Current status and application of airborne lidar in Canadian forest inventory programs

Operational Lidar Inventory Meeting

April 6, 2022

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Canadian Institute of Forestry
Institut forestier du Canada

2022 Annual LiDAR/EFI Cross-Country Checkup

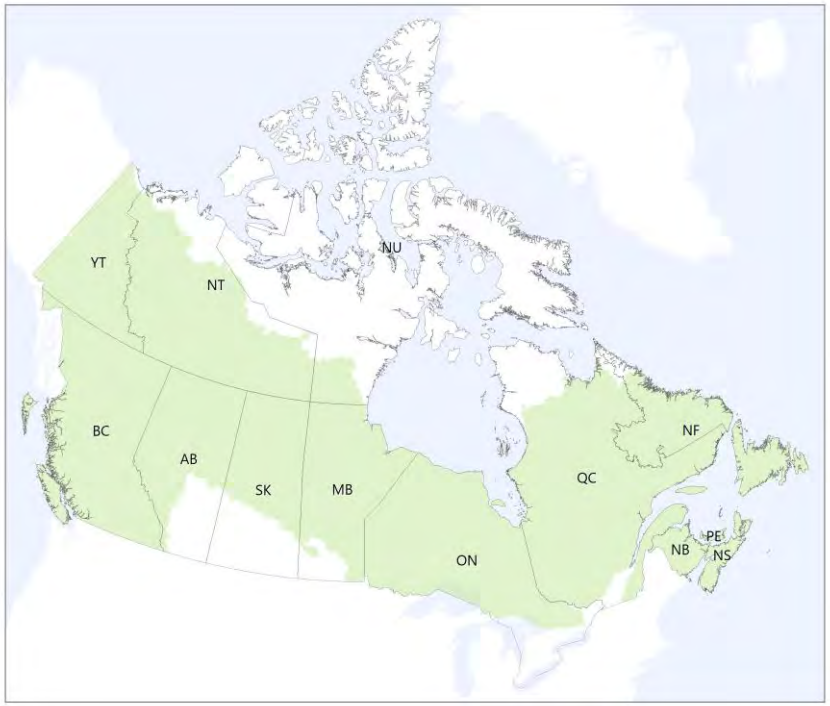
TITLE	PRESENTER	PDF	AUDIO	VIDEO	DATE
2022 Annual LIDAR/EFI Cross-Country Checkup	Adam Dick; Andrew Ing; Elizabeth McGarrigle; Dale Wilson; Antoine Leboeuf; Ian Sinclair; Lane Gelhorn; Chris Bater; Chris Butson			Video	02/07/2022

https://www.cif-ifc.org/what-we-do/e-lectures/open-access-e-lectures/

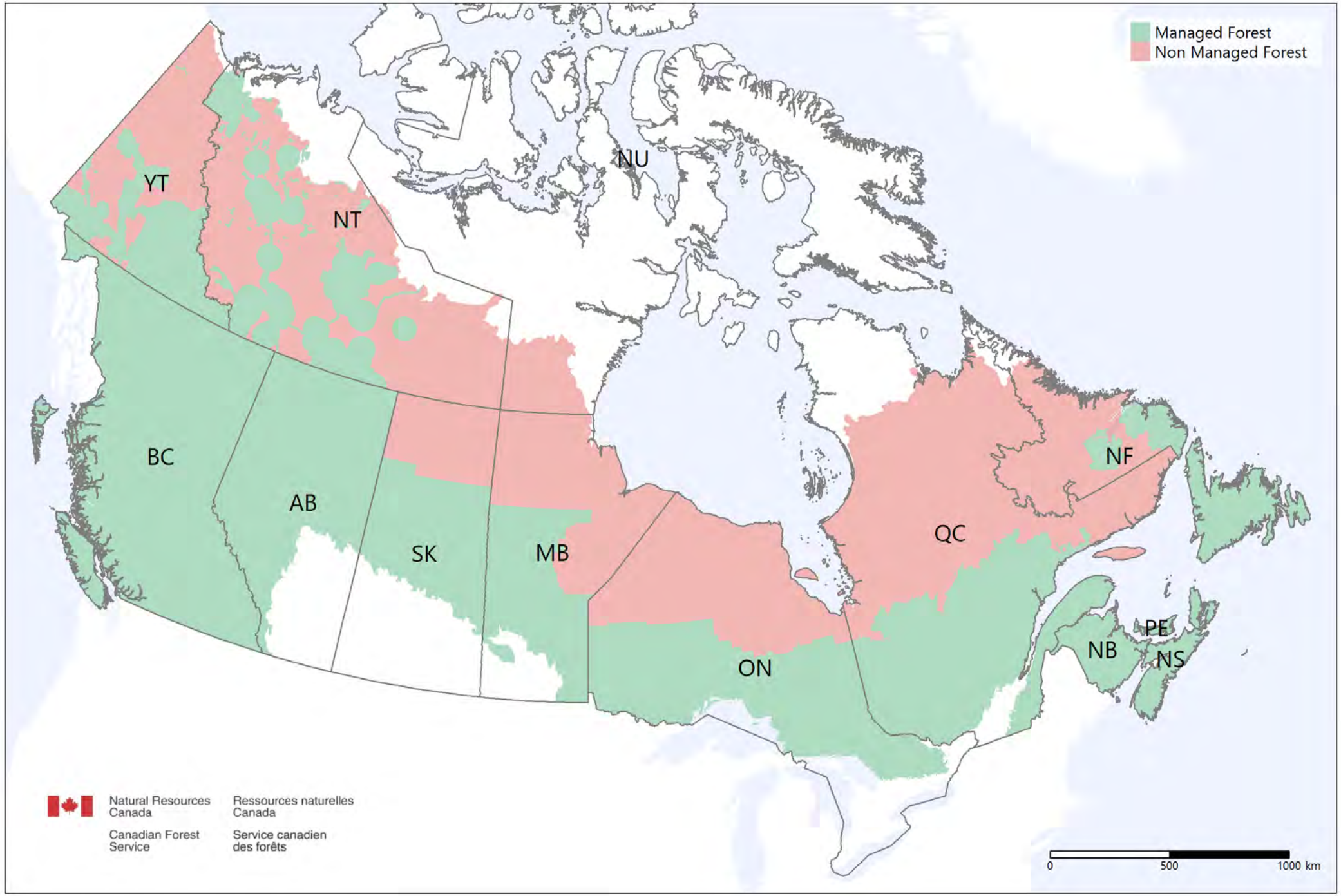
Organized by Adam Dick, Canadian Wood Fibre Centre, Canadian Forest Service

Introduction – forest inventory in Canada

- ~92% of forest lands are publicly owned
- Provinces/territories are responsible for forest management
- Each jurisdiction maintains its own inventory program with different specifications and standards (Tompalski et al. 2021)
- ALS coverage and usage differs by province:
  - From no ALS data to 100% ALS coverage
  - EFI solutions: in-house or outsourced
- Provinces that use ALS / develop EFI:
  - BC, AB, SK*, ON, QC, NB, NS, PE



Tompalski, P., White, J. C., Coops, N. C., Wulder, M. A., Leboeuf, A., Sinclair, I., Butson, C. R., & Lemonde, M. (2021). Quantifying the precision of forest stand height and canopy cover estimates derived from air photo interpretation. *Forestry: An International Journal of Forest Research*, 1–19. https://doi.org/10.1093/forestry/cpab022


Managed Forest
Non Managed Forest
YT
NT
NU
BC
AB
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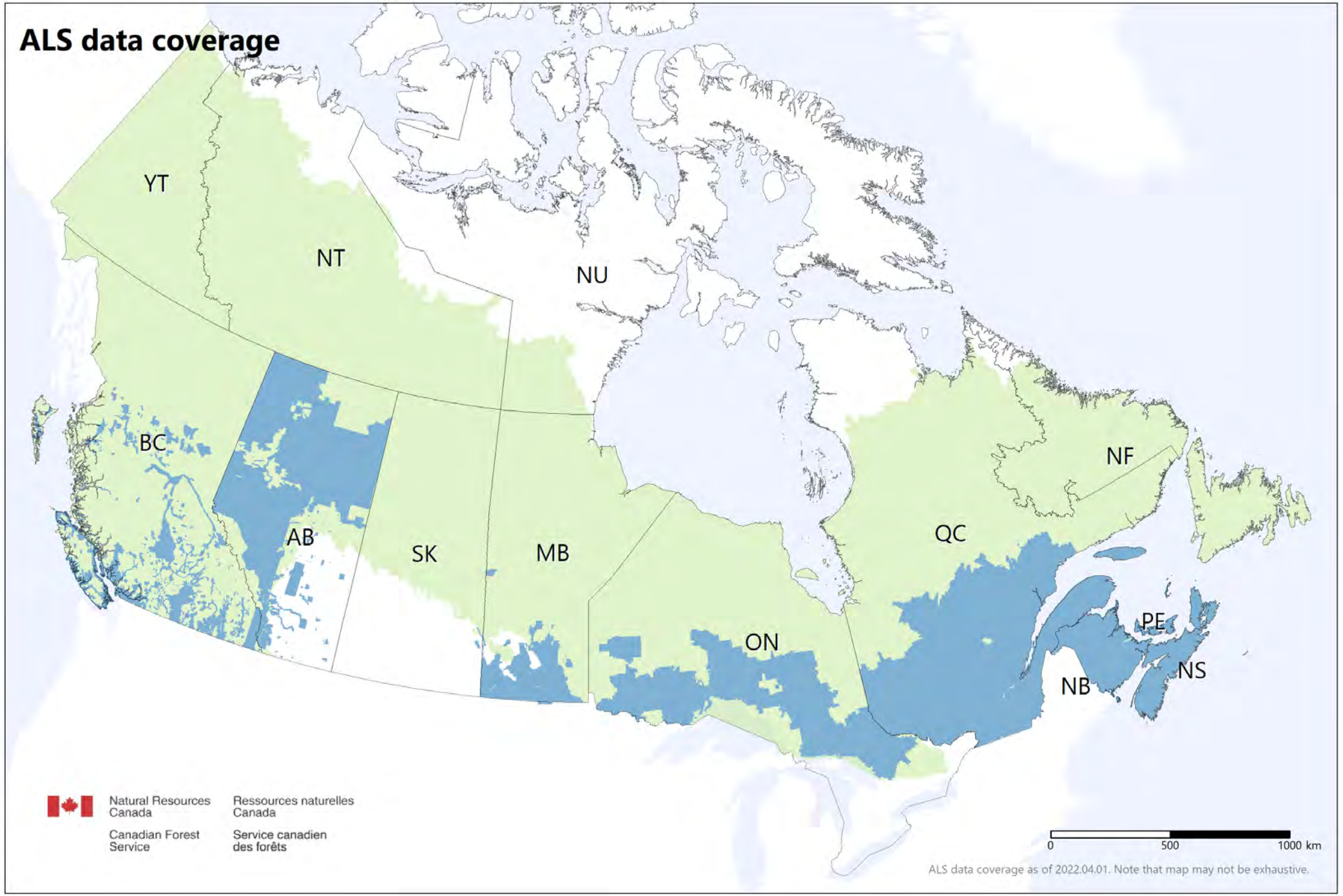
Natural Resources Canada
Ressources naturelles Canada
Canadian Forest Service
Service canadien des forêts
0
500
1000 km


ALS data coverage
YT
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Natural Resources Canada
Canadian Forest Service
Ressources naturelles Canada
Service canadien des forêts
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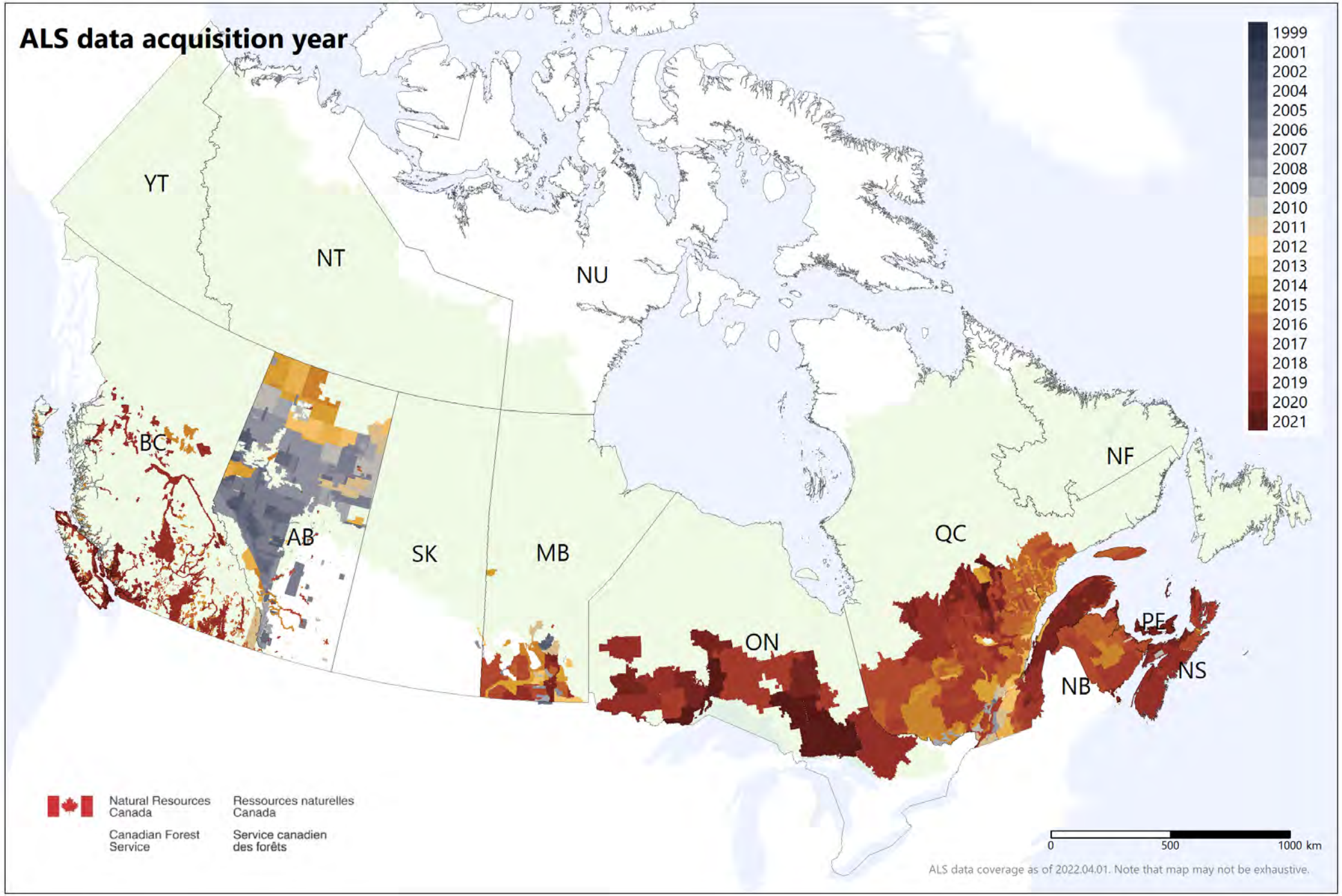
1000 km
ALS data coverage as of 2022.04.01. Note that map may not be exhaustive.


ALS data acquisition year
1999
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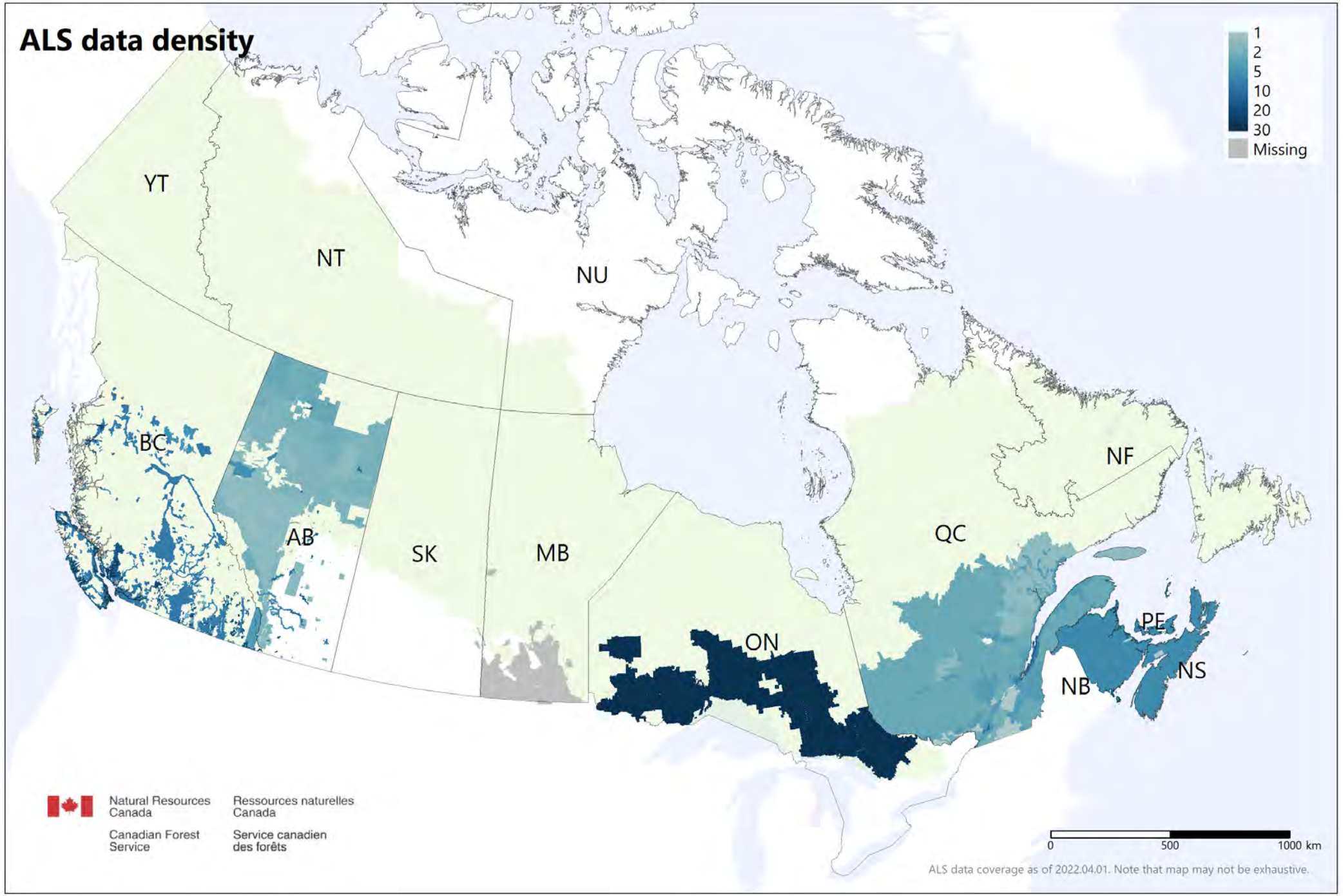
Canadian Forest Service
Service canadien des forêts
0
500
1000 km
ALS data coverage as of 2022.04.01. Note that map may not be exhaustive.


ALS data density
1
2
5
10
20
30
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Natural Resources Canada
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Canadian Forest Service
Service canadien des forêts
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1000 km
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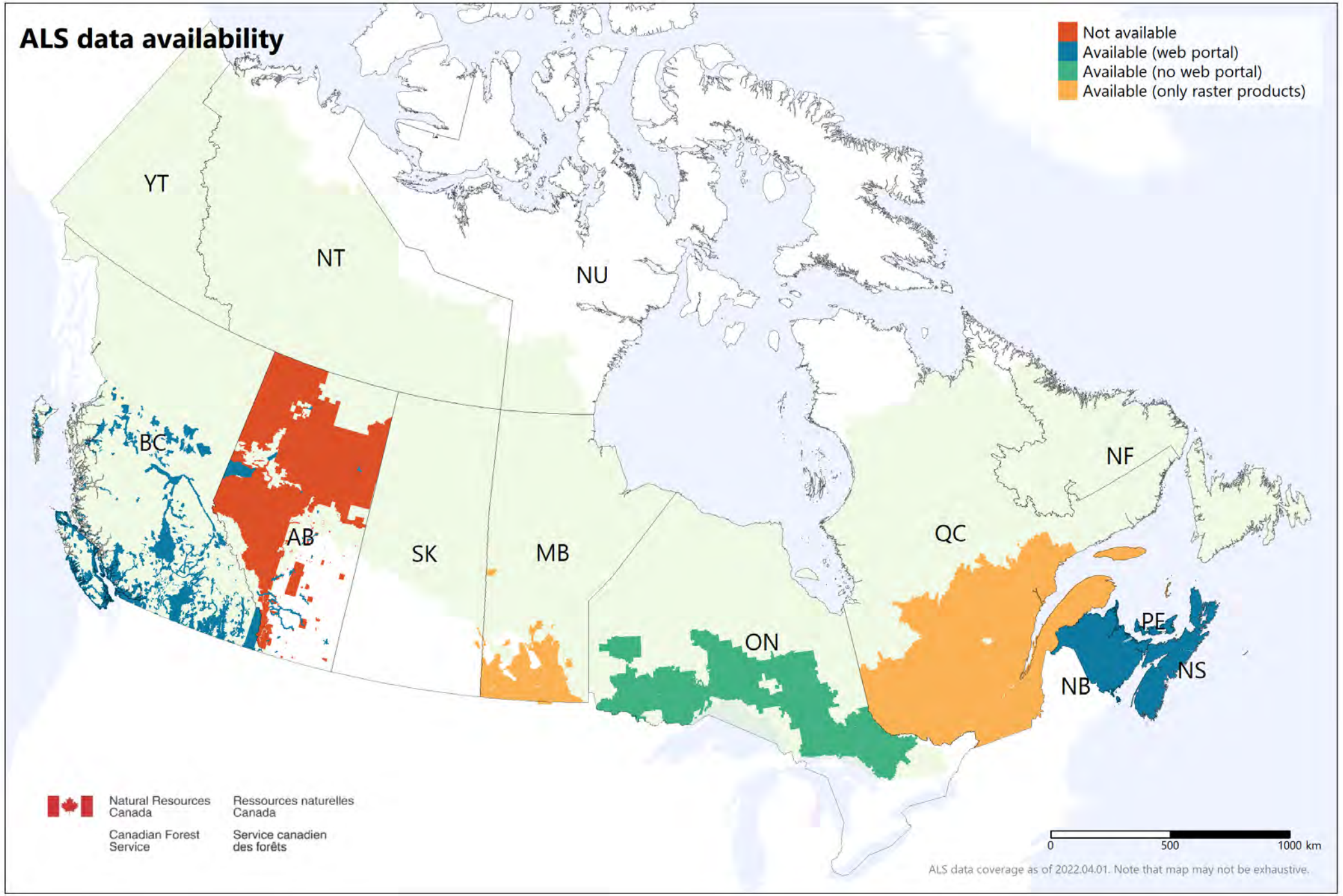
ALS data availability
Not available
Available (web portal)
Available (no web portal)
Available (only raster products)
YT
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BC
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SK
MB
ON
QC
NF
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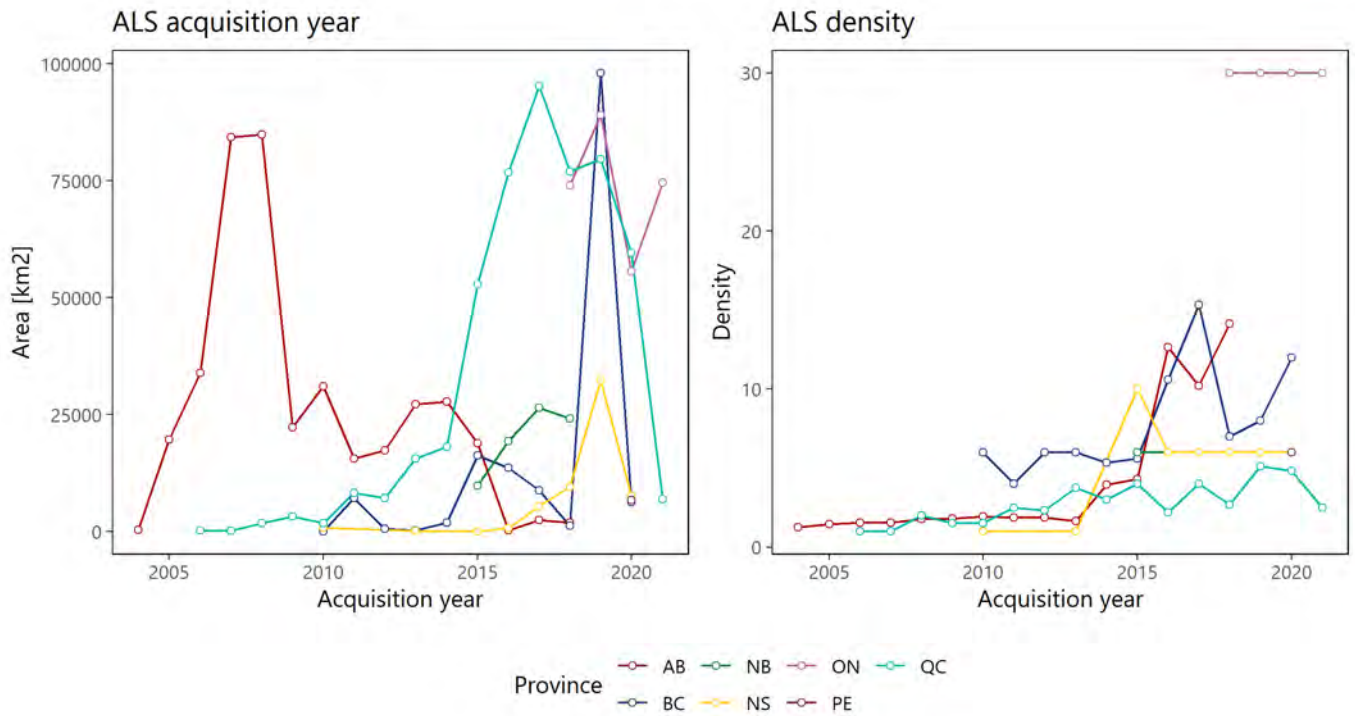
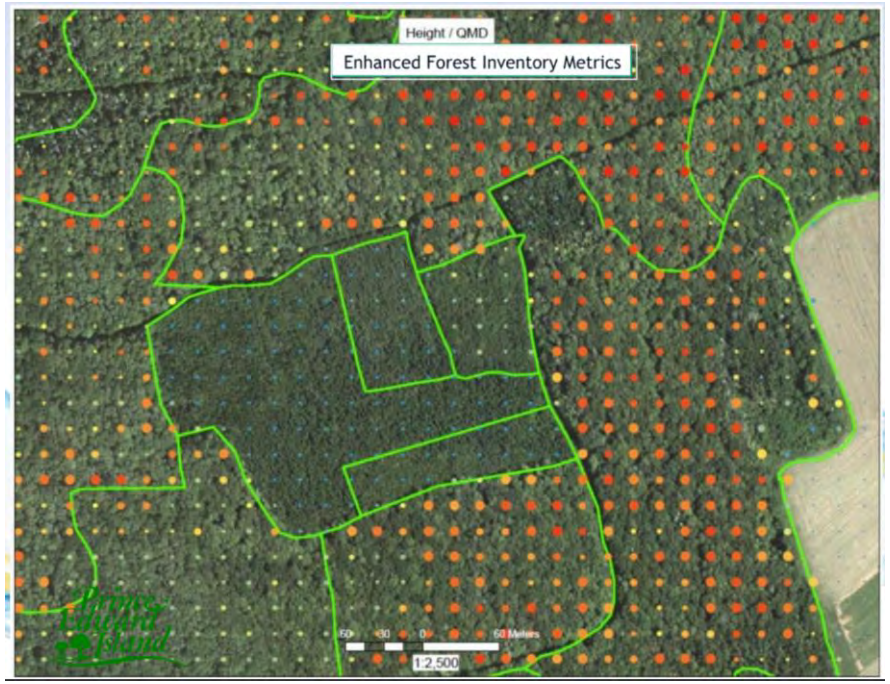
Natural Resources Canada
Ressources naturelles Canada
Canadian Forest Service
Service canadien des forêts
0
500
1000 km
ALS data coverage as of 2022.04.01. Note that map may not be exhaustive.

Province/Territory	Total area	ALS data	
	[km2]	[km2]	[%]
NU	2005993		
QC	1476334	504333	34.2
NT	1281157		
ON	1073591	293343	27.3
BC	915492	154217	16.8
AB	640375	387788	60.6
SK	632049		
MB	626730	82691	13.2
YT	455403		
NF	398609		
NB	74472	74472	100.0
NS	56605	56605	100.0
PE	5765	5765	100.0



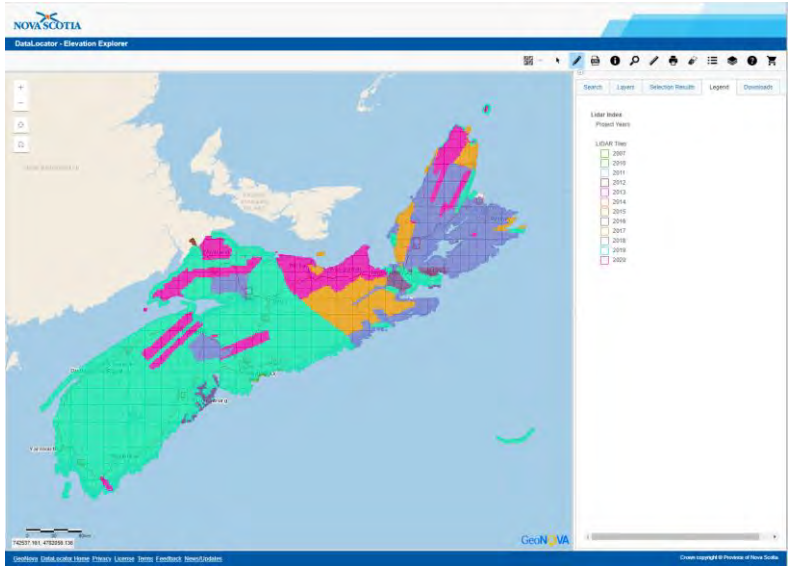
Prince Edward Island

- ALS
  - 100% coverage (2020)
  - At least 6 pts/m^2
- Plot measurements (2 field seasons 2020, 2021) ~830 plots in total
- Aerial photography (NIR + RGB @ 30 cm) > API
- EFI in development
  - Outsourced
  - Top height, dominant/co-dom height, base to live crown, BA, merch BA, QMD, merch QMD, gross total V, percent hardwood, percent BA in 2 cm classes
  - Sentinel-2 imagery to support species classification
- Drone imagery to support post disturbance activities and to update imagery data
- Contact: Andrew Ing (ARING@gov.pe.ca)



Nova Scotia

- ALS
  - 100% coverage,
  - All data available online (https://nsgi.novascotia.ca/datalocator/elevation/)
- EFI:
  - Collaboration with UNB
  - Systems of equations (Yang et al. 2021)
  - ALS predictions of V and HL only, other variables are derived based on these two
  - BA, QMD, and N derived, models developed using PSPs
- Contact: Elizabeth McGarrigle (elizabeth.mcgarrigle@novascotia.ca)



$$\mathrm{VOL} = \mathrm{BA} \Big/ \left(a_0 + \frac{a_1}{\mathrm{HT_L}} \right)$$

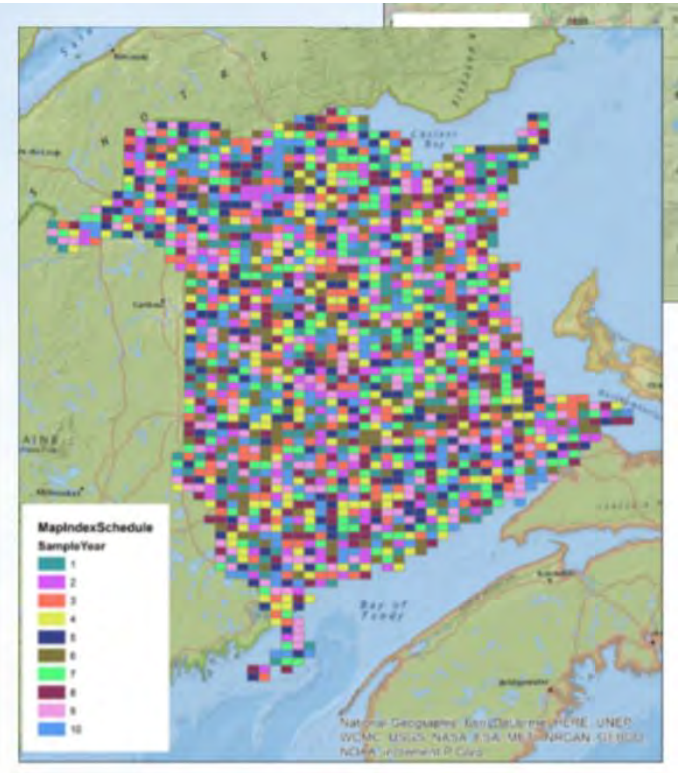
$$\mathrm{QMD} = 9 + d_0 (\mathrm{HT_L})^{d_1} (N)^{d_2}$$

$$N = \frac{\mathrm{BA}}{0.00007854 \times \mathrm{QMD}^2}$$

Yang, T. R., Kershaw, J. A., McGarrigle, E., Ducey, M. J., & Shukla, D. (2021). Application of allometric systems for compatible area-based lidar-assisted estimation in the province of nova scotia. *Canadian Journal of Forest Research*, *51*(11), 1688–1697. https://doi.org/10.1139/cjfr-2021-0070

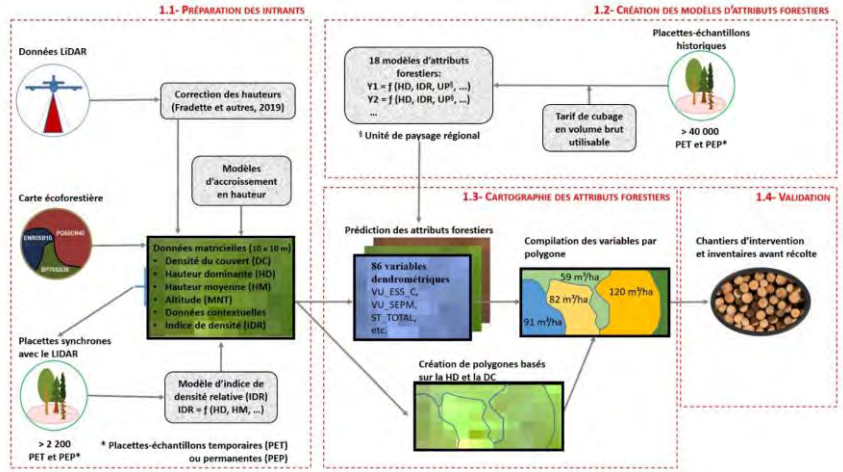
New Brunswick

- 100% ALS coverage:
  - Started in 2013 @ 1 PPM, currently 6 PPM
  - All data available online: http://geonb.snb.ca/
- Photointerpretation:
  - Aerial imagery (10–30 cm)
  - Hard to find photointerpreters – photointerp lite, simplified and automated
  - Needed to get species, ideally would like to stop API
- EFI:
  - Outsourced
  - HT & HT_L, BA, QMD, GMV, NMV, SawVol and many others (e.g. Biomass, diameter distrubition, %Hardwood etc)
  - 20 m grid
- Continuous Landscape Inventory
  - 2 km grid, 15k plots (3k are PSPs), 10% plots measured annually
  - Primary use: EFI calibration/validation; wood supply model calibration, G&Y calibration
- Contact: Dale Wilson (dale.a.wilson@gnb.ca)



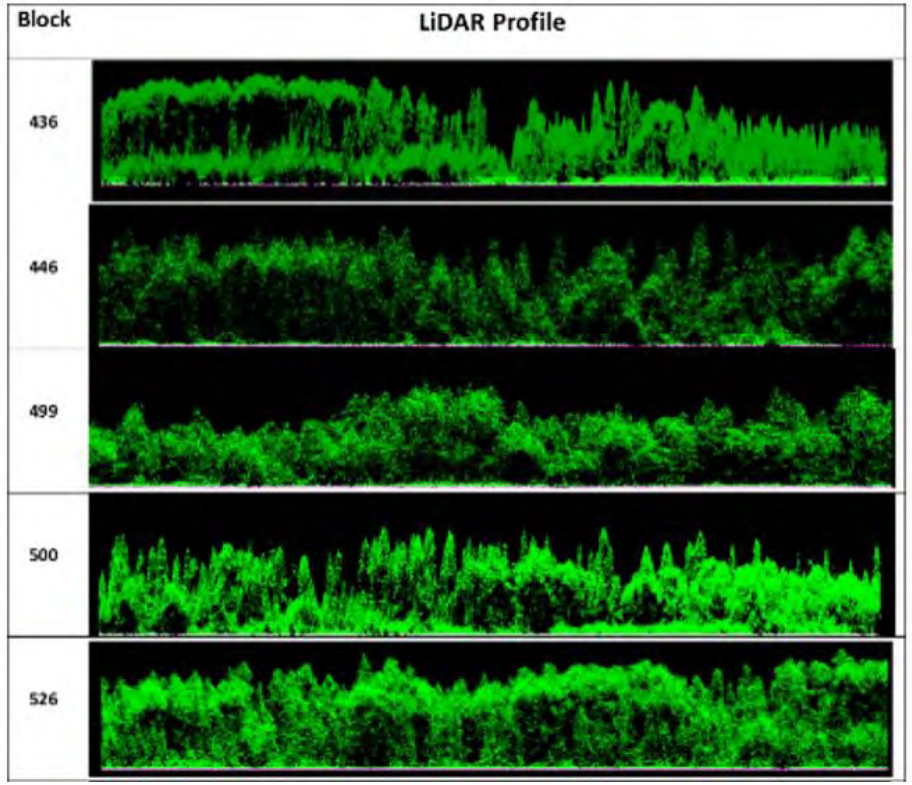
Quebec

- ALS
  - Currently 518,000 km^2 (2.82 x Wash.)
  - Coverage: 99% of managed forest, will be completed in 2022
  - Raster products (CHM, DTM, slope) – open data: https://www.foretouverte.gouv.qc.ca/
  - New ALS coverage starts in 2022 (T2 data; point cloud + 10 cm aerial photo)
- EFI:
  - In-house
  - Stand atributes (80% coverage)
    - >30k plots, kNN, dendrometric models (mffp.gouv.qc.ca/documents/forets/inventaire/carte-dendro-LiDAR.pdf)
    - Comparison to cutblock-based volume (R^2=0.82)
  - Hydrology:
    - topographic wetness index and stream network (vector) for 500,000 km^2 (open data)
    - riparian ecotones 250,000 km^2 (open data)
  - Road network corrections and identification of surface deposits from ALS
  - Species mapping with deep learning (partnership, ongoing)
- Strong emphasis on R&D
- Contact: Dr. Antoine Leboeuf (Antoine.Leboeuf@mffp.gouv.qc.ca)



Ontario

- ALS
  - Currently 227,000 km^2 - 50% of planned acquisition (1.23 x Wash.)
  - SPL; minimum density 25 pts/m^2, average ~30 pts/m^2)
- Plot data
  - ~1200 plots
  - Structurally-guided sampling
- EFI
  - Outsourced; collaboration
  - Ongoing research and implementation plan (White et al. 2021, Queinnec et al. 2021)
  - Subset of attributes predicted directly from ALS, other atributes derived; all on a 20 m grid (e.g. QMD, BA, N, H, V, Vmerch)
- Contact: Ian Sinclair (Ian.Sinclair@ontario.ca)

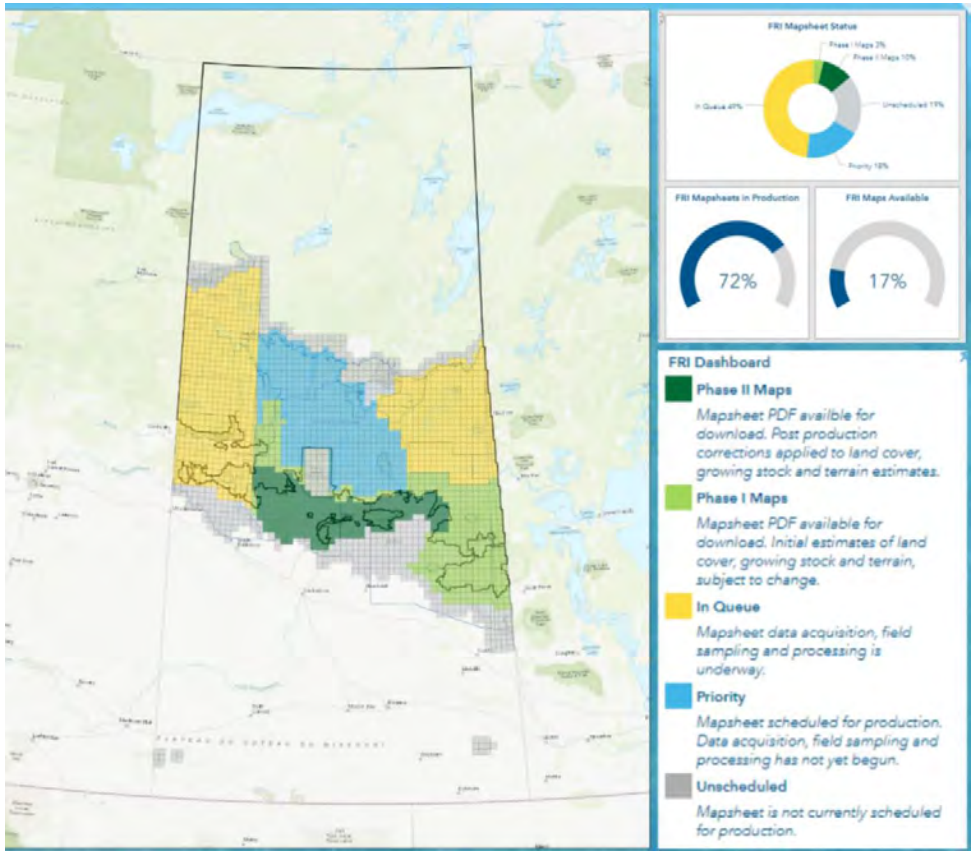


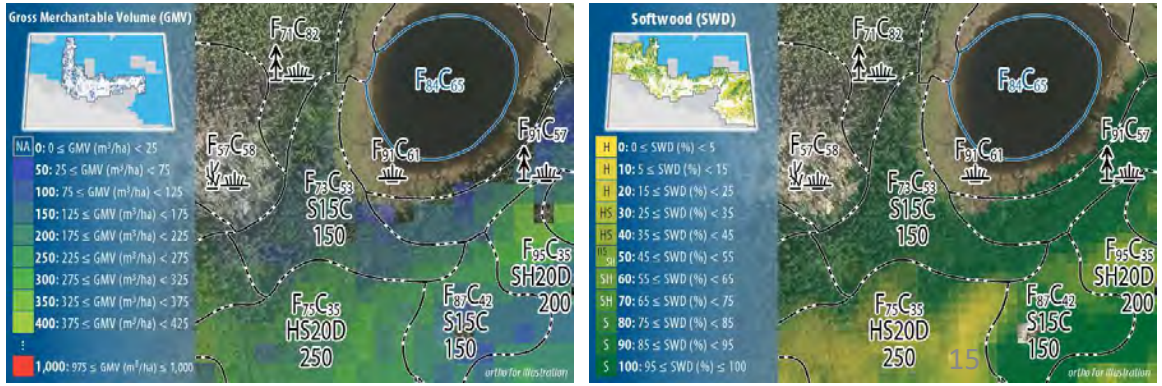
White, J. C., Penner, M., & Woods, M. (2021). Assessing single photon lidar for operational implementation of an enhanced forest inventory in diverse mixedwood forests. *Forestry Chronicle*, *97*(1), 78–96. https://doi.org/10.5558/tfc2021-009

Queinnec, M., Coops, N. C., White, J. C., McCartney, G., & Sinclair, I. (2021). Developing a forest inventory approach using airborne single photon lidar data: from ground plot selection to forest attribute prediction. *Forestry: An International Journal of Forest Research*, 1–16. https://doi.org/10.1093/forestry/cpab051

Saskatchewan

- ALS:
  - none, DSM from MAXAR imagery
  - DTM – SRTM-based (reprocessed)
- EFI
  - Outsourced
  - Based on satellite data, 20 x 20 m grid
  - Available online: https://environment-saskatchewan.hub.arcgis.com/pages/forest_resource_inventory
  - 2 phases
    - Phase1 – initial estimates
    - Phase2 – field audit to remove bias
- Innovation:
  - Dense ALS to replace phase 2 plots
  - Species:
    - Currently have %Softwood
    - Ideally – proportion of species at 20 m grid
    - Competition involving 7 vendors
    - Non-lidar remote sensing data





- Contact: Lane Gelhorn (lane.gelhorn@gov.sk.ca)

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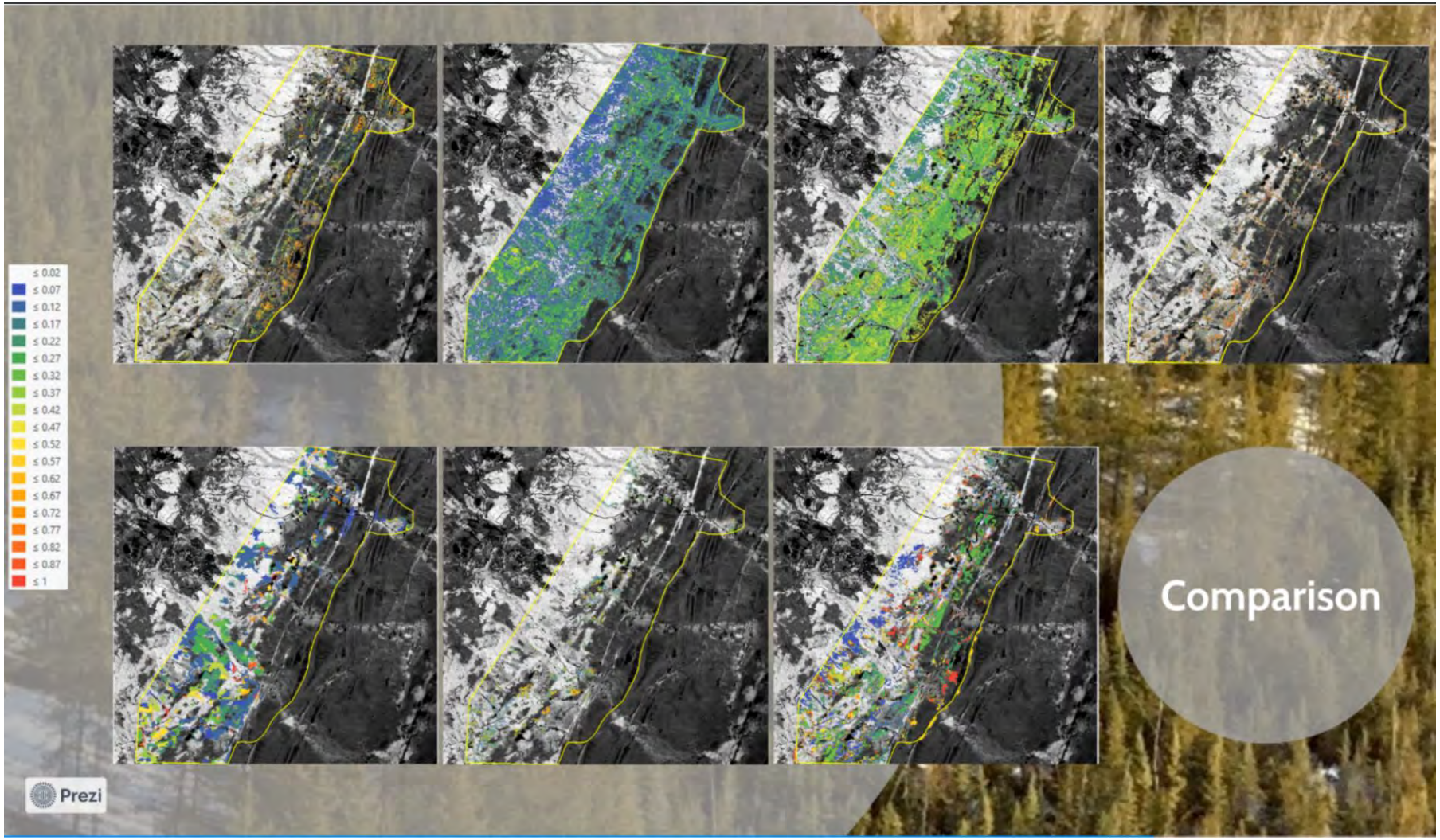
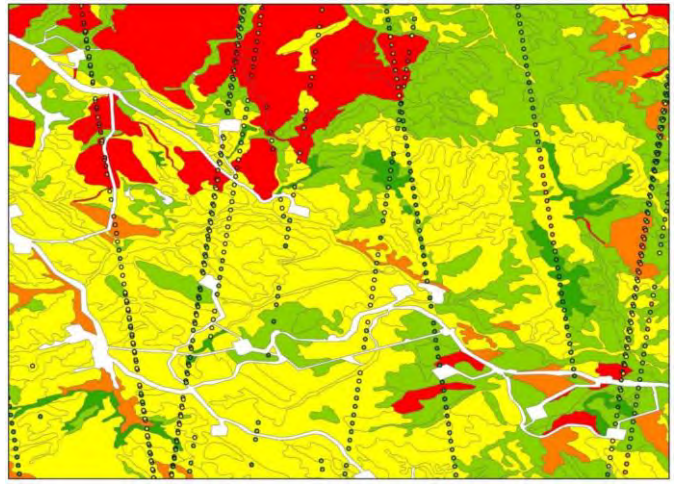
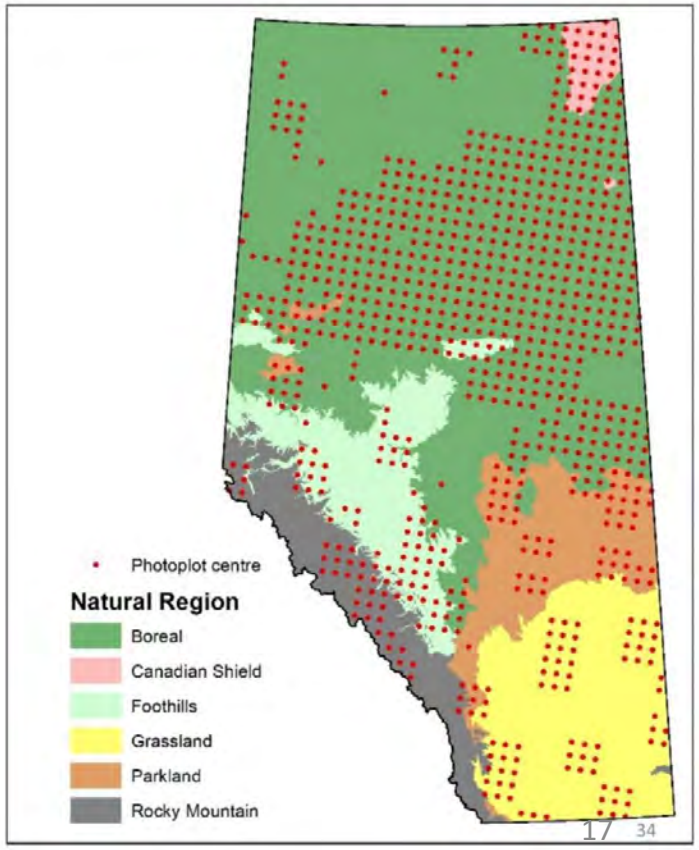
Proportion of white spruce



Alberta

- ALS
  - Most collected by 2008 @ 1-2 pts/m^2
  - Not collected anymore by the province (but many forest companies do collect)
  - Data not open
- EFI
  - Done by the companies (no province-wide standard for EFI)
  - ABA or ITC
- Photo plots for EFI calibration/validation
  - 20 x 20 km grid, each plot 3 x 7 km
  - Available online: https://abmi.ca/home/data-analytics/da-top/da-product-overview/Advanced-Landcover-Prediction-and-Habitat-Assessment--ALPHA--Products/Photoplot-Land-Cover-Data-Training-and-Validation.html
- Multiple ongoing research projects
  - Establishment of AB supersites to test "blackbox" EFI technologies
  - Estimating the area of merchantable stands in previously unmanaged areas (ICESat-2)
  - Assessing regeneration using UAV data
  - Many others
- Contact: Chris Bater (chris.bater@gov.ab.ca)





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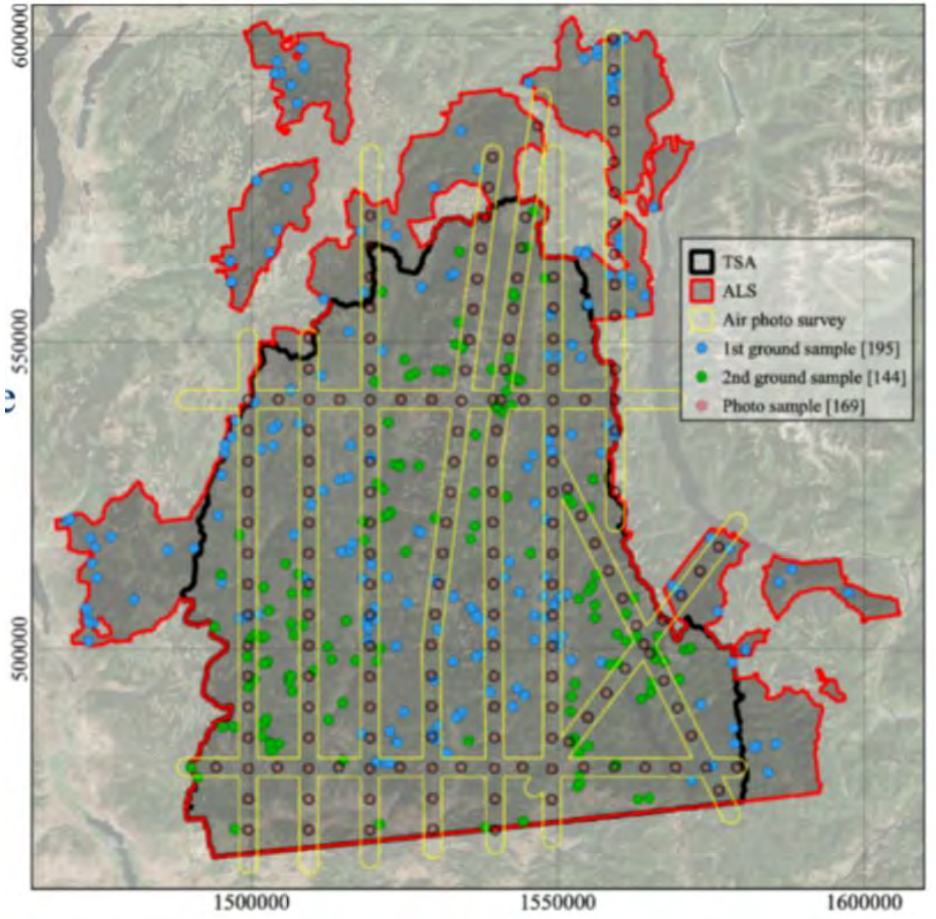
British Columbia

- ALS
  - 16% of BC covered
  - Available online (8 Mha): https://catalogue.data.gov.bc.ca/dataset/d08b2795-d192-4377-8056-eccef50296e6

- EFI
  - In development, in-house
  - Predictive Forest Inventories (PFI)
    - PFI-1 – regression-based inventory attribute prediction based on ground plots
    - PFI-2 – imputation-based inventory prediction designed to use large number of photo samples to predict **leading species and stand age**
    - PFI-2 is based on API, uses ~3 ha segments
    - Final product 20 x 20 m grid
    - Species – overall accuracy ~75%
  - Individual Tree Inventory (Pilot project)
- Contact: Chris Butson (christopher.butson@gov.bc.ca)



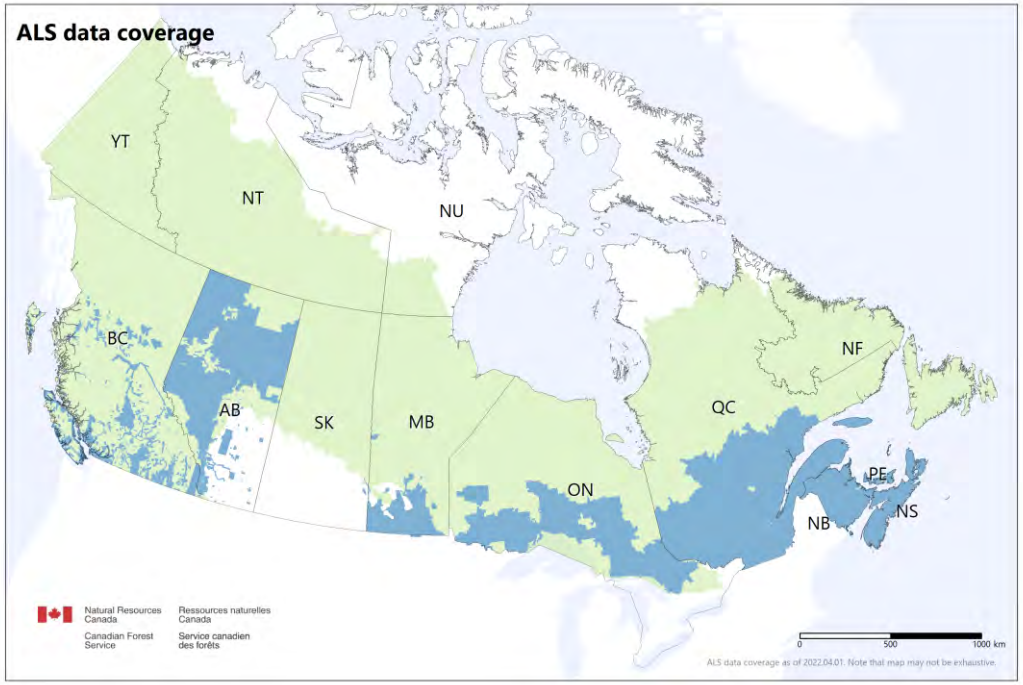
Summary

- Diversity in methods and data used but all have a similar goal: a suite of 20 x 20 m predictions of forest inventory attributes

- Challenges:
  - ALS is not a single-source solution (currently does not provide all info needed)
  - Species (provinces seek/use different solutions: e.g. API, satellite imagery (Sentinel-2), dense UAV lidar as reference data (SK).
  - API is costly and it is hard to find experienced interpreters
  - Capacity to allocate area-based predictions to different layers (ON) by identifying single vs. multi-layer stands and then allocating predictions
  - Except for SK - no widespread use of DAP data (some jurisdictions use simplified vendor products to support API)

Acknowledgements

- Adam Dick (adam.dick@NRCan-RNCan.gc.ca)
- Andrew Ing, Chris Butson, Chris Bater, Antoine Leboeuf, Ian Sinclair, Dale Wilson



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