

Multisensor Airborne Data

Horn River Project
2009

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Introduction

- Devised as a collaborative demonstration project between the University of Victoria and B.C. Oil and Gas Commission.
- The goals were to demonstrate how a multisensor dataset could provide useful information for large area detailed mapping.
 - Basic mapping at high resolutions (2 metres)
 - Morphometric-based models
 - Hyperspectral data for species identification
- Metric-based modelling and mapping.
 - Complex modelling based on vegetation LiDAR-point distributions, bare earth models and spectroscopy.
- My goal in this presentation is to provide some sense as to the possibilities of extracting information.
 - I will focus on two issues: 1) vegetation structure for biophysical mapping and assessment, and 2) geomorphic interpretation in aid of aggregate exploration.



Simultaneous collection of multiple datasets: Multisensor Airborne Platform (MAP1)

A data collection and processing system centered on a Beechcraft Navaho. The onboard instrumentation suite includes a...

- ▶ AISA - Dual (400-2500nm) imaging spectrometer
 - 492 channels max @ 2m spatial resolution
 - » 2.5 nm spectral sampling VNIR (resolution 3.3 nm)
 - » 6.0 nm spectral sampling SWIR (resolution 13 nm)
- ▶ First and last return LiDAR (150KHz)
 - » 9 bit intensity
 - » Updated to a 4 return system in 2010
- ▶ Small frame digital camera
- ▶ INS
 - » Applanix 410 IMU
 - » DGPS

* The MAP1 platform is owned by TERRA Remote Sensing Inc., Sidney, B.C., and operated in partnership with the Hyperspectral-LiDAR Research Group, Department of Geography, University of Victoria.

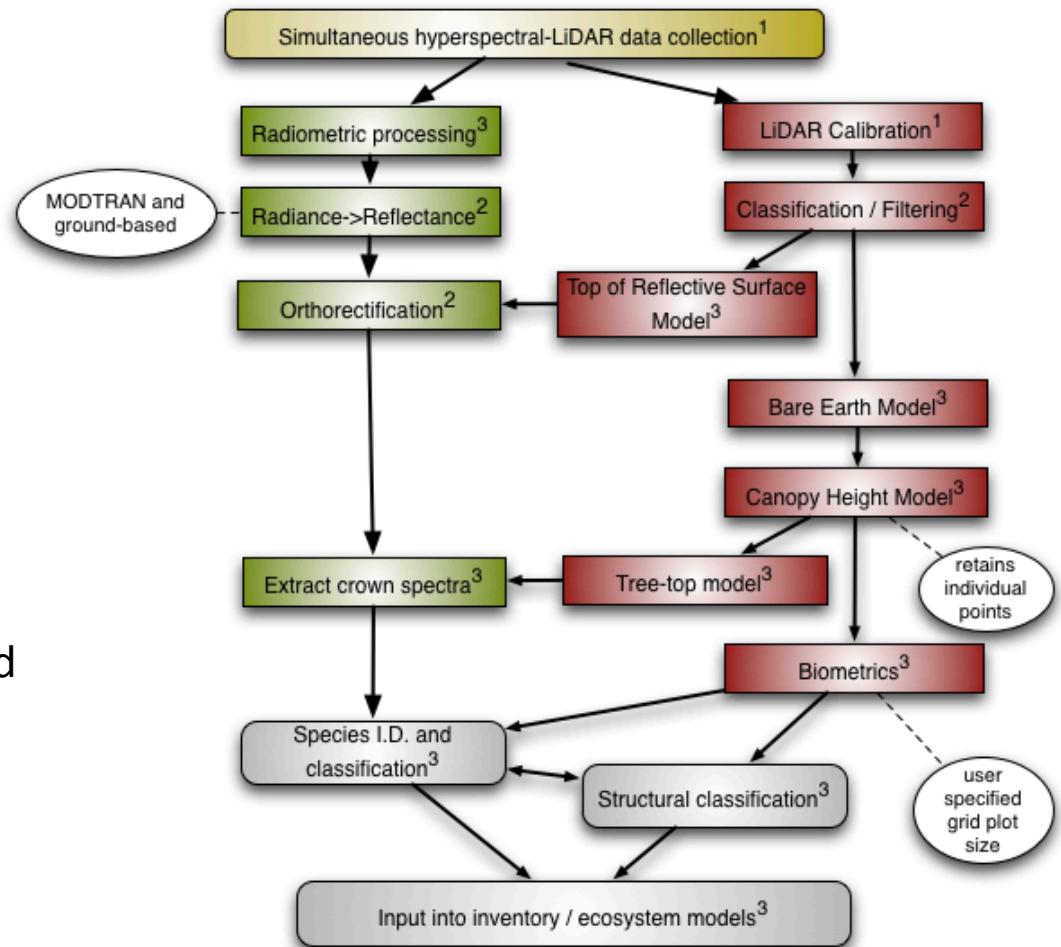
Hyperspectral * Lidar
Research Group

UNIVERSITY OF VICTORIA

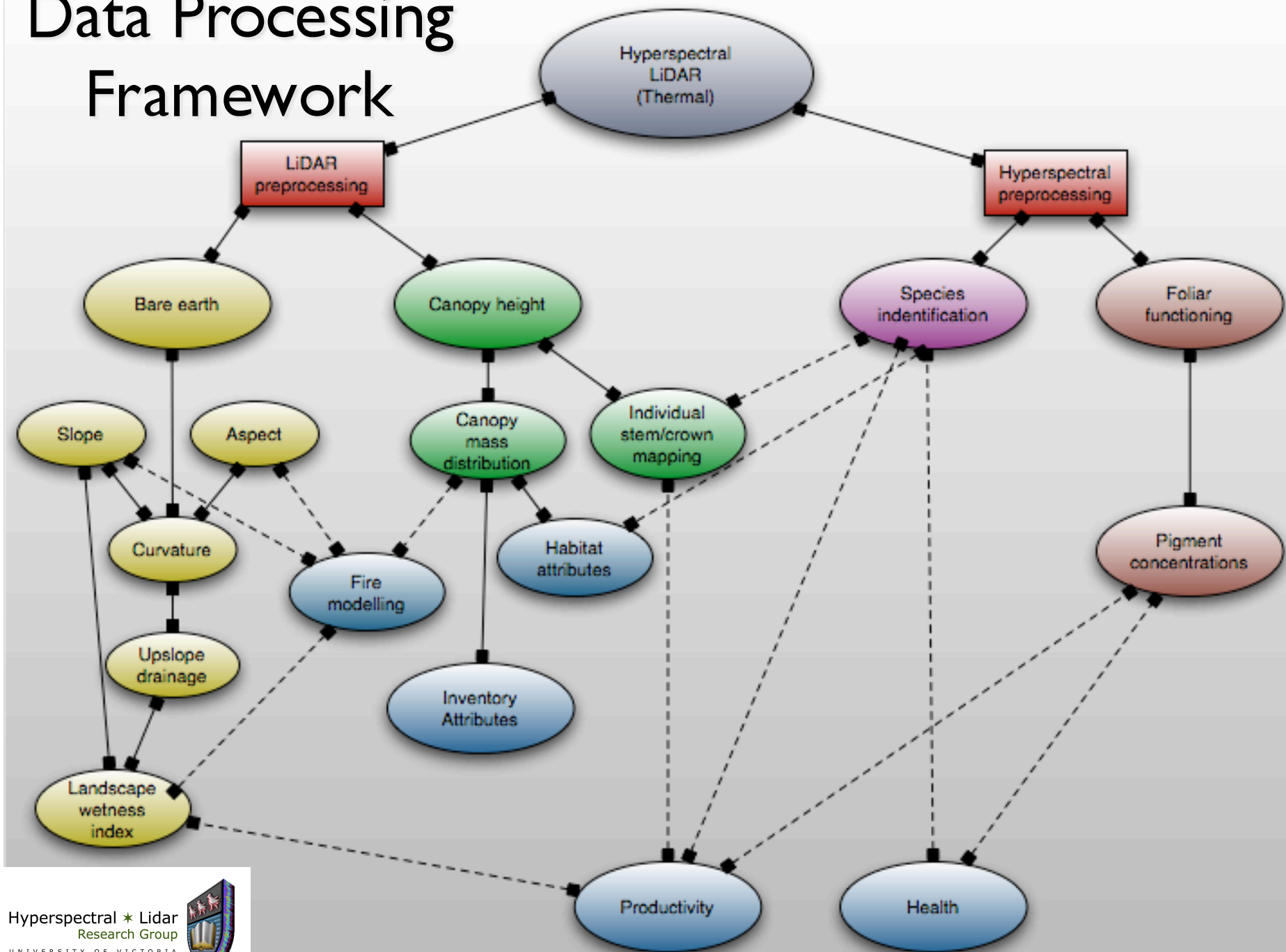


Processing Framework

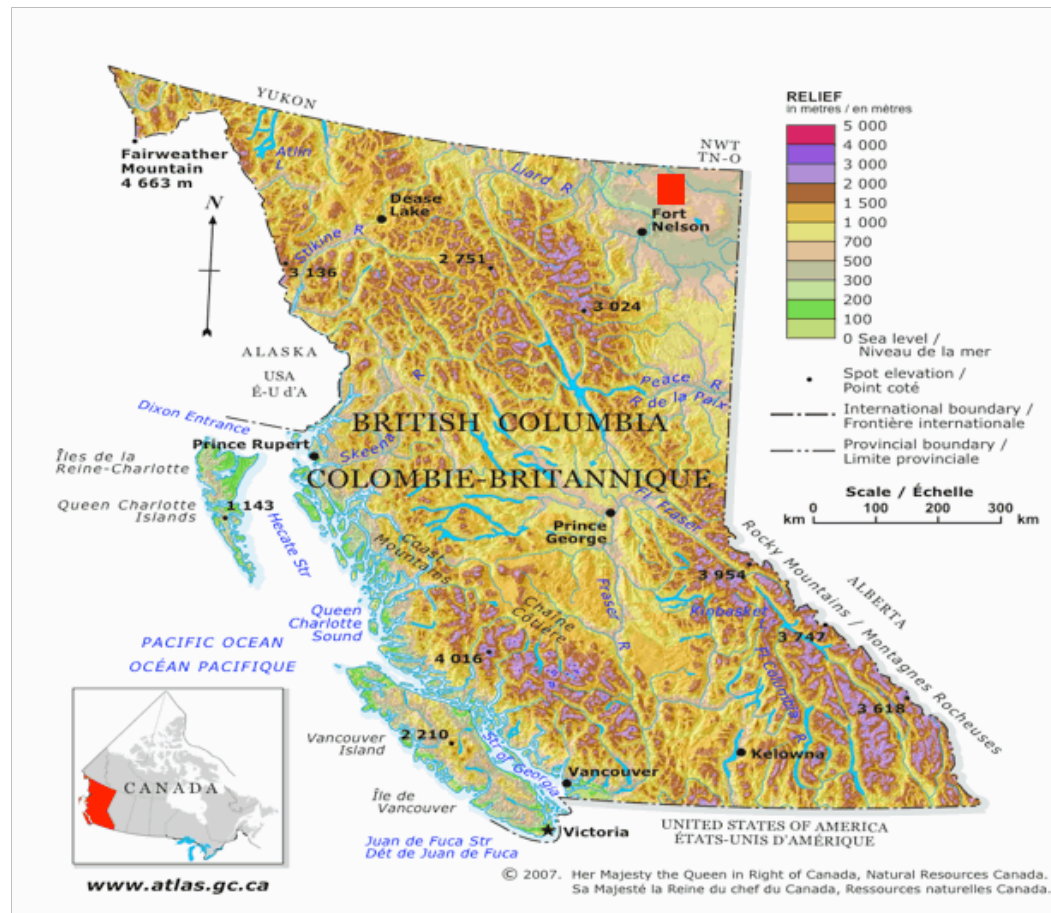
- The processing framework is designed to integrate the LiDAR, hyperspectral and aerial photography into a series of co-registered data products.
- The LiDAR data are interpreted for ground and vegetation points.
- They are then organized into user-specified grid cells and a series of canopy structure biometrics are generated, which are subsequently used to model forest attributes
- The hyperspectral data are processed to orthorectified radiance which are used to extract species identification



Data Processing Framework



Study Area



Typical Boreal –Mixedwood vegetation assemblages



Study Areas Flown 2009

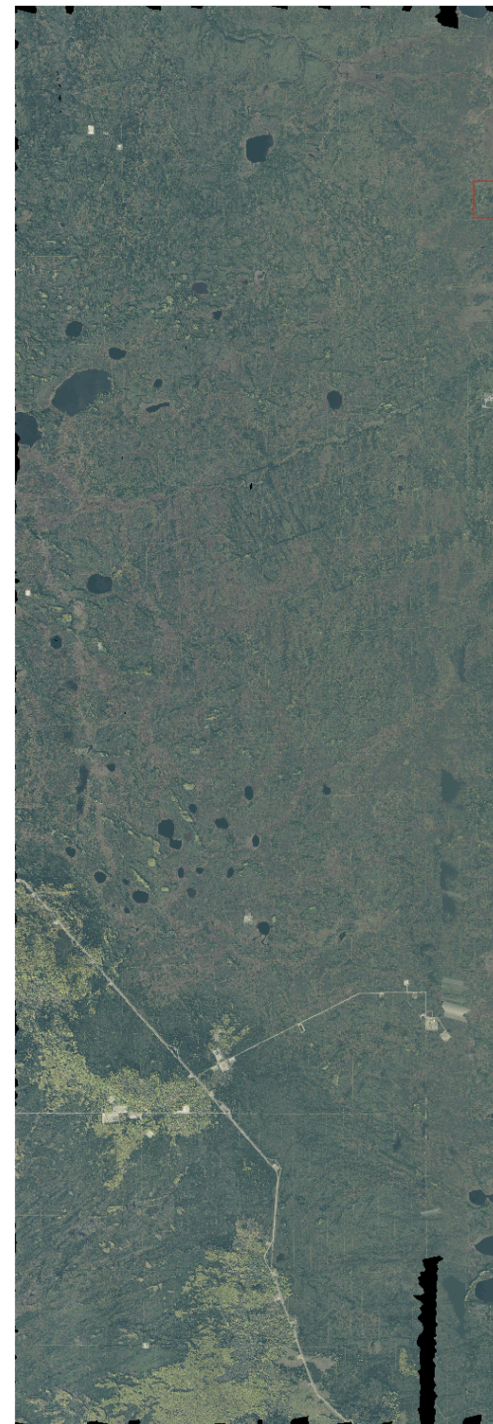
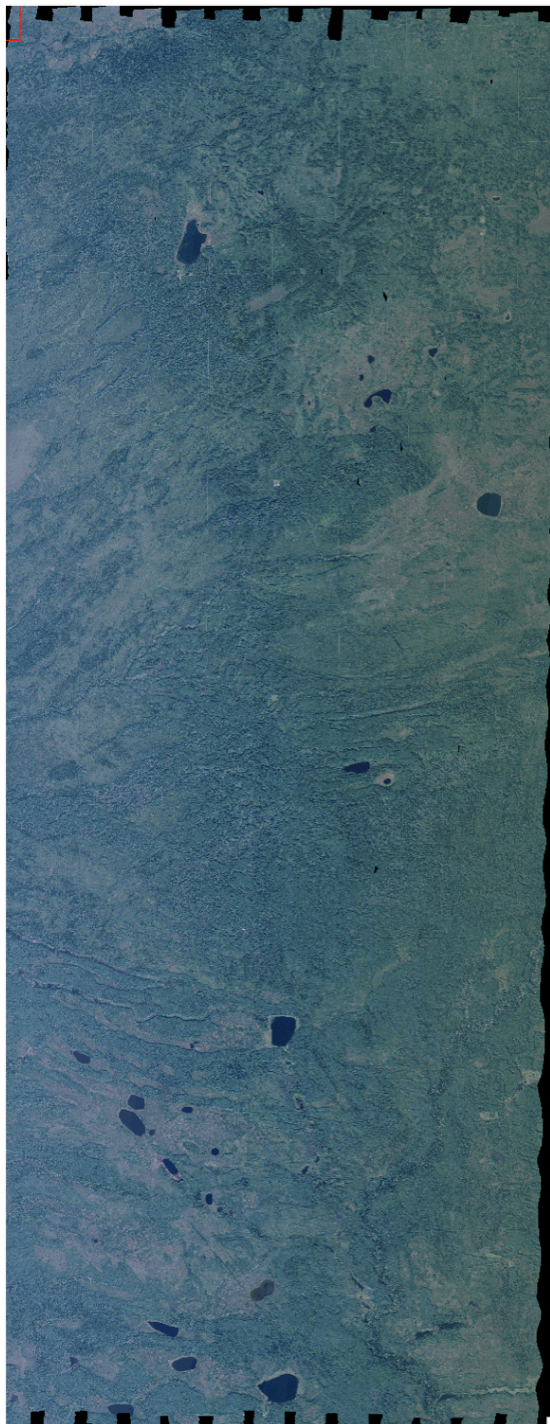


Flown: September 1, 2009

Flown: September 24, 2009



- Two areas were flown in 2009.
- Each area was approximately 300 km²
- One was flown later to address the effects of seasonality on the hyperspectral data.



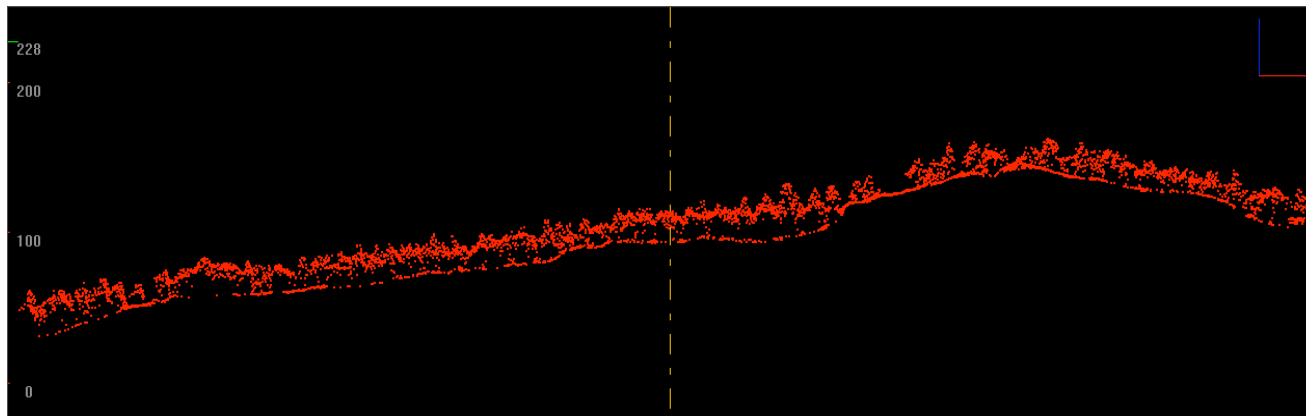
Basic Mapping

- The (vegetation/ground) classified LiDAR data were gridded to 2 metres.
 - Original PRF (pulse repetition frequency) of 60K.Hz. resulted in a posting density of 1.25 points/sq. m. at NADIR.
 - The vertical accuracy of the LiDAR system is typically better than 15 cm on a hard surface.

Canopy Height and Bare Earth Models

First step in LiDAR processing is to separate the vegetation cover from the ground surface.

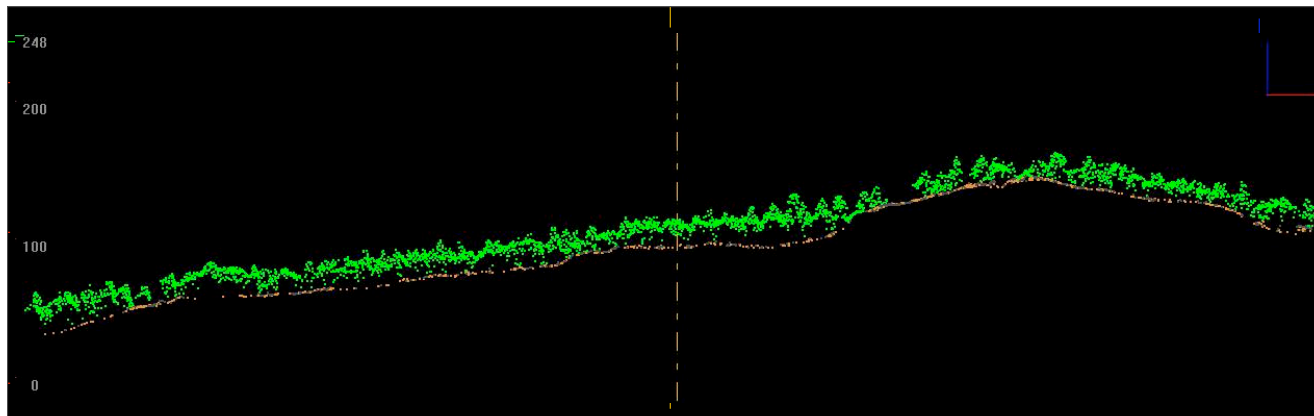
- For this we employ a series of filters that compare the spatial context of each point – ie the change in height (z) with the change in position (x,y).
- The result is a very detailed representation of both the non vegetated surface form and “canopy”.



Canopy Height and Bare Earth Models

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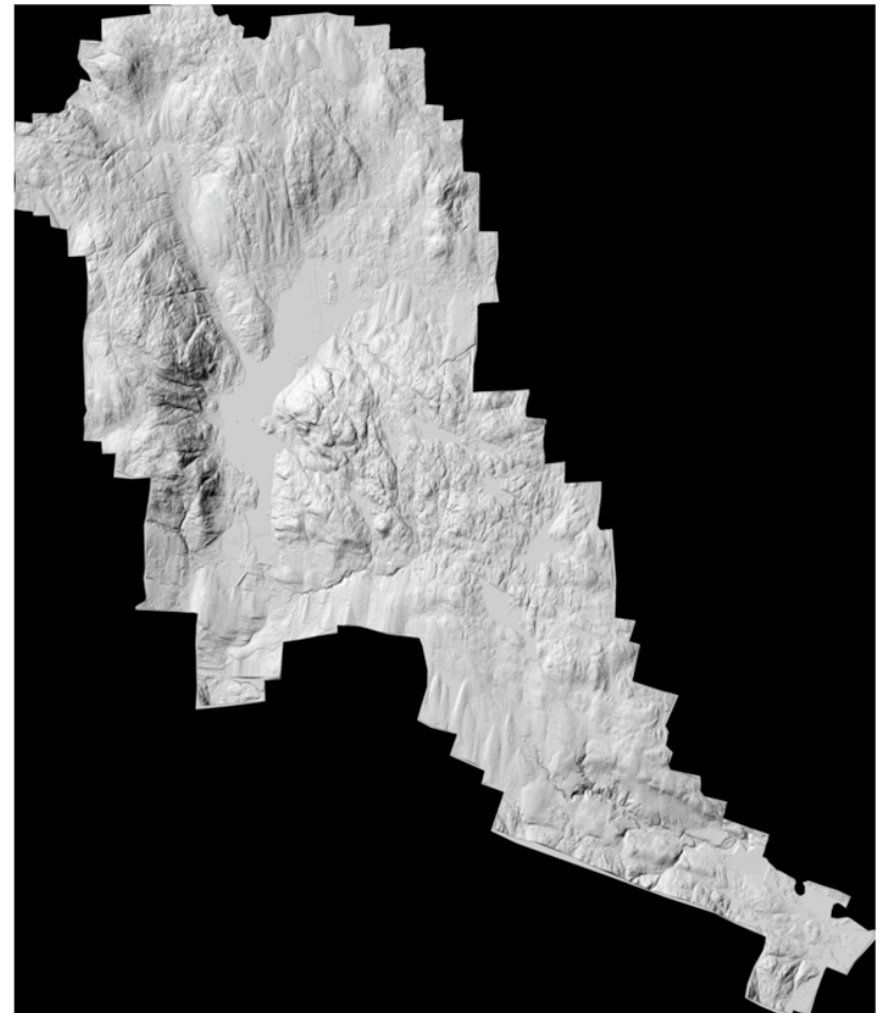
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Canopy Height and Bare Earth Models

First order models from LiDAR point data:

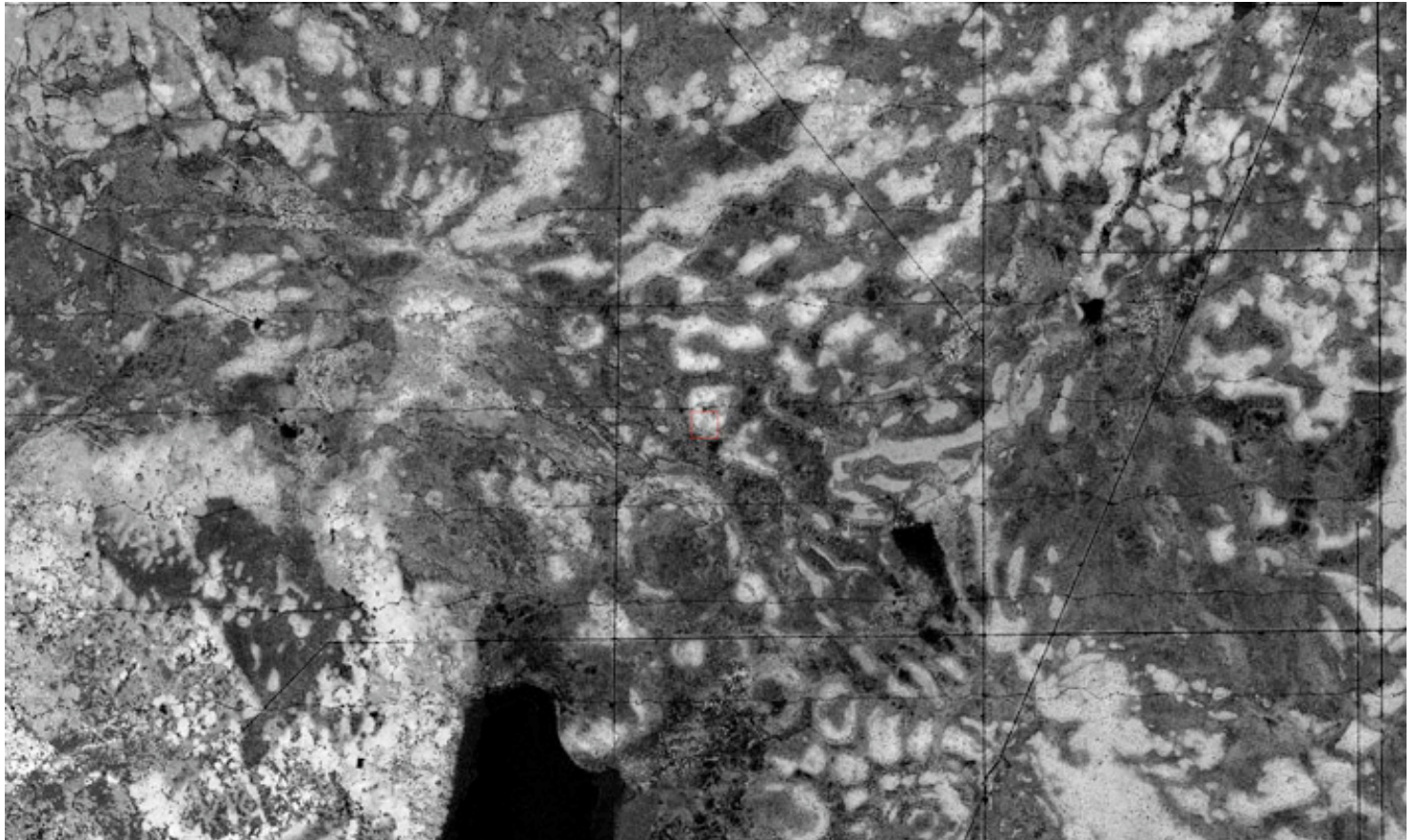
- A Bare Earth Model is one where the vegetation has been classified and removed leaving an accurate representation of the ground surface.



Canopy Height and Bare Earth Models

First order models from LiDAR point data:

- A Canopy Height Model (CHM) is a terrain-normalized representation of vegetation canopy heights...



Feature Classification and Mapping

- The CHM and Bare Earth data points can be used to characterize:
 - the structure of the canopy and to classify the vegetation cover based on this structure; and
 - the process based on the geomorphometry.

Canopy Height and Bare Earth Models

- Derivative (second-order) models from LiDAR point data, especially Bare Earth Models include:

- Slope
- Aspect
- Curvature (down and across slope)
- Flow models / upslope drainage area

- We can also derive complex models from the Bare Earth Model. These models integrate a number of the derivative models into a more complex morphometric representation of the surface, one that might represent a process.

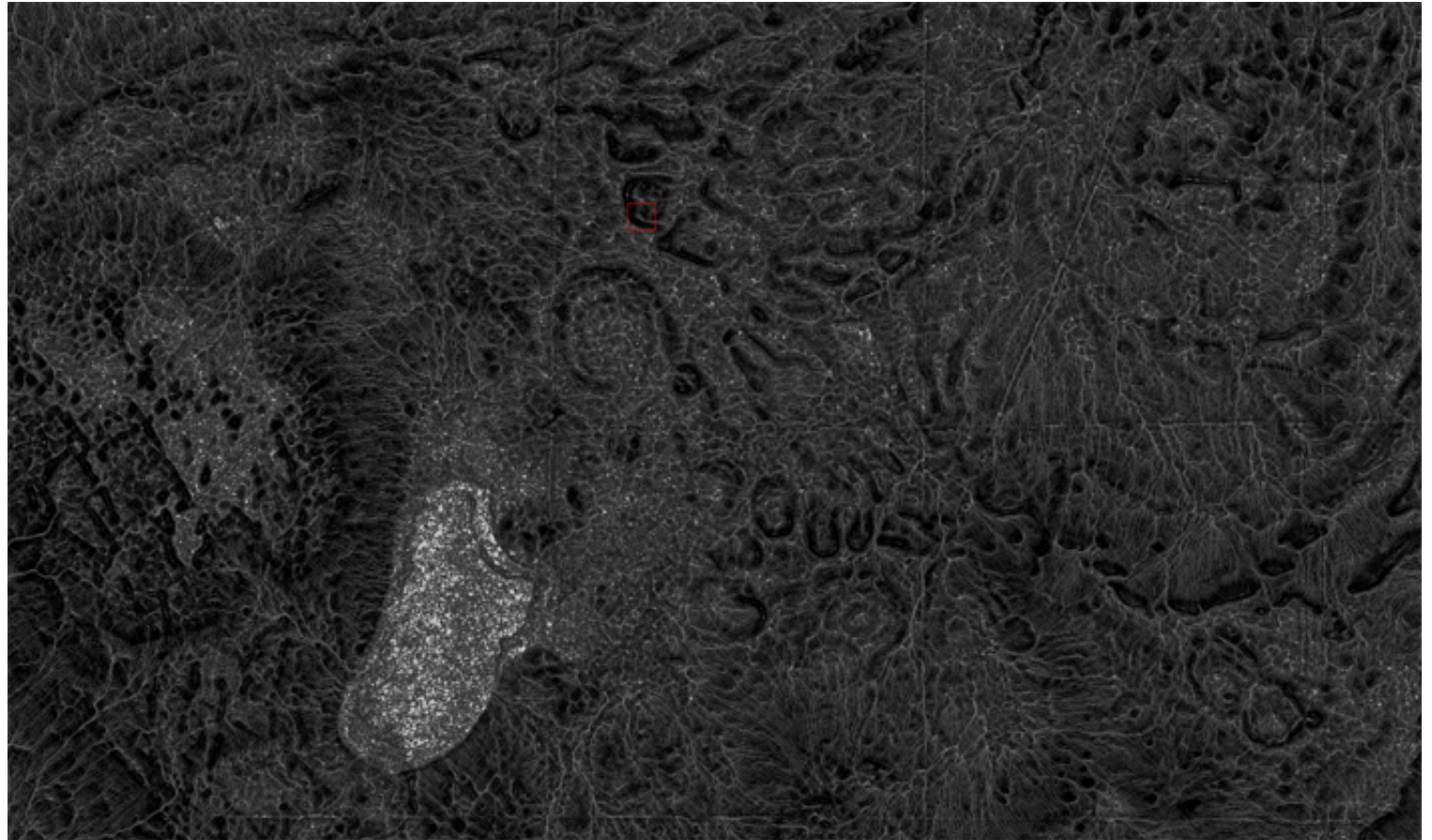
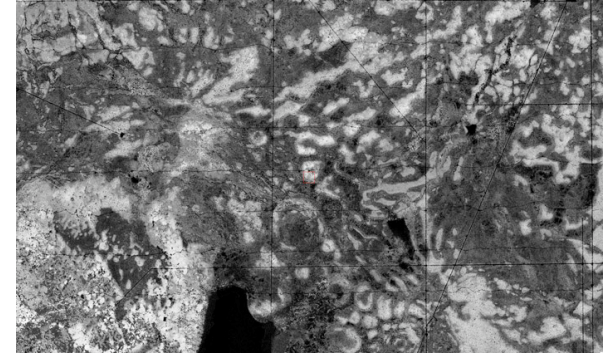
- In our case we derive a soil wetness index which integrates the upslope drainage area with a slope gradient model...

$$SWI = \frac{\ln(DA)}{\tan(slope_gradient)}$$

- where DA is the upslope drainage area.

Canopy Height and Bare Earth Models

Soil wetness index.....



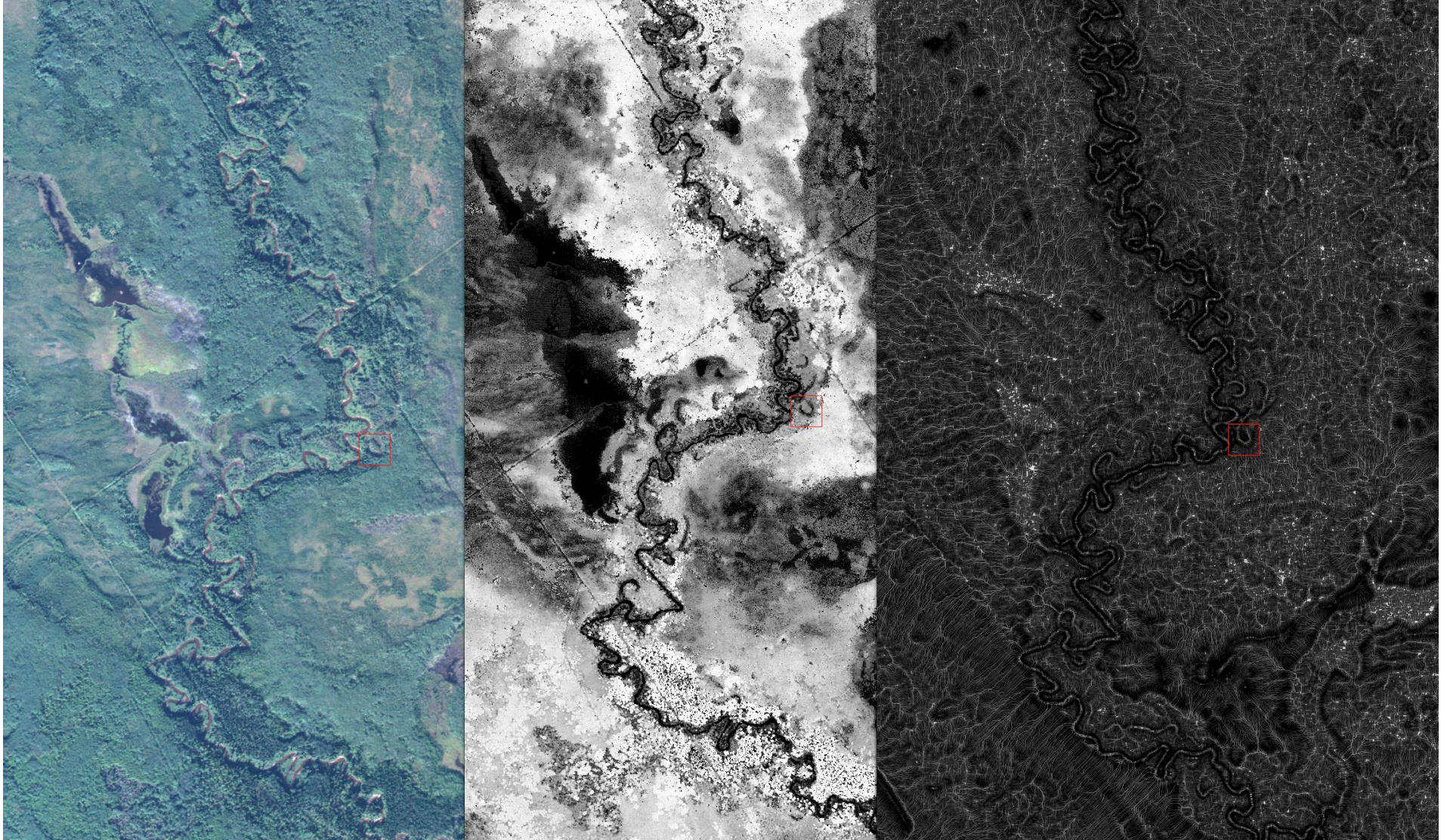
Canopy Height and Bare Earth Models

Comparison....

Hyperspectral

Canopy Height

Soil Wetness Index



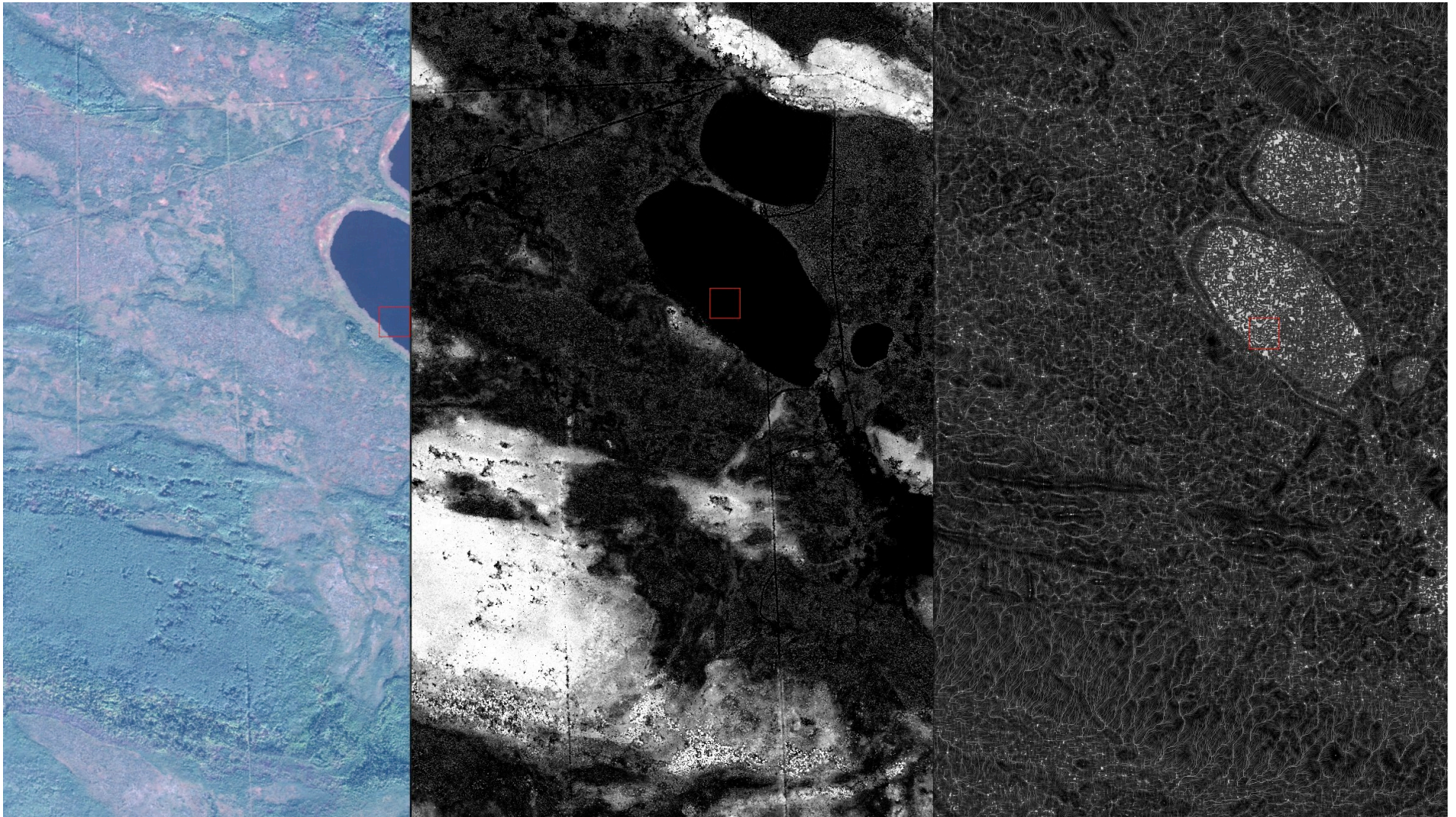
Canopy Height and Bare Earth Models

Comparison....

Hyperspectral

Canopy Height

Soil Wetness Index



LiDAR Information Extraction: Vertical Canopy Structure (Biometrics)

- Vertical structure of the canopy can be further described through the use of statistical moments (mean, variance, skewness, and kurtosis) of the point cloud.

$$b_0 = \frac{1}{n} \sum_{i=1}^n x_i$$

$$b_1 = \sum_{i=1}^{n-1} \left[\frac{(n-i)}{n(n-1)} \right] x_i$$

$$b_2 = \sum_{i=1}^{n-2} \left[\frac{(n-i)(n-i-1)}{n(n-1)(n-2)} \right] x_i$$

$$b_3 = \sum_{i=1}^{n-3} \left[\frac{(n-i)(n-i-1)(n-i-2)}{n(n-1)(n-2)(n-3)} \right] x_i$$

- We have adopted the use of L-moments rather than the more traditional moment measures as they have been found to be more stable.
- We defined the mean (Lh_{Mean}), coefficient of variation (Lh_{COV}), skewness (Lh_{Skew}), and kurtosis (Lh_{Kurt}) of the LiDAR canopy height distribution as λ_1, τ, τ_3 , and τ_4

Analogous to traditional moments

$$\lambda_1 = b_0$$

$$\lambda_2 = 2b_1 - b_0$$

$$\lambda_3 = 6b_2 - 6b_1 + b_0$$

$$\lambda_4 = 20b_3 - 30b_2 + 12b_1 - b_0$$

L-moments

$$\tau = \lambda_2 / \lambda_1, \quad (0 < \tau < 1).$$

$$\tau_3 = \lambda_3 / \lambda_2, \quad (-1 < \tau_3 < 1).$$

$$\tau_4 = \lambda_4 / \lambda_2, \quad (0.25(5\tau_3^2 - 1) \leq \tau_4 < 1)$$



LiDAR Information Extraction: Horizontal Canopy Structure (Biometrics)

- The rugosity is a measure of the bumpiness of the canopy surface
- The coefficient of variation is the rugosity decoupled from height
- The canopy gap fraction (CGF) is a measure of the openness of the canopy surface.

$$C = \sigma$$

Rugosity

$$C_v = \frac{\sigma}{\mu}$$

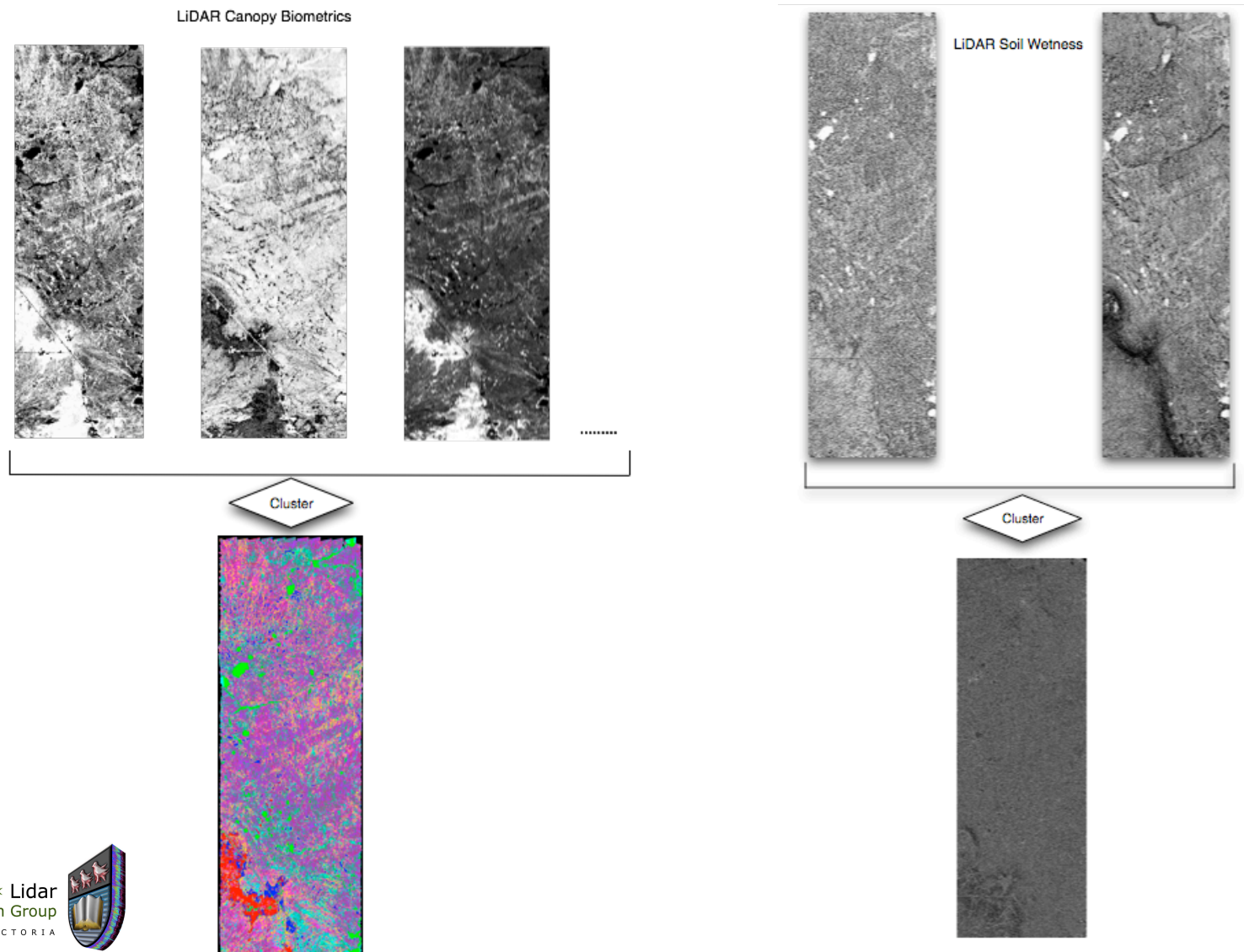
Coefficient of variation

$$CGF_{LiDAR} = 100 * \left[\frac{N_{lower}}{N_{total}} \right]$$

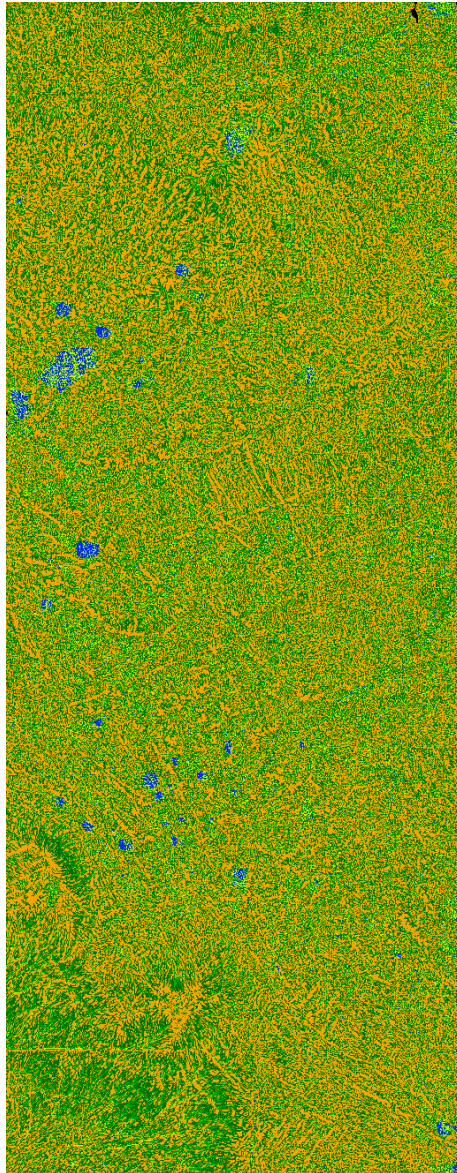
Canopy Gap Fraction

Feature Classification and Mapping

- Both the LiDAR canopy biometrics and the SWI are upscaled to 20 m resolution through a cluster analysis.
- The canopy data were clustered into 9 classes while the SWI were grouped into 5 based on mean and variance values for the 20 m grid cells.

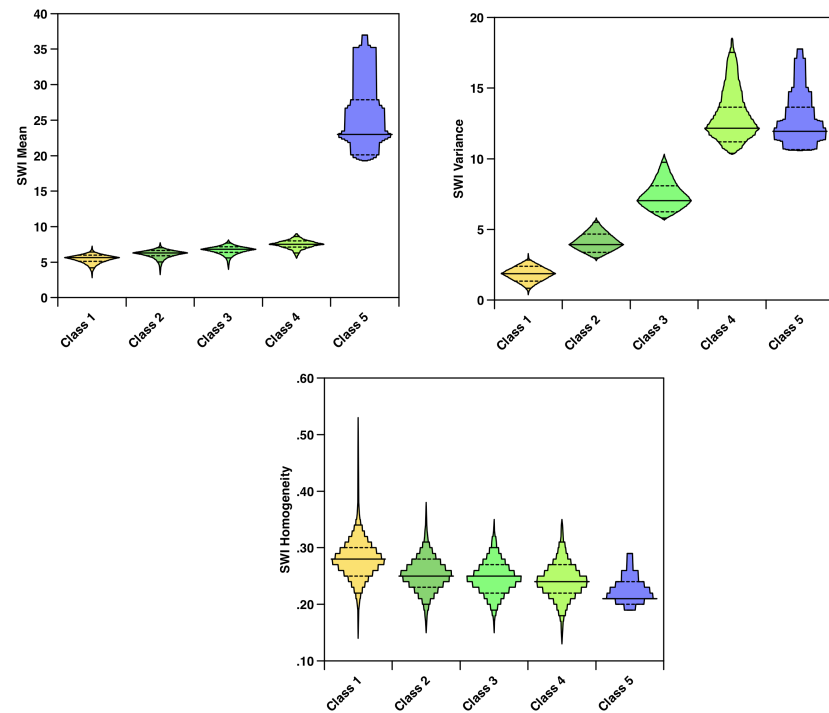


Feature Classification and Mapping

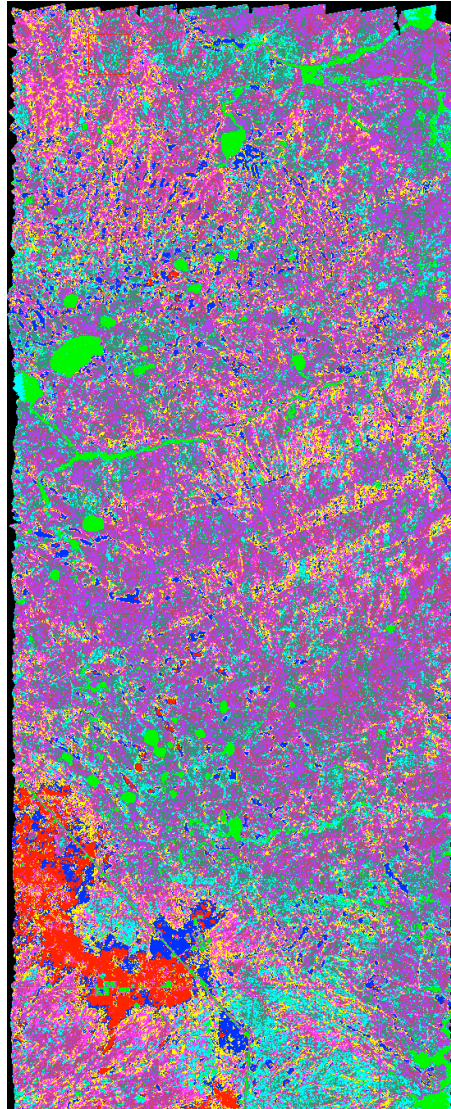


← SWI-based drainage map

Descriptive Statistics

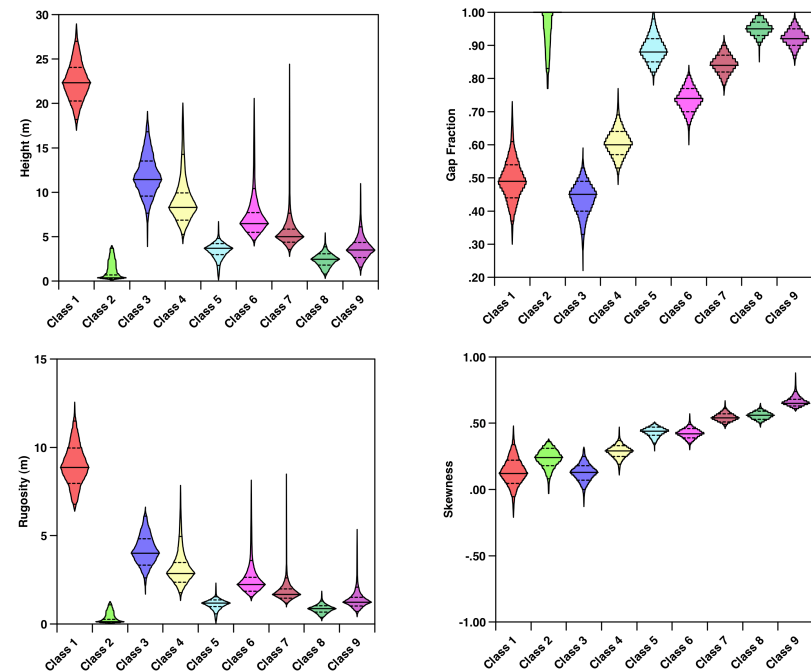


Feature Classification and Mapping



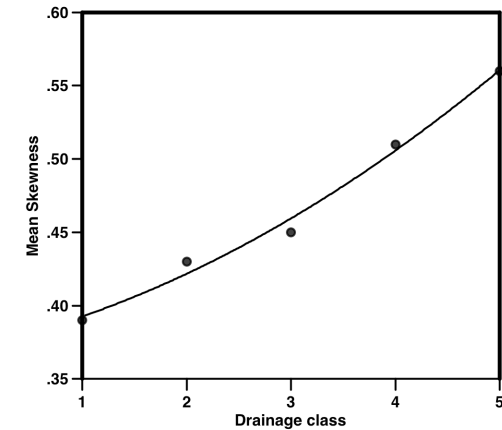
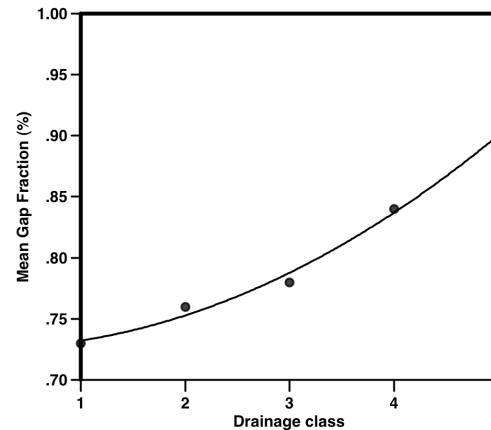
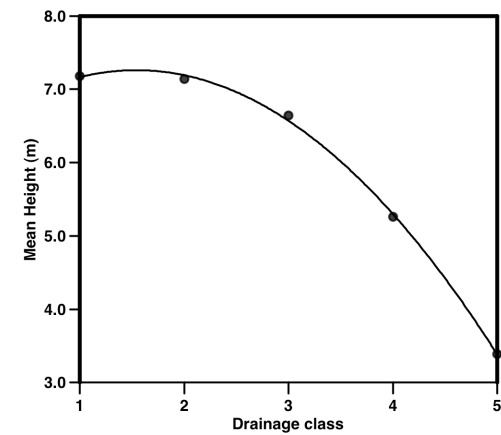
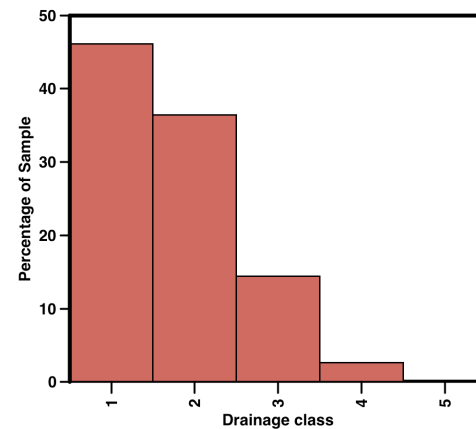
← Vegetation structure cluster map

Descriptive statistics



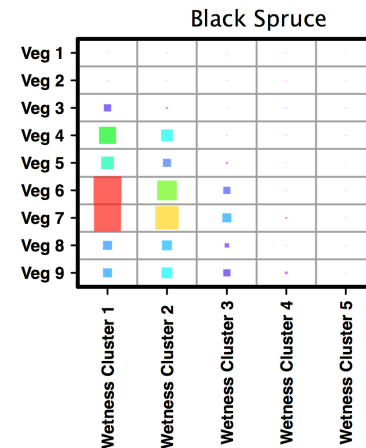
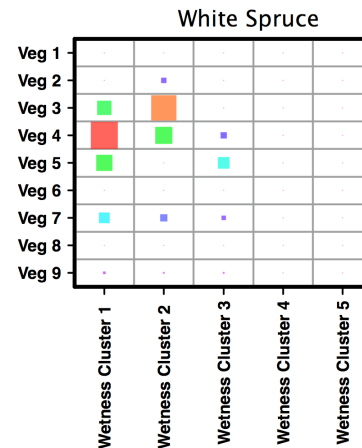
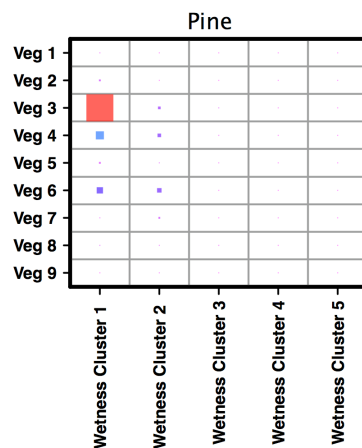
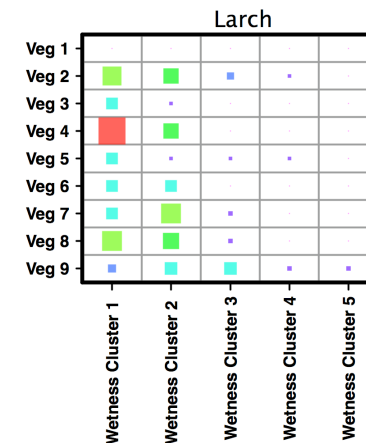
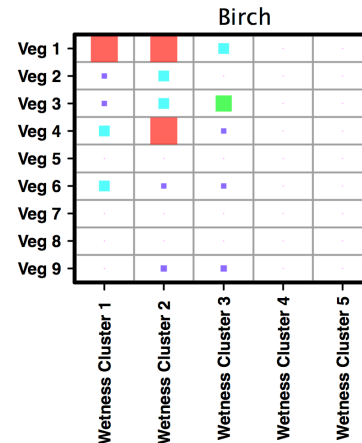
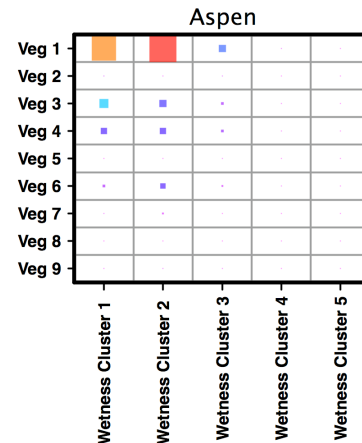
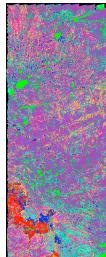
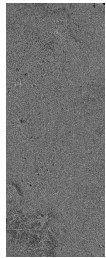
Feature Classification and Mapping

Comparison of vegetation structure by drainage class



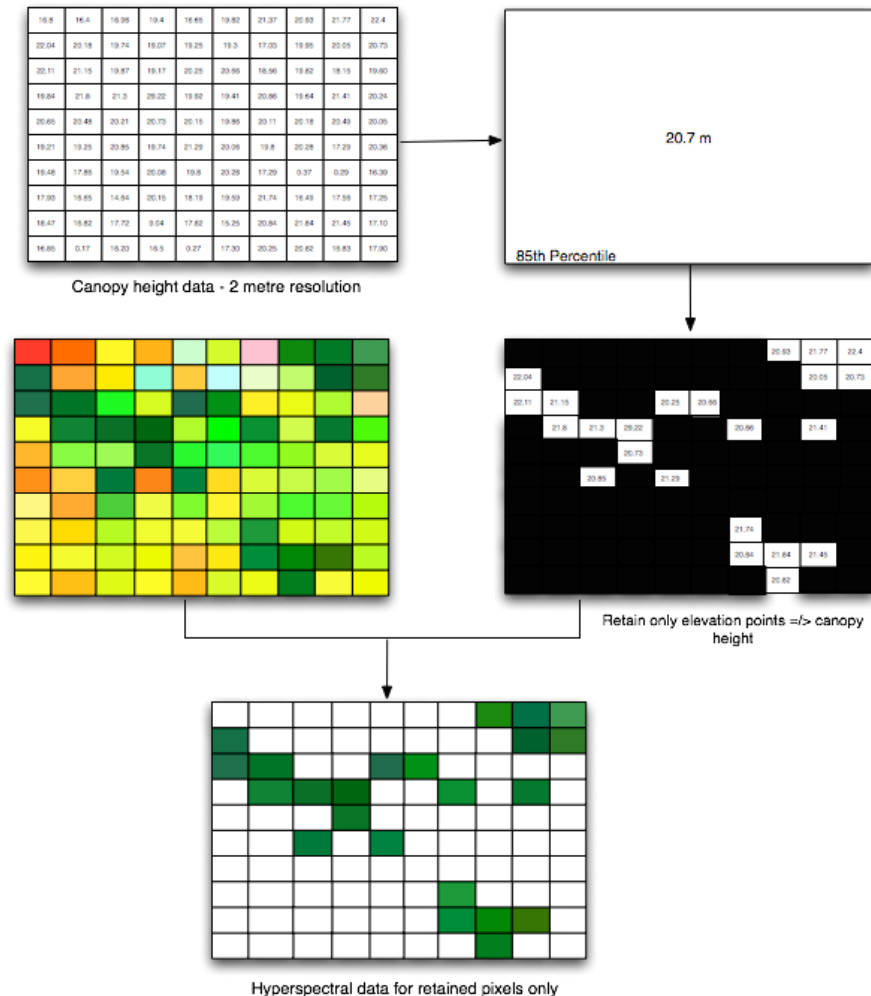
Feature Classification and Mapping

- a comparison of the effects of relationship between the forest species and structure/ drainage classes
 - these data matrices allow us to use the hyperspectral data to differentiate only conifer/deciduous/grass-sedges in senescent vegetation while the output is more closely related to species.
 - a Spectral Angle Mapper classifier is used to discriminate vegetation types.



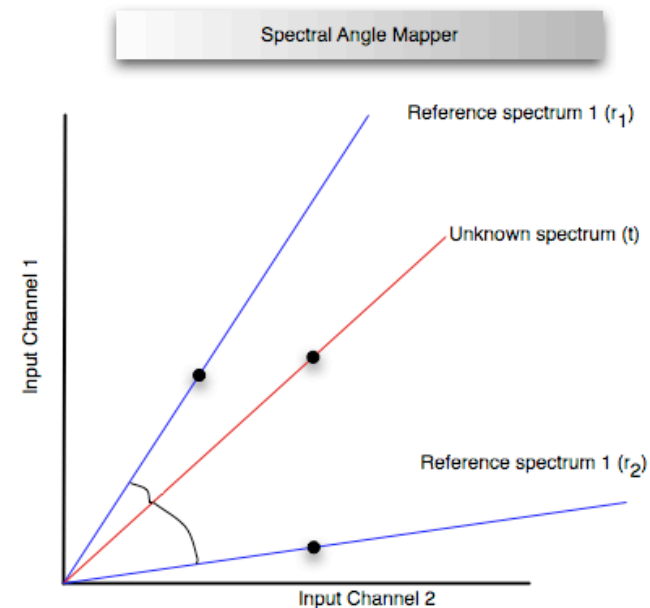
Hyperspectral Classification: Spectral Angle Mapper

- 2 metre hyperspectral data:
- Filtered using LiDAR data to retain only top of canopy spectra - removes those pixels that are subject to low S/N caused by shadows.
- Second filter for only the spectra with canopy heights less than 2 metres by greater than 0
- Third are only those areas with associated heights at 0 metres to silicate open gravel and water.
- Degrade the resolution to 20 metres to conform with the LiDAR-based modelling.
- We report only the maximum frequency pixels within each grid cell.



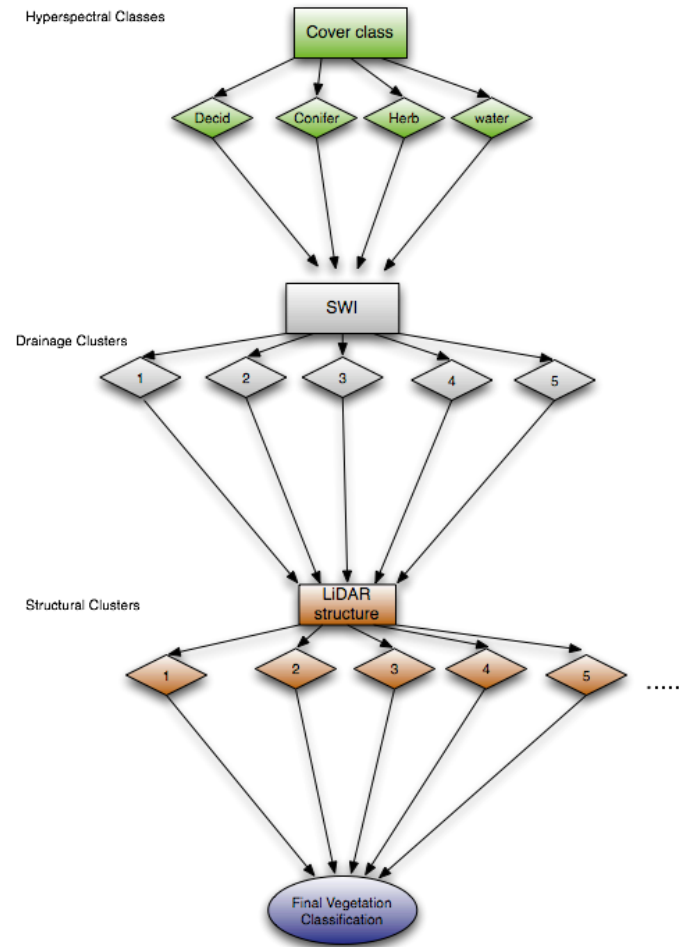
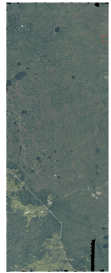
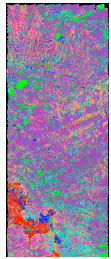
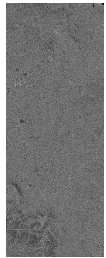
Hyperspectral Classification: Spectral Angle Mapper

- Non parametric classifier.
- *Theoretically* insensitive to variations in intensity and so should be able to achieve similar results from data flown under different conditions.
- We use an *endmember* approach to defining the reference library, rather than relying on *average representative* spectra - acknowledges that there may be structural - reflectance relationships that will change the shape of the reflectance curve.



$$\cos^{-1} \left(\frac{\sum_{i=1}^{nb} t_i r_i}{\left(\sum_{i=1}^{nb} t_i^2 \right)^{1/2} \left(\sum_{i=1}^{nb} r_i^2 \right)^{1/2}} \right)$$

Feature Classification and Mapping

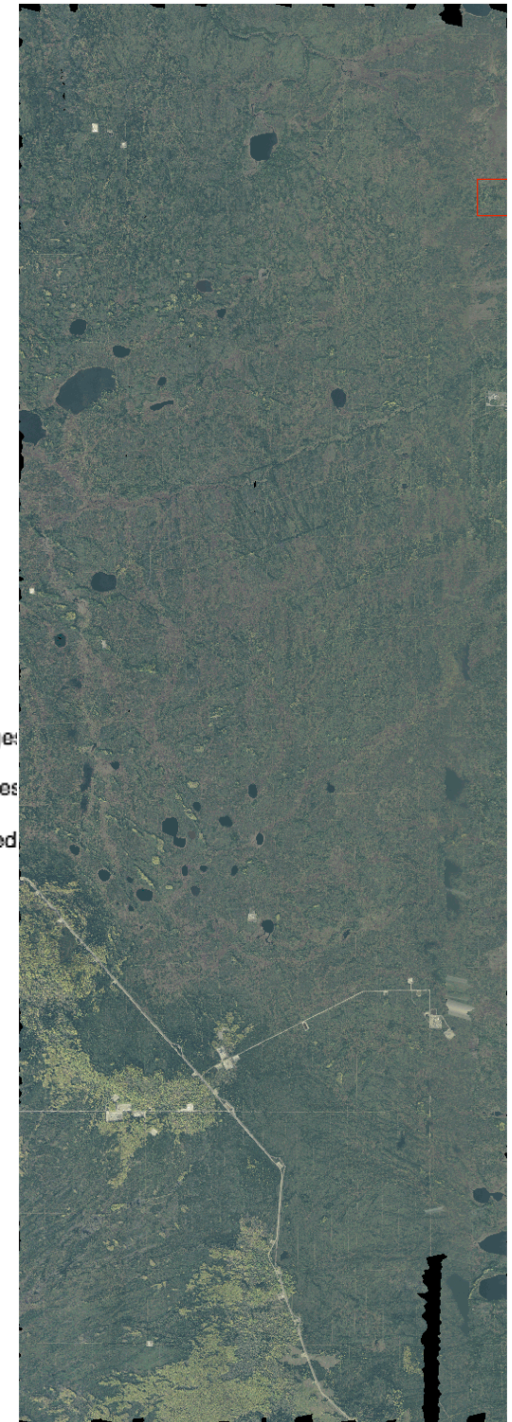
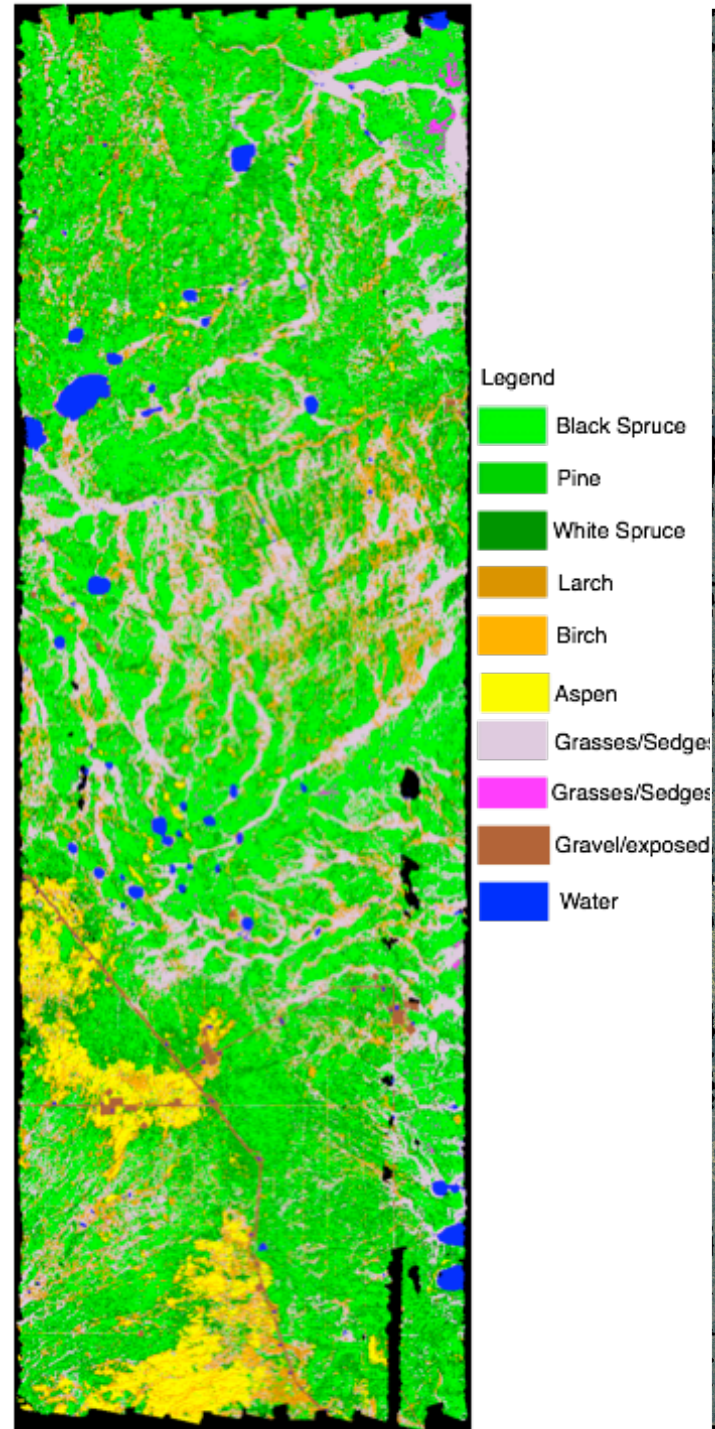


- a non parametric decision tree classifier was used to integrate the different data sources into a final species related classification



Final Classification

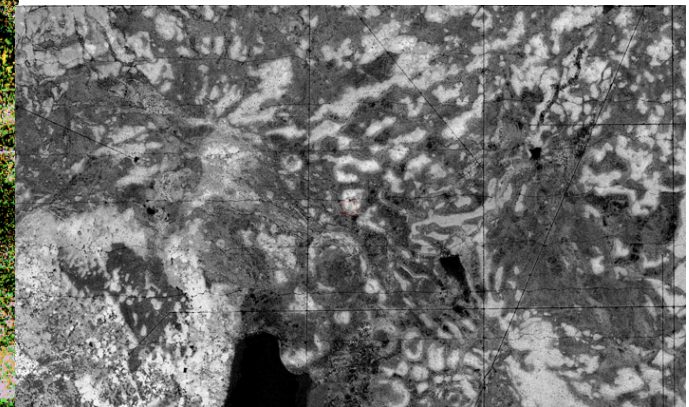
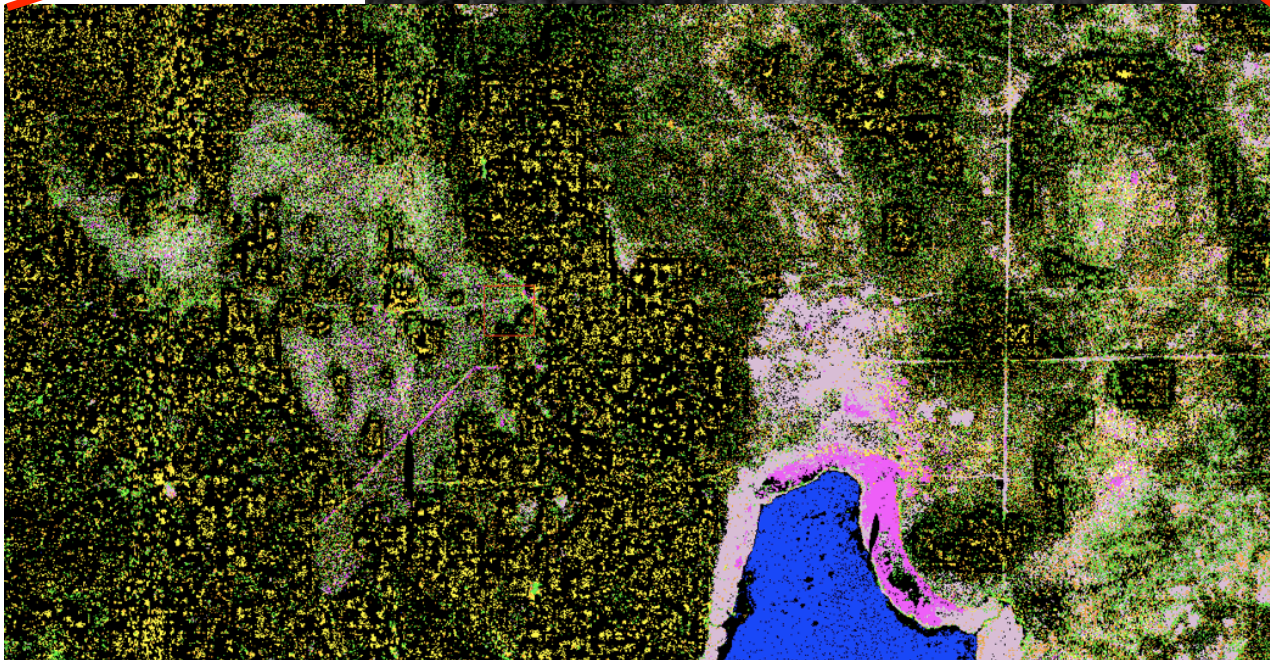
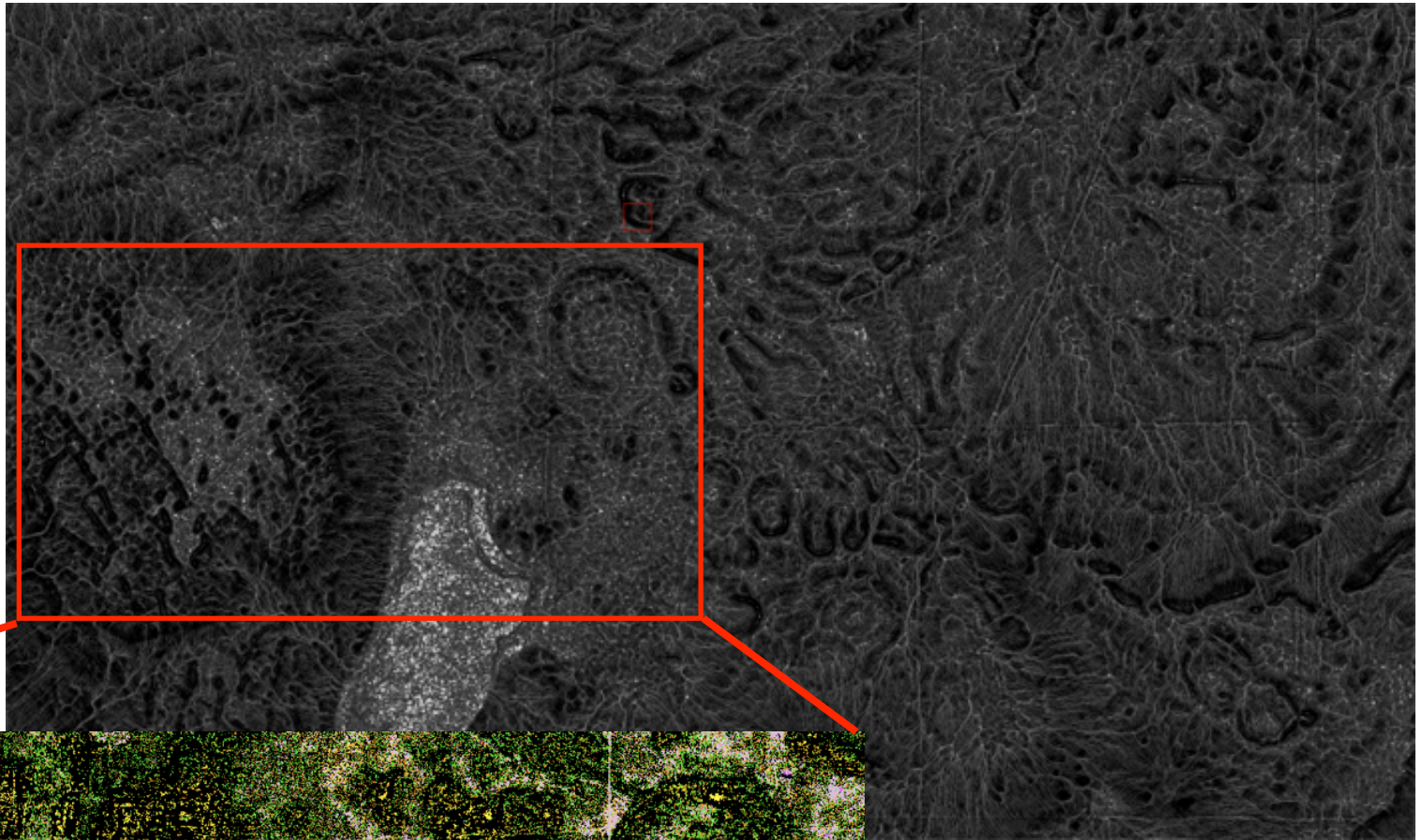
- major forest species mapped to a high degree of accuracy
- isolated major wetlands/paleo drainage networks (mauve/grey).



Classification

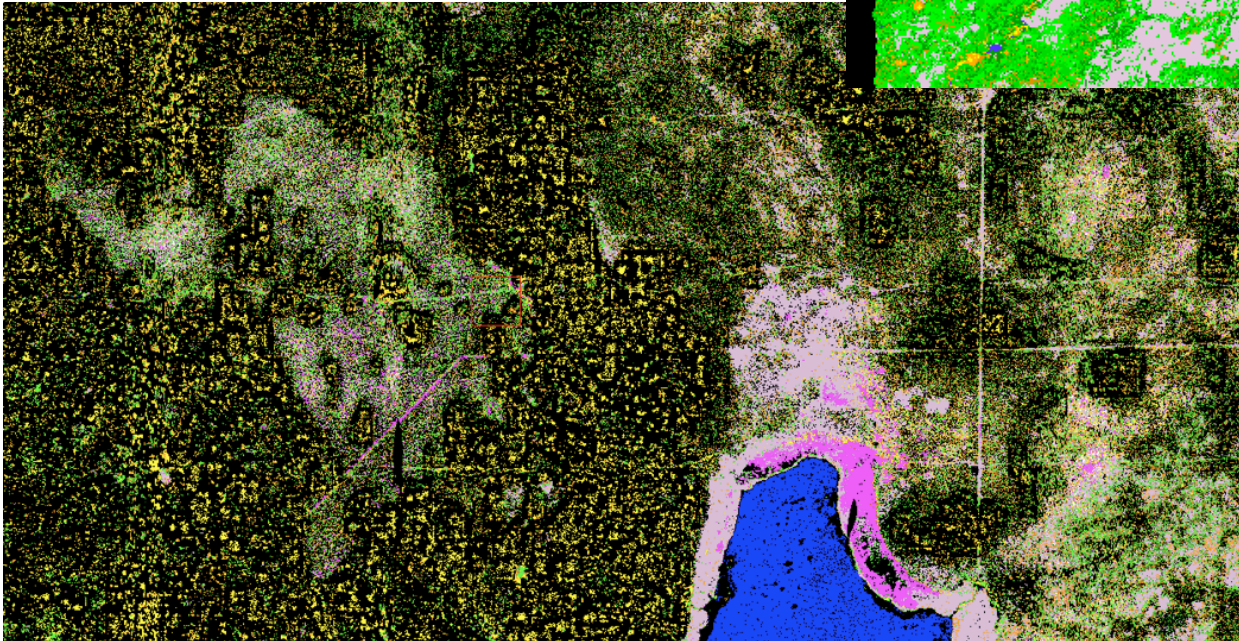
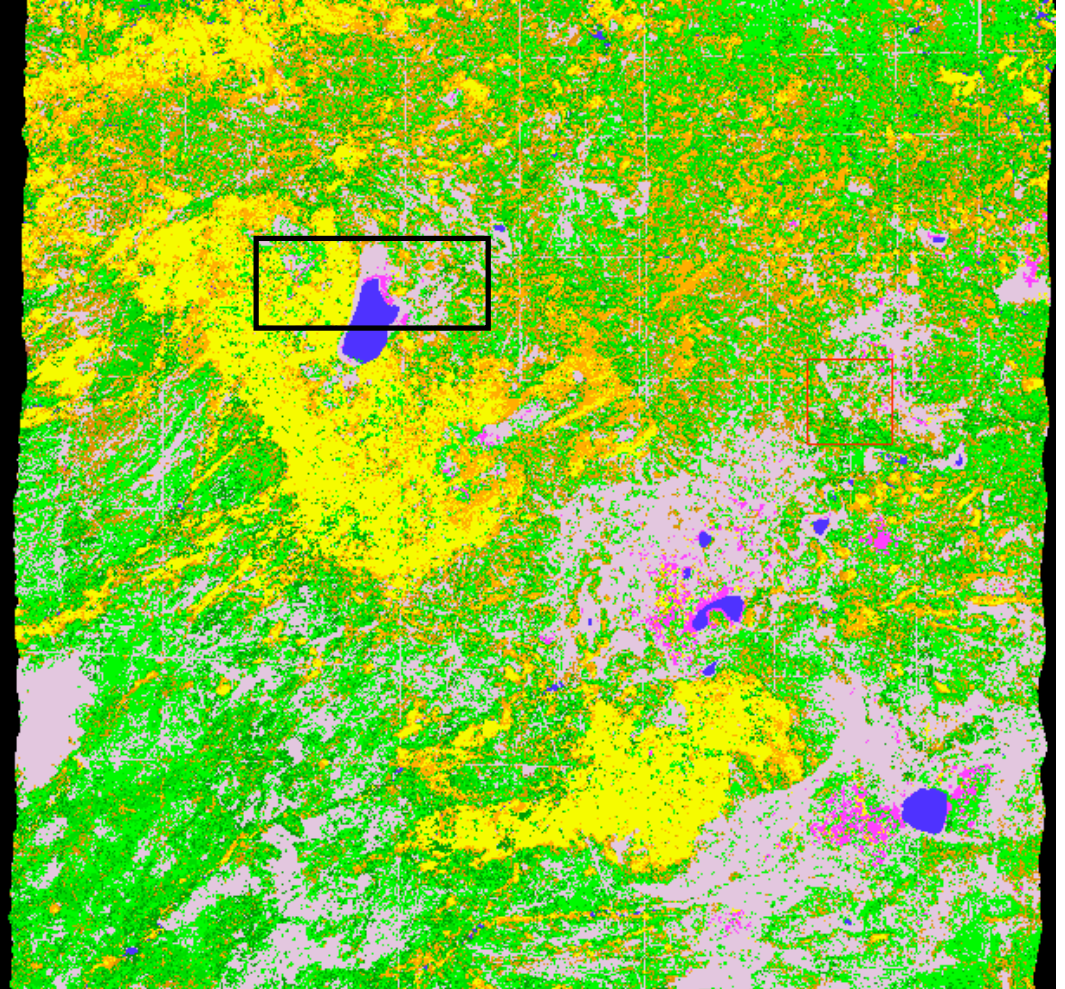
- 2 metres

- the classification is a combination of the three LiDAR-based masks
- the empty 2 m pixels result from shadowing, or noise caused by increasing amounts of shadow within a canopy.



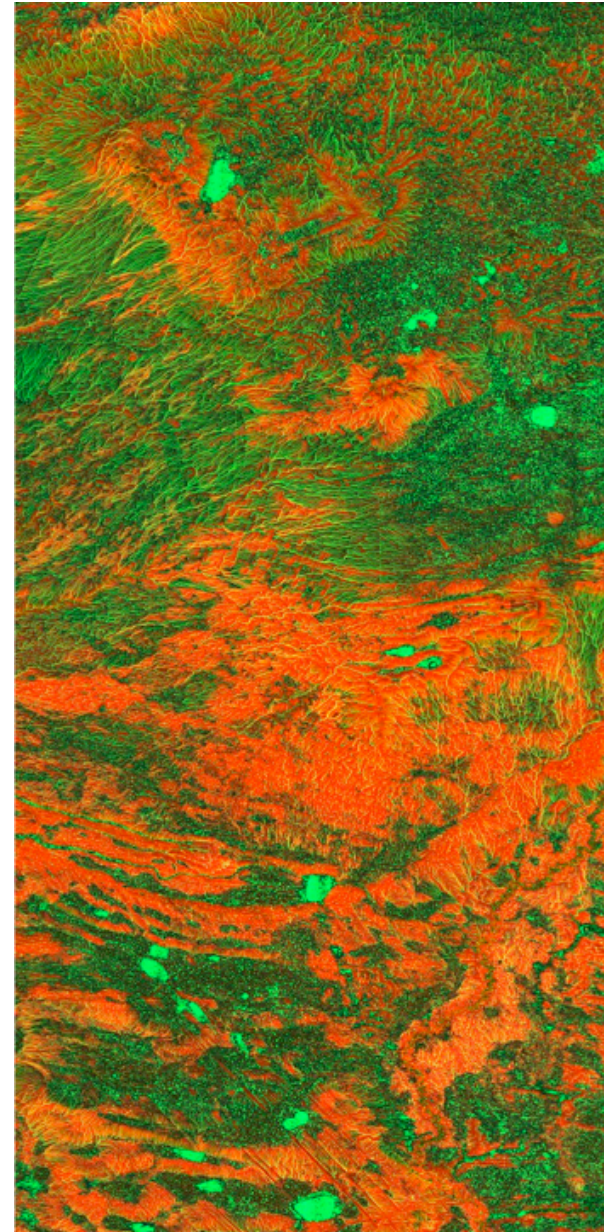
Classification - 20 metres

- We selected the dominant species in each of the 20 metre grid cells, ignoring the empty pixels, to represent that grid cell.



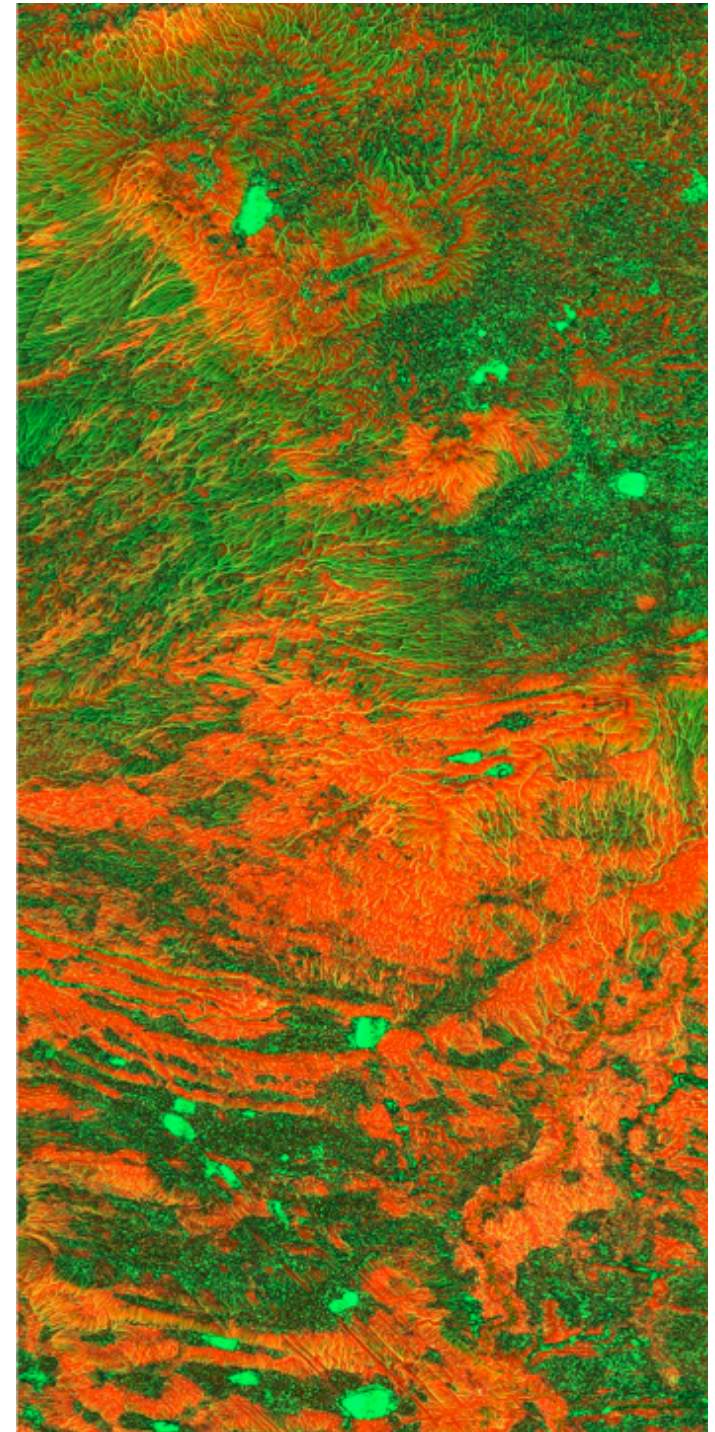
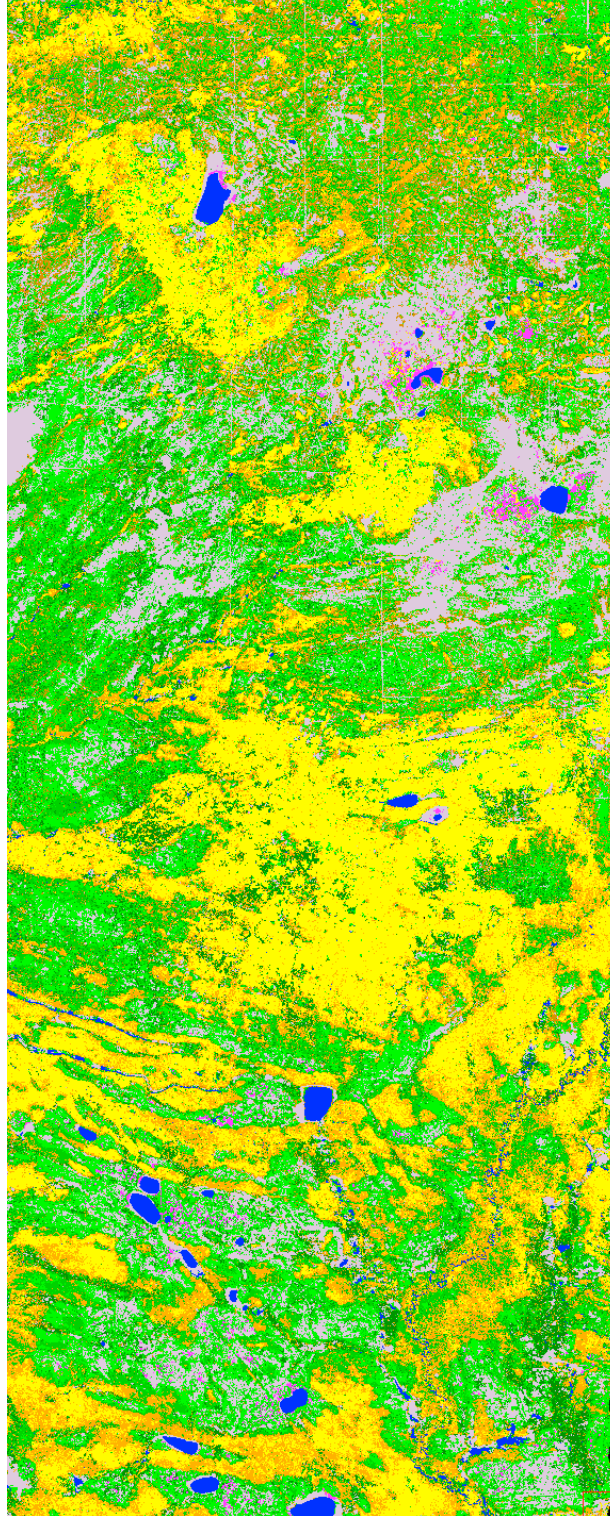
Geomorphological Mapping

- 3- colour representation of veg. height (red), SWI variance (green), SWI mean (blue)
- Areas that appear red indicate those areas that are better drained supporting taller (deciduous) vegetation.
- Drainage networks can be clearly mapped.
- Large wetland areas are also clearly discernable.



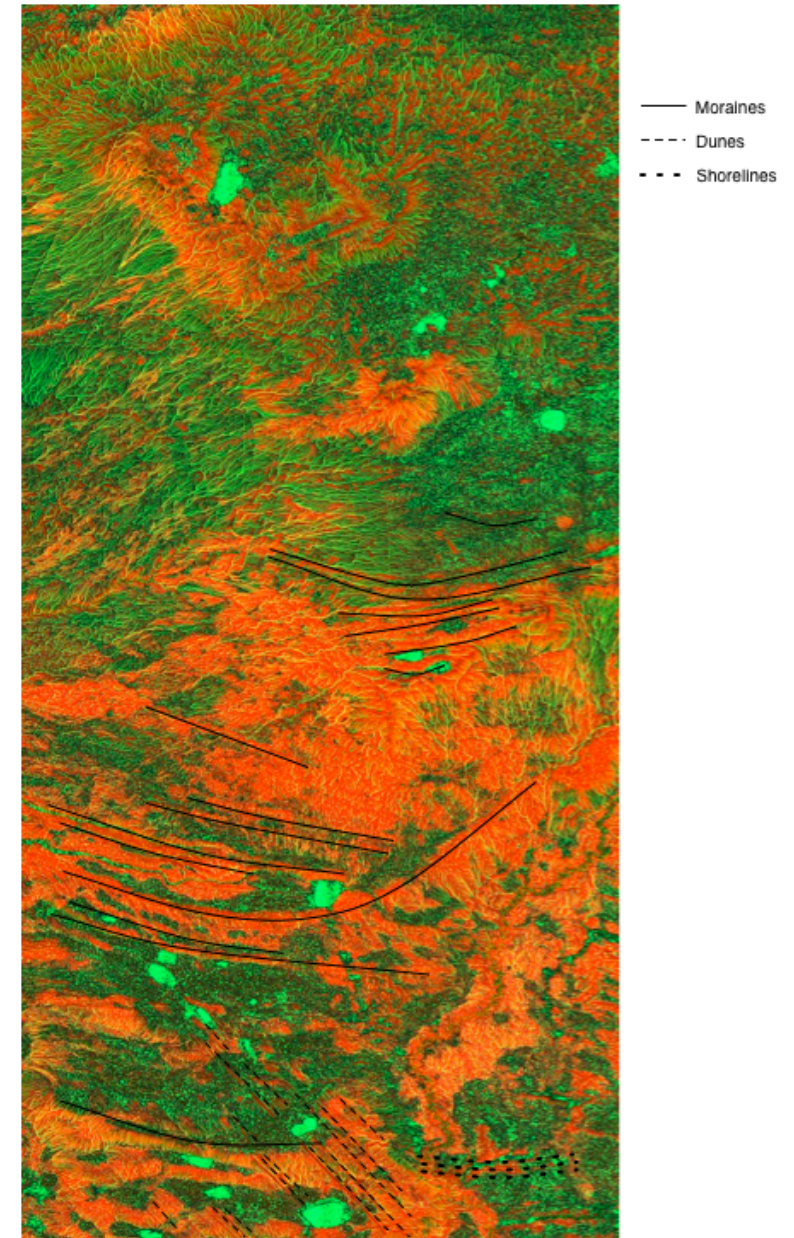
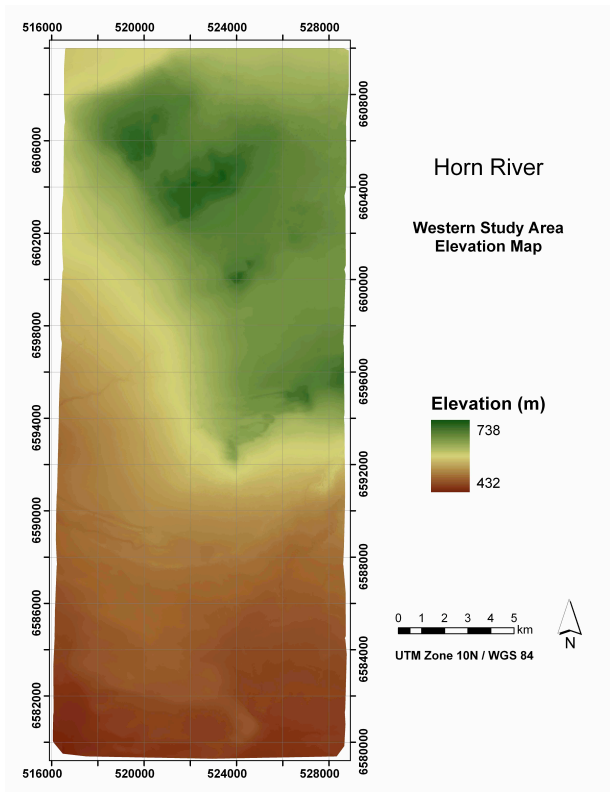
Species-Height-Soil Wetness

- a comparison of the classified hyperspectral data with the canopy height and SWI map presented on the previous page.
- note the correspondence of the deciduous classes with the taller vegetation concentrations.
- the conifers are lower in height and the grasslands correspond to the higher SWI mean and variance values.



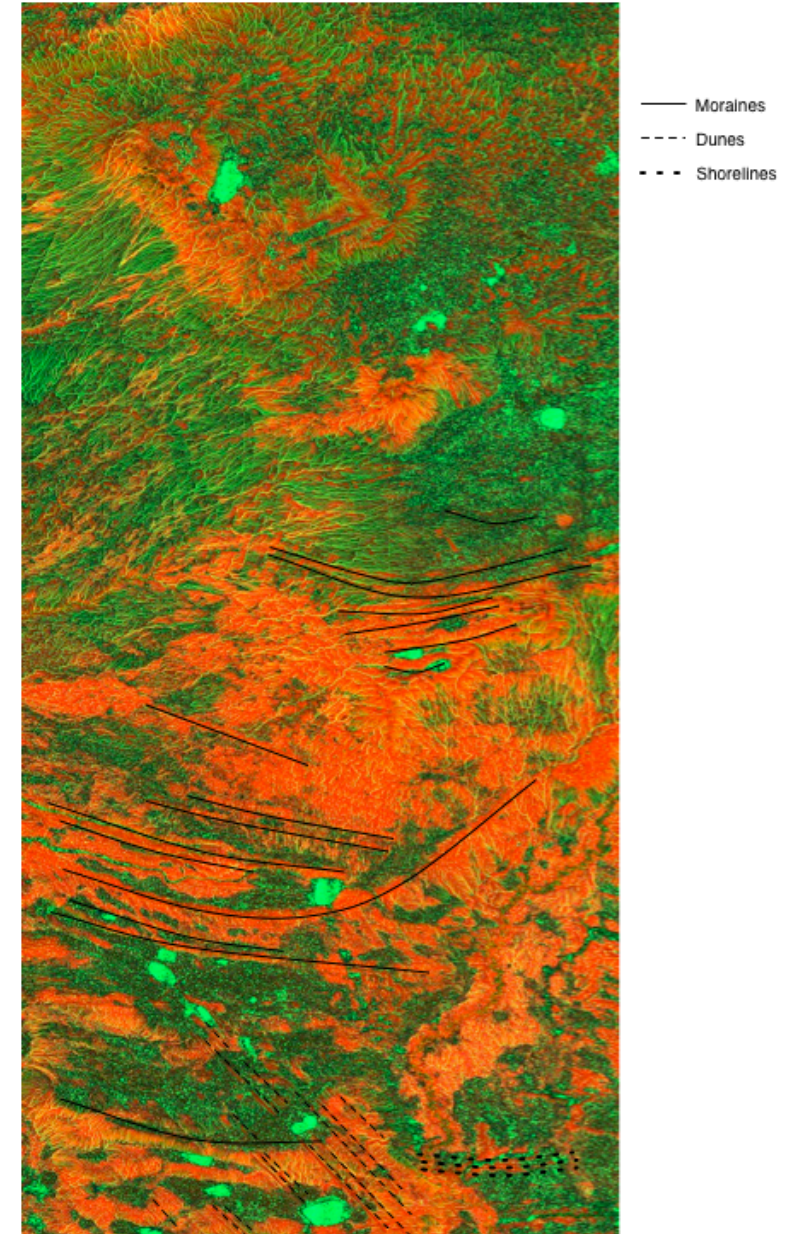
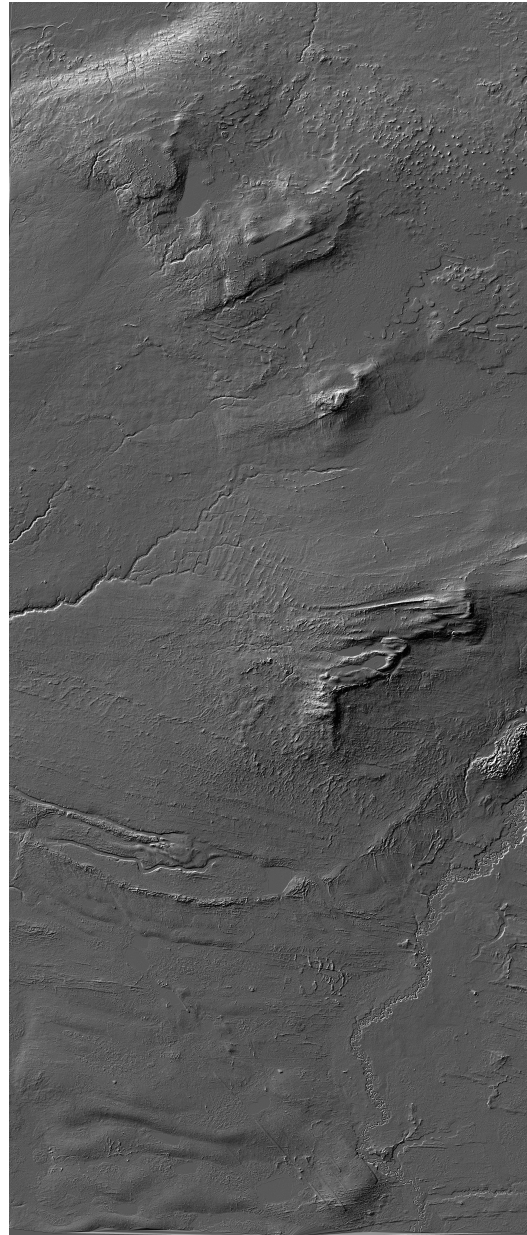
Geomorphological Mapping

- With some imagination we can start to interpret some of the surficial expressions of glacial/post glacial activity based on the LiDAR canopy and bare earth data.



Geomorphological Mapping

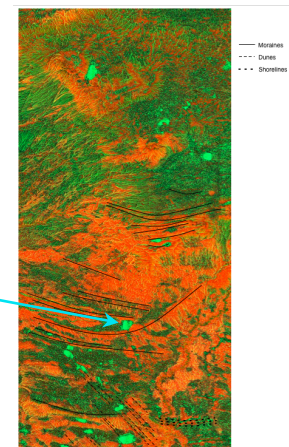
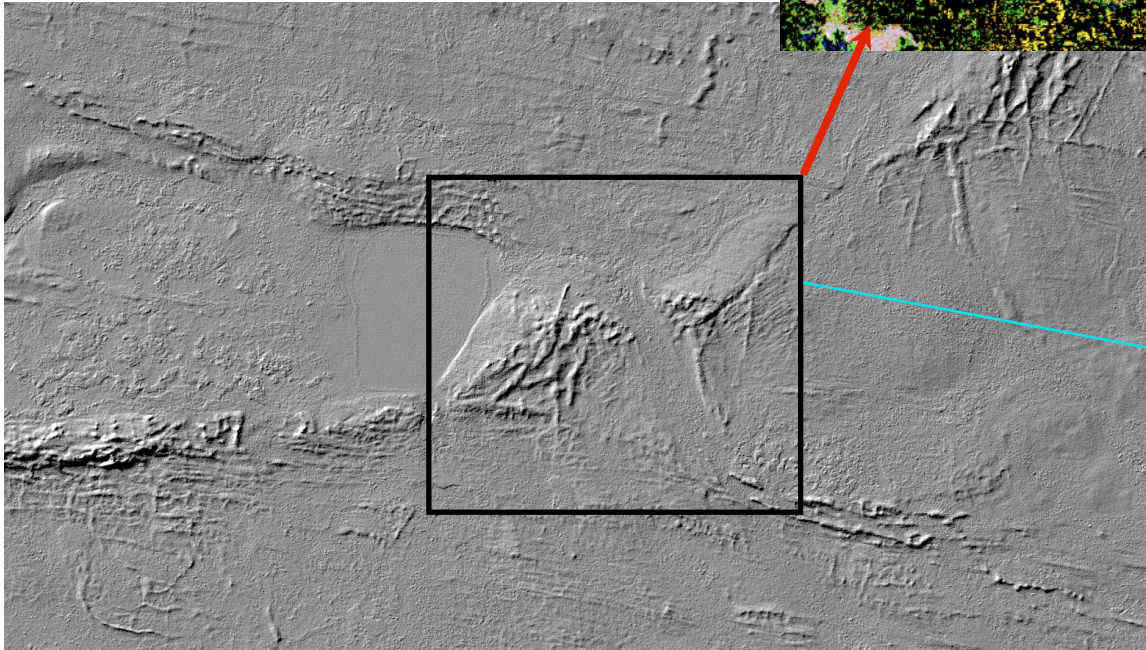
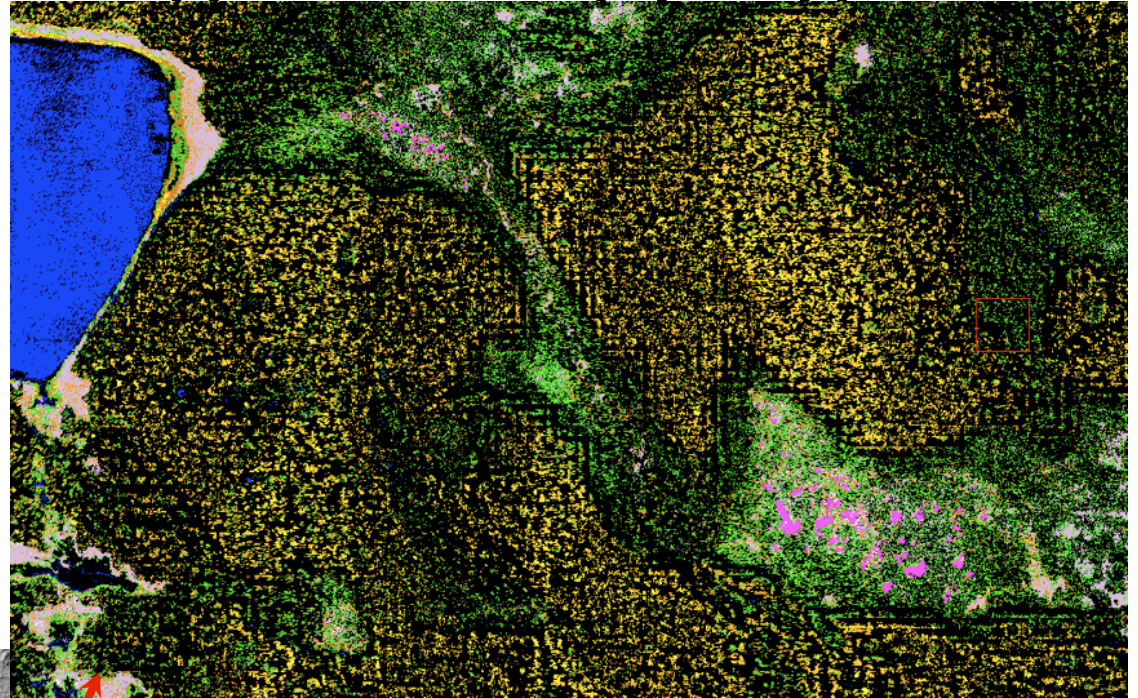
Bare earth model and canopy height/SWI models



Geomorphological Mapping

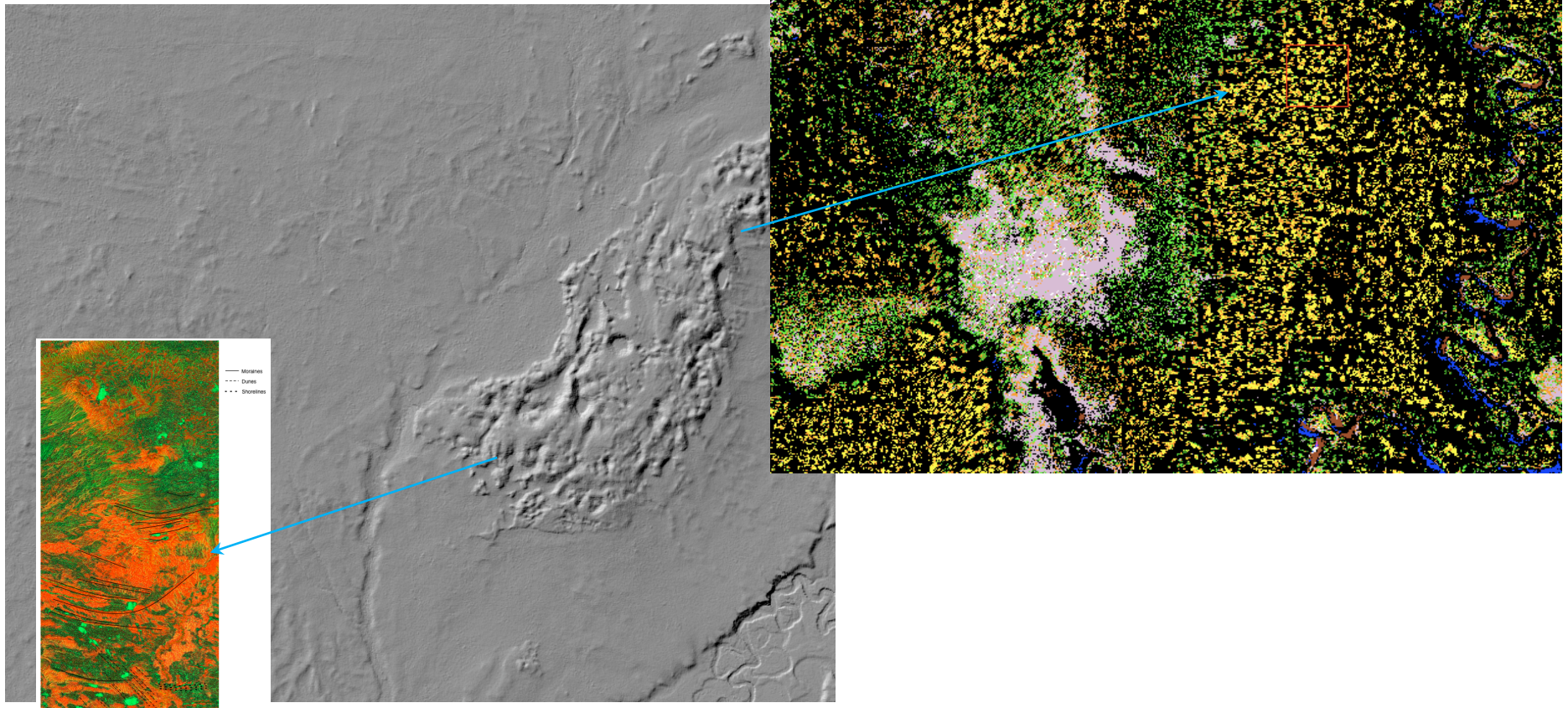
Area showing potential gravel deposits.

- The lake is behind a moraine which has been breached (most likely by a spillway).
- Downstream of the breach most likely represents areas where sorted aggregates are located
- deciduous vegetation marks areas of better drained soils.



Geomorphological Mapping

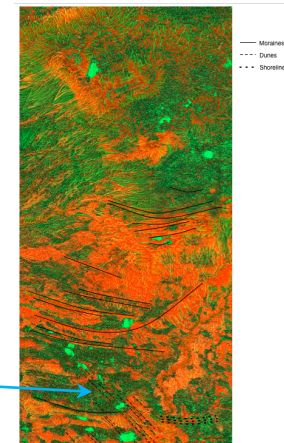
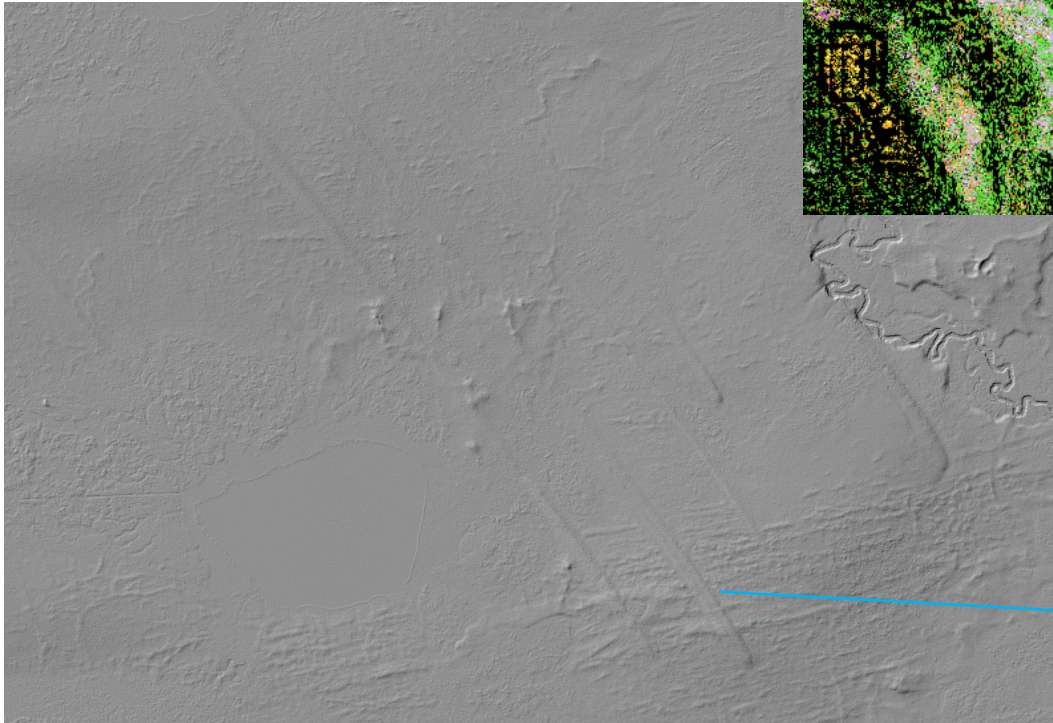
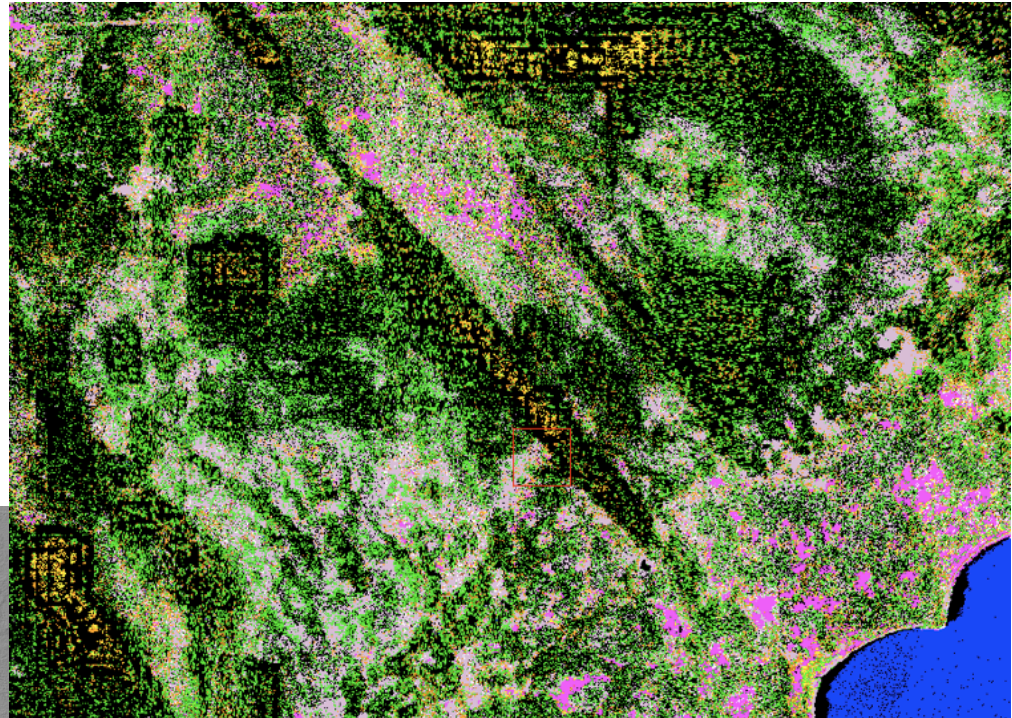
- very tall deciduous vegetation suggests that this deposit is very well drained.
- the surface morphology suggests that this is a remnant outwash feature. Features such as this typically have pockets of well sorted materials which may include gravel and sand deposits depending on the provenience of the source material.



Geomorphological Mapping

An example of part of a dune field found in the study area. The dunes are oriented in a SE to NW direction and are the result of the reworking of lacustrine sediments, or glaciofluvial sediments immediately after exposure.

The dunes appear to be not particularly well drained (supporting mostly conifer (white spruce and possibly pine vegetation). This might suggest that they are either relatively low in height or composed of very fine silts, rather than sands.



Summary

- Multiple datasets collected concurrently are represent an extremely rich source of information.
- LiDAR data can be used to extract multiple surface components that in themselves can be used to model surface form.
- These form models can be useful in deriving an understanding of both the canopy structure as well as the past process shaping the terrain.
- Hyperspectral data, in this instance as a compliment to the LiDAR, can supply the missing vegetative information, complimentary to the LiDAR form to sufficiently characterize the vegetative cover.
- In other environments LiDAR forms a compliment to hyperspectral in supplying the form to assist in stratifying and characterizing surface materials.