully take advantage of the information provided from LiDAR, enhancing land use planning, flood mapping, climate change mitigation and other important priorities.

"Once the LiDAR is captured, we essentially have a snapshot of every tree," said Mr. Dick. "Every time we improve our models, we can reach back into the LiDAR and generate an improved estimate. We couldn't do that before. Once your interpretation was finished, you couldn't reach back and do it again. That's all changed now. We've iterated through our modelling process three times now, so it's enabled us to make continuous improvements."

"Every tree has been measured and our ability to describe that tree is getting better every year without the LiDAR changing," added Mr. Kidman.