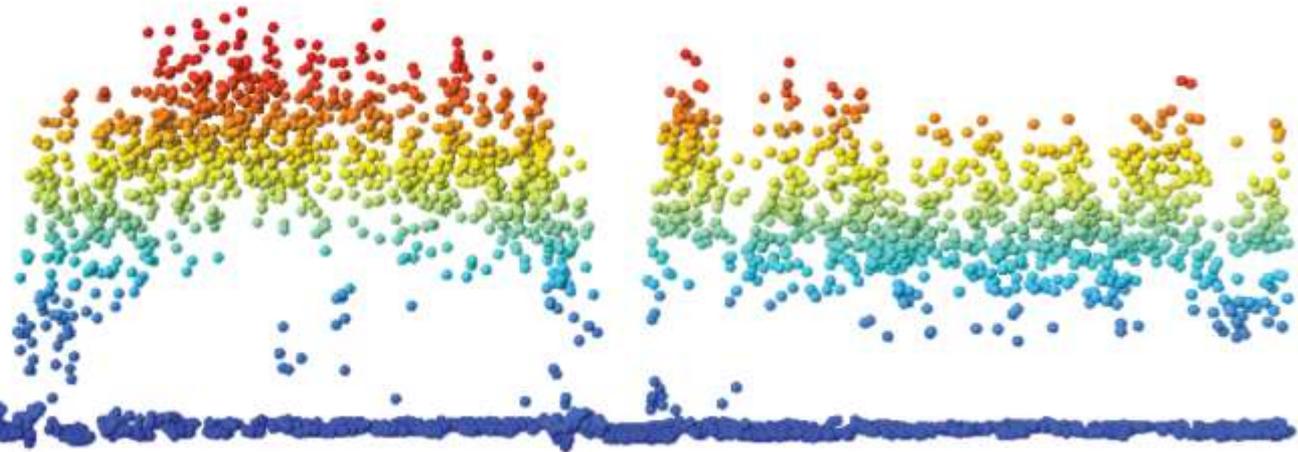


# Enabling wise forest management through the application of airborne laser scanning

With examples from biodiversity and  
riparian conservation

Chris Bater, Forest Management Specialist  
Forest Management Branch, Alberta Agriculture and Forestry



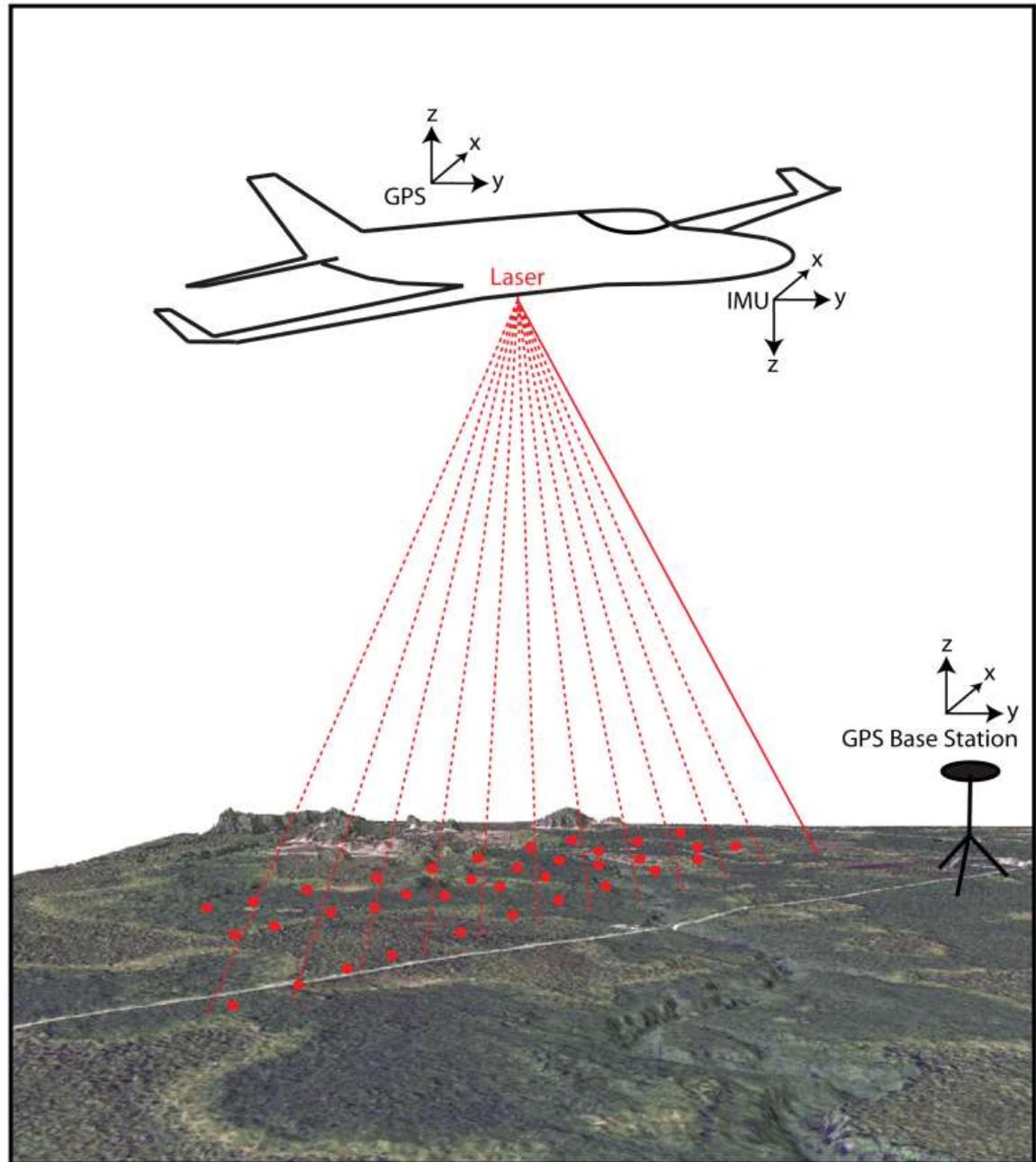
## Lidar described

Light detection and ranging

Combination of three technologies

- An infrared laser
- A global positioning system (GPS) with ground control
- An inertial measurement unit (IMU)

Can simultaneously map terrain morphology and vegetation height and vertical structure

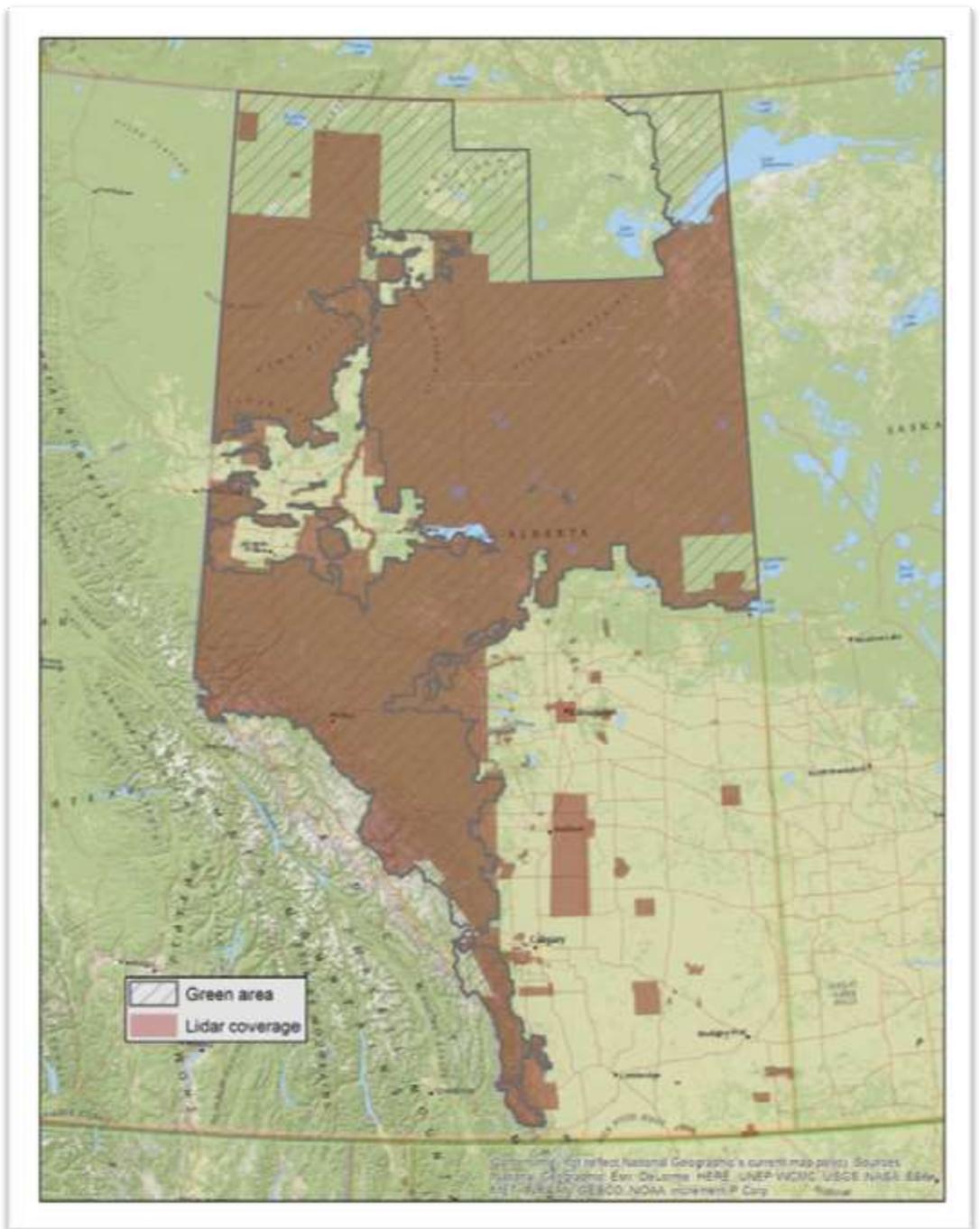


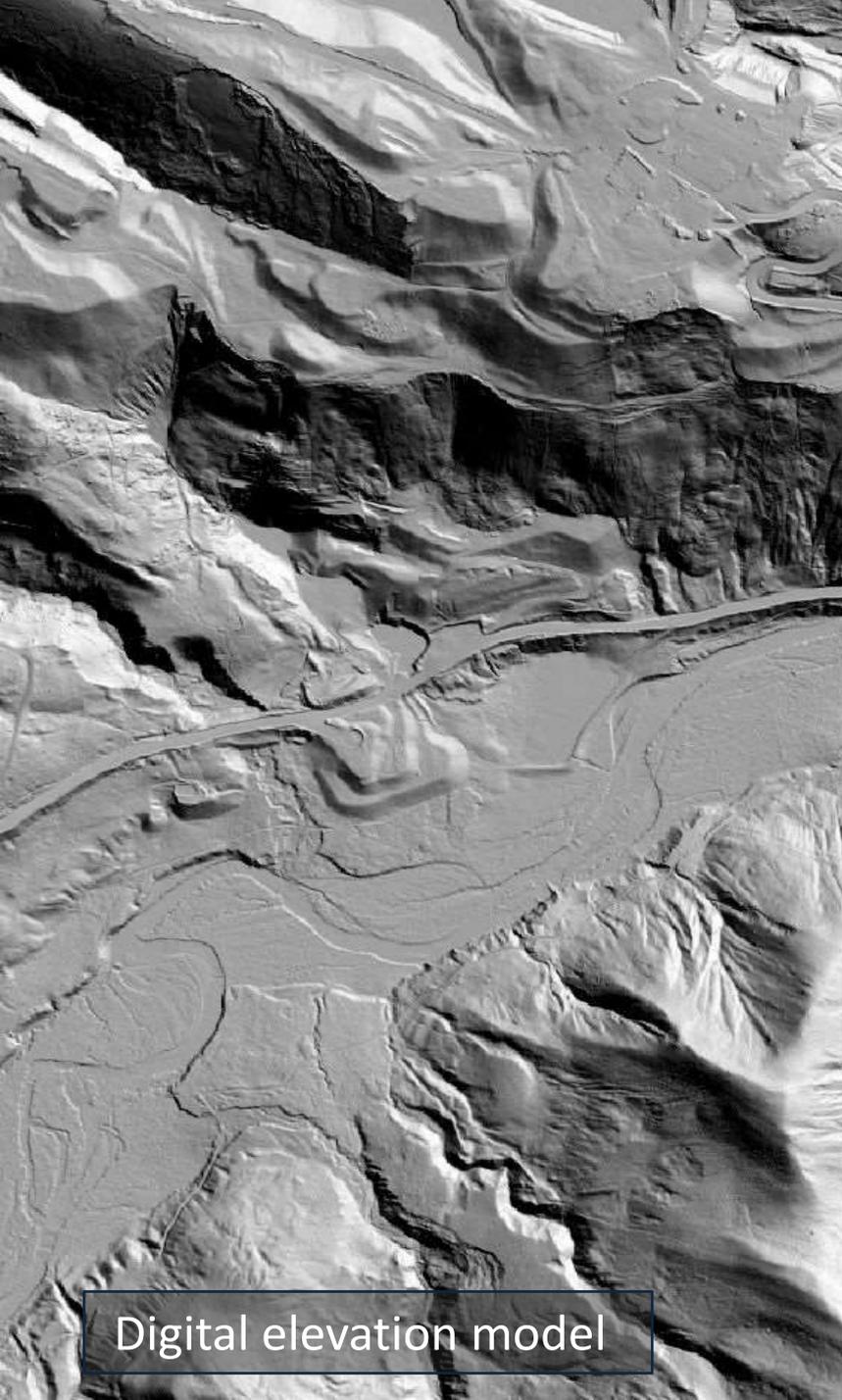
## Current status

33 million ha and counting

Green area

Provincial parks and protected areas



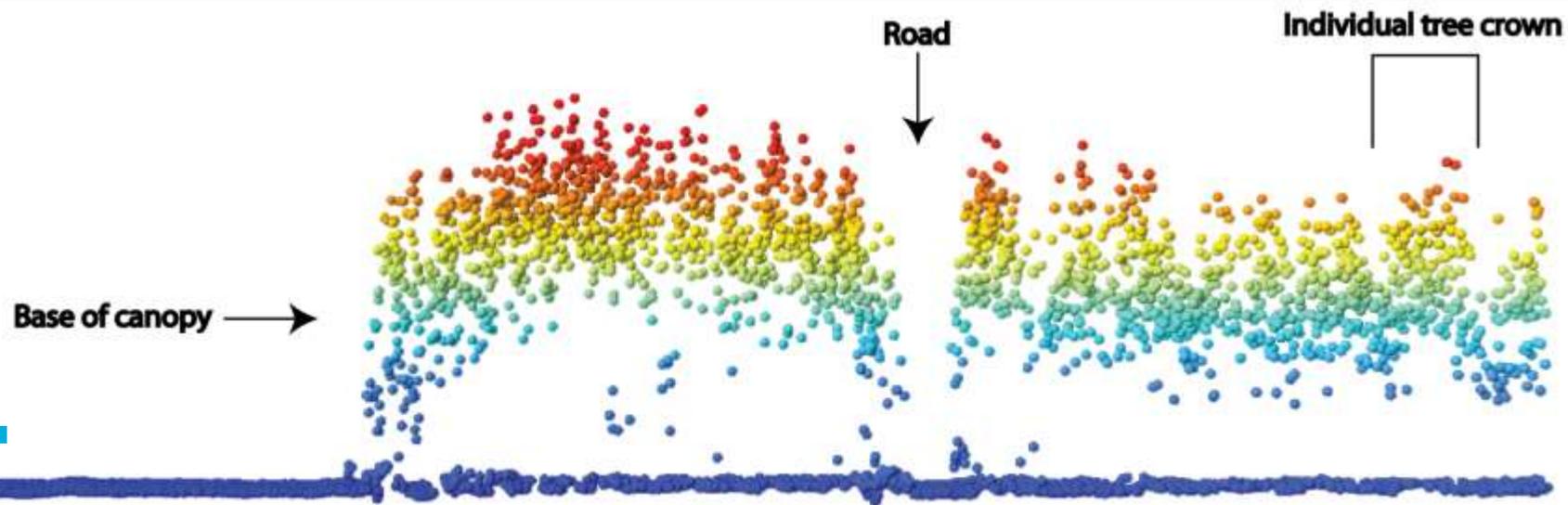


Digital elevation model



Digital surface model

Lidar is a point cloud



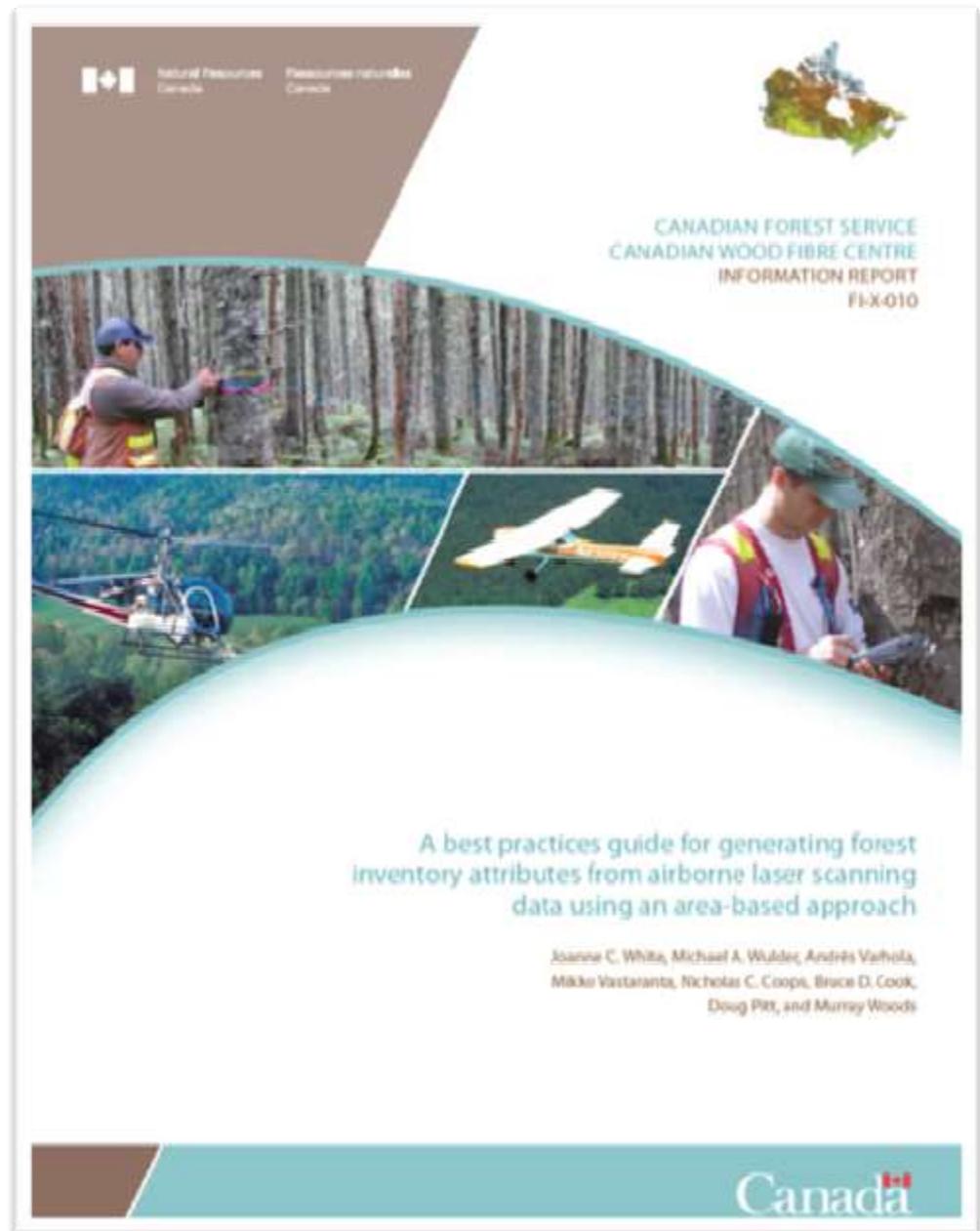
# Lidar-enhanced forest inventory

The image shows an aerial view of a forest landscape. A prominent feature is a winding stream that flows from the upper right towards the lower left. The forest canopy is color-coded, likely representing different tree species or canopy heights derived from Lidar data. The colors range from dark blue and purple (possibly indicating lower canopy or specific species) to bright green and yellow (indicating higher canopy or other species). Several small, irregularly shaped ponds or wetlands are scattered throughout the forest, appearing in shades of cyan and light blue. The overall scene is a detailed, multi-colored map of a forest ecosystem.

# Enhanced forest inventory

An exercise in applied science...

A number of sources available describing methods to get from disparate data sources to completed inventory



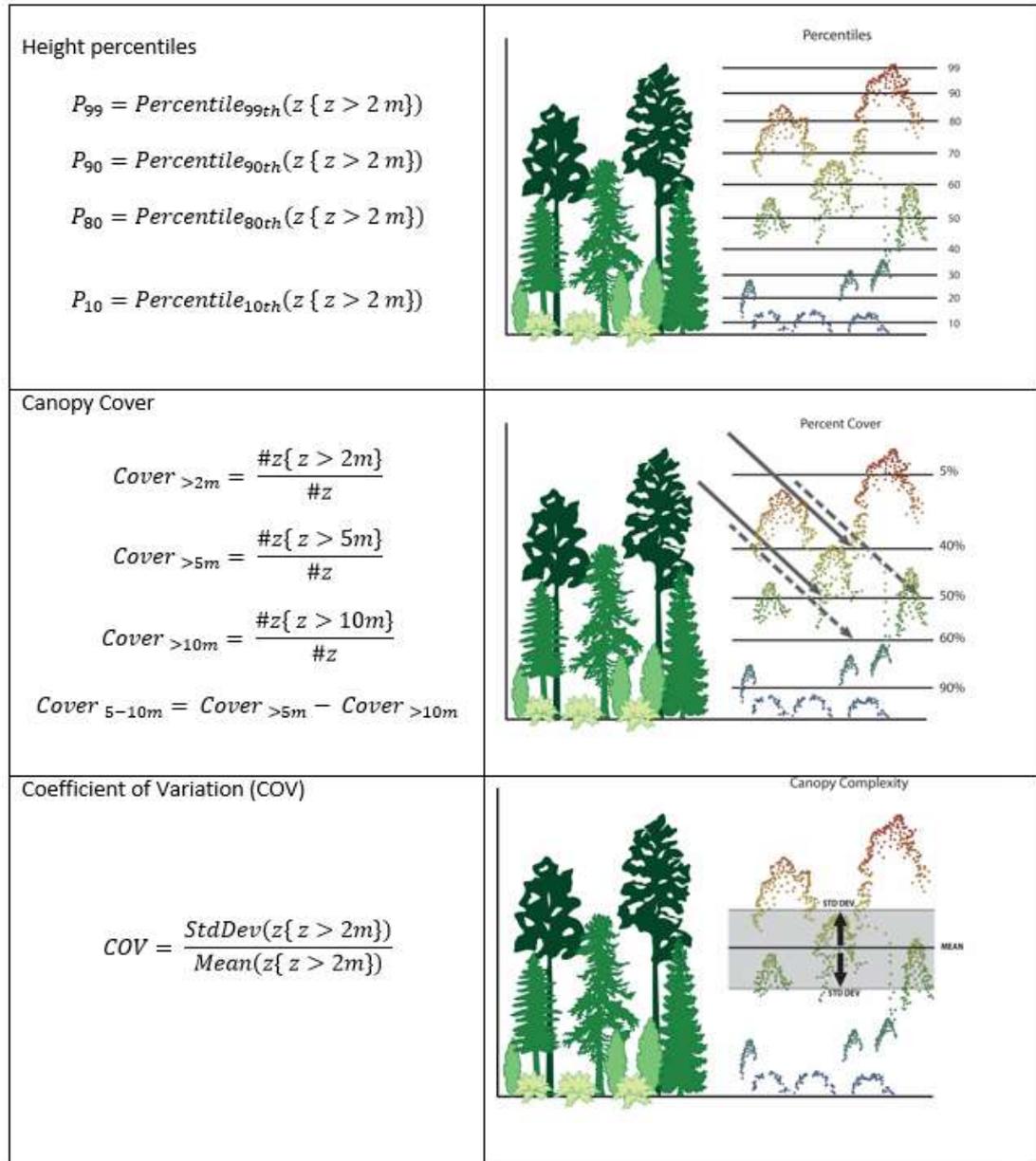
# Lidar-derived vegetation metrics

Lidar can be used to gather a tremendous amount of detail relating to forest structure and the vertical organization of plant biomass.

Lidar is generally considered “blind” to plant health and species (with caveats, of course).

Fundamentally, vegetation metrics are related to:

- height
- vertical structure
- cover



Source: Coops, N.C. and Nielsen, S. 2015. Biodiversity and ecosystem characterization supported with LiDAR. Unpublished report. Forest Management Branch, Alberta Agriculture and Forestry. Edmonton, Alberta.

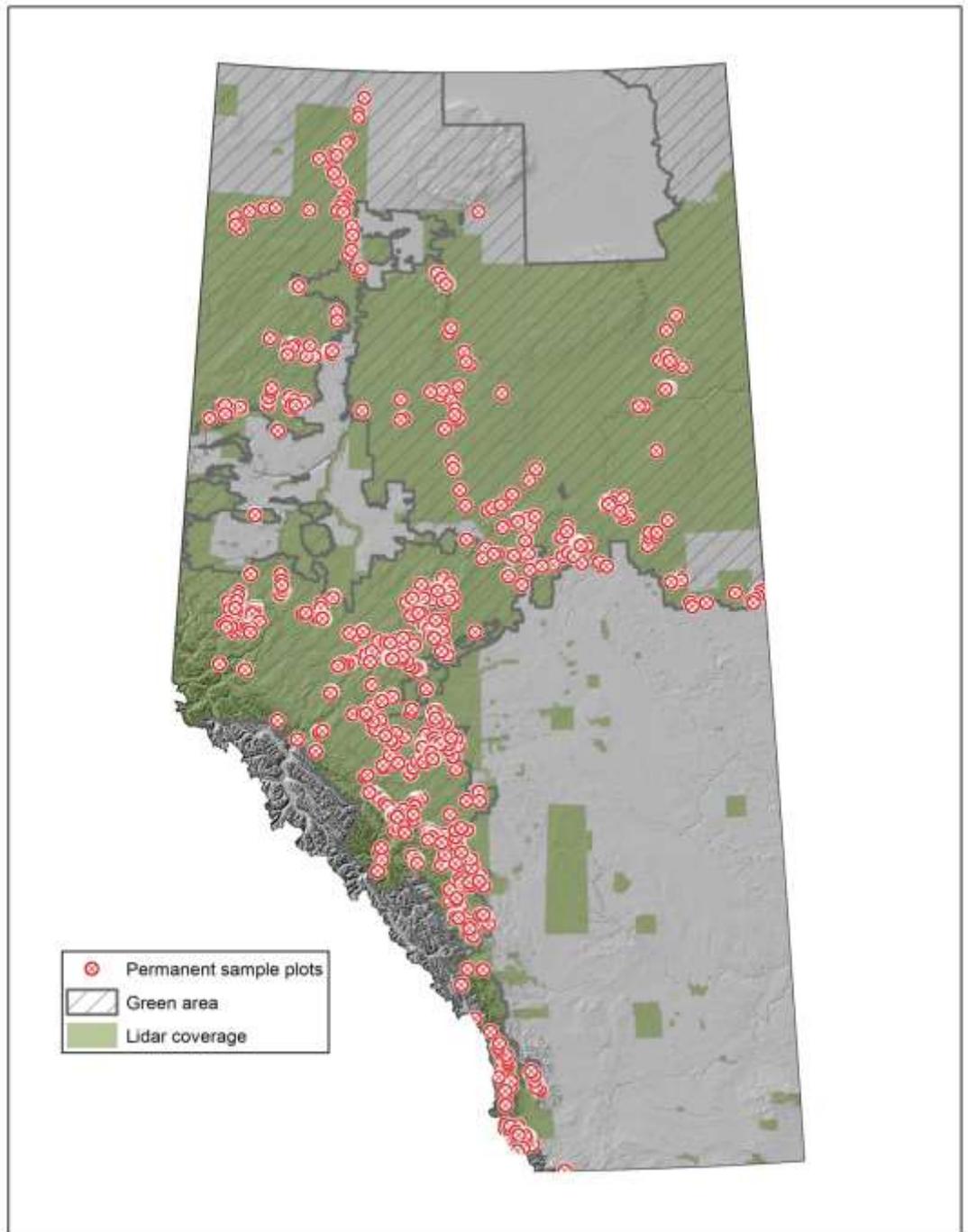
## Permanent sample plots

n = 1,411

Predominantly located in mature stands

Individual tree attributes collected for all stems  $\geq 9.1$  cm and include:

- Species
- Diameter at breast height
- Height
- Height to base of live crown
- Tree location

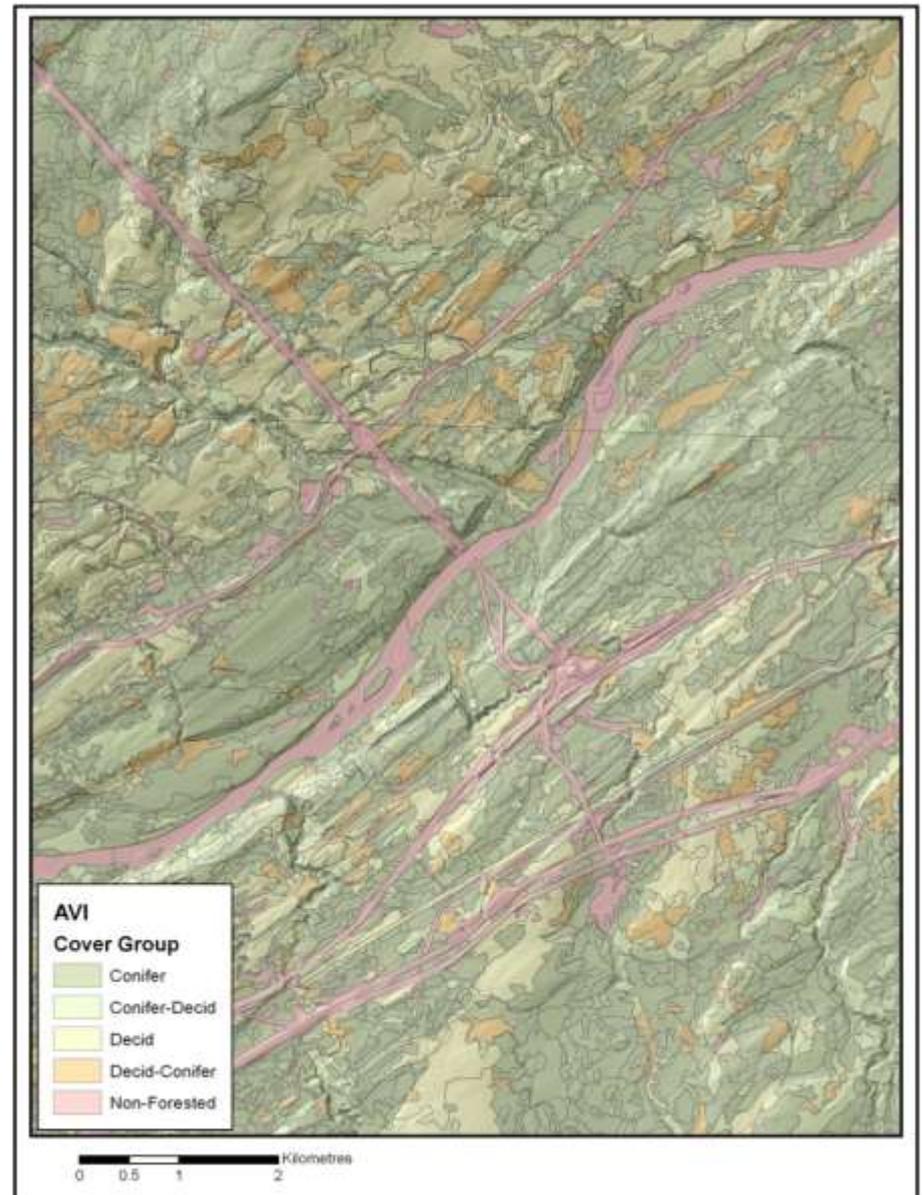


# The Alberta Vegetation Inventory (AVI)

A photo-based digital inventory interpreted by trained specialists.

Species composition, age, and structure summarized by polygon.

Identifies the type, extent and conditions of vegetation, where it exists and what changes are occurring.



## Enhanced forest inventory

Stand attributes of interest include:

- Volume (m<sup>3</sup>/ha)
- Basal area (m<sup>2</sup>/ha)
- Top height (average height of the 100 largest diameter trees per ha)
- Height to live crown (m)
- Canopy bulk density (kg/m<sup>3</sup>)

Three key datasets:

- Lidar metrics
- Ground plot data
- Existing photo-based forest inventory (AVI)

$$\hat{T}_{PPS} = \frac{1}{n} \sum_{i=1}^n \frac{y_i}{p_i}$$

$$\widehat{var}(\hat{T}_{PPS}) = \frac{1}{n(n-1)} \sum_{i=1}^n \left( \frac{y_i}{p_i} - \hat{T}_{PPS} \right)^2$$

$$\bar{y}_{SYS} = \frac{1}{n} (y_1 + y_2 + \dots + y_n) = \frac{1}{n} \sum_{i=1}^n y_i$$

$$s^2 = \frac{1}{n-1} \sum_{i=1}^n (y_i - \bar{y}_{SYS})^2$$

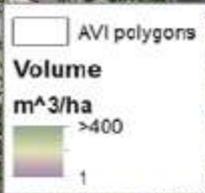
$$\widehat{var}(\bar{y}_{SYS}) = \left( \frac{N-n}{N} \right) \frac{s^2}{n}$$

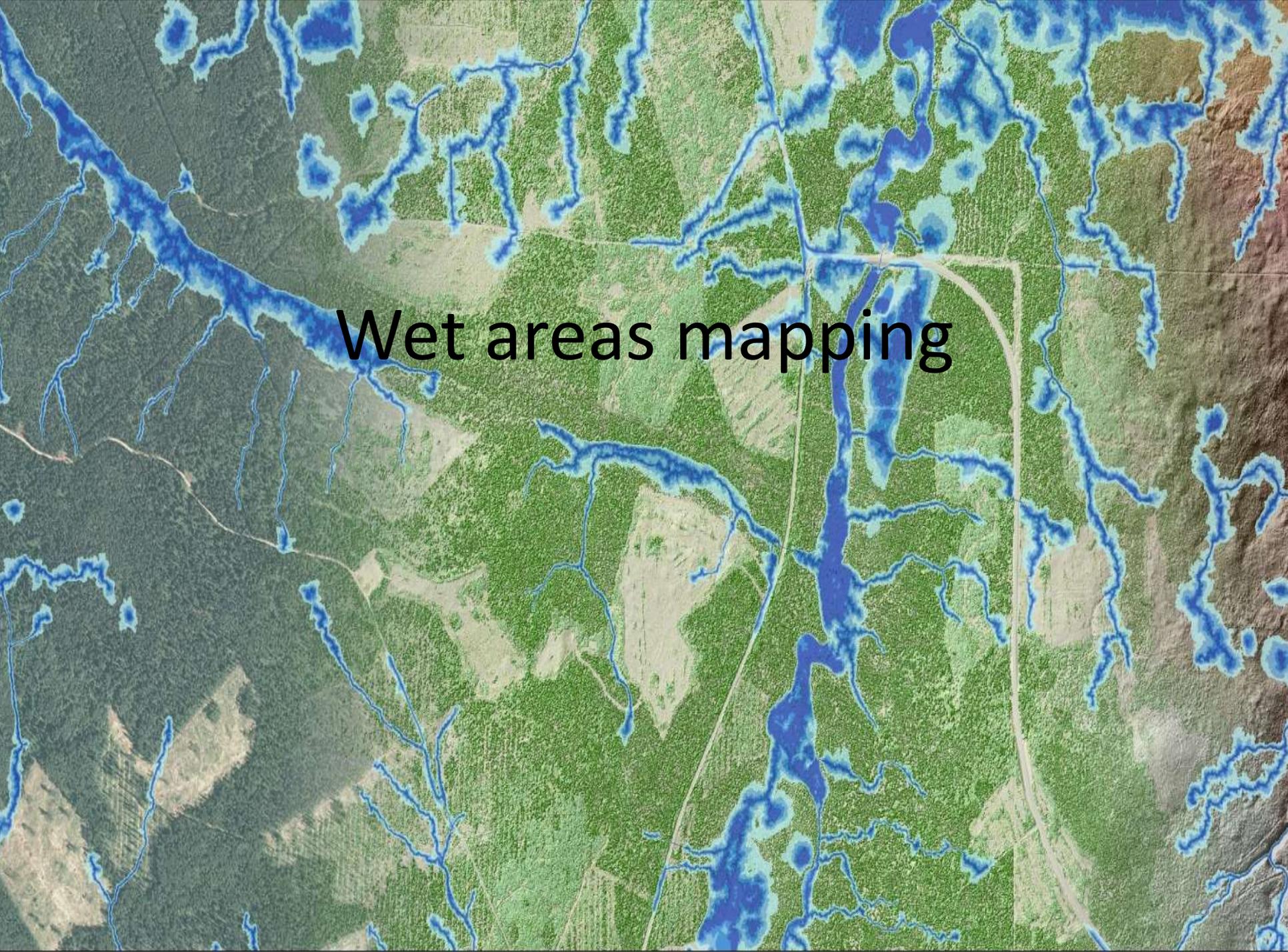
$$\hat{T}_{SYS} = N\bar{y}_{SYS} = \frac{N}{n} \sum_{i=1}^n y_i$$

$$\widehat{var}(\hat{T}_{SYS}) = N^2 \widehat{var}(\bar{y}_{SYS}) = N(N-n) \frac{s^2}{n}$$

## Total stem volume

An estimate every 30 m across the landscape



An aerial photograph of a rural landscape with a semi-transparent blue overlay. The blue overlay highlights a complex network of waterways, including a large river on the left and numerous smaller, branching streams and ponds. The background shows a mix of green agricultural fields, brownish-tan soil or dry vegetation, and a road network. The text "Wet areas mapping" is centered over the image in a black, sans-serif font.

# Wet areas mapping

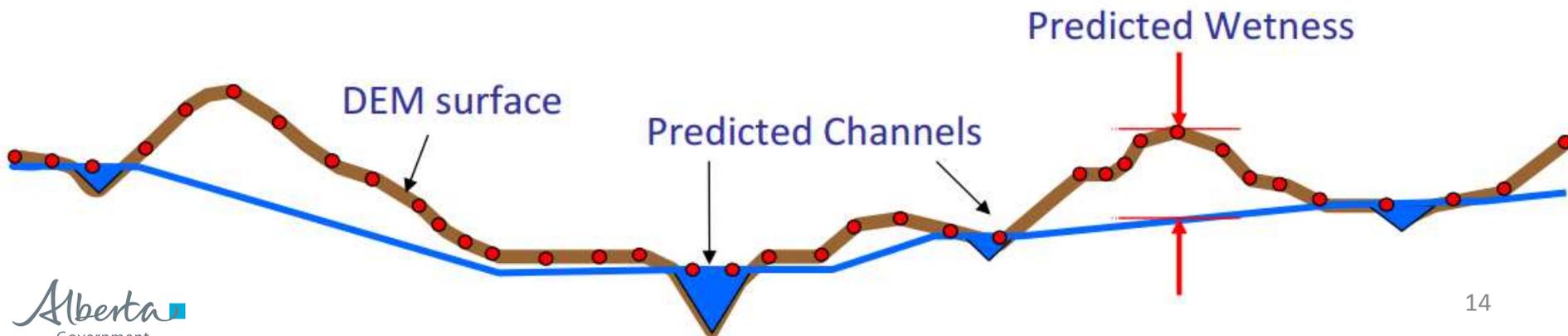
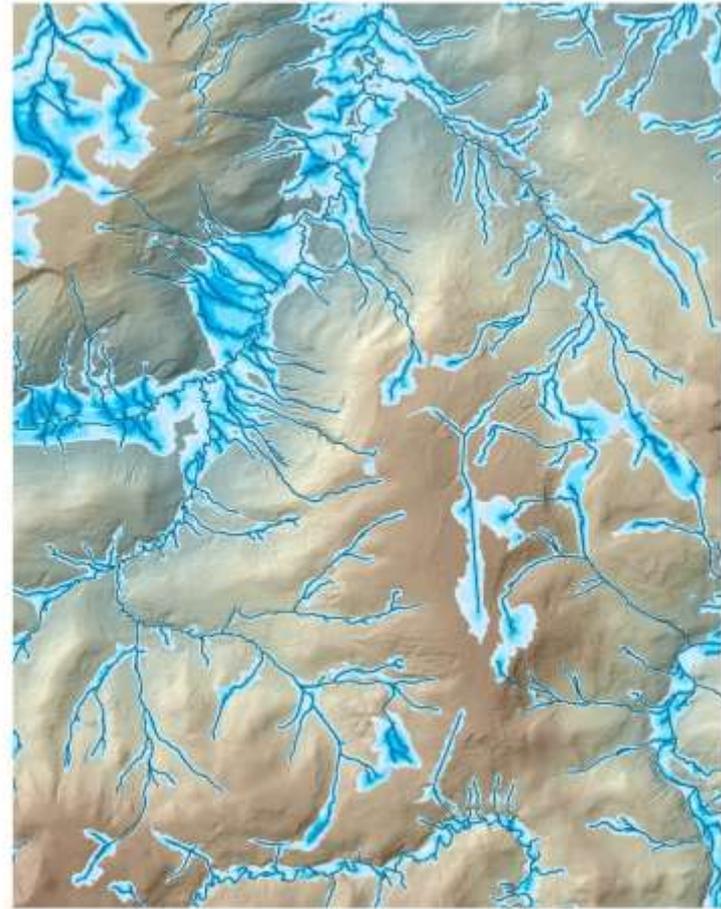
## Wet areas mapping

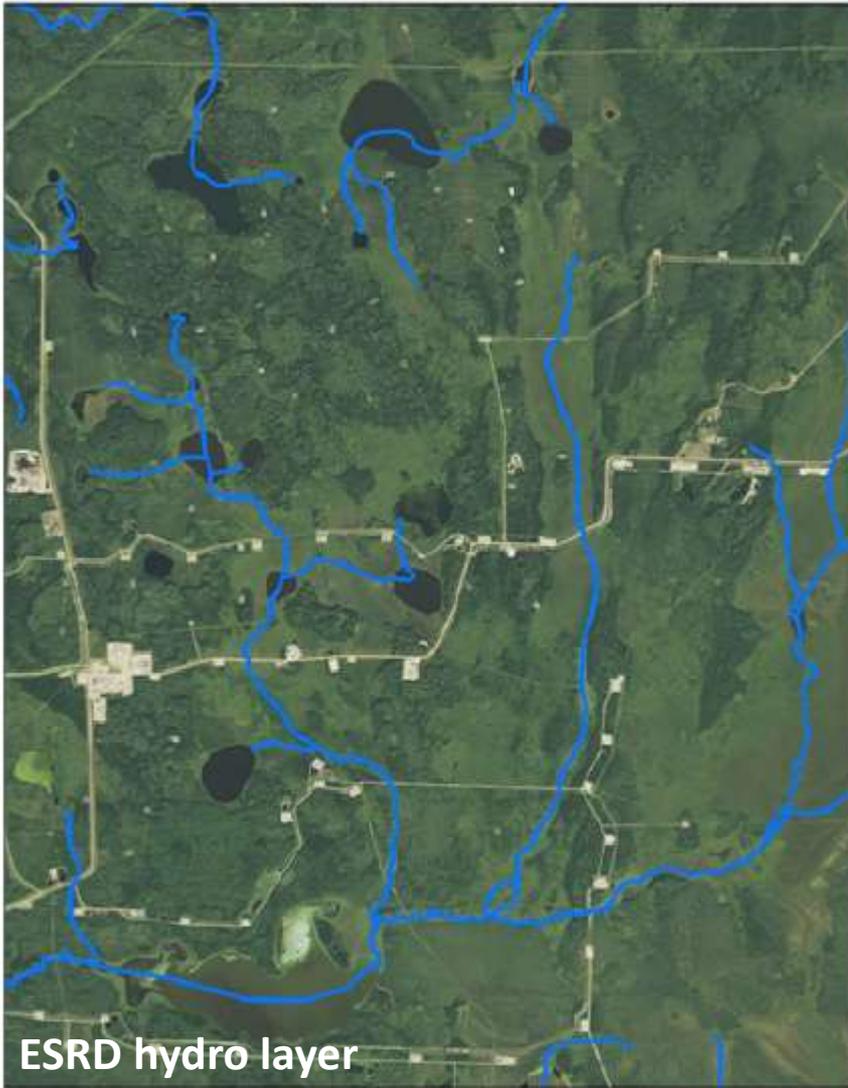
To date the largest initiative involving the province's lidar holdings

Includes two key products:

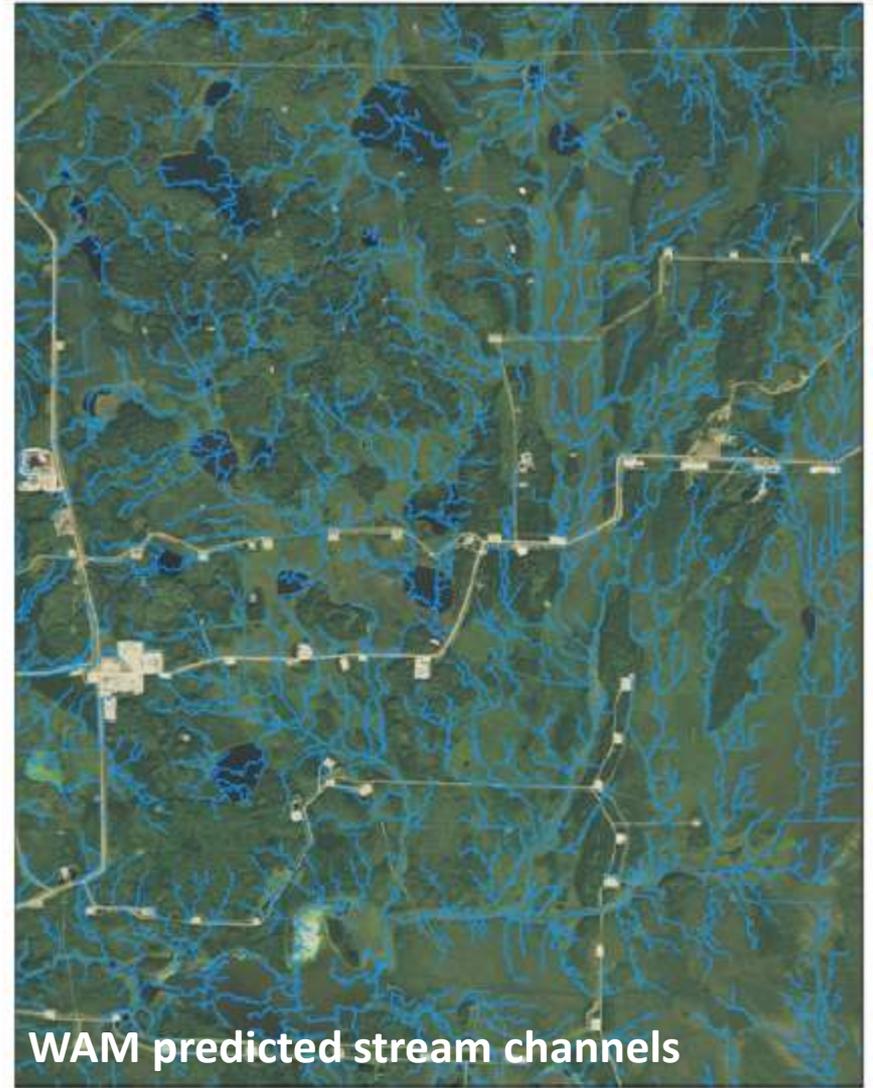
- Predicted stream channel lines
- Depth to water estimates

Their combination yields predicted topographic moisture gradients across a landscape





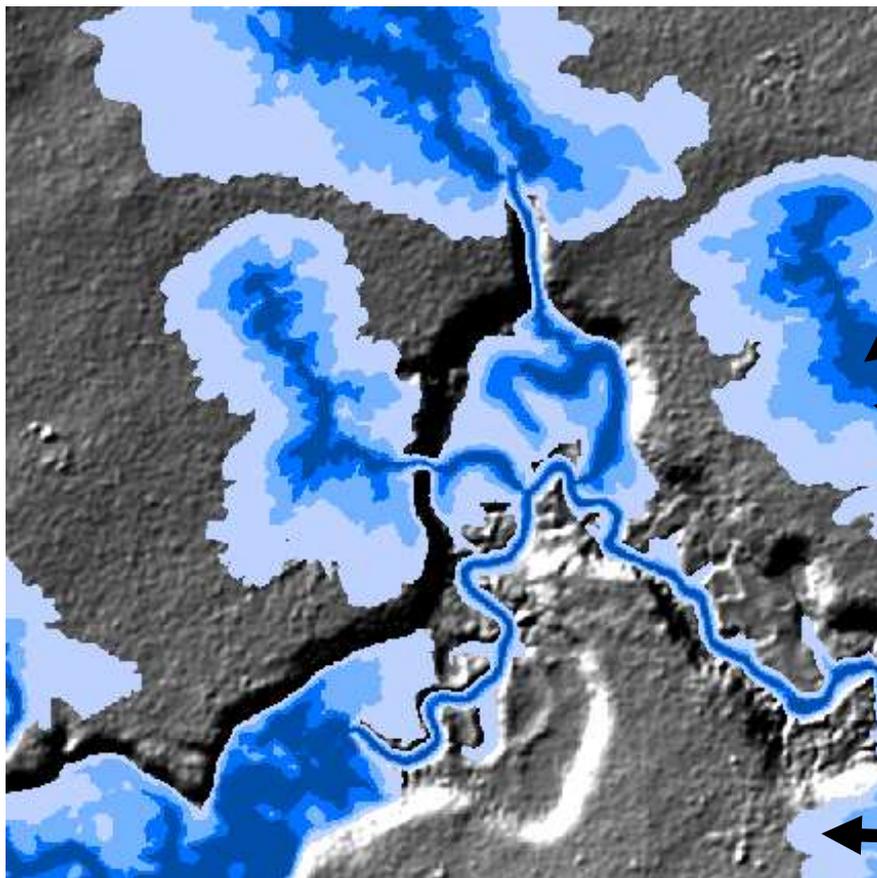
**ESRD hydro layer**



**WAM predicted stream channels**

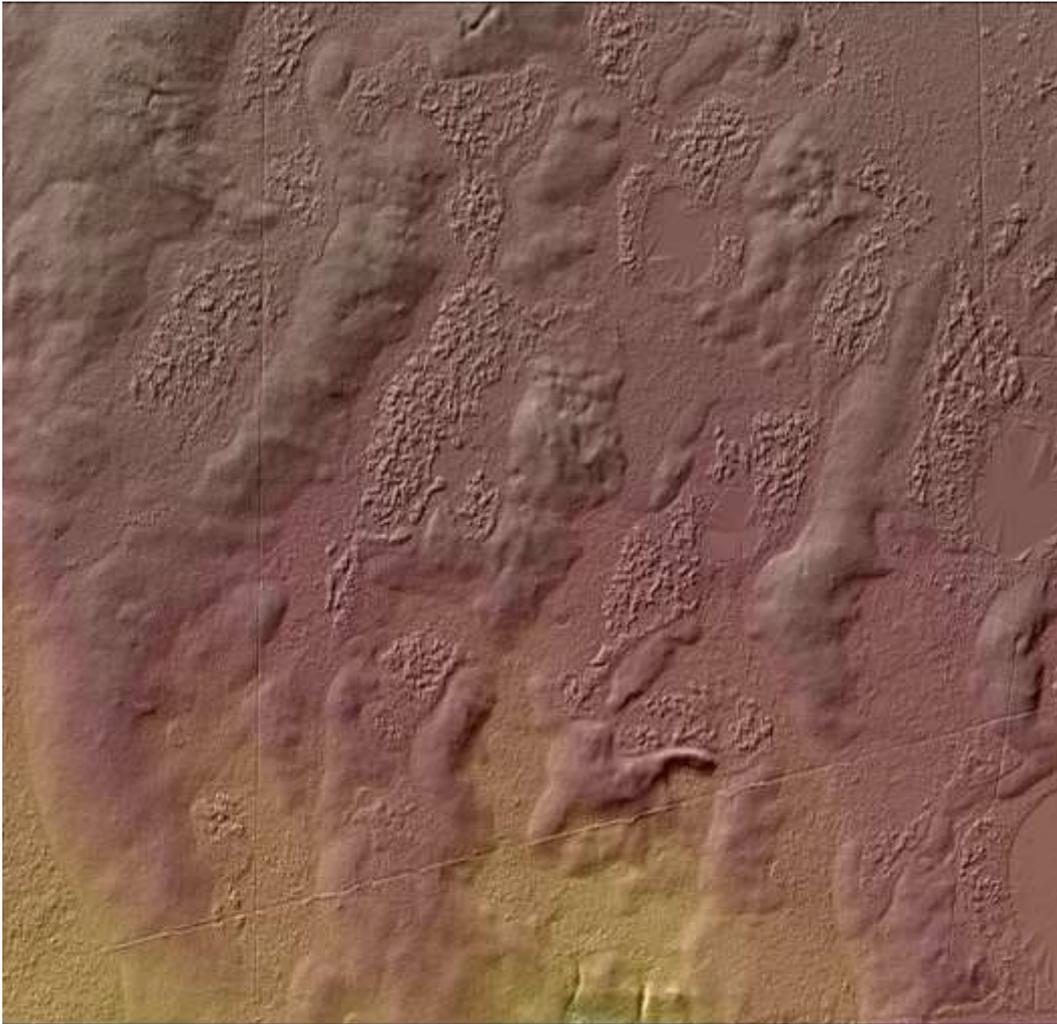
# Wet Areas Mapping

## Depth to water



# Wet Areas Mapping

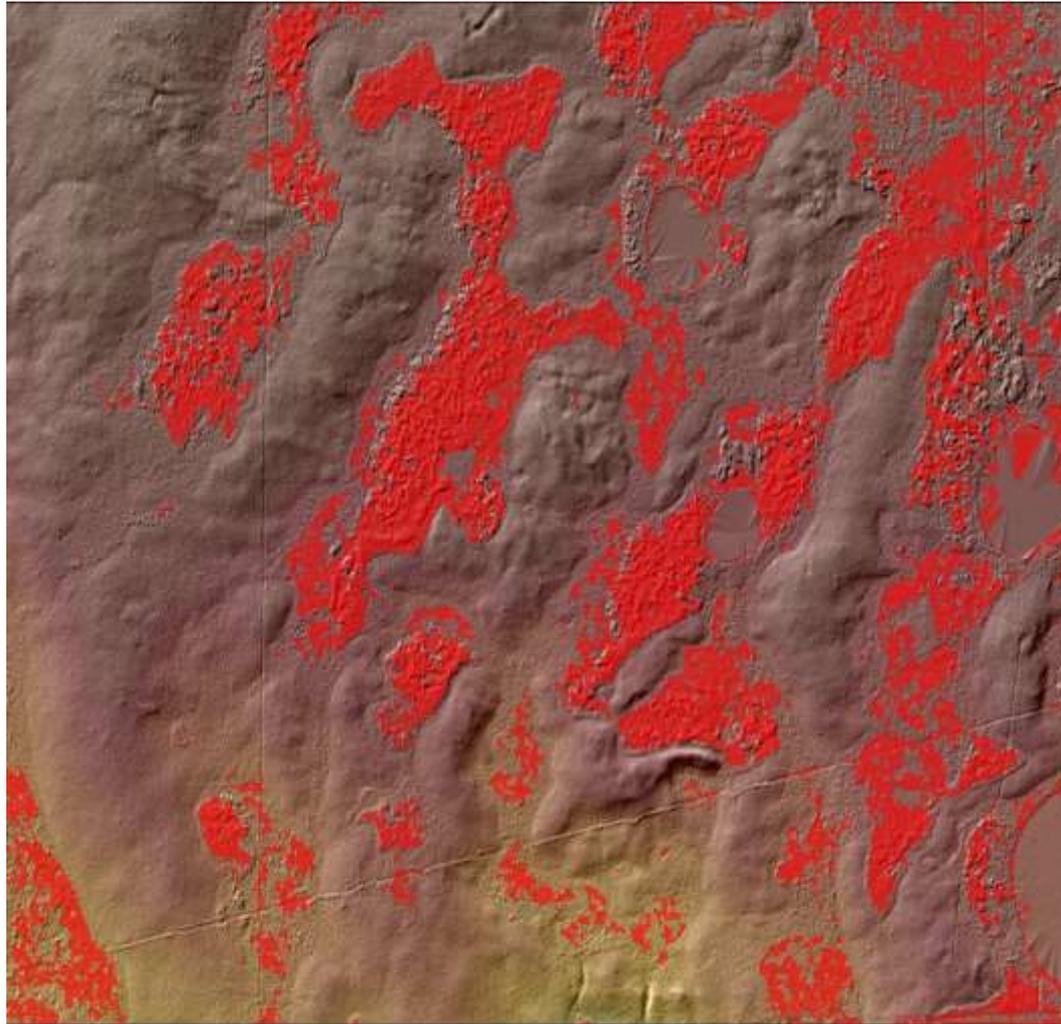
## Raised bog features



- WAM is driven by overland flow (topography)
- Raised bog features appear as dry islands without proper consideration
- A LiDAR-based solution was required
- Layers to explore:
  - Bare Earth DEM
  - Full Feature DEM
  - Intensity Image

# Wet Areas Mapping

## Raised bog features



DEM-based

Reliant on:

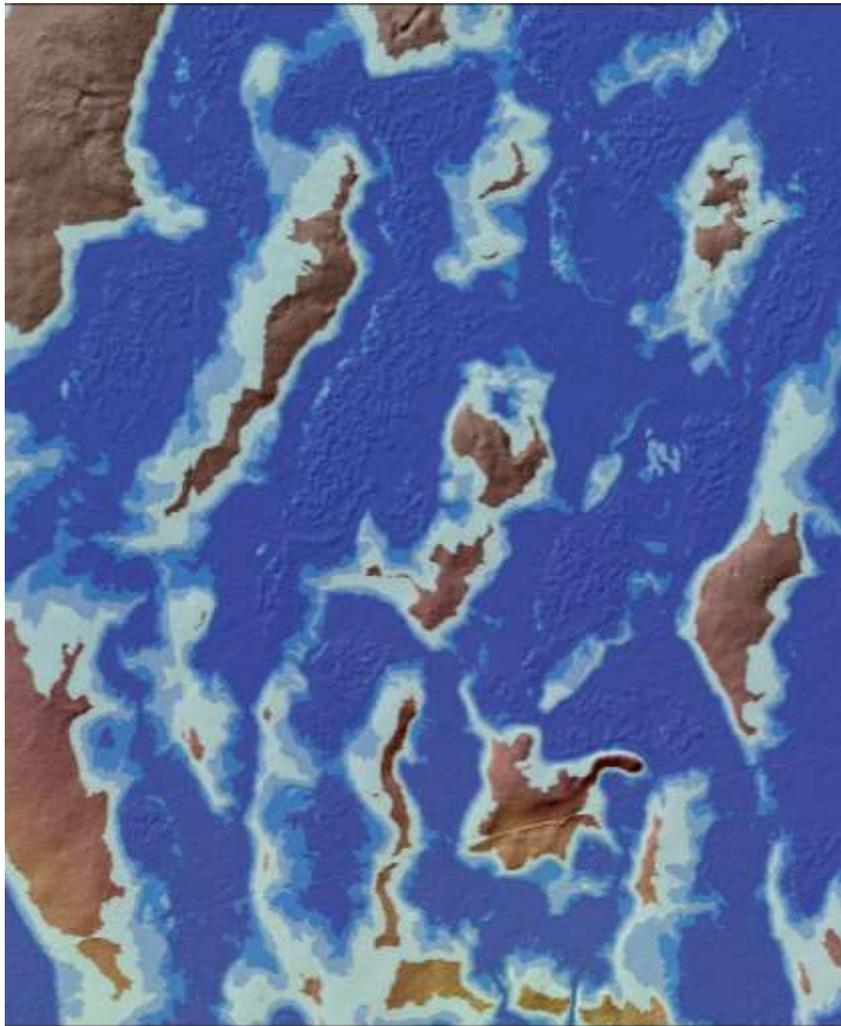
- Canopy Height
  - height of dominant canopy
- Canopy Texture
  - roughness
  - homogeneity
- Bare Earth Texture
  - roughness

Landform & Textural Analysis >  
Computer Vision & Image  
Segmentation

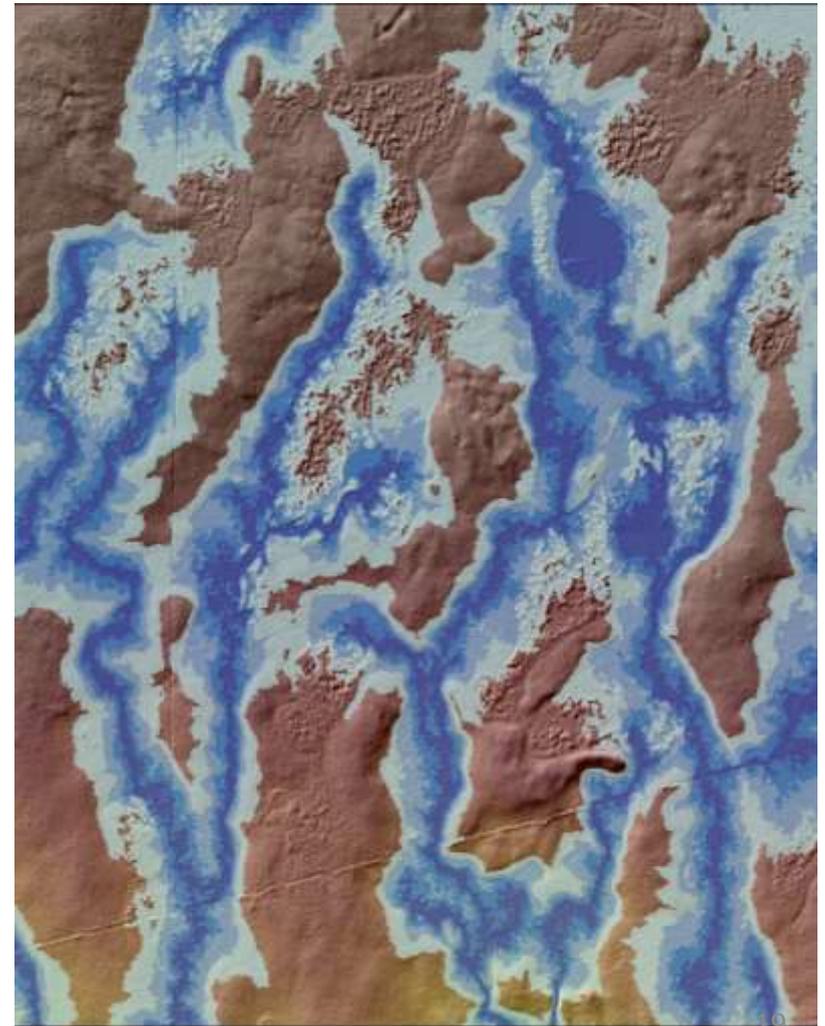
# Wet Areas Mapping

## Raised bog features

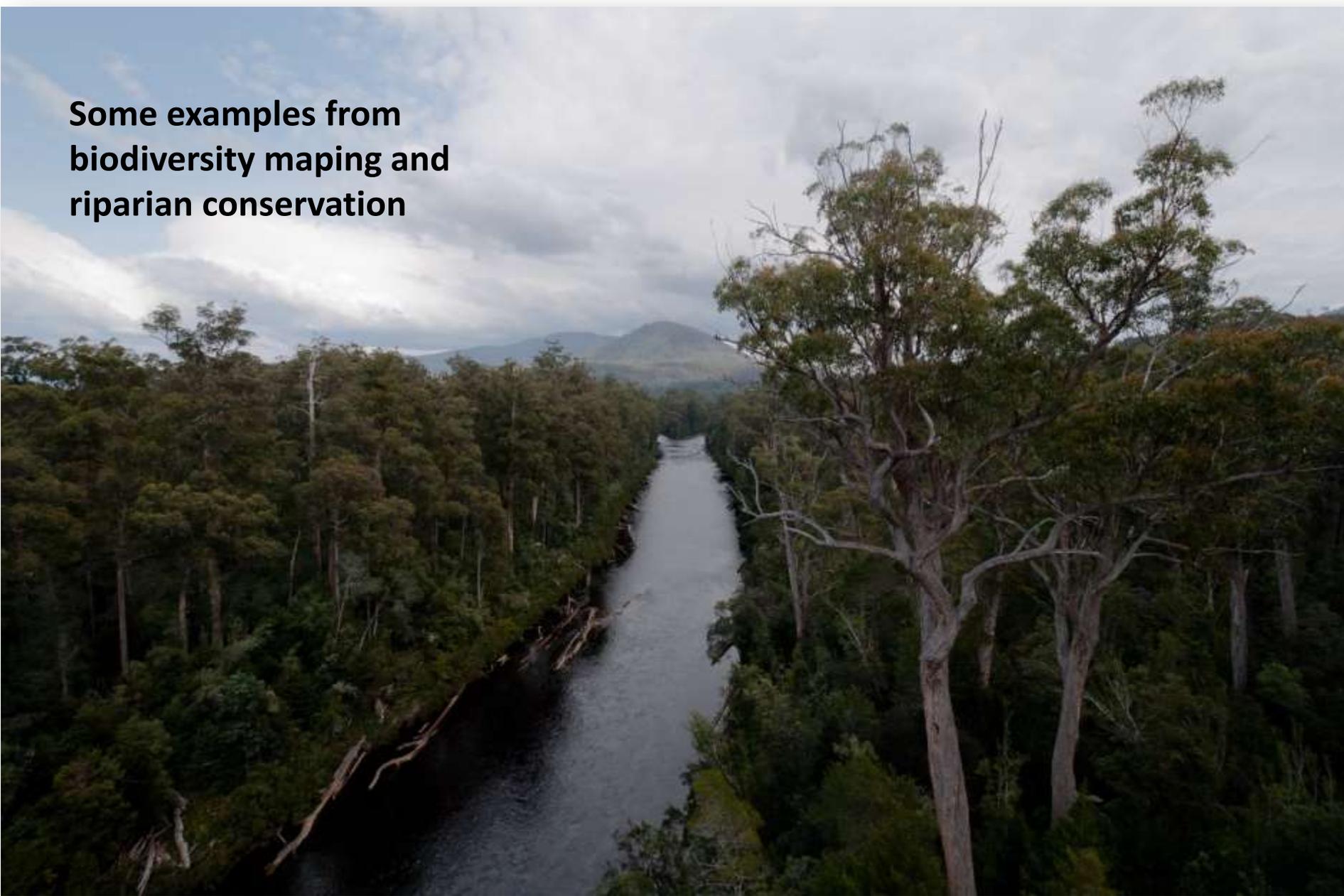
With Wetland Extraction

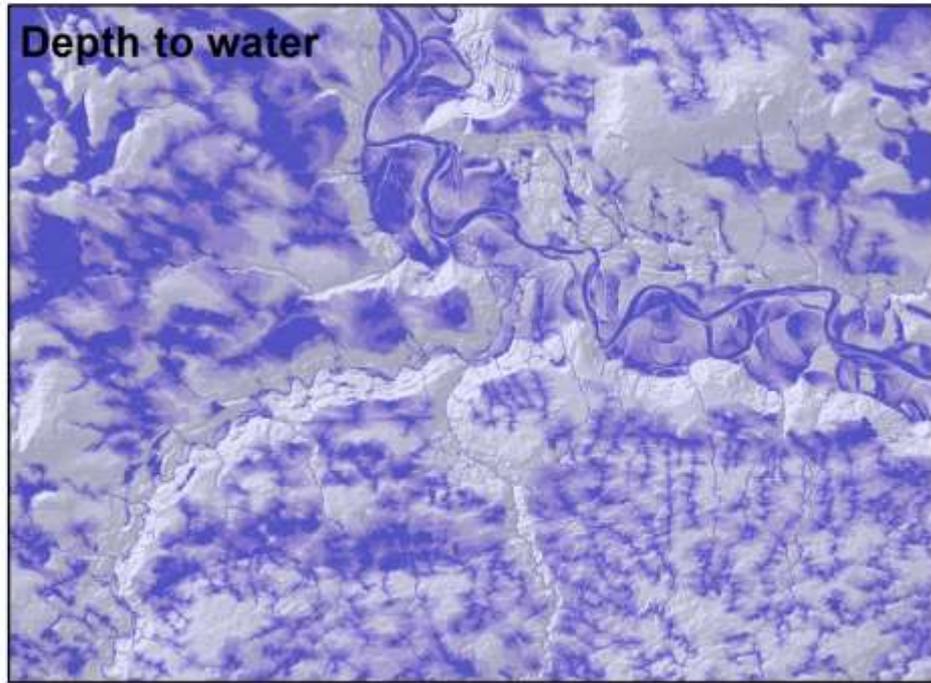
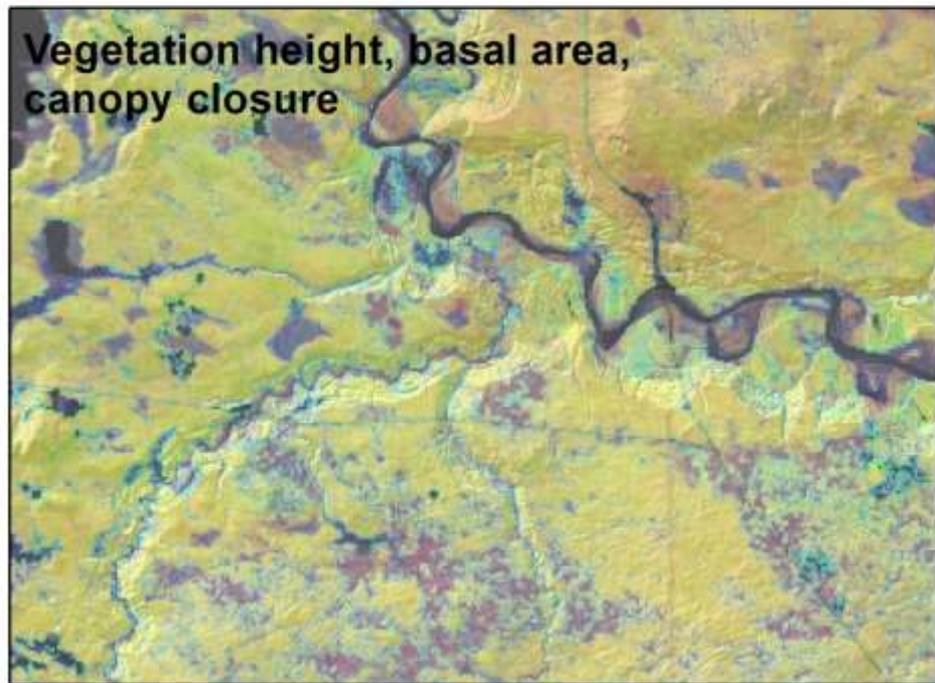
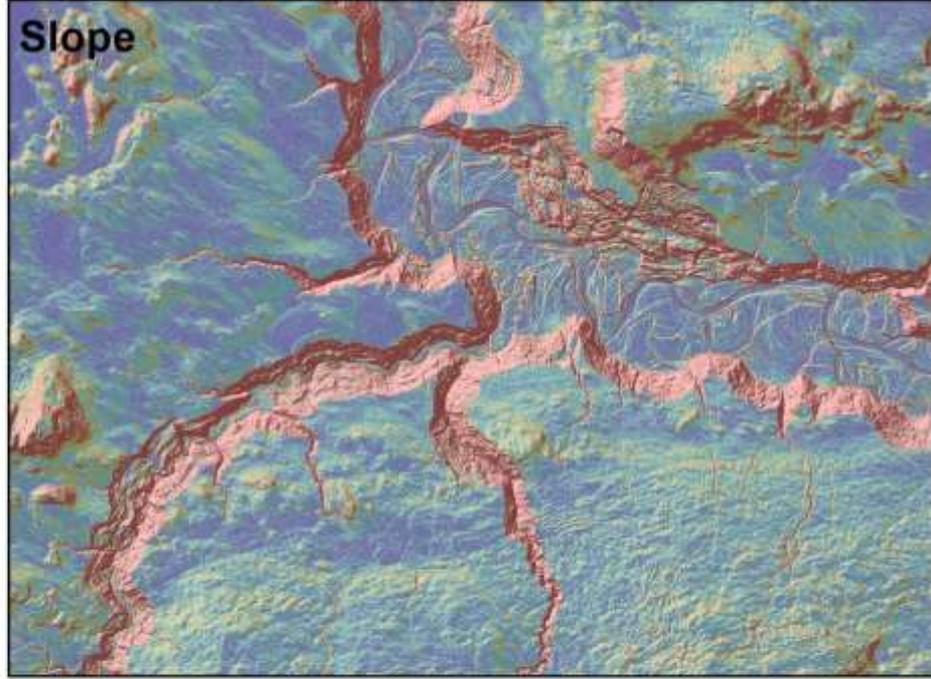
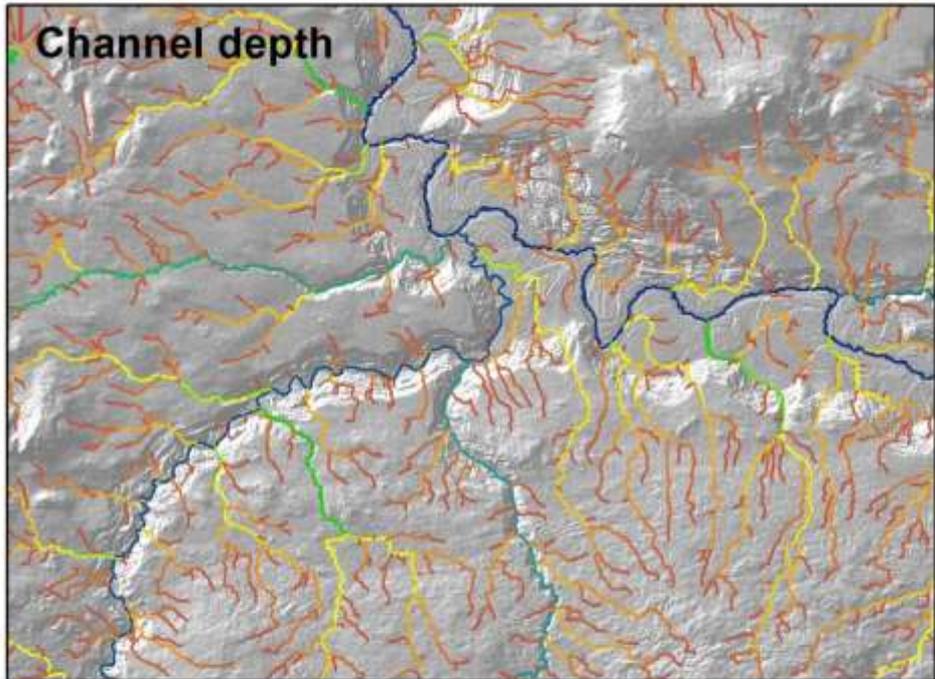


Without Wetland Extraction

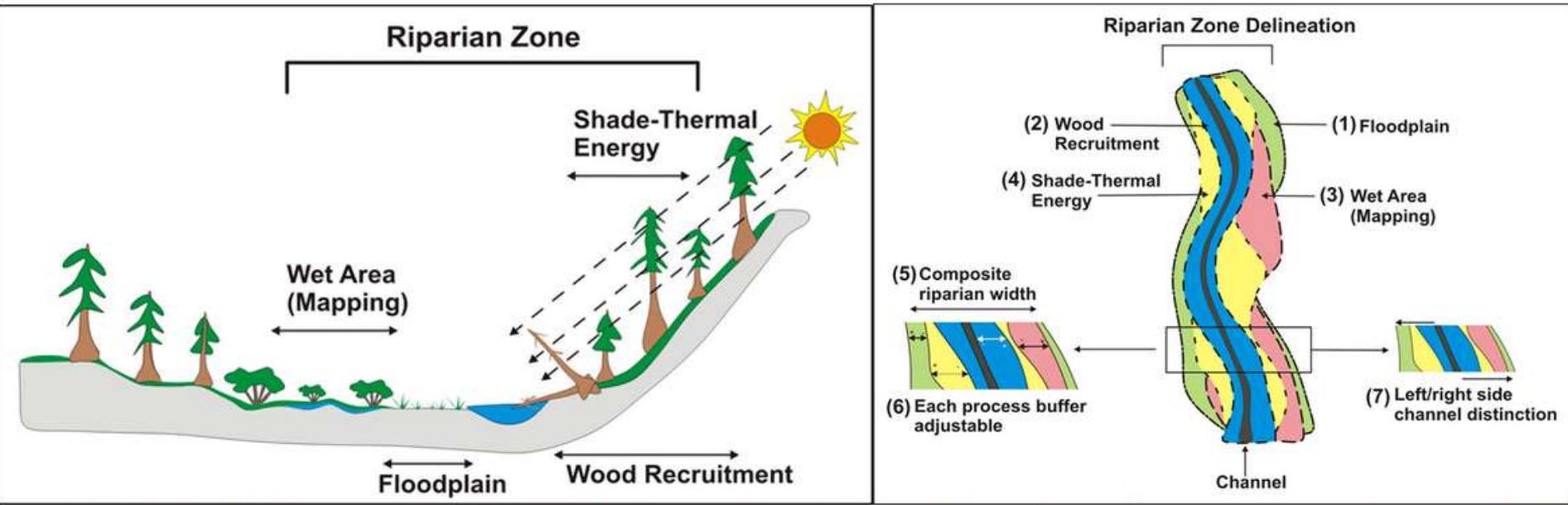


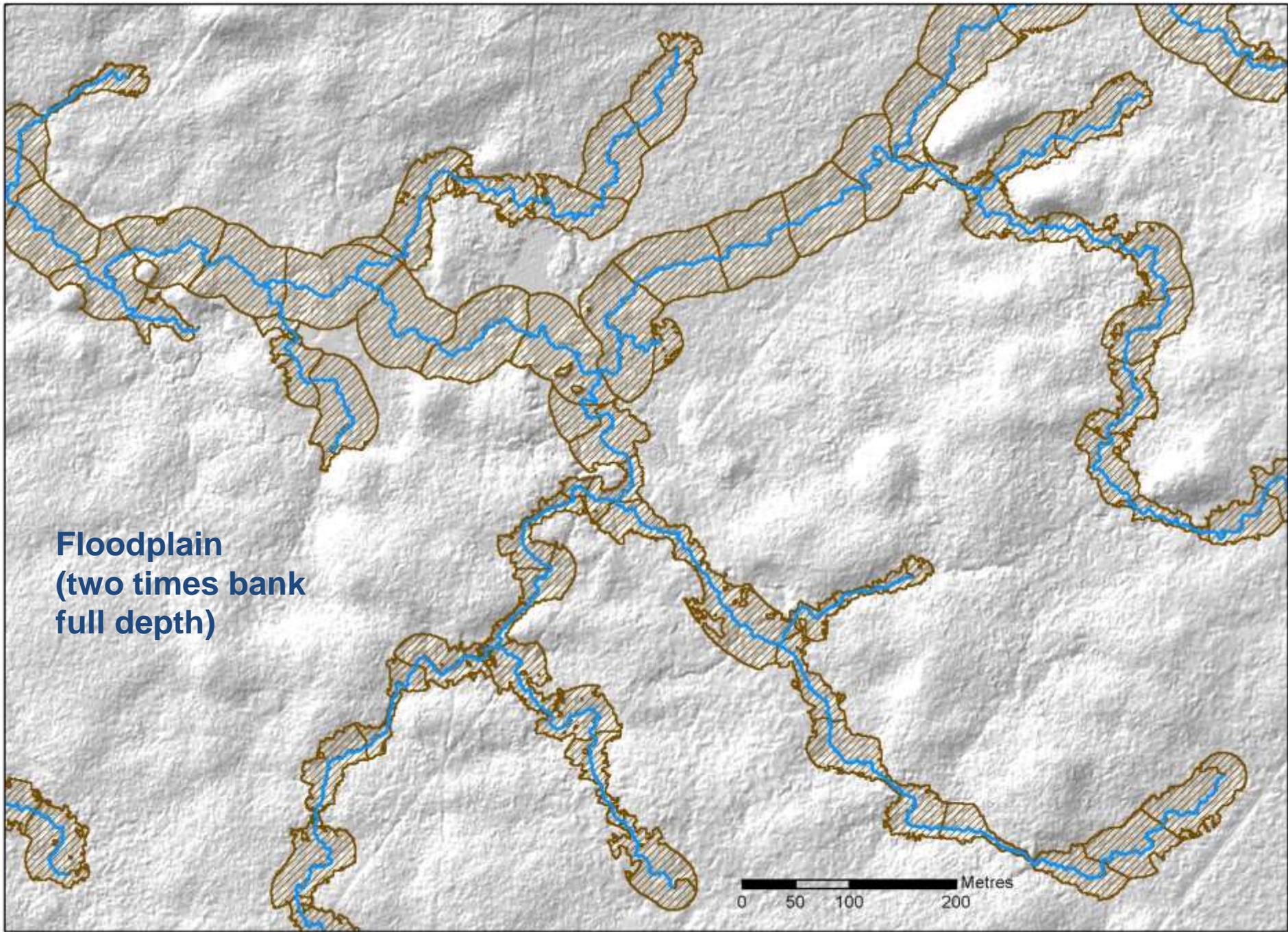
**Some examples from  
biodiversity mapping and  
riparian conservation**





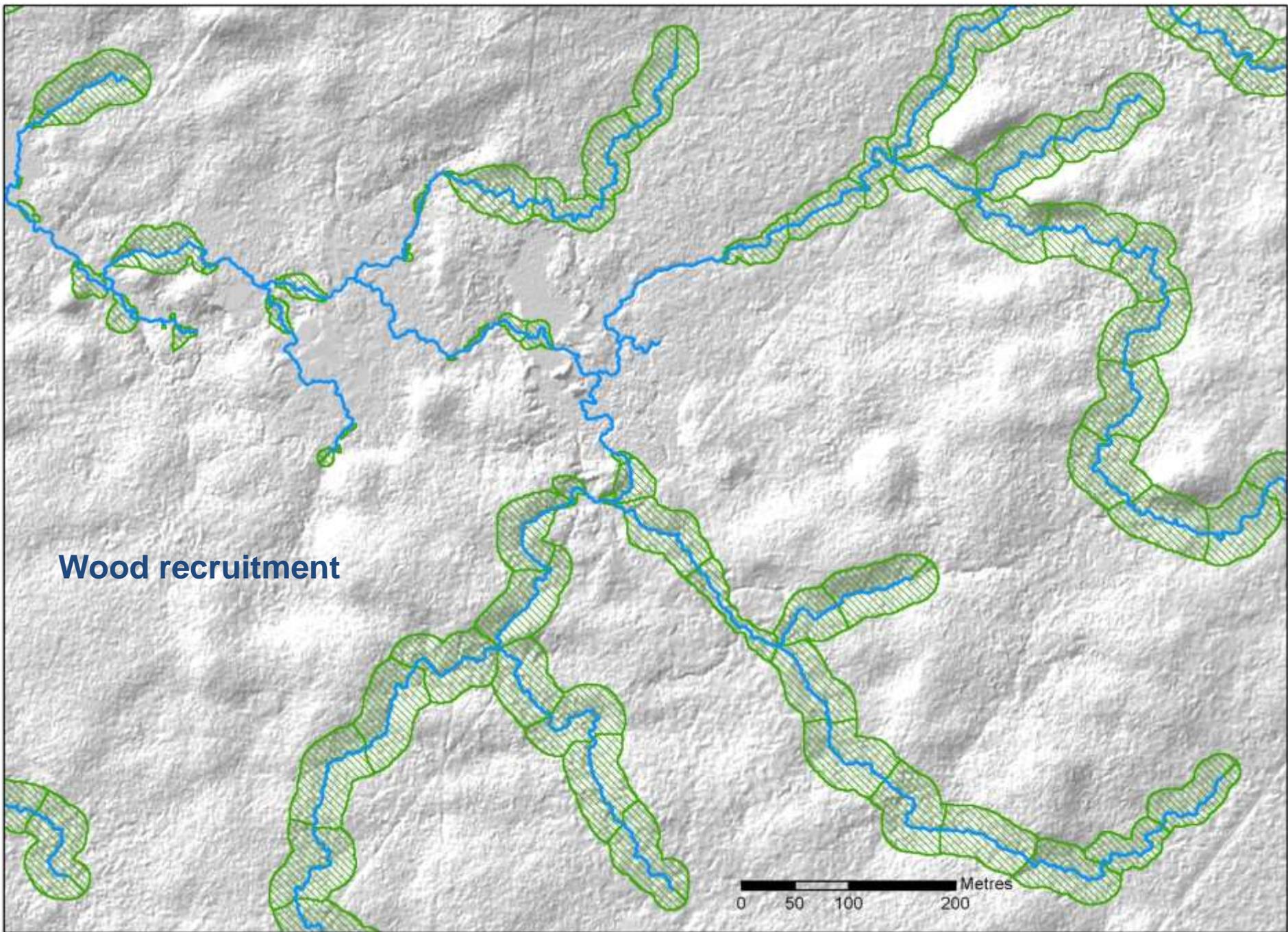
# Riparian zone mapping with Netmap – a pilot project





**Floodplain  
(two times bank  
full depth)**

0 50 100 200 Metres

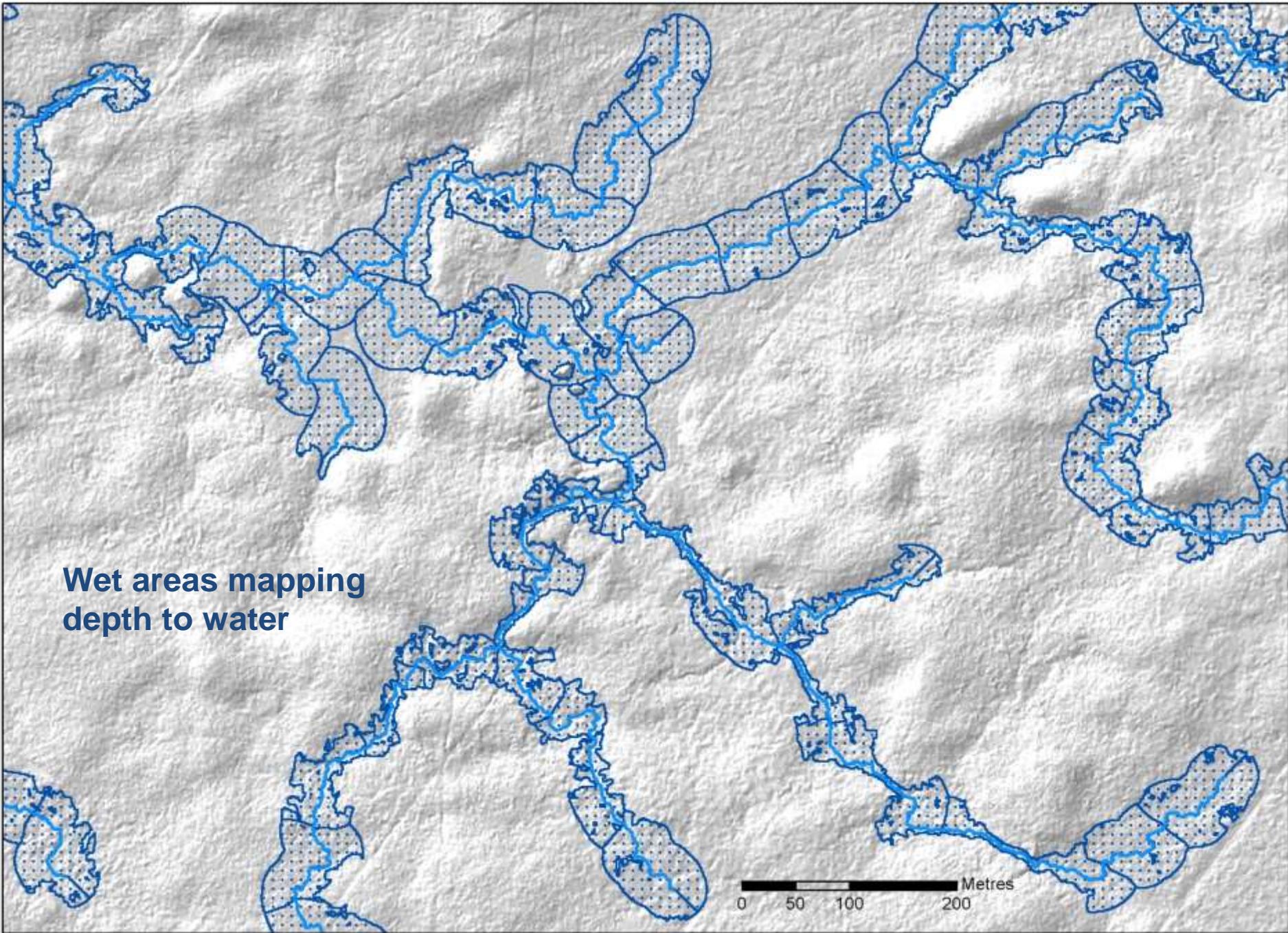


**Wood recruitment**

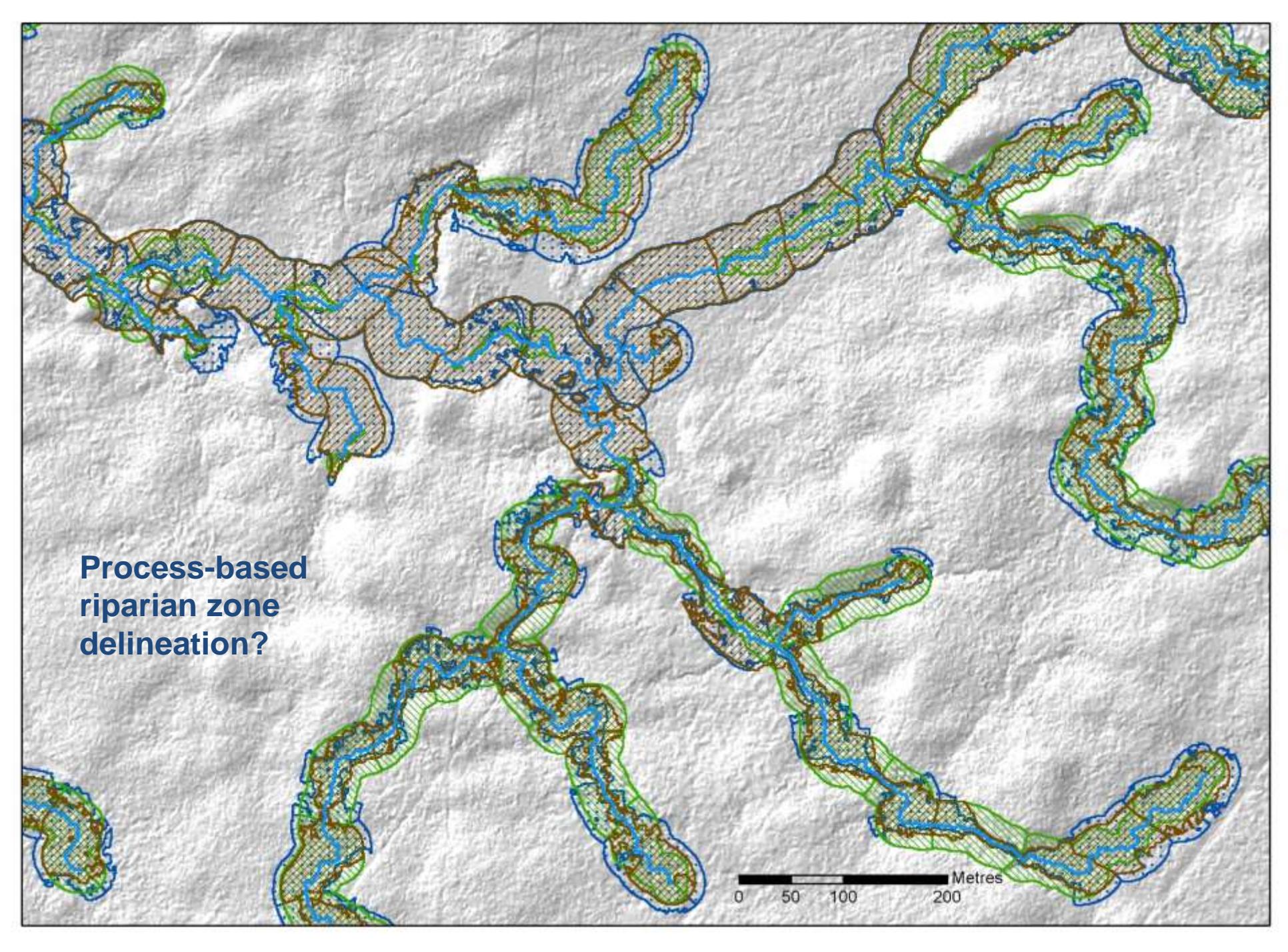
0 50 100 200 Metres

**Wet areas mapping  
depth to water**

0 50 100 200 Metres



**Process-based  
riparian zone  
delineation?**



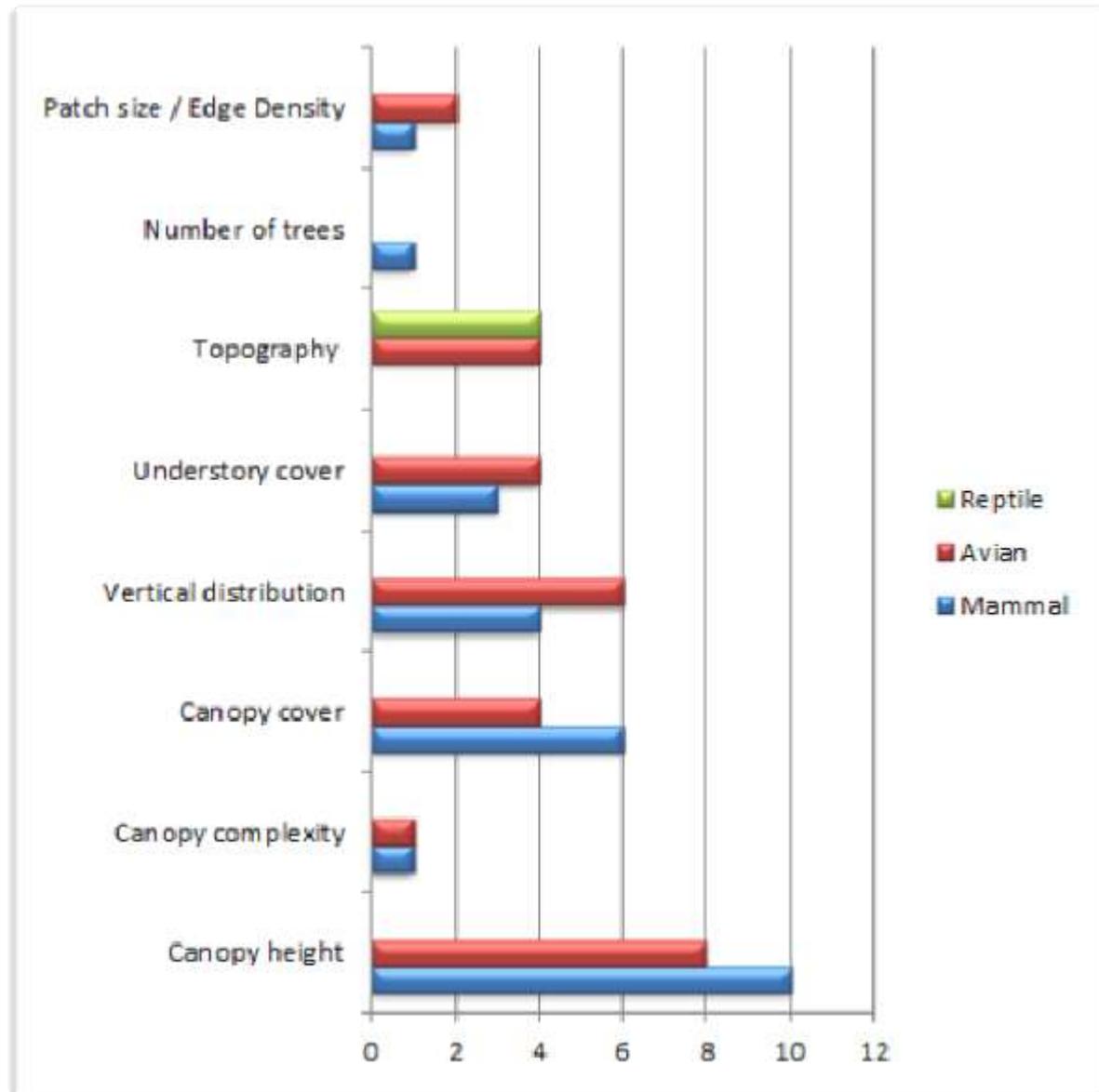
A topographic map showing a river network. The river channels are highlighted in blue. The riparian zones are delineated with green and brown hatched patterns. A scale bar at the bottom right indicates distances in metres, with markings at 0, 50, 100, and 200.

0 50 100 200 Metres

## Biodiversity mapping

Develop fine scale indicators that match the spatial grain at which most species (including resource managers) operate.

Vegetation structure and soil moisture are indicators of biodiversity → enter lidar.



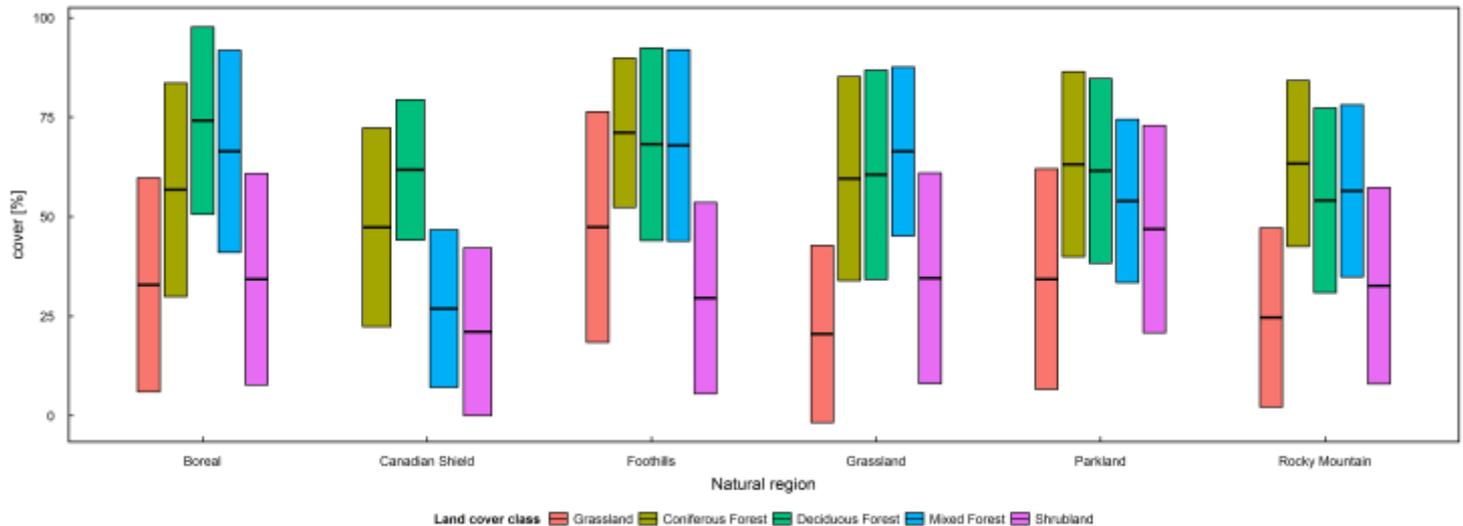
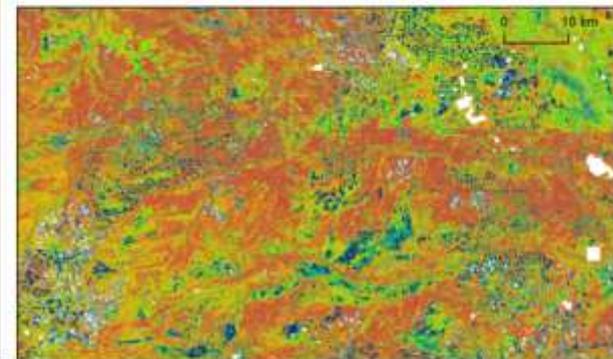
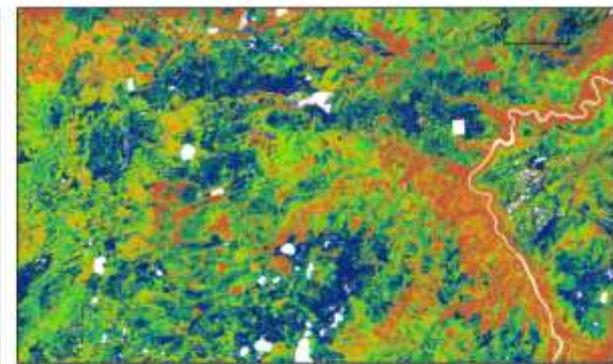
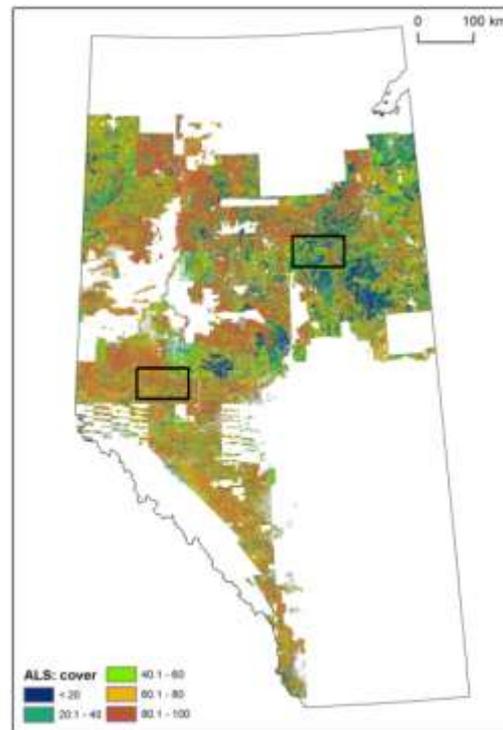
Source: Coops, N.C. and Nielsen, S. 2015. Biodiversity and ecosystem characterization supported with LiDAR. Unpublished report. Forest Management Branch, Alberta Agriculture and Forestry. Edmonton, Alberta.

# Biodiversity mapping

Multi-scale framework

How do key lidar metrics vary by natural region and land cover type?

Ultimately link lidar metrics to ground measures of biodiversity.



## Summary

Lidar allows us to explore problems related to both terrain and vegetation with extreme spatial detail

Alberta Forest Management Branch has had several successes

- Enhanced forest inventory
- Wet areas mapping

The future: create cutting edge, spatially explicit decision tools to minimize and mitigate risk, e.g.....

- Process-based riparian mapping
- Biodiversity indices

Remote sensing allows us to be smarter and quicker, but is not a replacement for walking through the forest

**Questions: [chris.bater@gov.ab.ca](mailto:chris.bater@gov.ab.ca)**

## Acknowledgements

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(University of British Columbia)

Scott Nielsen (University of Alberta)

Barry White, John Diiwu (Alberta Forest  
Management Branch)

TerrainWorks (Netmap)  
(<http://www.terrainworks.com/terrainworks>)