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NOVA SCOTIA FOREST DATA ASSESSMENT AND RECOMMENDATIONS

A review of available data and potential technologies to support sustainable forest management in Nova Scotia

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Kari Easthouse Resource Consulting, February 2025

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INTRODUCTION

Effective forest management relies on access to accurate, comprehensive, and up-to-date data. In Nova Scotia, a wealth of information is already available to support sustainable forestry practices, from GIS datasets to long-term monitoring initiatives like the Nova Scotia Permanent Sample Plot (PSP) System. However, opportunities also exist to enhance these efforts through the acquisition and integration of additional data sources, such as advanced satellite imagery, drone-based imagery acquisition and aerial LiDAR technologies. Application of machine learning technologies to this information is also opening a variety of opportunities to add further value to this data.

This report provides an overview of currently available forest data and also explores potential data sources that could be acquired to improve forest management and operational practices. The aim is to highlight existing resources, their applications, and opportunities to leverage emerging technologies to support data driven forest management and decision support. By doing so, this report seeks to inform forest managers, policymakers, and industry stakeholders about the tools and strategies available to improve forest resource and operational management in Nova Scotia.

The report also provides a list of specific recommendations for ways to improve the effectiveness and efficiency of sustainable forest management in Nova Scotia through the application of digital technologies and data driven processes. These recommendations reflect the unique context off Nova Scotia, both its unique land ownership pattern and its move towards ecological based forestry and forest restoration.

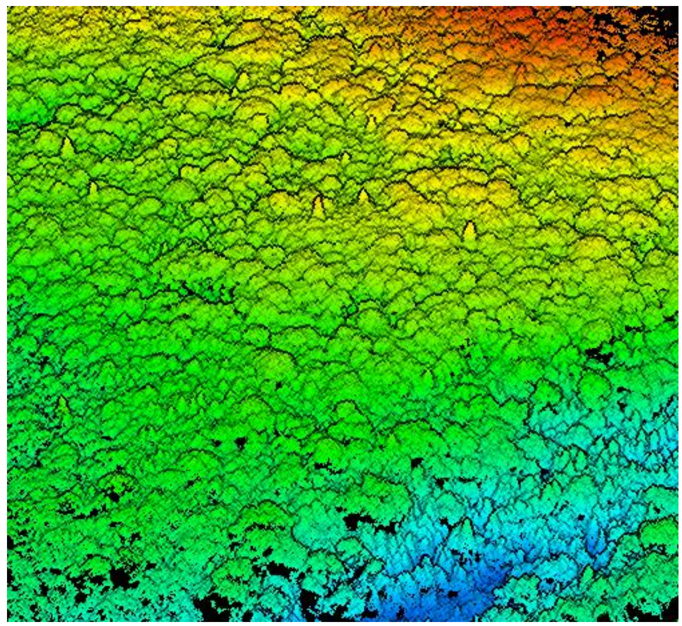


Figure 1. UAV Acquired 3D model, Glendale Cape Breton

CURRENTLY AVAILABLE FOREST DATA

There is a large amount of data already freely available in Nova Scotia to support forest management and operations. The majority of this information is in use on a daily basis by forest practitioners to support forest management and operations in Nova Scotia.

GIS INFORMATION

A full spectrum of GIS data is available in Nova Scotia, covering forest inventory, infrastructure, ecological values, wildlife and other areas. The majority of this information is available for download through Provincial government websites and portals. A complete inventory of this data, including data type, use, source and availability information is provided in Appendix 1. This dataset is the starting point for any forest enterprise in Nova Scotia and is the backbone of forest management in Nova Scotia. It includes information on forest growth, structure, composition and access. I wide range of information on forest ecology and environmental values is also available that supports sustainable forest management.

Perhaps as important as the breadth of data available is the ease with which this information can now be accessed. A recently opened data access portal is now available to anyone allowing quick and easy access to the most up to date versions of many forest related data products (https://nsgiwa.novascotia.ca/arcgis/rest/services).

A database of available GIS information (valid as of December 2024) is provided in Appendix 1. Note however that new data is continually added, and it is recommended that the base sources be checked for any updates.

NOVA SCOTIA PERMANENT SAMPLE PLOT (PSP) SYSTEM

The Nova Scotia Permanent Sample Plot (PSP) System is a comprehensive forest monitoring initiative aimed at collecting and analyzing long-term data on forest growth, health, and composition across the province. The system provides critical insights for sustainable forest management, ecological research, and policy development.

Purpose	Description
Forest Growth and Yield Monitoring	Tracks forest development over time, focusing on metrics such as volume, biomass, and productivity.
Sustainable Forest Management	Supplies essential data for developing and refining management practices.
Research and Policy Support	Facilitates ecological studies and informs forest-related policy decisions.

The system has about **3,250 permanent sample plots** across the province.

- **1965–1970:** Established around 1,765 plots, adding 250–420 per year.
- **1998–2002:** Expanded to about 3,250 plots for better inventory precision.
- **Measurement Cycle:** Plots are re-measured every five years to track forest changes.

A wealth of data is collected for each of the plots and is resampled every 5 years.

Category	Measurements
Tree-Level Measurements	Species identification, Diameter at breast height (DBH), Tree height and crown condition, Indicators of tree health
Forest Composition	Species diversity, stand density, and structural attributes
Site Conditions	Soil type, moisture levels, slope, and aspect to contextualize growth patterns

The Nova Scotia Permanent Sample Plot (PSP) System is managed by the Nova Scotia Department of Natural Resources and Renewables (NSDNRR). Data is stored in a centralized database, which is accessible to government agencies, researchers, and industry partners for analysis and decision-making through Data Share Agreements. Currently however it is policy to only release the data when it will not lead to a product that will be sold.

Nova Scotia's PSP network will be extremely valuable for leveraging, and adding value, to remotely sensed forest information.

It is worth noting that the Nova Scotia PSP system has a higher sampling intensity, and history of sampling, then many other jurisdictions in Canada. There is tremendous opportunity here in Nova Scotia for the application of Machine Learning and other analytic techniques to improve our understanding of our forests with this rich dataset.

WOODLOT OWNER EXTENSION, MANAGEMENT AND INVENTORY

Unlike most provinces in Canada, the majority of the forest area in Nova Scotia is privately owned. As a result, any information about these forests is of critical importance. Nova Scotia has a long history of support and extension to small private woodlot owners, and much of this work has been digitally captured over the last 15 years. This information includes woodlot owner objectives, forest area, prescribed treatments and field sampled forest inventory information. With the recent advancements in AI and machine learning, there is tremendous potential to use this data to better understand and support woodlot owner objectives. In addition, the extent of field sampled area could be valuable for training Enhanced Forest Inventory models.

Table 1 Area field sampled and treatment prescription through Woodlot Owner extension programs

Cover Type	Hectares
Mixed wood	26,899
Softwood	47,282
Alders Brush	5,502
Christmas Trees	205
Sugar woods	201
Burn	102
Treed Bog	72
Corridor	1,648
Barren Bogs Swamp	2,057

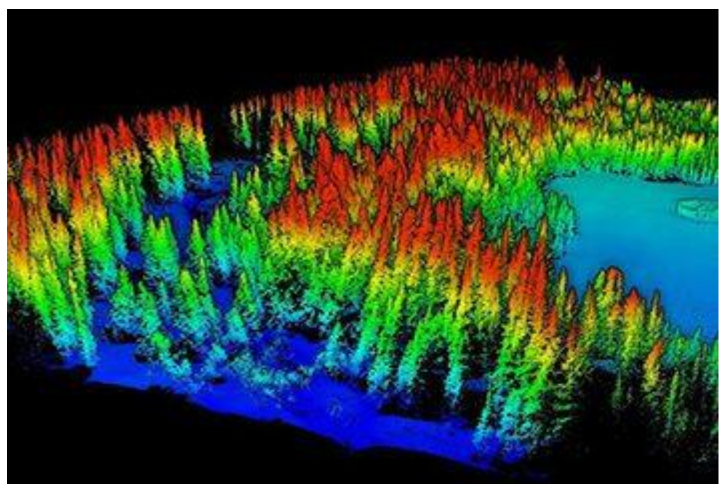
Cutover	3,362
Hardwood	22,756
Total	**110,086**

All areas that are field cruised have a prescribed treatment assigned, where appropriate, reflecting the site conditions and specific objectives of the woodlot owner. Given the financial limitations of directly supporting all 30,000 woodlot owners in the province, alternative extension methods at scale should be considered. The data can be used to develop tools and techniques for this purpose.

LIDAR AND ENHANCED FOREST INVENTORY

LiDAR (Light Detection and Ranging) is a remote sensing technology that uses laser pulses to measure distances and generate highly detailed, three-dimensional representations of the Earth's surface. In forest management, LiDAR is crucial for assessing forest structure, estimating tree height, canopy cover, biomass, and identifying changes over time. By providing precise and efficient data collection over large areas, LiDAR supports sustainable forestry practices and informed decision-making. For these reasons it has become the preferred method of acquiring forest inventory and stand structure information.

Nova Scotia undertook a 'wall-to-wall' LIDAR acquisition and enhanced forest inventory project in the late 2010's. Unfortunately the contractor hired to undertake this project went out of business before the project could be completed. However, a significant data set has been acquired and is available for forestry use. The data set includes raw LIDAR point clouds, as well as derived product information including a Digital Terrain Model and Canopy Height Model. Work is continuing to produce and Enhanced Forest Inventory based on this dataset.



POTENTIAL DATA FOR ACQUISITION IN FOREST MANAGEMENT

While there is considerable data already available in Nova Scotia to support Forest Management, there are also many other data sources available that could be purchased or otherwise acquired. The rest of this report focuses on these opportunities, providing an overview of the source and outlining both opportunities and challenges.

SATELLITE IMAGERY

HISTORY AND EVOLUTION:

The use of satellite imagery in forest management began with the launch of the Landsat program in 1972, revolutionizing the ability to monitor forests on a global scale. Early applications focused on forest cover mapping and detecting large-scale changes such as deforestation and wildfires. Over the years, advancements in spatial resolution, spectral capabilities, and data accessibility have expanded its use to include fine-scale analysis, biodiversity monitoring, and carbon estimation. The development of high-resolution commercial satellites in the late 1990s, along with free data from platforms like Sentinel-2, has made satellite imagery a key tool for forest managers.

TYPES OF SATELLITE IMAGERY

Type of Imagery	Description	Examples	Applications
Optical Imagery	Captures visible and near-infrared (NIR) light reflected from Earth	Landsat, Sentinel-2, SPOT, WorldView	Mapping forest types and land cover,
Synthetic Aperture Radar (SAR)	Uses radar signals to penetrate clouds and collect surface data	Sentinel-1, RADARSAT, TerraSAR-X	Monitoring forest cover in cloudy regions, Estimating forest structure and biomass, Mapping wetland and mangrove forests
LiDAR (Light Detection and Ranging)	Uses laser pulses to measure distances and create detailed 3D maps	GEDI	Estimating canopy height and biomass, Mapping terrain for forest management
Multispectral and Hyperspectral Imagery	Captures data across a wide range of wavelengths, including visible, NIR, and beyond	MODIS, PRISMA, AVIRIS	Identifying tree species and forest composition, Detecting stress from pests or disease, Monitoring soil and understory conditions. Monitoring vegetation health using indices like NDVI
Thermal Infrared Imagery	Captures surface temperature and heat emissions	Landsat Thermal Infrared Sensor (TIRS), ECOSTRESS	Identifying fire hotspots, Assessing water stress through evapotranspiration monitoring

APPLICATIONS IN FOREST MANAGEMENT

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Category	Activities
Forest Inventory and Mapping	Mapping forest extent, type, and condition. Estimating forest metrics like basal area and canopy height.
Monitoring and Conservation	Tracking illegal logging and forest degradation. Supporting biodiversity conservation in protected areas.
Disaster Management	Assessing damage from hurricanes, wildfires, and pest outbreaks. Mapping blowdown and windthrow areas after storms.
Carbon Estimation and Climate Change Mitigation	Estimating forest carbon storage for climate initiatives like REDD+. Monitoring afforestation and reforestation projects.
Forest Health and Productivity	Detecting vegetation stress due to drought or pests. Supporting precision forest management.

ADVANTAGES AND CHALLENGES OF SATELLITE-BASED DATA IN FOREST MANAGEMENT

Advantages	Challenges
Large-Scale Coverage: Enables monitoring of extensive and remote forest areas.	Cloud Cover: Optical sensors are hindered by cloud cover, especially in tropical regions.
High Temporal Resolution: Frequent revisits allow near-real-time monitoring of changes.	Resolution Limitations: Coarse resolution may not capture small-scale forest features or individual trees.
Cost-Effective: Reduces the need for extensive ground-based surveys.	Data Complexity: Processing and interpreting satellite data require expertise and computational resources.
Repeatability: Standardized and consistent data collection over time.	Sensor Bias: Variability in sensor calibration can affect consistency across platforms.
Accessibility: Open datasets (e.g., Landsat, Sentinel) make it affordable for all users.	Costs for High-Resolution Data: Commercial high-resolution imagery can be expensive.
Versatility: Supports a wide range of applications, from health monitoring to disaster response.	Integration with Ground Data: Satellite-derived insights often need validation with field data for accuracy.

Satellite imagery has become an indispensable tool in forest management, offering unmatched scalability and accessibility. However, overcoming challenges such as cloud cover, resolution trade-offs, and integration with ground data is critical to maximizing its potential.

CURRENTLY AVAILABLE SOURCES

Satellite/System	Resolution	Key Uses	Archive Data Range	Estimated Cost per sq. km	Access/Purchase Link
Landsat (USGS)	30m (optical); 15m (panchromatic)	Forest cover mapping, vegetation health (NDVI), change detection, fire monitoring	Since 1972	Free	USGS EarthExplorer
Sentinel-2 (ESA)	10m (optical); 20m (SWIR)	Detailed forest cover mapping, tree species classification, vegetation health, land use change	Since 2015	Free	Copernicus Open Access Hub
Sentinel-1 (ESA)	10m (SAR)	Monitoring forest structure, biomass estimation, mapping in cloudy regions	Since 2014	Free	Copernicus Open Access Hub
MODIS (NASA)	250m to 1km	Large-scale forest health monitoring, fire detection, carbon flux estimation	Since 1999	Free	NASA Earthdata
WorldView (Maxar)	30cm to 50cm	Individual tree crown analysis, tree health monitoring, forest inventory, urban forestry	Since 2007	~$16 per sq. km	Maxar Satellite Imagery
PlanetScope (Planet)	3m	Monitoring small-scale deforestation, vegetation health, and precision forestry	Since 2016	~$8 per sq. km	Planet Imagery
RADARSAT (Canada)	3m to 100m	Biomass estimation, wetland monitoring, forest disturbance detection	Since 1995	Varies; contact provider	MDA RADARSAT
TerraSAR-X (DLR)	1m	Forest structure mapping, biomass estimation, monitoring in cloud-covered areas	Since 2007	Varies; contact provider	Airbus TerraSAR-X
GEDI (NASA)	Spot measurements (LiDAR)	Canopy height, biomass estimation, forest structure	Since 2019	Free	NASA GEDI
PRISMA (ASI)	30m	Forest species classification, stress detection, soil and vegetation health	Since 2019	Free (for research purposes)	ASI PRISMA
QuickBird (Maxar)	60cm	High-resolution forest mapping, species identification, tree crown delineation	2001–2015	~$16 per sq. km	Maxar Satellite Imagery
Ziyuan (China)	2m to 10m	Forest inventory, canopy height mapping, deforestation monitoring	Since 1999	Varies; contact provider	CRESDA
IKONOS (Maxar)	82cm	Forest inventory, high-resolution mapping, site-specific analysis	1999–2015	~$16 per sq. km	Maxar Satellite Imagery
SPOT (Airbus)	1.5m to 6m	Forest mapping, deforestation monitoring, biomass estimation	Since 1986	~$8 per sq. km	Airbus SPOT
ECOSTRESS (NASA)	70m	Monitoring water stress, evapotranspiration, drought impacts on forests	Since 2018	Free	NASA ECOSTRESS

Note: Cost estimates for commercial satellites are approximate and may vary based on factors such as licensing agreements and processing requirements. Typically a minimum contiguous acquisition area is also required for purchase.

EMERGING TRENDS

Satellite imagery has evolved significantly in recent years, becoming a powerful tool for forest management. Advances in technology and new analytical techniques are providing forest managers with insights into forest health, carbon sequestration, and land-use changes. Here are some of the emerging trends in satellite imagery with potential to support forest management and operational planning.

1. High-Resolution Imagery and Increased Temporal Frequency

Recent advancements have made higher resolution imagery available, with some commercial satellites now offering sub-meter resolution. This enables forest managers to observe individual trees and conduct more detailed analyses of forest conditions. Additionally, increased temporal frequency allows for near real-time monitoring of forest cover changes, such as those caused by logging or natural disturbances. This frequent coverage helps manage risks like pest outbreaks or storm damage, enabling rapid response.

2. Integration of Multispectral and Hyperspectral Data

Multispectral and hyperspectral sensors on satellites have tremendous potential to support forest management. Multispectral data provides insights into vegetation health, while hyperspectral sensors can capture detailed information about tree species composition, leaf chemistry, and stress factors. These data types are invaluable for identifying early signs of disease, assessing biodiversity, and differentiating species in mixed forests.

3. Advances in Synthetic Aperture Radar (SAR)

Synthetic Aperture Radar (SAR) has become essential for forest monitoring, especially in areas with frequent cloud cover, such as rainforests and northern climates. SAR can penetrate clouds and operate day and night, providing consistent data. Recent advancements in SAR technology have improved the ability to monitor forest biomass and estimate carbon stocks, supporting climate action initiatives and sustainable forest management.

4. Development of Satellite-Based LiDAR

Satellite-based LiDAR is an emerging trend that holds great potential for forest management. LiDAR (Light Detection and Ranging) uses laser pulses to create detailed 3D models of forest structure, including tree height, canopy density, and biomass. While traditionally used from airplanes, recent developments are making LiDAR technology available on satellites, allowing for large-scale forest monitoring with improved accuracy in measuring forest canopy and biomass. This technology is particularly promising for enhancing carbon stock assessments and supporting precision forestry practices.

Although still likely years away, satellite-based LiDAR technology will revolutionize forest management and operations once it becomes widely available.

Satellite-based LiDAR has the potential to revolutionize forest management by providing comprehensive, high-resolution 3D data across vast areas. Unlike traditional aerial or terrestrial LiDAR, satellite systems can cover larger regions more frequently, enabling continuous monitoring of forest dynamics. This technology offers new opportunities for assessing forest biomass, carbon storage, and health while enhancing precision in inventory and land-use planning. Potential future applications include mapping forest structure to guide selective harvesting, tracking post-disturbance recovery, identifying areas at risk for pests or disease, and monitoring changes in carbon sequestration over time. As satellite-based LiDAR continues to advance it will become an essential tool for sustainable forest management, offering a cost-effective solution for large-scale analysis and decision-making.

5. AI-Driven Analytics for Forest Monitoring

Machine learning and AI are being applied to satellite imagery for automated analysis, enabling faster and more accurate detection of changes. AI is used for monitoring deforestation, flagging illegal logging activities, and estimating carbon sequestration. Additionally, AI helps predict the impacts of climate change by analyzing historical data and projecting future changes, allowing forest managers to develop adaptive strategies to mitigate climate risks.

6. Cloud-Based Platforms for Easy Access and Collaboration

Cloud platforms like Google Earth Engine and Microsoft's Planetary Computer are making satellite imagery and analytical tools more accessible. These platforms allow forest managers to access historical and near-real-time data without the need for extensive local storage or computational power. They also facilitate collaboration by providing shared access to critical information for forest managers, researchers and policymakers.

7. Focus on Carbon Monitoring and Reporting

The growing interest in carbon markets has increased the focus on using satellite imagery for carbon monitoring. Recent innovations allow for accurate mapping of forest carbon stocks and tracking changes over time, which is crucial for participating in carbon credit programs. This enhances transparency and credibility in carbon sequestration efforts, enabling forest owners to generate revenue while contributing to climate action.

USE CASES IN NOVA SCOTIA

Satellite imagery has become a powerful tool in modern forestry, providing significant benefits across forest management in Nova Scotia. High-resolution and multispectral imagery helps foresters and land managers make informed decisions and respond effectively to challenges. Below are key areas where satellite imagery can support forestry practices:

Application	Description
Forest Management	Satellite imagery provides a comprehensive view of forest health, composition, and structure. Helps assess species distribution and canopy density, aiding in silvicultural treatments, reforestation, and sustainable growth.
Forest Monitoring	Enables continuous monitoring, detecting disturbances like illegal logging, fires, and storm damage. Useful for monitoring forests after extreme weather events.
Wood Supply Projections	Supports wood supply projections by providing data for forest inventory models. Estimates timber volume and growth rates for accurate projections of future wood availability.

Supporting Forest Operations	Aids in planning forest operations, optimizing harvest block layout and access roads while minimizing environmental impacts. Helps monitor progress in real time, particularly in remote areas.
Carbon Sequestration and Climate Change Mitigation	Used to monitor carbon sequestration and assess forests' role in climate change mitigation. Estimates carbon storage, helping develop strategies to enhance forests as carbon sinks.
Biodiversity and Habitat Mapping	Supports biodiversity conservation by mapping habitats and monitoring changes over time. Tracks habitat changes, supports conservation, and aids in creating habitat corridors.
Land Use Planning and Policy Development	Provides a broad view of forested landscapes, aiding land use planning and policy development. Helps identify areas suitable for conservation, recreation, and timber production.
Disaster Response and Recovery	Critical for disaster response and recovery in forestry. Helps assess damage from hurricanes, wildfires, and floods, enabling rapid evaluation of affected areas and prioritizing recovery efforts.

AERIAL LIDAR

Aerial-based LiDAR (Light Detection and Ranging) is a powerful tool for forestry management, providing detailed three-dimensional information about forest structure. This technology supports sustainable forest management, inventory assessments, and environmental monitoring. LiDAR's ability to capture high-resolution data allows forest managers to gain insights into the health, growth, and composition of forests, contributing to better decision-making and resource management.

HISTORY AND OVERVIEW

Aerial LiDAR systems, mounted on aircraft or drones, use laser pulses to capture precise location data of terrain and vegetation. They efficiently scan large areas, producing outputs like Digital Elevation Models (DEMs), Canopy Height Models (CHMs), and 3D point clouds. These are critical for assessing forest structure, estimating biomass, and deriving key metrics. LiDAR's ability to penetrate forest canopies provides unique insights unavailable through traditional aerial imagery.

Originally developed in the 1960s for aerospace applications, LiDAR became viable for forestry by the late 1990s with advancements in GPS, laser scanning, and inertial measurement units. In Canada, its adoption began in the early 2000s, led by British Columbia and Alberta for large-scale forest assessments. By the mid-2010s, LiDAR was widely used for forest inventory, wildfire risk assessment, and biodiversity conservation, involving provincial agencies, private companies, and research institutions.

Today, LiDAR is a standard tool in Canadian forestry, valued for its adaptability and accuracy in applications from individual tree inventories to ecosystem monitoring. Improved data processing and greater availability of datasets have further integrated LiDAR into forest management practices.

LIDAR-BASED ENHANCED FOREST INVENTORY

LiDAR-based Enhanced Forest Inventory (EFI) uses high-resolution LiDAR data to generate detailed forest metrics, combining it with field sampling for comprehensive models of forest attributes. Forest inventory can be conducted at the stand or individual tree level. Stand-based inventory estimates overall attributes like volume, density, and average height, while individual tree-based inventory focuses on measuring each tree's attributes, such as height, crown diameter, and estimated diameter at breast height (DBH). LiDAR is crucial for detecting and measuring individual trees, enabling precision forestry by providing detailed spatial information on tree characteristics.

EFI development involves data collection, processing, and integrating field plot data to validate models. The process begins with collecting LiDAR data, which involves scanning the forest with laser pulses to create a point cloud representing the landscape. These point clouds are processed to derive meaningful forest metrics, such as tree height, canopy cover, and terrain elevation. Field plot data is collected simultaneously to calibrate and validate the LiDAR-derived models, ensuring their accuracy. Machine learning algorithms are often employed to predict various forest attributes across the surveyed area, improving the quality and reliability of the inventory. EFI supports sustainable management, harvest planning, and carbon accounting by providing precise forest metrics that inform decision-making.

CHALLENGES AND LIMITATIONS OF AERIAL LIDAR

Limitation	Details
High acquisition costs	Prohibitive for smaller forestry operations, especially for extensive areas or repeat surveys
Specialized data processing	Requires advanced software and technical expertise
Weather conditions	Dense cloud cover, rain, or fog can interfere with laser pulses
Dense vegetation or steep terrain	Obtaining full coverage can be challenging, resulting in incomplete datasets

LIDAR USE IN NOVA SCOTIA

LiDAR data was acquired for Nova Scotia in the late 2010's, however the project ran into problems and was not completed de to the company contracted to do the work going out of business. The data and products that were developed is provided by Service Nova Scotia, and primarily includes classified LiDAR point clouds, digital elevation model (DEM) and a canopy height model (CHM). These products do provide considerable value to some users in Nova Scotia, however adoption has not been widespread.

Development of an Enhanced Forest Inventory (EFI) from the data was not completed, however the Department of Natural Resources and Renewables is working on the development of one. A draft version for review is expected in early 2025, and depending on the results a public version should be available at some time in 2025.

COST-BENEFIT ANALYSIS OF LIDAR

LiDAR provides significant economic and environmental benefits for forestry management. Economically, it allows forest managers to optimize timber harvests by identifying high-value areas and minimizing resource wastage. The accuracy of LiDAR-derived inventories helps reduce the costs associated with traditional ground-based surveys and ensures that harvesting operations are efficient and sustainable. By providing precise information on stand volume and tree quality, LiDAR helps maximize economic returns while minimizing unnecessary expenditures.

LiDAR data acquisition from commercial providers can cost between $200 and $500 per square kilometer, with processing adding $100 to $300 per square kilometer. Despite these costs, the benefits of LiDAR often outweigh traditional ground-based surveys due to its enhanced efficiency and accuracy. Traditional surveys are time-consuming and labor-intensive, while LiDAR can cover large areas in a fraction of the time, providing comprehensive data that supports better decision-making.

The ability to create accurate digital elevation models, canopy height models, and other forest metrics leads to significant cost savings in forest operations, optimized harvests, and improved forest health. Additionally, as technology advances and more providers enter the market, the cost of LiDAR acquisition is expected to decrease, making it a more accessible tool for a wider range of forestry operations. The detailed insights provided by LiDAR help forest managers allocate resources more effectively, leading to long-term cost savings and enhanced forest productivity.

FUTURE TRENDS IN LIDAR FOR FORESTRY

Aspect	Details
Use of UAV-based systems	Flexibility and cost savings, capturing data in difficult-to-reach areas, cost-effective for smaller-scale surveys
Advances in sensor technology	Higher-resolution data, more detailed insights into forest structure and dynamics
Comparing datasets over time	Detect changes in canopy cover, tree height, forest density, assess forest health, plan future activities. Monitor growth, assess changes, evaluate management interventions by comparing results over time

DRONED BASED IMAGERY

HISTORY OF DRONES IN FORESTRY

The use of drones, or Unmanned Aerial Vehicles (UAVs), in forestry began in the early 2000s. Initially, their use was experimental and limited due to high costs and regulatory challenges. Early adopters were mainly research institutions exploring the potential of aerial imagery for forest monitoring. By the 2010s, advancements in drone technology, decreasing costs, and improved regulations facilitated broader adoption within forestry. Modern drones are now frequently deployed by foresters, environmental agencies, and forest management companies to conduct efficient, cost-effective surveys that previously required manned aircraft or satellite data.

Today, drones have evolved from niche research tools into integral components of forest management strategies. They enable high-resolution, on-demand data collection, leading to improved forest health monitoring, timber inventory, and rapid assessments of post-disturbance scenarios such as wildfires or storm damage.

TYPES OF DRONES AND DATA COLLECTED

Drones used in forestry can generally be categorized into two main types:

Type of Drone	Characteristics	Ideal Use
Multi-rotor Drones	Versatility, maneuverability, short-distance flights, hovering	Inspecting individual trees, mapping smaller areas, health assessments
Fixed-wing Drones	Airplane-like design, longer flight times, greater range	Surveying large tracts of forest, mapping large plantations or natural forests

Drones equipped with different sensors can collect a wide variety of data, including:

Imagery Type	Uses
RGB Imagery	Mapping forest structure, boundaries, identifying visible signs of damage or disease
Multispectral and Hyperspectral Data	Assess tree health, chlorophyll content, stress levels
Thermal Imagery	Detect heat signatures, identify areas of pest infestation, water stress, hotspots during wildfire monitoring
LiDAR	Generate elevation models of forest floor, capture data on canopy height, forest density, individual tree measurements

COMPARISON OF DRONES VS. SATELLITE IMAGERY

Feature	Drones	Satellite Imagery
Resolution	Very high (down to a few centimeters)	Lower (typically 10-30 meters)
Flexibility	On-demand, real-time imagery	Limited by satellite schedules
Coverage Area	Small to medium areas	Large areas
Operational Cost	Moderate to high (equipment, pilots, etc.)	Low for publicly available data
Historical Data	Limited	Decades of consistent data (e.g., Landsat)
Cloud Interference	Minimal (deployable in suitable weather)	Significant impact

REGULATORY CONSIDERATIONS AND CHALLENGES

The use of drones in forestry is subject to various regulatory considerations, which can vary by country and region. In Canada, drone regulations are governed by Transport Canada, which requires drone operators to hold a valid certificate, either a Basic or Advanced Operations certificate, depending on the type of operation. Expected changes to legislation here in Canada will allow for flying drones beyond line of sight, which will greatly increase the utility of drones for forestry. These regulations impact how forest managers plan and execute drone missions, requiring careful consideration of compliance to ensure the safe and legal use of drones.

COST-BENEFIT ANALYSIS

Drones vs. Satellite Imagery:

Aspect	Drones	Satellite Imagery
Cost	Higher upfront costs due to equipment purchase, maintenance, and operator training	More economical for large-scale monitoring (free sources like Landsat), but high-resolution commercial imagery can be costly
Resolution and Flexibility	Superior resolution (up to a few centimeters), deployed on demand for targeted assessments	Resolutions typically between 10-30 meters, ideal for broad monitoring over large areas
Temporal Analysis	Flexible but not practical for frequent or historical data collection over large regions	Consistent, long-term datasets, ideal for historical analysis and monitoring changes over time

Operational Costs	Require operators, regulatory compliance, and regular maintenance, expensive for frequent, large-scale use	Low operational costs once launched, particularly for publicly available data

DRONES VS. CONVENTIONAL FOREST MEASUREMENT TECHNIQUES

Aspect	Conventional Forest Measurement	Drone Deployment
Cost and Labor	Labor-intensive, time-consuming, high cost for skilled labor	Lower cost, timesaving
Accuracy and Coverage	Detailed measurements, crucial for tree diameter and species identification, limited spatial coverage	Efficient large area coverage, data on canopy height, structure, understory conditions
Health and Safety	Hazardous in difficult or dangerous terrain	Reduces need for field crews in dangerous areas, improves safety

USE CASES

Drones are being used in various forestry applications to improve efficiency, accuracy, and sustainability. Below are some of the primary use cases:

Application	Description	Example
Forest Inventory	Drones for accurate mapping of tree species, canopy height, and biomass estimation.	Equipped with RGB, multispectral, and LiDAR sensors.
Change Detection	Drones detect changes in forest conditions over time.	Identify changes in canopy cover, tree health, and illegal logging.
Monitoring	Continuous monitoring of forest conditions, including pest infestations and disease outbreaks.	Multi-rotor drones with multispectral sensors used in Canada.
Operation Planning	Drones provide terrain and canopy information for planning forestry operations.	Fixed-wing drones used after a major storm for salvage logging.
Silviculture Assessments	Assess the success of silvicultural activities like planting and thinning.	High-resolution imagery to evaluate plant survival rates and free-to-grow status.
Insect and Disease Monitoring	Drones detect early signs of insect infestations or diseases.	Thermal and multispectral sensors analyze tree temperature or chlorophyll levels.
Wildfire Risk Assessment and Monitoring	Assess wildfire risk and monitor fire progression in real time.	Thermal imaging and LiDAR used in the United States and Canada.

DATA PROCESSING TOOLS, MACHINE LEARNING

The data collected by drones must be processed to generate meaningful insights. Advanced software tools and machine learning algorithms are increasingly used to analyze drone data in forestry:

Category	Tools/Techniques	Outputs/Uses
Photogrammetry Software	Pix4D, Agisoft Metashape	Ortho mosaics, 3D models, mapping, monitoring tree health, calculating tree heights
LiDAR Processing	LiDAR data	DEMs, DTMs, CHMs, forest density, biomass, structural characteristics
Machine Learning Applications	Species Classification, Health Monitoring, Inventory Predictions	Classify tree species, detect disease, pest infestations, water stress, estimate timber volume, carbon stock, biomass

The integration of machine learning with drone data has enabled faster, more accurate, and scalable analysis of forest conditions, reducing the time and costs associated with traditional ground-based surveys.

FUTURE TRENDS IN DRONE TECHNOLOGY FOR FORESTRY

The future of drone technology in forestry looks promising, with several emerging trends expected to enhance their capabilities and integration into forest management:

Advancement	Description
Sensor Technology	New sensor technologies, including hyperspectral and thermal imaging, are becoming more compact and affordable. This will allow drones to capture more detailed and diverse data, improving the accuracy of assessments related to forest health, stress detection, and biodiversity monitoring.
Automation and AI	The use of artificial intelligence (AI) and machine learning is expected to expand, particularly in the automation of data analysis. Autonomous drones capable of planning and executing missions without human intervention are also becoming more feasible, which will make forest monitoring even more efficient.
Swarm Technology	The development of drone swarm technology could revolutionize large-scale forestry operations. Multiple drones working collaboratively can cover extensive areas quickly, providing synchronized data collection for applications such as large-scale forest inventory and change detection.
Integration with IoT	Integrating drones with Internet of Things (IoT) networks can significantly enhance data collection and transmission. This integration allows for real-time monitoring of forest parameters and enables linking drone-collected data with other environmental sensors deployed on the ground, providing a more comprehensive understanding of forest ecosystems.
Extended Flight Times and Battery Improvements	Advances in battery technology and the use of solar-powered drones are expected to extend flight times, making it more practical to survey larger areas or conduct longer missions. This will address one of the key limitations of current drone technology in forestry.
Regulatory Changes	As drone technology continues to prove its value, regulatory frameworks are expected to evolve to accommodate their use in forestry.

MULTI-TEMPORAL LIDAR UPDATING

An emerging technique that is important in the context of Nova Scotia is 'Multi-Temporal LiDAR Updating'. Multi-temporal LiDAR updating is a methodology that uses existing LiDAR data in conjunction with new, targeted data acquisitions. In Nova Scotia, where the current wall-to-wall LiDAR dataset is out of date, this approach provides a cost-effective way to keep forest inventories current without the expense and logistical complexity of collecting new LiDAR over the entire province. By aligning and comparing the older baseline LiDAR with newer, high-resolution drone imagery or LiDAR, analysts can detect growth, disturbances, or any other structural changes in forested areas at a fraction of the cost of a complete re-fly.

Combining existing LiDAR data with updated UAV data offers a lot of potential in the Nova Scotia Context.

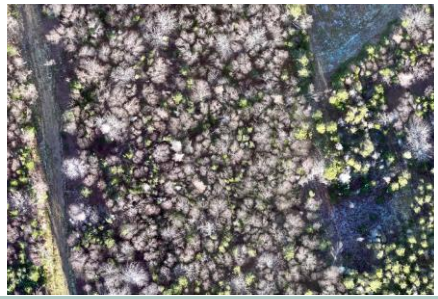
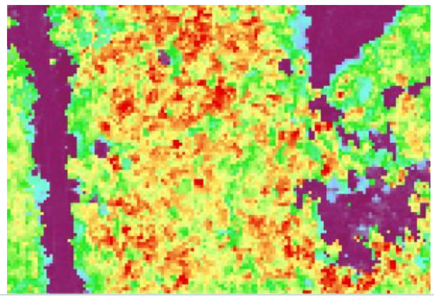
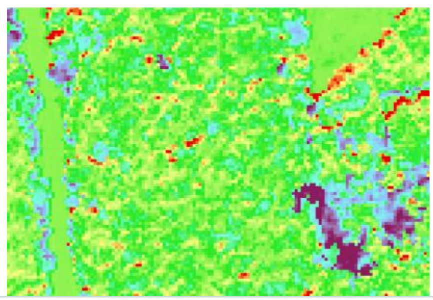
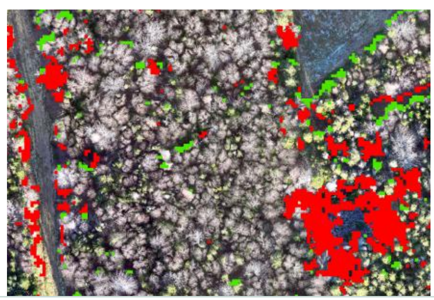
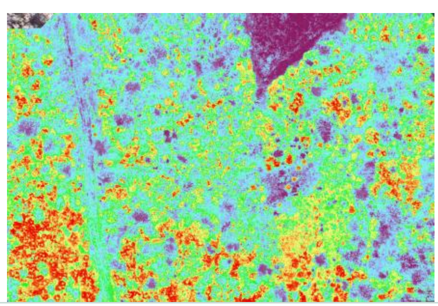
This strategy is particularly well-suited to Nova Scotia due to the province's fragmented landbase and diverse ownership. Conducting new, province-wide LiDAR flights under these conditions would be both expensive and complicated by differing ownership priorities. In contrast, multi-temporal LiDAR updating uses the existing baseline coverage to provide province-wide context, while allowing UAV flights to be carried out on smaller targeted priority areas.

CASE STUDY: USING UAV DATA TO SUPPORT ECOLOGICAL FORESTRY IN NOVA SCOTIA

Nova Scotia's **Ecological Forestry** approach was initiated as a response to concerns over industrial forestry practices and their impact on biodiversity, ecosystem health, and long-term sustainability. The province's ecological forestry vision is guided by the Lahey Report (2018), which outlined recommendations to shift forestry practices toward a more ecologically focused approach. This requires site-specific planning to align forest management with local ecological conditions. As a result. forestry operations must be tailored to the specific characteristics of each site rather than applying a one-size-fits-all approach. Planning for, and implementing these approached is very labor intensive, and supporting it with UAV imagery and derived data products has tremendous potential.

In addition to high resolution ortho imagery, processing of drone imagery can produce current and accurate Canopy Height Models of a site. This within-stand detail is essential when planning for operational detail at a sub-stand level. Further processing, and comparison to historical LiDAR data allows for the calculation of growth (change in canopy height), recent mortality, and even canopy expansion. The following workflow shows a portion of a sample site in Cape Breton where these techniques were applied.

Figure 2 Example of the ortho mosaic detail possible through UAV imagery. Glendale Cape Breton.

Drone (DJI Mavic 3M) data captured for sample area	
Canopy height model (CHM) calculated through photogrammetry. Each pixel represents the maximum tree height observed.	
Change in canopy height since 2018 is calculated by comparison to 2018 LiDAR data.	
Canopy expansion (green) and mortality (red) calculated based on change detection	
Multi-spectral imagery (e.g. NDVI) can be used to identify areas of potential stress or other forest health issues.	

RECOMMENDATIONS AND OBSERVATIONS

LEVERAGE THE USE OF EXISTING DATA SETS AND TECHNOLOGIES

While there are considerable gains to be made through strategic investment in, and adoption of, digital technologies in forestry, there are also many immediate things that we as individual forest practitioners can also do. Many valuable digital tools are readily available that are not being fully utilized. The following are examples I have specifically noted based on research for this work and interactions with local forest practitioners.

- The CHM (canopy height model) derived from the LiDAR survey is an extremely valuable tool that is not always taken advantage of in operational planning. This may be to a lack of awareness, or difficulty in accessing it. (https://nsgi.novascotia.ca/datalocator/elevation/). While the heights are currently 6 to 8 years out of date, they can still provide significant value for within stand operational planning, as well as identification of operable areas.

- A significant portion of the GIS data available to support forestry in Nova Scotia is now available through one easy to access rest location. By connecting to https://nsgiwa.novascotia.ca/arcgis/rest/services through either QGIS or ESRI GIS tools, you can be sure you have the latest version of the data, and also avoid downloading and storing the data locally.

- QGIS has developed into a fully functional GIS system, that is as powerful and complete as ESRI products. In the past it was thought of as an inferior product, however it is now a complete GIS system, available at no cost. There are many instructional videos and a very active support community for it, so there is no reason for GIS not to be in the hands of any forest professional. (https://qgis.org/download/)

- Google Earth (not google maps) has historical satellite imagery available that can be extremely useful for change detection or comparing leaf on / leaf off imagery.

PROMOTE THE FURTHER ADOPTION OF DIGITAL TECHNOLOGY

Nova Scotia faces a number of challenges that impact adoption of digital technologies in the forest industry. Firstly, we are a relatively small jurisdiction, with an important, but relatively small forest industry. In addition, or forest landbase is fragmented, both in forest type and ownership. At the same time, we are working to implement very progressive forest management in a very complex forest structure, where we will need to rely on technological support if we are to be successful.

There is strong consensus that if we are to be successful in the future as a forest industry, both financially and ecologically, we need to quickly move forward with adoption of a strong digital strategy and ethos. Fortunately, by incorporating scale appropriate technologies and leveraging existing data sets and processes through machine learning, it is possible to do this in a cost effective and relatively low risk manner. Sample recommendations to increase the adoption of digital technology include:

- Demonstrate value and support the adoption of existing digital tools for forest contractors
- Increase the utilization of drone-based imagery and LiDAR to reduce planning costs
- Make PSP data more publicly available to support innovation and development
- Develop and support digital tools to reduce the transactional costs of managing '000s of woodlots.

Further details on these recommendations are provided in Appendix 2.

APPENDIX 1. DIRECTORY OF CURRENTLY AVAILABLE FOREST DATA

Note: The following data is also available as a separate digital file, including hyperlinks to the data source.

Category	Data Name	Description	Source Type	Comments
Data Directory	Geographic Data Directory	Directory of spatial data collections available in Nova Scotia. Note that all data listed is available as downloadable gis shapefiles / gdb. Map services are listed where available. Map services listed below are available as downloads from this directory URL. Prominent data sets for Forestry (ELC, forinv, others) are both listed in this document.	Public gis download directory	Most, not all, publicly available map services and shapefile / gdb dowload links are listed in the directory. Includes non-forestry related data. Many, not all, of the sources listed below originate from this directory.
Data Directory	Geosciences and Mining GIS Data Dowloads	Geosciences and Mining GIS Data Dowloads	Downloadable GIS Data	Source page for geosciences and minerals data (not directly forestry related data)
ELC	ELC Map Service	Version 2015 of Land Systems mapped at 1:50,000 from the Nova Scotia Biophysical Land Classification were used to define the physical attributes of the smallest mapped unit of the ELC - the Ecosection (1:50,000)	Map Service	
ELC	ELC Download	2007 and 2015 ELC gis downloads	GDB / shapefile downloads	Ecological Land Classification (ELC) is a mapping tool that identifies and describes areas of similar enduring physical attributes. It is based on features such as climate, elevation, topography, bedrock formation, and vegetation.
Forest Inventory	forinv Map Service	This service is comprised of data from the NS forest inventory as interpreted from aerial photography. Detailed information about forest stands is presented at large scales. Thematic layers for leading forest species, land cover, forest height and forest volume are presented at smaller scales.	Map Service	Inventory components are part of the complete Landscape Viewer direct web service
Forest Inventory	Forest Inventory Dowload	Layers containing polygons for all lands in the province as described in the Photo Interpretation Specifications. Includes water, forested and non-forested areas with additional identification of freshwater wetlands and coastal habitat area classifications. The original source data was interpreted and digitized from 1:10,000 air photos into a base layer containing Nova Scotia Geomatics Centre's lakes, rivers	Data Download	Starting with 2007 photography, the scale of the photographs changed from 1:10,000 to 1:12,500 and the analog photos were digitally scanned and orthorectified so that editing/updating of forest stands could be done using ArcGIS.

Category	Data Name	Description	Source Type	Comments
		and shoreline, in addition to buffered areas (paved roads and railways).		
Base Mapping	roads	Roads theme map service created using the Nova Scotia Road Network (NSRN) data in the UTM/NAD83 projection/datum. Map displays and symbology have been designed for custom UTM scale levels.	Map Service	
Base Mapping	roads trails and rails	Roads theme map service created using the Nova Scotia Topographic Database (NSTDB) data in the UTM/NAD83 projection/datum. Map displays and symbology have been designed for custom UTM scale levels.	Map Service	
Property	NSPRD Property Map Service	Nova Scotia Property Records Database (NSPRD) property boundaries and limited attribution.	Map Service	Web map service of current NS PIDs. Only geometric info and PID #s are listed.
Property	NSPRD Property PID download	Mgmt units can be purchased individually or en masse through geomatics dept in Amherst containing all attribute info (names, addresses, etc.) Cost is $8,000-$10,000 for the province for a point in time purchase; free for non-profits but you must prove non-profit status	Data Download	Acquisition info sheet is the URL
Base Mapping	Elevation LIDAR Index, Nova Scotia	Map Service displaying the indexes for Nova Scotia LIDAR coverage and LIDAR derived products.	Map Service	This is a way to quickly identify the individual tiles for download from the Elevation Explorer download site
Base Mapping	ELEV/ELEV_LIDAR_Projects_Hillshade_UT83	Map Service displaying the hillshades from LIDAR derived DEM's. Read only map service used for display purposes.	Map Service	Individual tiles can be downloaded seperately for performing raster functions
Base Mapping	Datalocator/elevation	LiDAR products. Includes raw LiDAR points and Canopy Height Model.	Data Download	Must be downloaded by tile.
Base Mapping	FOR/FOR_ProvLandscapeViewer_WM84	Provincial Landscape Viewer layers for the NS Ecological Land Classification 2015 and forestry-related data. Comprised of the Ecological Land Classification (ELC 2015) and the following forestry-related data: the NS Old Forest Policy, forest treatment data, forest inventory, wet area mapping (WAM), the road index, dominant natural disturbance, seral stage, development class, forest community and ecological emphasis class.	Map Service	This is the complete ns landscape viewer layer sets available as a map service; It is what you see on within the 'forest' and 'ecological' headings within the landscape viewer layers.

Category	Data Name	Description	Source Type	Comments
Imagery	BASE/BASE_NSODB_10k_UT83 (MapServer)	Nova Scotia Orthophotomap Database (NSODB) map service created using the most current provincial resource series (1:10,000) colour aerial photography coverage in the UTM/NAD83 projection/datum.	Map Service	Completely merged ortho sets for the province; most recent flight years are displayed
Wetlands	National Wetland inventory NS	National Release based on NS data; does not contain protected status. Select NS from the list for download; updated 2024	Download gdb	This federally approved list of delineated wetlands in NS; The federal wetland inventory dept has confidence in this data over others for NS wetland inventories
Data Directory	LIDAR Tiles	Index of LIDAR 1km x 1km tiles along with associated tile information/metadata.	Raster individual tiff downloads Data Locator NS Elevation Explorer	The full set can be loaded onto a physical hard drive for a nominal fee through NS Geomatics in Amherst
Data Directory	10K Derived Products	Index of LIDAR derived products in 1:10,000 map sheet windows along with associated derived product information/metadata.	Individual target area dowloads	1-8 products per tile; variations of canopy height model (CHM), digital elevation model (DEM), Hillshades (HILL) primarily in .tiff format
Wildlife	WoodTurtle known with buffers	Wood turtle observations gathered by MTRI (Mersey Tobeatic Research Institute), the ACCDC (Atlantic Canada Conservation Data Centre), and the BIR reporting system were used to select the "wood turtle streams".	data sharing DNRR	Any observation that was found to be within 200 metres of a stream was used in this process. (Any points greater than 200 metres from a stream were not included). 3) For each turtle observation, 2 kilometres upstream and 2 kilometres downstream were selected. The 2 kilometres is stream length, not as the crow flies distance.
Wildlife	Sighab	Significant habitats: Sites where species at risk or other species of conservation concern can be found and/or; sites where unusually large concentrations of wildlife occur and/or; habitats that are rare in the province. Attribute information is limited in detail for rare / at risk values for protection purposes (prevent exploitation); A data sharing agreement is possible for full attribute information if warranted and not for commercial purposes	Data Download	The maps and data base only include sites known to staff of the Department of Natural Resources or sites that have been supplied by knowledgeable naturalists, museums, universities, the Nova Scotia Museum of Natural History, the Atlantic Canada Conservation Data Centre and other government departments
Wildlife	ACCDC	The Atlantic Canada Conservation Data Centre (AC CDC) maintains linked databases that document what species occur in each Atlantic Canadian province, and the locations at which provincially-rare species are known. Species' conservation status is assessed in collaboration with other experts and is summarized in a sub-national status rank (S-rank) for each species in each province. AC CDC maintains S-ranks for all terrestrial vertebrates, vascular plants, bryophytes (mosses and	Point in time data purchase	Data sharing purchase agreement directly with ACCDC: http://accdc.com/en/data-request.html

Category	Data Name	Description	Source Type	Comments
		related plants), macrolichens and for many invertebrate groups. As of June 2024 our databases have provincial ranks for over 21,900 species, subspecific taxa and ecological communities. Species' provincial S-ranks are available here.		
Crown	Crown Lands and Parks	Nova Scotia Department of Lands and Forestry property holdings	Map Service	
Crown	Crown Harvest Planner	This map shows the locations of the Crown Land Harvest Plans	map Service	
Soils	Agriculture Canada AgCansoils	The NSDB is a collection of geospatial datasets which contain soil, landscape, and climatic data for all of Canada. It serves as the national archive for land resources information that was collected by federal and provincial field surveys, or created by land data analysis projects.	Download	Individual detailed soil surveys have been stitched together to create compiled datasets for each province. Scroll down to Nova Scotia; single data set for the entire province at 1:75,000; this is historic agriculture soil inventories for the province
Soils	NSSoilTypes	Predicted NS FEC Soil Types based on ELC, wet areas mapping and other info. Predictive only!	Download	Required DSA with DNRR
Land Designation	RLUL	Restricted Land Use Layer 2007. Old data set not currently available or supported	data sharing	Old data (2007); layer largely unavailable now
Ecosites	SigEco	Significant Ecosites 2009. Old data set not currently available or supported	data sharing	Old data (2009); layer largely unavailable now
Watersheds	Watersheds NS	Watershed boundaries for the Land Use Planning and Economic Growth (LOCUS) project. Includes primary, secondary, tertiary and sub-tertiary boundaries.	webviewer	
Base Mapping	NS boundaries		webviewer	
Raster Index	Hurricane Juan Imagery	Aerial photography was flown in October and November of 2003, and used to create digital orthomosaics which are available for download. The images were captured at a scale of 1:24000.	tile downloads	.SID map tiles
Forest Inventory	Provincial Sample Plots (PSPs)	Info: https://novascotia.ca/natr/forestry/programs/inventory/services.asp	data sharing DNRR	Only available on a request basis; not for use for commercialization of data

Category	Data Name	Description	Source Type	Comments
Raster Index	Acadian Forest Productivity Index - Version 1	Biomass Growth Index. A measure of the maximum biomass growth rate (kg/ha/yr) of a forest area as a partial function of climate, soil, and topographic covariates.	Raster layers (20 m; TIFF; ~300 MB each); 1 for each province / state	To provide a single quantitative measure of productivity for the majority of the Acadian forest region for the purposes of improving and also simplifying stand growth model forecasts. This site map is currently being used as a covariate in the Open Stand Model for this area.
Hydrology	Wet Areas Mapping (WAM)	The WAM model predicts where water will naturally flow and/or accumulate in the landscape based on digital elevation (DEM) data and the known location of surface water bodies and wetlands. In essence, WAM is a "cartographically derived depth-to-water index.	Data Download	Flow data (polyline) is available as a single download; WAM polygon downloads are available by clicking the desired county at the bottom of the page.
Protected Areas	Protected Areas Map Service	Included here are: National Parks, National Wildlife Areas, Provincial Wilderness Areas, Provincial Nature Reserves, selected Provincial Parks and selected land trust properties and easements.	Map Service	2024 updated
Protected Areas	Protected Areas Data Download	Included here are: National Parks, National Wildlife Areas, Provincial Wilderness Areas, Provincial Nature Reserves, selected Provincial Parks and selected land trust properties and easements.	Data Download	2024 updated
Ecological	Predictive Ecosystem Mapping for Nova Scotia	The predictive ecosystem mapping (PEM) classification is a hierarchical standard for mapping the diversity and distribution of extant ecosystems in Nova Scotia based on existing spatial data	Data Download	
Protected Areas	Protected Areas Policy NS	Included here are: National Parks, National Wildlife Areas, Provincial Wilderness Areas, Provincial Nature Reserves, selected Provincial Parks and selected land trust properties and easements. This combination of federal, provincial and private lands contributes to both provincial and national land conservation and biodiversity goals. This map is a graphic representation and is meant solely to be an informative resource. It is not intended for legal, surveying, or navigation purposes.	Map Service	
Imagery	Google Satellite Imagery	Google produced satellite imagery base map service	Map Service	Comparing NS Ortho Layer, Google Satellite, ESRI satellite provides 3 options for most recent imagery amid relative quality differences

Category	Data Name	Description	Source Type	Comments
Imagery	ESRI Satellite Imagery	ESRI produced satellite imagery base map service	Map Service	Comparing NS Ortho Layer, Google Satellite, ESRI satellite provides 3 options for most recent imagery amid relative quality differences
Old Forest	Old Forest Scoring Data	Under the Old-growth Forest Policy (effective 18 August 2022) about 30,000 hectares of old-growth forest and restoration opportunities on Crown Land are protected. Further, more than 280,000 hectares of actual and potential old-growth forest are in legally protected areas.	Data Download	See NS old forest resources - https://novascotia.ca/natr/forestry/programs/ecosystems/oldgrowth.asp
Wind Exposure Raster	Digital Wind Exposure Map for Nova Scotia	Raster-based wind exposure map provides a consistent and robust estimate of wind exposure and may be considered the definitive "first call" for PTA related exposure classification in Nova Scotia. Potential wind exposure associated with geographic location and topographic position	Data Download	See Research Report https://www.novascotia.ca/natr/library/forestry/reports/Wind_map_FRR_99.pdf
Land Capability	Land Capability for Forestry	Classification of all mineral and organic soils in Nova Scotia into one of seven classes based on their inherent ability to grow commercial timber.	Data Download	The inventory was designed primarily for strategic planning rather than operational management. It will not provide the detailed information required for management of small individual parcels of land.
Historic Forest Cover	Fernow 1912 Forest Cover	Digitization of origianal 1912 NS forest cover survey maps covering the province	Data Download	In 1912, the Canadian federal Commission of Conservation published, "Forest Conditions of Nova Scotia", written by B.E. Fernow and assisted by C.D. Howe and J.H. White. The report was based on information gathered from a reconnaissance forest survey of the Province, carried out under the direction of Dr. B.E. Fernow, then Dean of the Faculty of Forestry at the University of Toronto.
Geology	NS Surficial Geology	The digital product contains layers for surficial geology features such as: beaches, cirques, deltas, drumlins, eskers, surficial geologic units, hummocks, kettles, moraines, meltwater, roche moutonnees, terrace scarps, glacial striations and other geological features.	Data Download	Digital Version of Nova Scotia Department of Natural Resources Map ME 1992-3, Surficial Geology Map of the Province of Nova Scotia

APPENDIX 2 – RECOMMENDATIONS

Challenge	Discussion	Digital Strategy	Barriers	Recommendation
Contractor Profitability	Contractors in NS are typically small compared to other regions and lack the capacity or scale to adopt digital support solutions that would help them dramatically reduce costs.	Demonstrate value and support the adoption of existing digital tools	SLA Capacity Long term funding mechanism covering on-going support needed	Encourage and support ongoing work by the contractor's association.
Implementing Ecological Forestry	Applying ecological forestry significantly increases planning costs due to the within-stand detail required. Applying this at scale will need significant support.	Utilization of drone-based imagery and LiDAR to reduce planning costs	High cost and technical threshold of image and LiDAR processing High cost of LiDAR drones	Broad demonstration and business case development project. Development of training program for current forest professionals through NSCC
Reducing Wood Cost	Small tree size, the fragmented nature of our forests, combined with the need to manage at smaller and smaller scales for ecological objectives results in high delivered wood costs.	Access to better forest inventory information to improve planning and reduce costs	High cost of wall-to-wall LiDAR and EFI Lack of publicly available machine learning suitable training data	Make PSP data more publicly available to support innovation and development Harvester head data collection project for ML/EFI training data Monitor development / cost of Satellite or Air born LiDAR
Unlocking Private Supply Potential	In order to fully reach the potential of the forest industry in Nova Scotia we must find a way to engage and support all 30k landowners in a cost effective way.	Develop and support digital tools to reduce the transactional costs of managing '000s of woodlots.	Mechanism to share development and support costs	Support current technology platform development