ASSISTING OTTAWA VALLEY FOREST TRANSITION TO T2 FRI

JWRL Geomatics Inc.

Forestry Futures Ontario

Enhanced Forest Resource Inventory

Knowledge Transfer & Tool Development Program

Project Number: KTTD 11A-2021

PRESENTATION

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Andy Welch, andy@jwrl.ca

JWRL Geomatics Inc.

JWRL was formed in 2011, following the closure of Dendron Resource Surveys (Dendron) Ltd., one of Canada's top forestland survey companies. From ~1985 – 2023, over 500 “forest inventory” projects, some photo-based, some satellite based, some both, progressing through:

Hard copy photos and pocket stereoscopes
Large-scale Aerial Sampling Photography (LSP)
ITC work (Definiens)
stereo photogrammetry

all provinces/territories and several US States
private and public sector clients
various forest inventory requirements, specifications and data uses
diverse ecological conditions.

Considerable Ontario FRI work, for the province and for forestry companies.

JWRL's UNDERSTANDING OF ONTARIO'S "T2" eFRI:

- No optical imagery.
- LiDAR data for heights, crown closures and volume related metrics.
- an eventual move to rasterized vs polygonal product.
- a continuous forest inventory model.

For the 1st 5 or so years:
Existing FRI polygonal products (from photo interpretation) may be used in the transition towards new inventory models and products.

THE PROBLEM:

Key inventory attributes such as tree species, mixedwood characteristics and multi-tiered stands may present challenges to the T2 approach, especially in the Great Lakes St. Lawrence Forest region (GLSL).

- The quality of the existing polygonal FRI for these attributes can be inconsistent.
- In the case of the Ottawa Valley Forest (OVF), the T1 eFRI was rejected.
- They are using a 1998 FRI product.

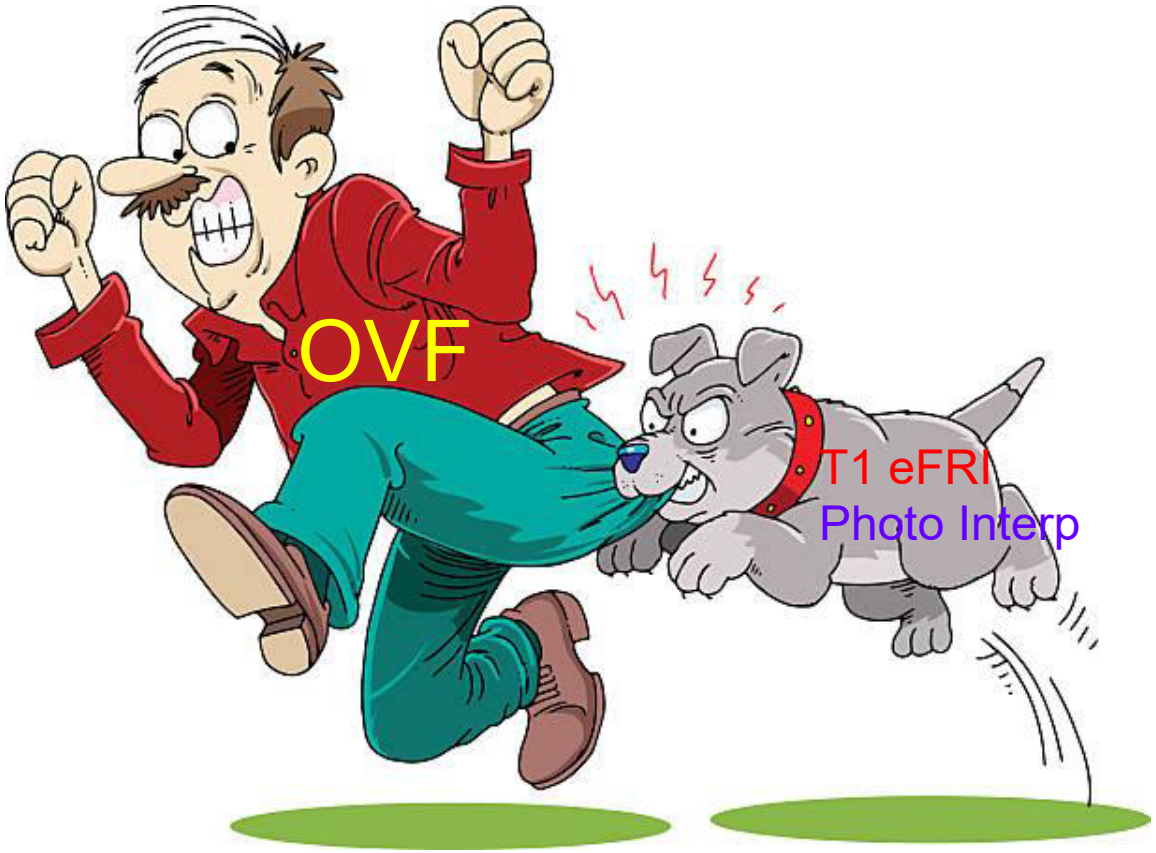
It is suspected that other Management Units in the GLSL forest are dealing with similar situations.

TO HELP OVF TRANSITION TO THE T2 EFRI:

- Provide an operational alternative for species identification, which may be challenging for T2 approaches.

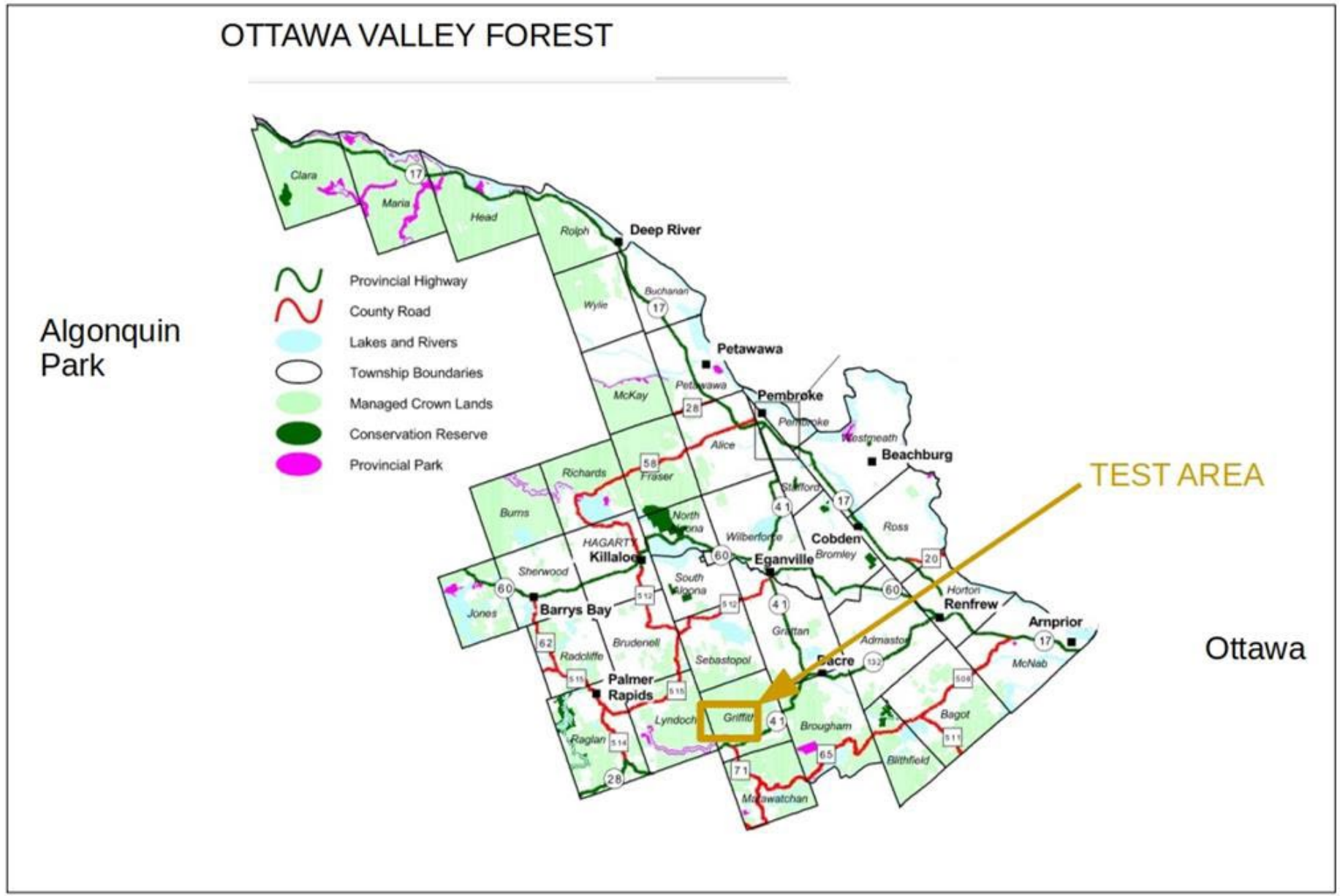
- In so-doing, improve the baseline polygonal FRI base which can be incorporated into calibration/validation processes related to the T2 FRI.

Challenge # 1: finding a collaborator

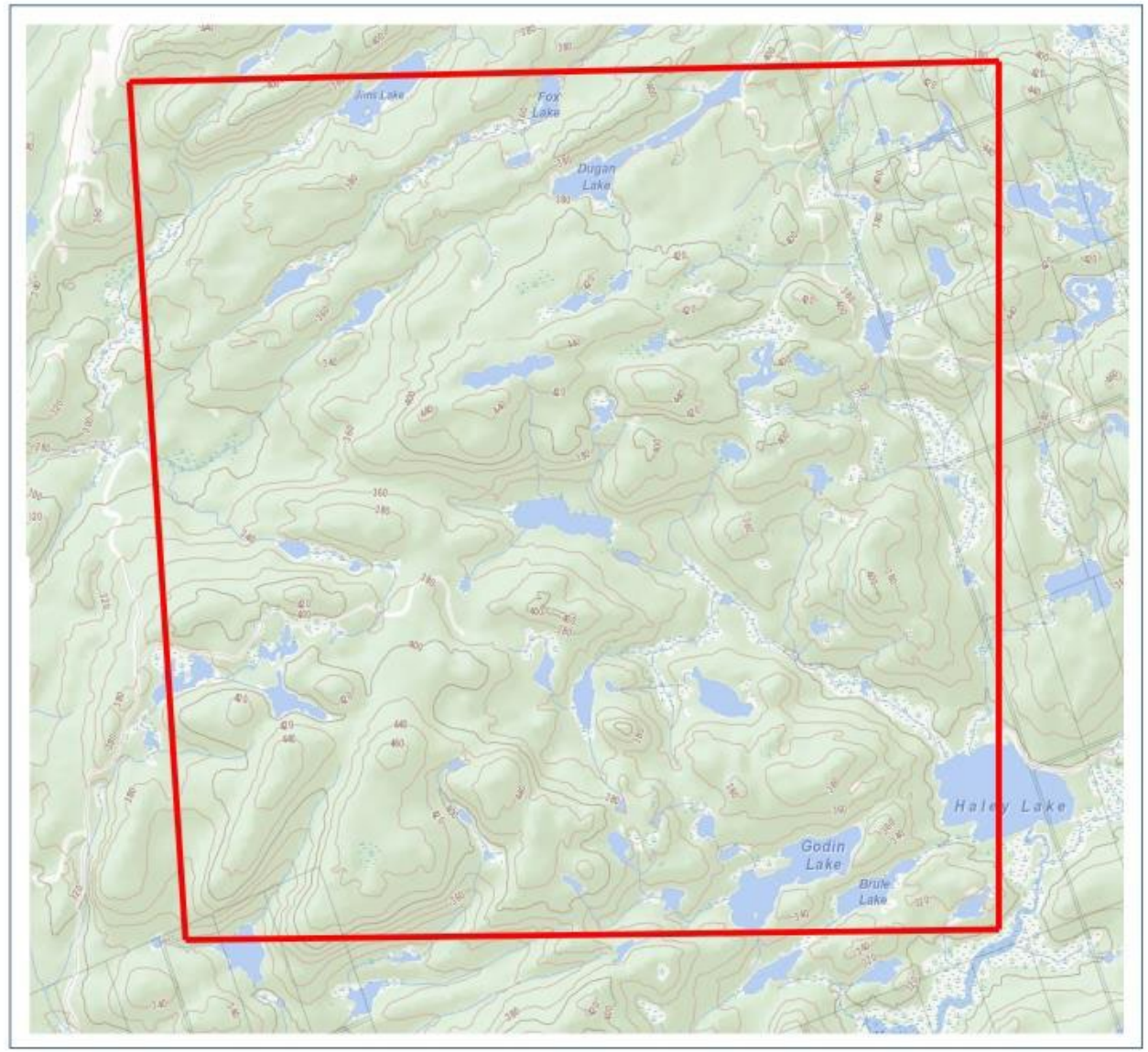


JWRL's Message: "don't throw out the baby with the bathwater" (still remains a hard sell)
Photo Interpretation is a proven technique which should be part of the FRI Toolbox, for T2 and beyond

OTTAWA VALLEY FOREST

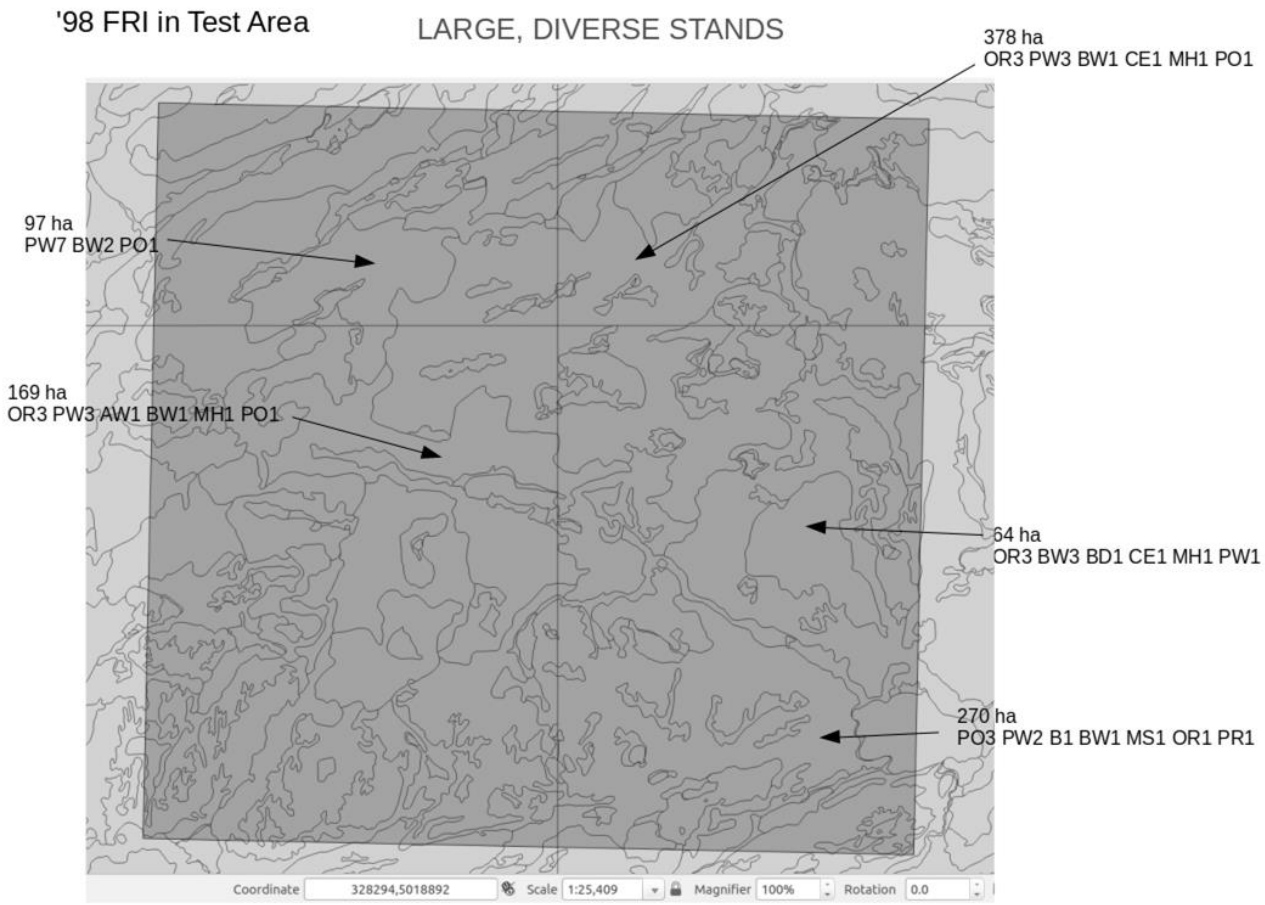


OVF, Griffith Township, Test Area: Madawaska Highlands, GLSL Forest



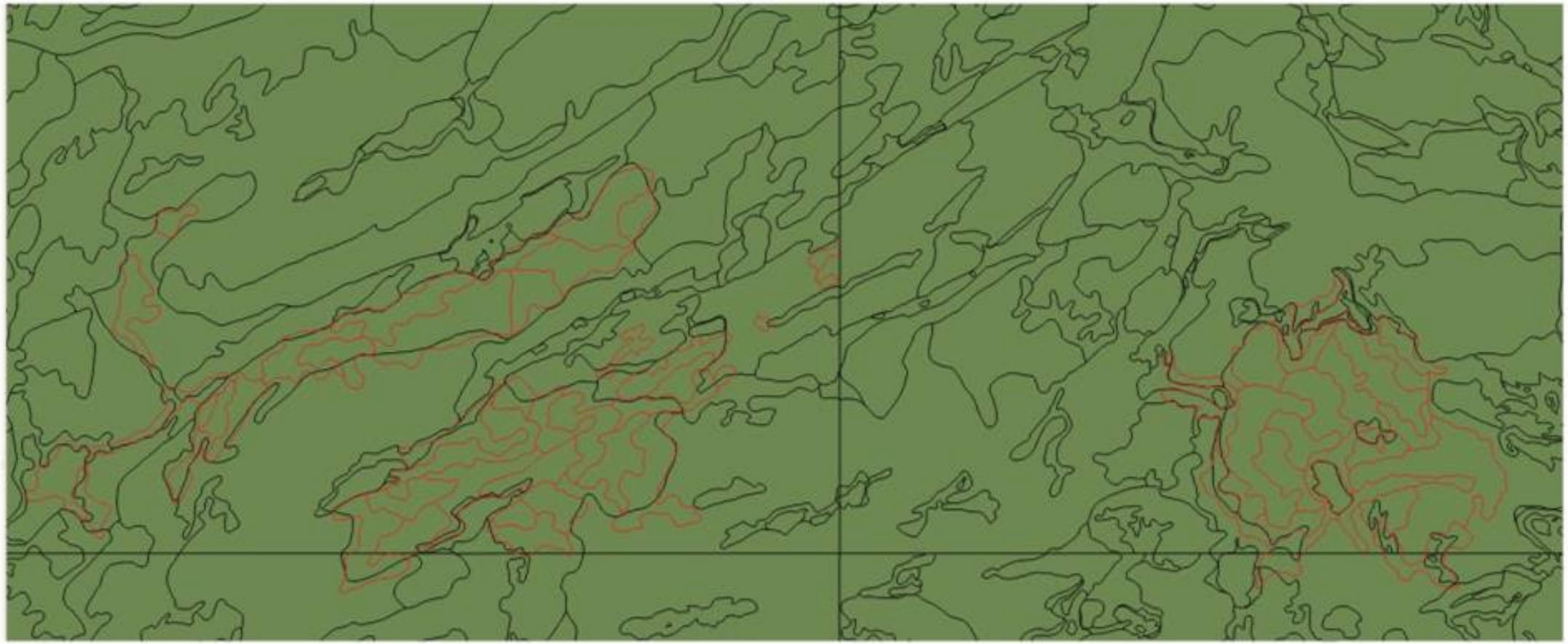
Mature, mixed-wood, GLSL Forest: primary commercial interest in pine and tolerant hardwoods

OVF's "Current" Forest Inventory



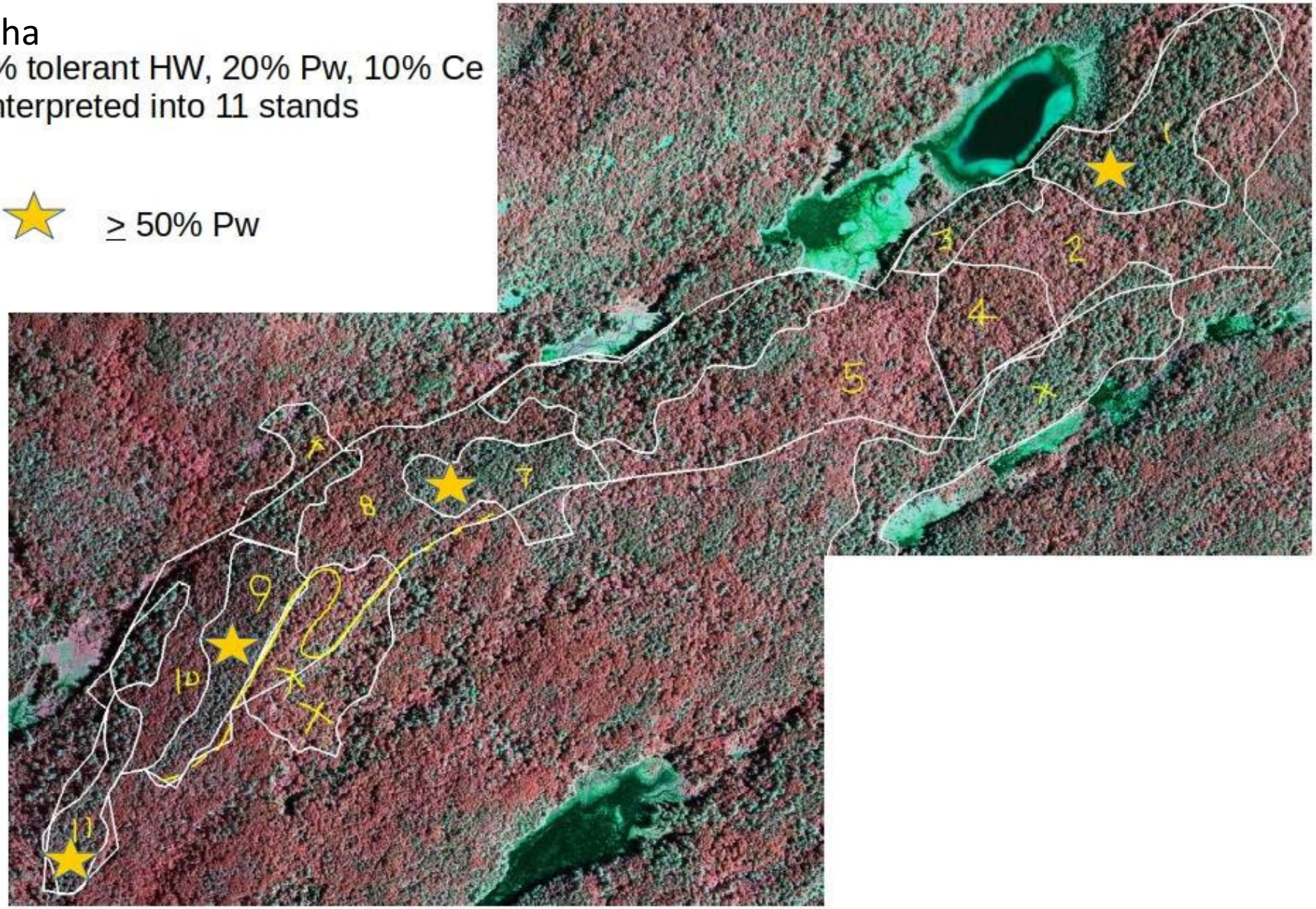
JWRL's main task: conduct a reinterpretation, using the 2009 eFRI imagery (T1),
using a highly experienced Photo Interpreter

1998 FRI stands (black lines) reinterpreted (red lines)



68 ha
70% tolerant HW, 20% Pw, 10% Ce
reinterpreted into 11 stands

≥ 50% Pw



1998 FRI: stand 82110: OR3 MH2 PW2 BE1 BY1 CE1 – 68 ha - 19m

i.e.: OrMh stand, 70% hw

Reinterp (using 2009 imagery)
to 11 stands

poly 1 - Pw6 Pt2 Or 1 Mh1, 26m	Pw60
poly 2 - Mh4 Or2 Pw2 Pt1 Ce1, 17m	MhOr60
poly 3 - Ce4 Pw2 Pt2 He1 Fb1, 14m	sw80 with CeHe50
poly 4 - Pt6 Mh2 Pw1 Sw1, 20m	Pt60
poly 5 - Mh4 Or2 Pw2 Sw1 Pt1 – 17m	MhOr60
poly 6 - Pw5 Pt2 Mh2 Or1 - 24m	mixed Pw50 MhOr30
poly 7 - Pw7 Mh1 Pt1 Or1 -18m	Pw70
poly 8 - Or2 Pw2 Pt2 Mh2 Sw1 Fb1 – 22m	mixed OrMh40 Pw20
poly 9 - Pw6 Pt2 Sw1 Or1 – 14m	Pw60
poly 10 - Pt4 Pw3 Mh1 Sw1 By1 – 17m	mixed Pw30 MhBy20
poly 11 - Pw6 Pt1 Or1 Fb1 – 22m	Pw60

Summary with hts (m):
4 Pw stands, 26, 18, 14, 22
2 MhOr stands, 17, 17
3 mixed Pw MhOr, 24, 22, 17
1 sw (with 50% Ce & HE), 14
1 hw stand, 20

SUMMARY OF ISSUES WITH OVF'S EXISTING INVENTORY:

Many of the '98 FRI stands in the Griffith test area are large and diverse.

- Commercial timber areas are not well located or quantified (species, heights, areas). Also, a possible problem with the '98 FRI misidentifying Red Pine as Hemlock.

- Wildlife habitat management is similarly difficult, with cedar and hemlock areas for deer management not well identified.

WITH RESPECT TO THE T2 eFRI

In a 2022 email, Dr. Margaret Penner kindly provided this with respect to tree species composition in the T2 eFRI:
"The polygon boundaries as well as species composition and age will be taken from the T1 inventory. Heights, volumes, basal area and most other quantitative tree attributes for T2 will be predicted from LiDAR (and field calibration plots). These LiDAR-derived attributes will be provided at the raster scale (20 x 20m) as well as rolled up to the T1 polygons."

Polygon boundaries and species composition will remain problematic for OVF if LiDAR results are merged with the '98 FRI stands – they are too large & diverse.

Through the reinterpretation process, the polygons were considerably reduced in size, with much more reliable species information. This will:

- provide a much more reliable T2 eFRI,
- better locate tree species of commercial importance,
- provide better data for planning with respect to harvest methods (e.g., selection vs shelterwood),
- better locate suitable deer yard areas which affect 40% or more of OVFs allocations.

OVF COMMENTS:

After an initial review of the reinterpretation, but before any field visits, the following comments were provided by OVF:

- Overall positive impression re the improvement in species composition and stand delineation vs the '98 FRI,

- Any reinterpretation costs, borne by OVF, would have to be matched with cost savings in Field Operational Planning (FOP) work (e.g., FOP pre-walking planning, mapping of treatment areas). This has yet to be determined.

- Due to existing schedules and priorities, field checking of JWRL re-interpretation will take some time.
  (a key forest inventory (not just Photo Interp) characteristic)

Probably the preferred approach (for OVF) would be for MNR to create a brand new eFRI for the OVF, with new aerial imagery providing up-to-date stand boundaries and species composition.

If this is not possible, the reinterpretation approach undertaken during this project could be utilized.

Since the T2 eFRI LiDAR data should provide all the height related metrics, the reinterpretation process:

- can be focused on stand delineation and tree species and composition, making the process faster and more cost effective (CHM for delineation?).

The process could be further streamlined:

- applied only to areas likely to be of interest in the short-medium term,
- restricted to species/species groups of most interest,
- restricted to stands > 4ha.

Subsequent to the project, discussions with end-users indicate:

A process based on using in-house (SFL) resources makes a lot of sense:

- species identification is readily (but not quickly) learned,
- in particular by those with familiarity with the forest,
- an ongoing interpretation process could be scheduled for slow periods, with ongoing field work providing calibration/validation.

Need to address:

- Training: at least 3-5 years (not full time)
- Internal Quality Control

FYI:

Based on this initial work JWRL estimated a price of just under $2.00/ha to undertake just the interpretation component, as an independent contractor.

This covers overhead and profit on the interpretation component of the work.
It does not cover such things as:

- field calibration work,
- imagery cost,
- GIS management costs.

OTHER PROJECT SUBJECTS

Inventory Update

'98 FRI information 30 years old,
T1 eFRI imagery 10-15 years old,

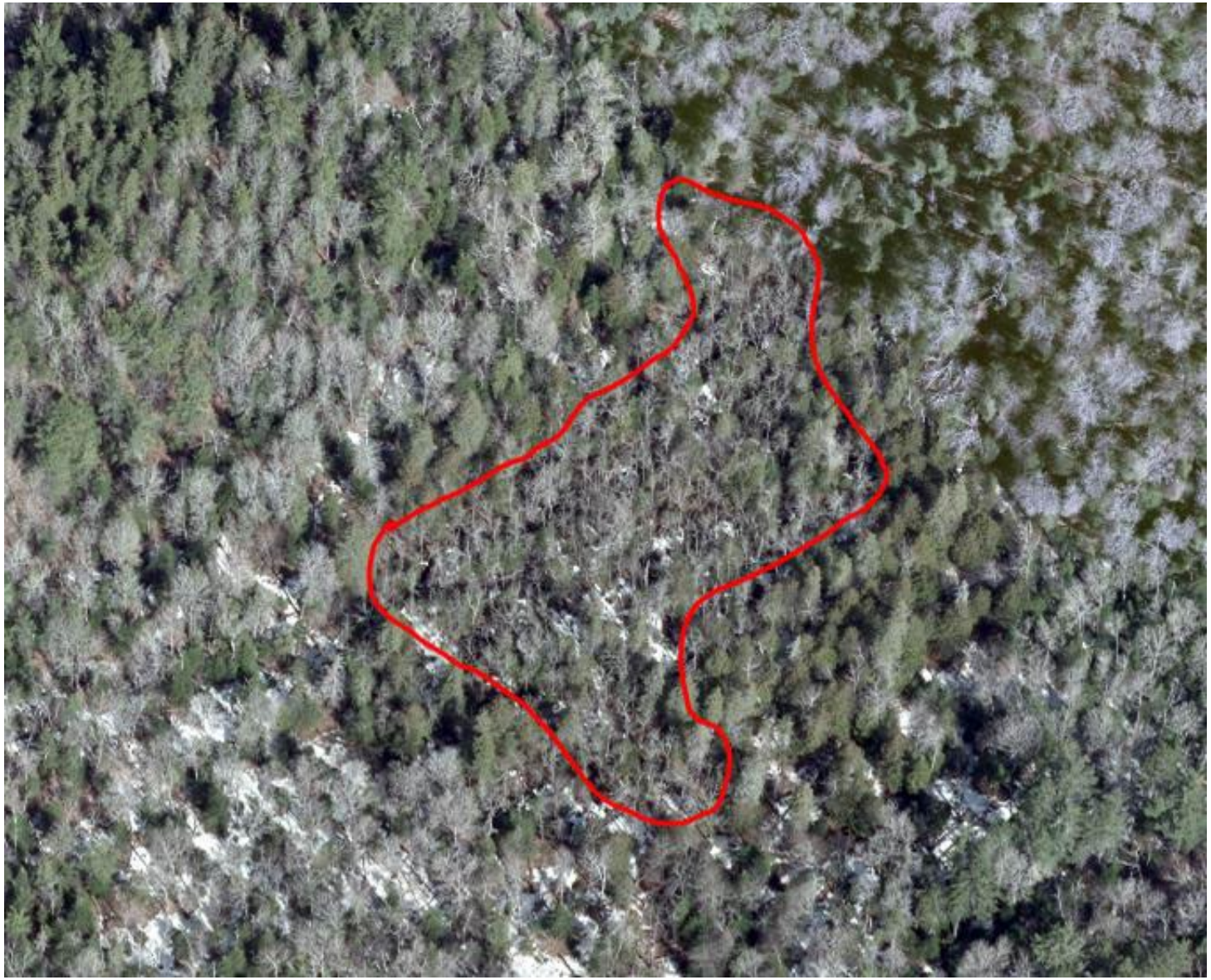
Updating for disturbance only, not growth (LiDAR)

Readily available, 2019, DRAPE imagery (and possibly every 5 years??).

- Orthorectified Tiles - 1km x 1km, Pansharpened, 16cm resolution, 8-bit, RGBNiR in .TIF format (150MB/tile) and a compressed tiled .TIF format (approx. 10MB/tile)
- Stereo data - Vexcel UltraCam X and Vexcel UltraCamEagle frame based - 12 cm resolution, 16 bit, RGBNiR (sizes vary, please see index)

Main Constraint: Imagery flown in leaf-off conditions, making species interpretation in deciduous areas a challenge.

DRAPE orthophoto image quality



INTERPRETER OBSERVATIONS

The 2019 DRAPE would be very useful for reinterpretation:

- for disturbance update,
- for ancillary information during the interpretation.

The stereo product and related viewing techniques are recommended but a good job is possible using the ortho product only.

Softwood species can be identified quite well on the ortho DRAPE (stereo would improve results).
Poplar and birch were easier to identify than other hardwoods (oak, maple, beech, basswood, ash) on the leaf-off imagery. Stereo imagery is unlikely to significantly improve results.

Because of the leaf-off condition, deciduous and coniferous species are better distinguishable from each other than under full leaf conditions.

- improved species composition attributes in areas where conifer cover is often partially obscured by deciduous.
- applicability for other applications such as conifer understories.

CANOPY HEIGHT MODEL (CHM)

Canopy Height Models (CHM) derived from LiDAR data are expected to play a major role in the eFRI and FMP processes.

Canopy height is a key determinant of stand delineation and attribution and as such, having related products available during interpretation could improve products/process.

Even without any photo interpretation being undertaken these products could be of help during operational planning, in particular if large, diverse stands such as those in OVF's ‘98 FRI are being utilized. Species information may remain problematic.

LiDAR derived CHM were not available for this project so a photogrammetrically derived CHM was created for the project by Aeroquest Mapcon utilizing stereo DRAPE imagery.

Overall, the leaf-off nature of the DRAPE imagery resulted in a CHM which considerably underestimated canopy heights of deciduous components of the stands.

While some observations relevant to interpretation are made in the Final Report, this subject was not pursued further.

The LiDAR derived CHM would support the reinterpretation especially with respect to stand delineation.

SENTINEL-2 (S2) SATELLITE IMAGERY DEMONSTRATION

Ecological variability on the ground makes **automated** FRI-level species identification and composition a challenge.

One bright light: Sentinel-2 (S2) optical satellite imagery.

- freely ($$) available,
- acquired every 5 days, with historical sets dating back to 2015-16.
- 10 m (and 20 m) spatial resolution.

While the spatial resolution may be relatively coarse, it is in line with the possible 10m T1 eFRI raster product.

The cost (free) and frequency (every 5 days) provides a new model of image analysis to address the FRI species identification issue - a multi-temporal analysis of known conditions on the ground (eg. phenological, weather) may help solve the FRI species identification problem.

Not a quick fix for the species identification issue. Considerable site-specific R&D will be required.

Ground Truth for Image Analysis

From JWRL reinterpreted stands, 58 were selected:

- 12 stands with Ce as the leading species,
- 15 stands with the combined species composition of Mh and Or leading,
- 20 stands with the combined species composition of Pr and Pw leading,
- 11 with Pt leading,

where ‘leading’ was defined as 60 to 100% species composition.

The polygons containing each of these species characteristics were assessed on S2 images, via Normalized Difference Vegetation Index (NDVI)

measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs)

for all available S2 images over a 3-year period, 2019 – 2021, without discriminating for image quality (e.g. cloud cover)

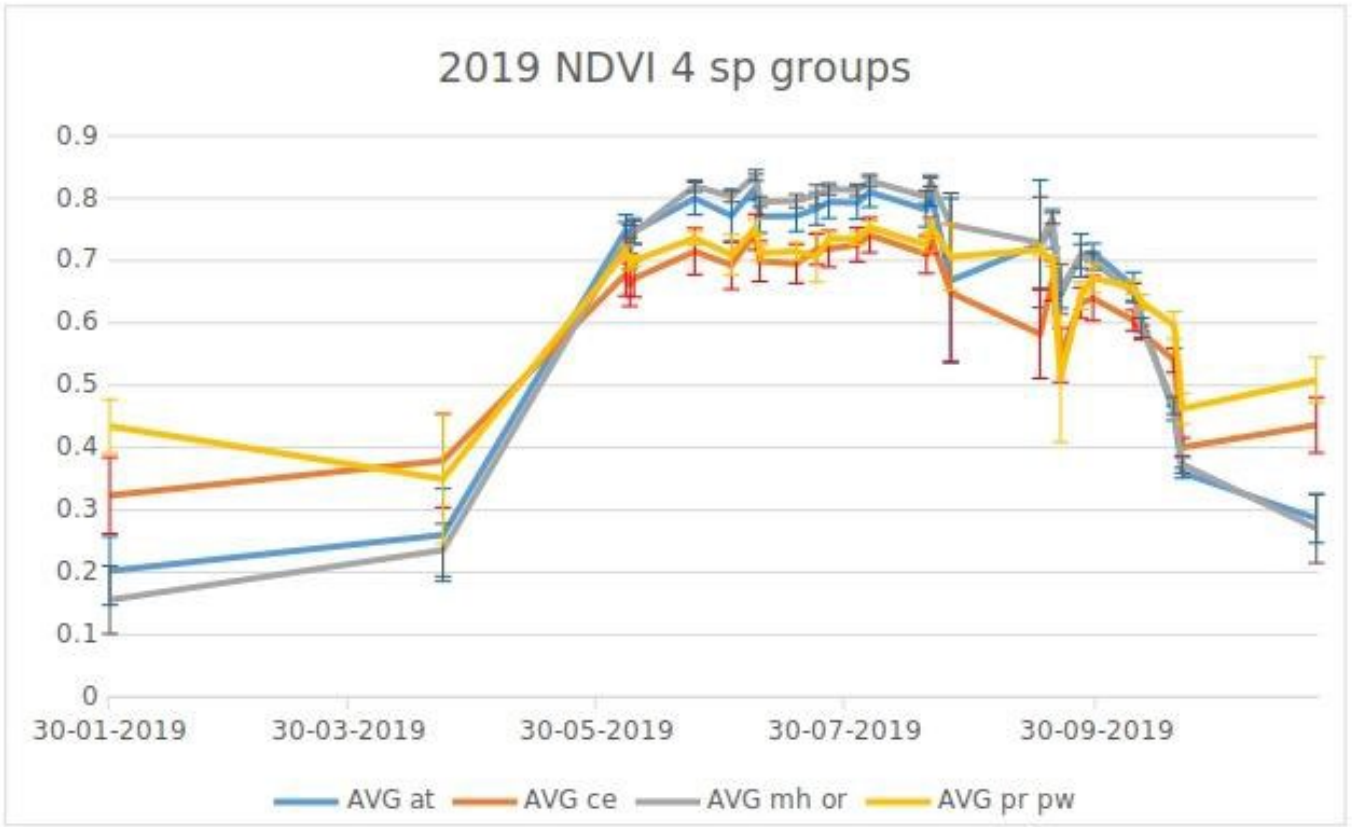
JWRL accessed and prepared a time series of S2 images covering the OVF test area, for each of 2019, 2020 and 2021

Dates of S2 imagery			
2019	2020	2021	Total
27 images	33 images	25 images	85 images
30-01-2019	17-01-2020	04-02-2021	
22-04-2019	06-04-2020	29-03-2021	
06-06-2019	22-04-2020	02-04-2021	
07-06-2019	23-04-2020	08-04-2021	
08-06-2019	06-05-2020	23-04-2021	
23-06-2019	13-05-2020	13-05-2021	
02-07-2019	18-05-2020	27-05-2021	
08-07-2019	21-05-2020	31-05-2021	
09-07-2019	23-05-2020	10-06-2021	
18-07-2019	24-05-2020	12-06-2021	
23-07-2019	07-06-2020	15-06-2021	
26-07-2019	15-06-2020	17-06-2021	
02-08-2019	17-06-2020	20-06-2021	
05-08-2019	18-06-2020	22-07-2021	
19-08-2019	20-06-2020	04-08-2021	
20-08-2019	04-07-2020	24-08-2021	
25-08-2019	05-07-2020	31-08-2021	
16-09-2019	07-07-2020	16-09-2021	
19-09-2019	25-07-2020	20-09-2021	
21-09-2019	12-08-2020	28-09-2021	
26-09-2019	14-08-2020	23-10-2021	
29-09-2019	26-08-2020	27-10-2021	
09-10-2019	31-08-2020	28-10-2021	
11-10-2019	06-09-2020	04-11-2021	
19-10-2019	20-09-2020	24-11-2021	
21-10-2019	22-09-2020		
23-11-2019	25-09-2020		
	23-10-2020		
	30-10-2020		
	31-10-2020		
	09-11-2020		
	12-11-2020		
	14-11-2020		

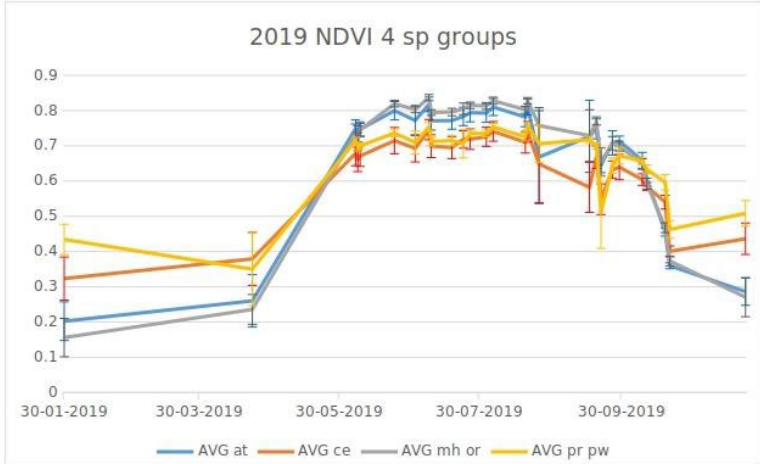
This wealth of data not available previous to S2

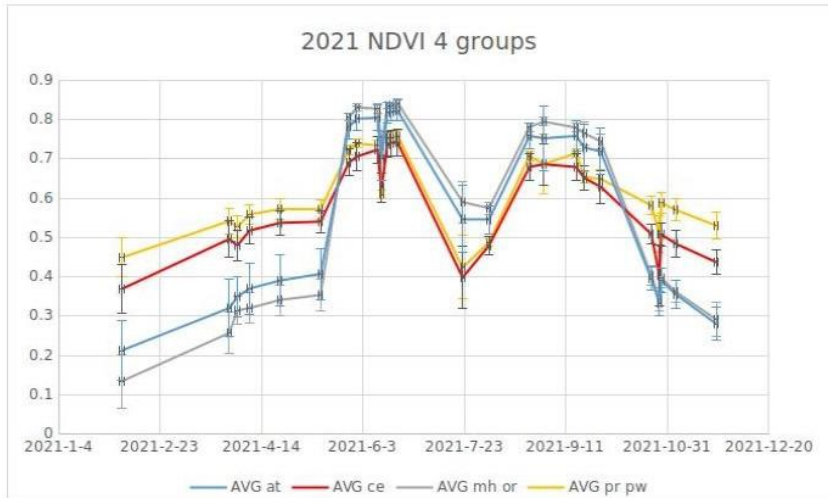
NDVI Assessment

Using Google Earth Engine, NDVI averages and standard deviations were calculated for each stand of species groups, on each S2 image.



at	Trembling Aspen
ce	Cedar
mh	Hard Maple
or	Red Oak
pr	Red Pine
pw	White Pine


2019 NDVI 4 sp groups
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30-01-2019
30-03-2019
30-05-2019
30-07-2019
30-09-2019
AVG at
AVG ce
AVG mh or
AVG pr pw


2021 NDVI 4 groups
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2021-1-4
2021-2-23
2021-4-14
2021-6-3
2021-7-23
2021-9-11
2021-10-31
2021-12-20
AVG at
AVG ce
AVG mh or
AVG pr pw

Preliminary Observations:

The NDVI seasonal curves show some differences for the four tree species groups, and,
A number of the differences are consistent over the 3 years.

During leaf-off periods (before April, after October) of each year, all 4 groups may be differentiated,

During leaf-on, possibly only deciduous versus conifers can be differentiated.

It may, therefore, be possible for these 4 groups to be classified via automated means,
although the error bars show classification will produce confusion among groups.

Considerably expanded R&D is required to show:

Whether these initial observations hold promise

Whether other distinctions are possible

Possible components of expanded R&D:

- an evolving stack of time series S2 data, 7 years of data are currently available,
- individual tree species versus species groupings,
- calibration/validation data from photo interpretation – the stands used for preliminary observation ($\geq$ 60% leading species composition) could be easily broken into more homogeneous subsets (e.g. 1 ha ‘pure’ samples),
- drone imagery as part of an expanded field campaign,
- additional image analysis, expanded beyond only NDVI,
- accounting for the impacts of factors such as snow on the ground, cloud cover, etc.,
- Accounting for differing ecological conditions (elevation, slope, aspect….)
- +++???

IN CONCLUSION:

Photo Interpretation can provide an efficient and cost effective means of supporting FRI efforts, for T2 and beyond. Province-wide programs may not be necessary or effective.

Requirements:

- Experienced Photo Interpreters (with target areas), 3-5 year training period.
- Ongoing and systematic internal Quality Control.
- Expanded involvement of end-user groups (e.g. SFL holders).
- Expanded and dynamic tool-box approach, whereby proven tools (LiDAR, photo interp) are constantly updated.

JWRL thanks the KTTD Program for supporting JWRL on this project
and for their patience in letting a small production shop stumble through R&D work.

andy@jwrl.ca