Topographic normalization, satellite data source and classification method for alpine vegetation mapping in Sweden

Heather Reese and Håkan Olsson

Section of Forest Remote Sensing

Department of Forest Resource Management

SLU, Umeå

E-mail: heather.reese@slu.se

SLU

Swedish University of Agricultural Sciences

Objectives

To map alpine vegetation types and to test:

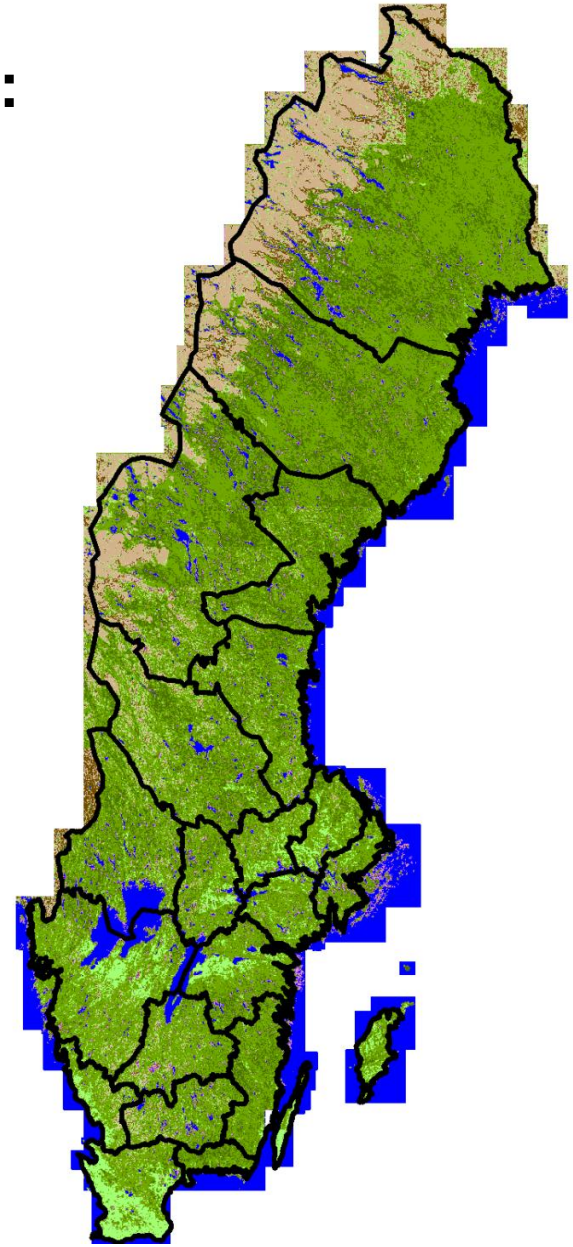
- Different satellite data sources

- Effect of including elevation derivatives

- Different quantity and configurations of training data

- Two supervised classification algorithms

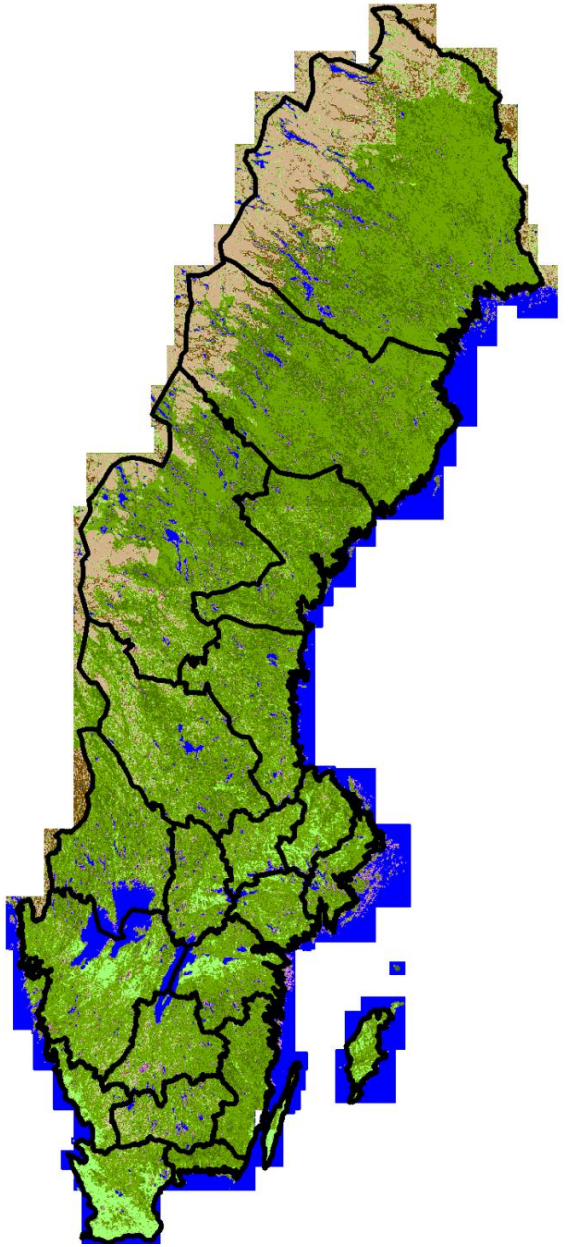
To develop a reliable procedure for performing c-correction



Objectives

Evaluated satellite data sources:

- SPOT (10 m)
- Landsat (25 m)
- IRS AWiFS (60 m)

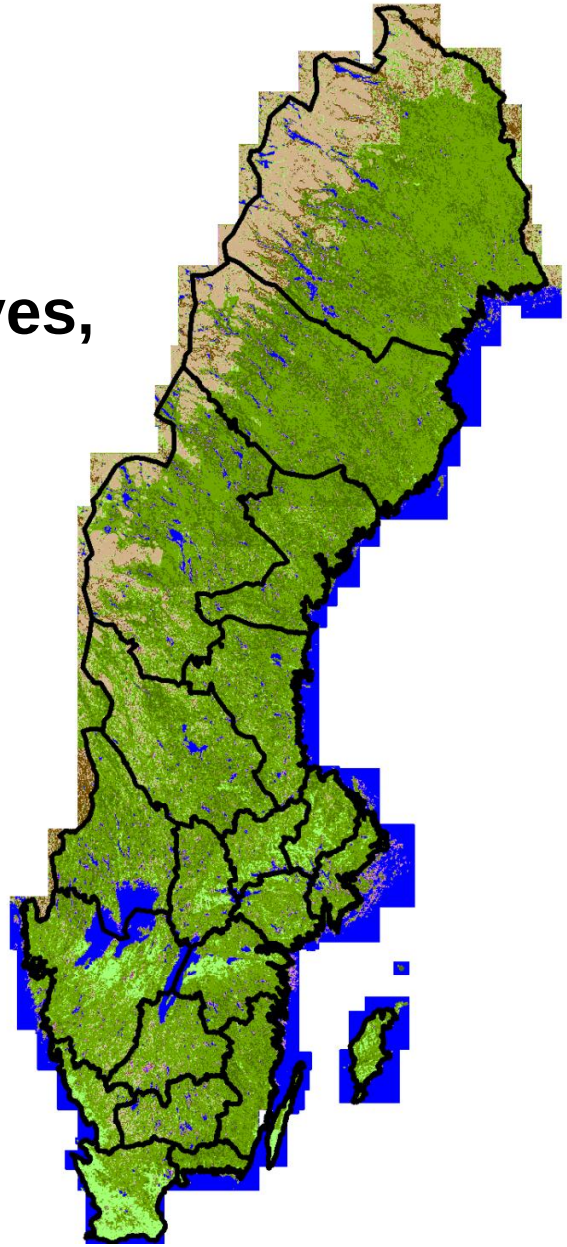


Objectives

Effect of including elevation derivatives,

Using a 50 m DEM:

- Elevation
- Slope
- Aspect
- Topographic wetness index



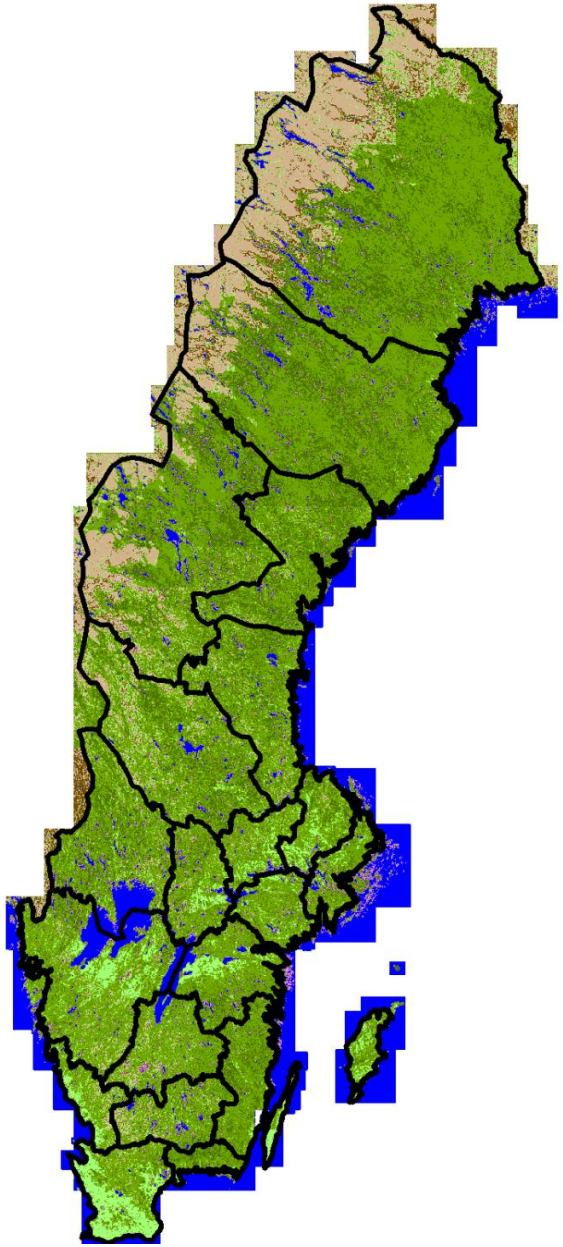
Objectives

Test of different quantity and configurations of training data

- 2300 air photo interpreted plots, from systematic sample

- 200 air photo interpreted polygons, subjectively chosen

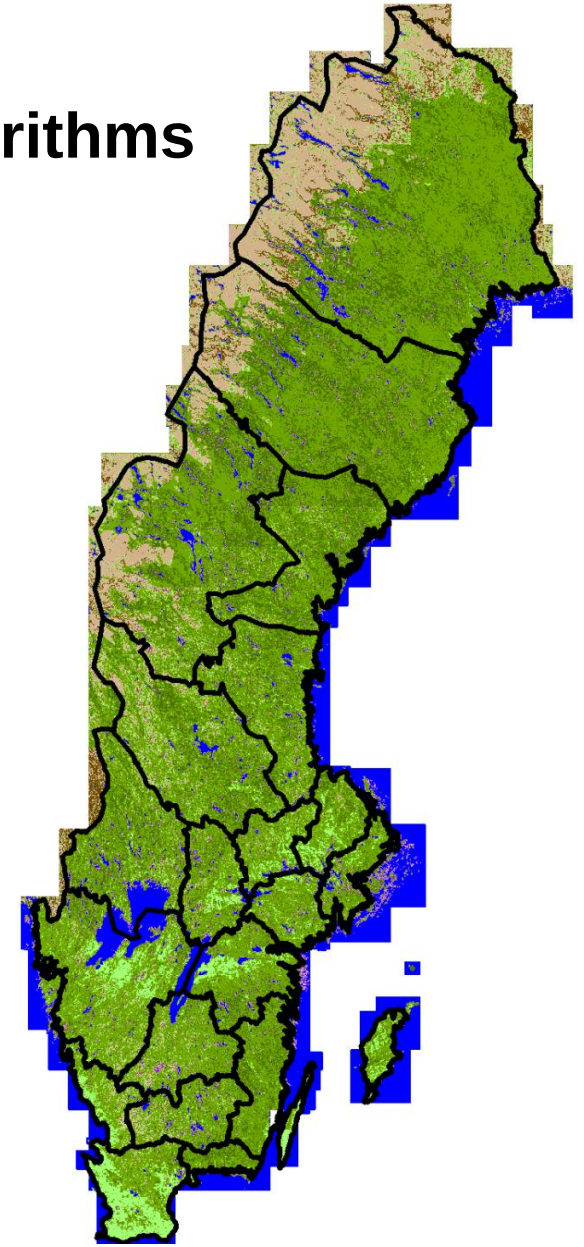
- 100 field plots, from the national inventory of landscapes (NILS)



Objectives

Test of two supervised classification algorithms

- Quadratic Discriminant Analysis
- Random Forest

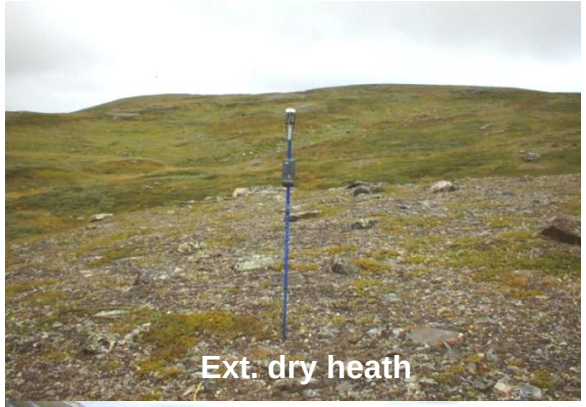


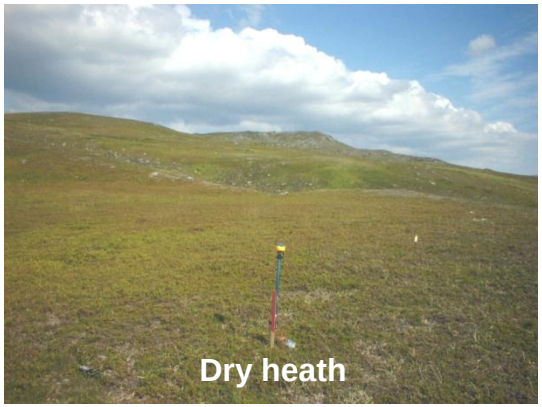
Vegetation types

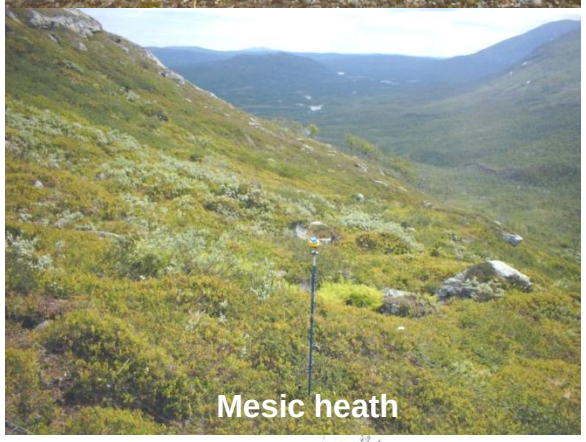
Classes are defined by vegetation composition, height, and density, and moisture regime

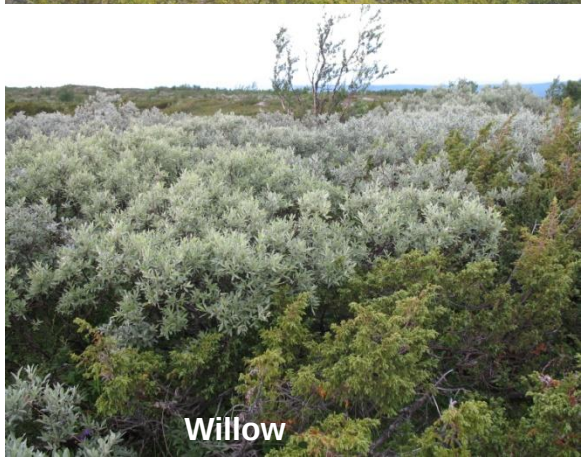
<u>15 Classes</u>

Bare rock
Extremely Dry Heath
Dry Heath
Mesic Heath
Wet Heath
Grass Heath
Short alpine meadow
Tall alpine meadow
Snow bed vegetation
Willow
Mire
Mountain Birch (shrub layer)
Mountain Birch (forb layer)
Snow/Ice
Water







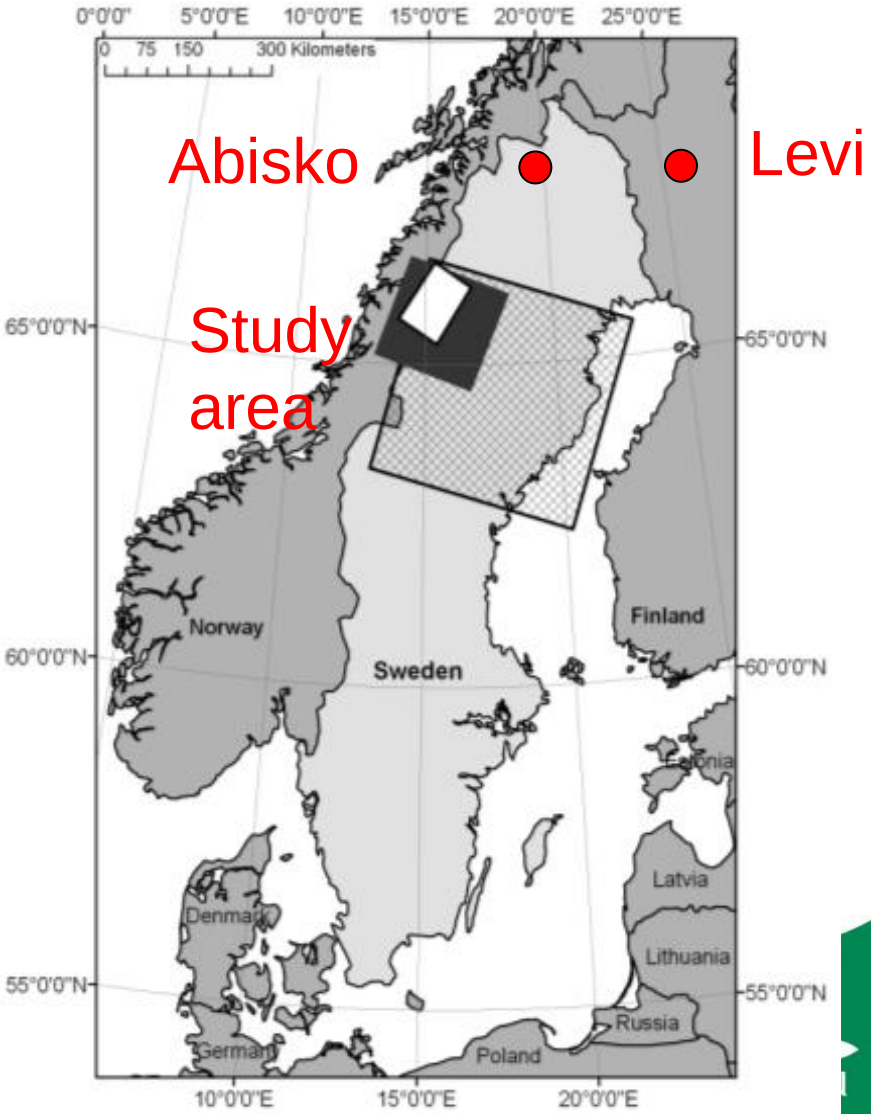


Study area

Study area
Vindelfjällen Nature Reserve

Is an area with both northern and southern alpine vegetation types

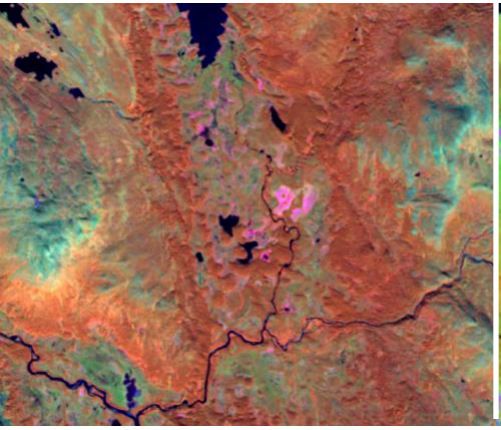
Vegetation season
mid-June to mid-August



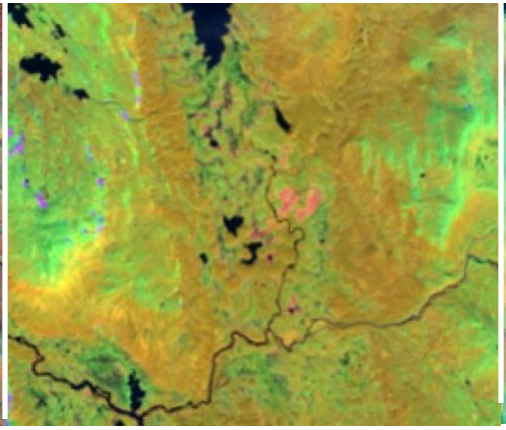
Satellite data

Used the overlap area between sources

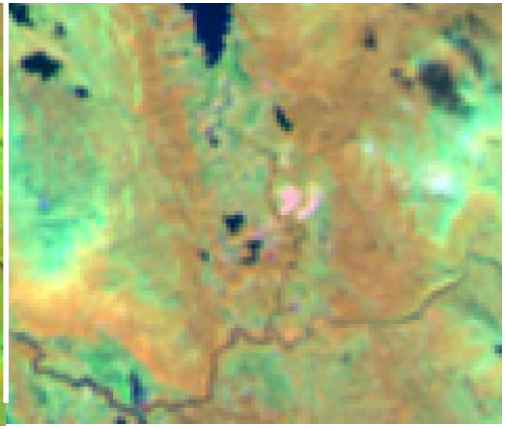
SPOT 5 HRG
10 m

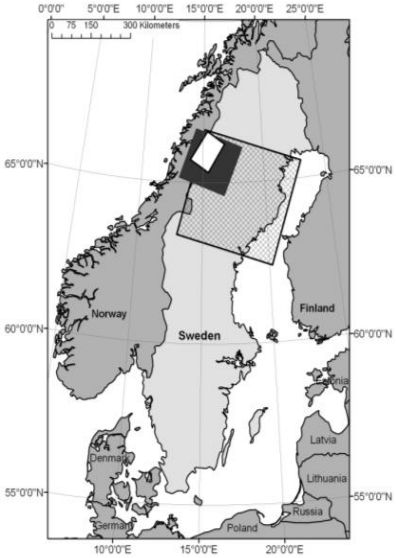


Landsat TM
25 m

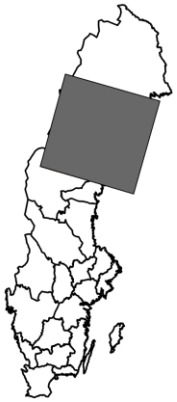


AWiFS
60 m





Two scene mosaic



Satellite data

- Used single date of imagery (due to cloud cover)

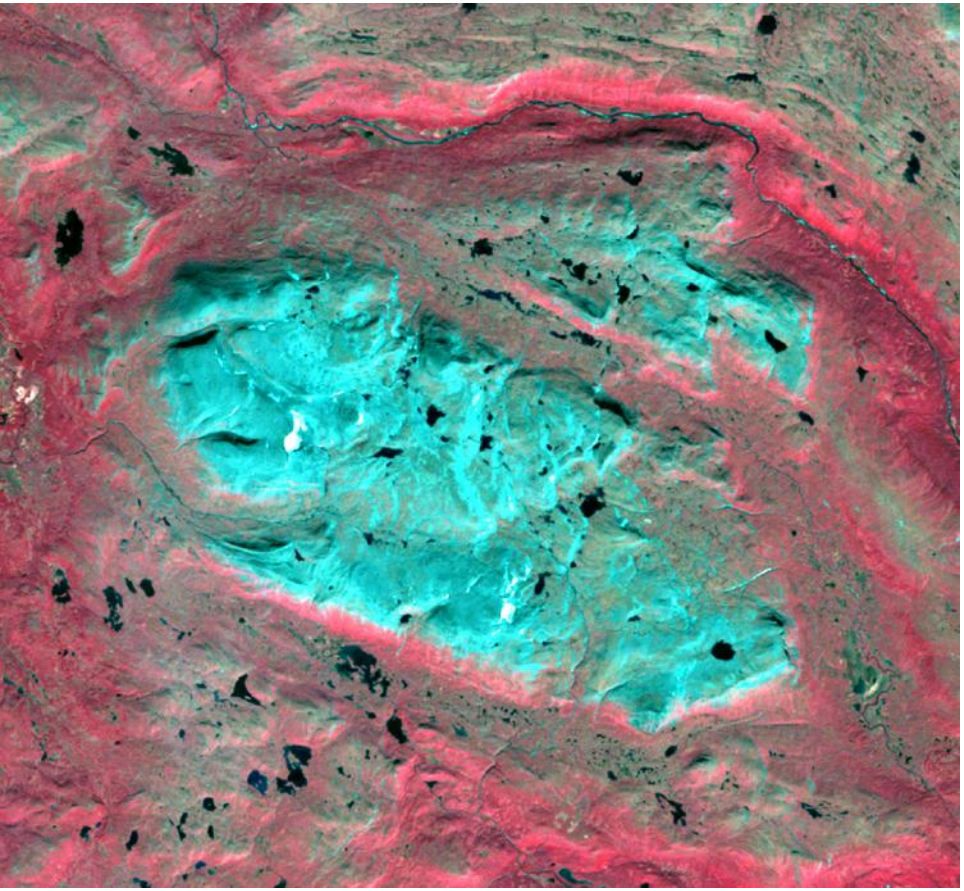
- Where possible, two dates of imagery were used to classify vegetation typified by its quickly changing nature, namely snow bed vegetation and wetlands

- Indices included: NDVI, NDII and SAVI

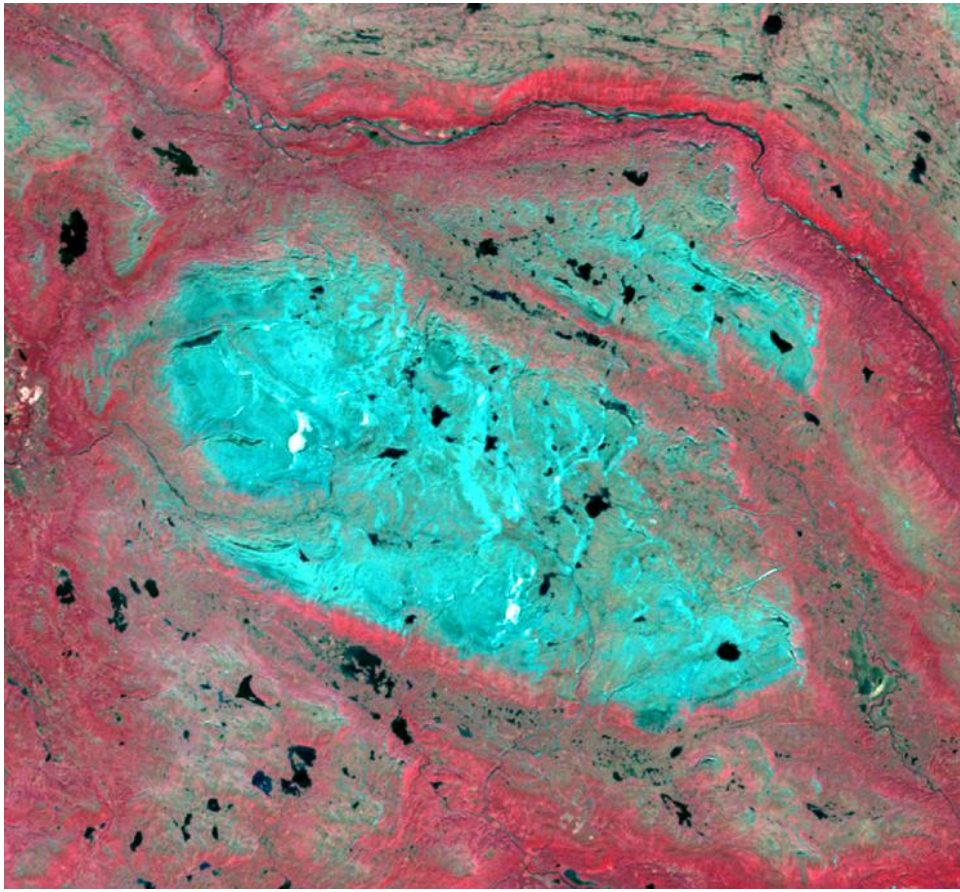
Topographic Normalization

Topographic normalization with C-correction

Before



After

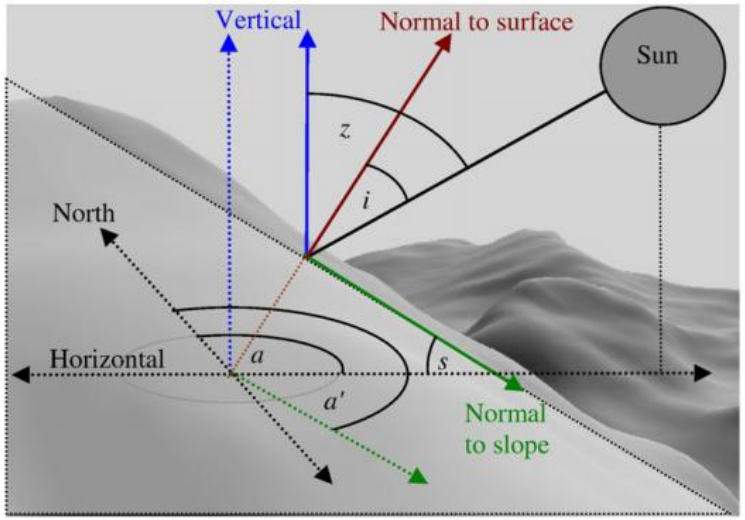


Topographic Normalization

Topographic normalization with C-correction

After applying a topographic normalization using ”*c*” calculated from a large random sample, the <u>classification accuracy became lower</u> than that for an non-normalized image.

Something was wrong!



$$\hat{\rho}_{\lambda h} = \hat{\rho}_{\lambda t} \frac{\cos z + c_\lambda}{\cos i + c_\lambda}$$

<u>C-correction (Teillet et al., 1982)</u>

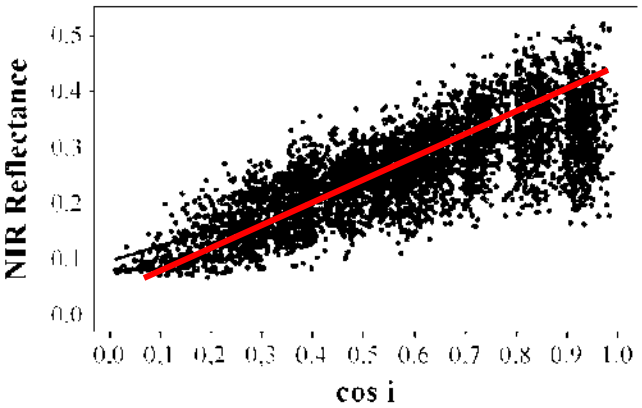
Corrects for shadowing in an image based on
- sun angle
- surface slope
- plus the empirical parameter ”*c*”, calculated from a sample of the satellite data and the corresponding angle of illumination, *i*

Where $\hat{\rho}_{\lambda t}$ is the reflectance for band *λ* still influenced by topography (i), *z* is the solar zenith angle, and *i* is the solar incidence angle upon the surface.

Topographic Normalization

To calculate *c*, a sample of values of cosine of *i* and the corresponding spectral data are needed

Very few papers give any information about the sample used to derive the empirical *c*-parameter (except Civco 1989). They often only say they've used a "large" sample.



C = intercept / gradient

In the literature, two ways to sample emerge:

1) subjective selection of small number of observations (*n*<100) for a single vegetation type for a range of topographic conditions

2) random sample over an entire image or subset of image

Topographic Normalization

Methods

1) "random sample"
   a random sample with a "large" number of observations

2) "aspect sample"
   a stratified random sample where observations were stratified by
   aspect (north- and south-facing slopes)

3) "cos*i* sample"
   a stratified random sample where observations were stratified by cosine of *i*

All samples were taken on alpine vegetation only, excluding rock, snow, water, mires, and forest

Topographic Normalization

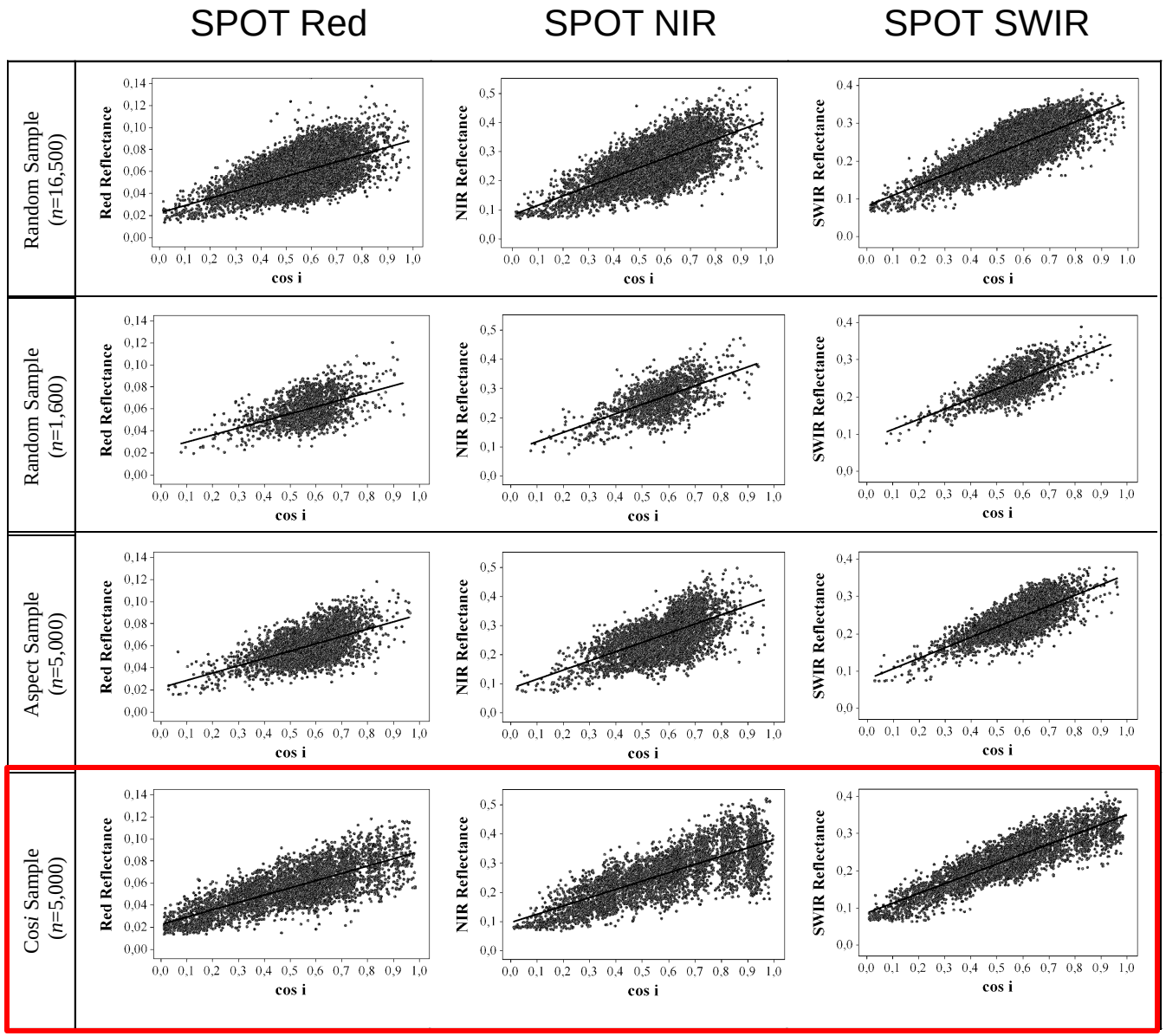
Results

Large random sample (n=16,500)

Most studies use
Smaller random sample (n=1,600)

Aspect stratified sample (n=5,000)

Best results
Cosine of *i* stratified sample with optimal (power) allocation (n=5,000)



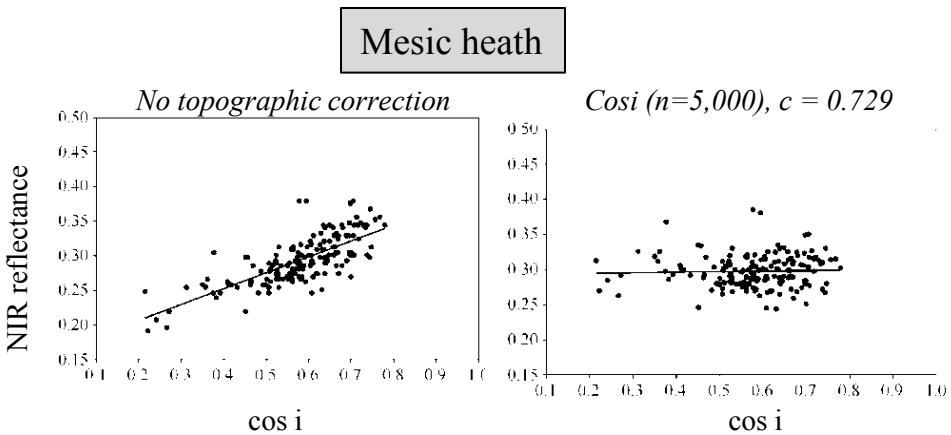
Topographic Normalization

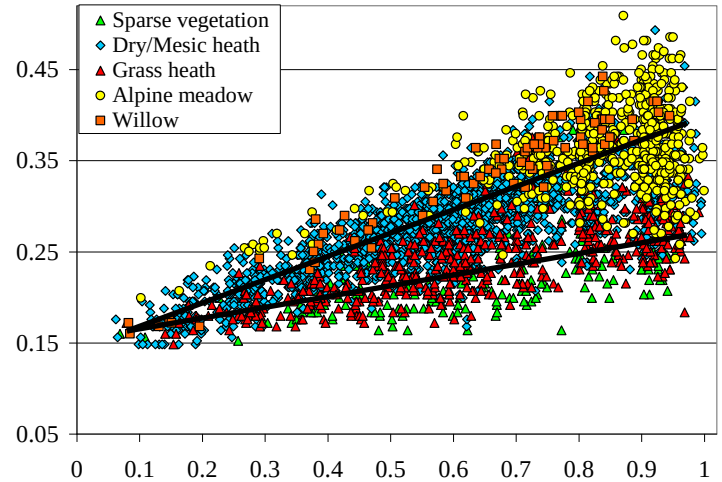
<u>Conclusions from topographic normalization with c-correction</u>

Calculation of *c* was more precise and accurate using a sample stratified on cosine of *i*

The sampling method does influence the outcome of *c,* and therefore the topographic normalization

Different vegetation types, most likely with influence of vegetation cover and background soil reflectance, have a different value of *c* for optimal topographic normalization.



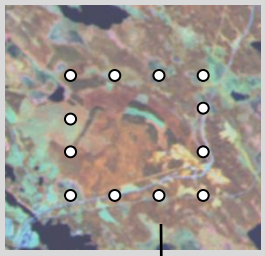


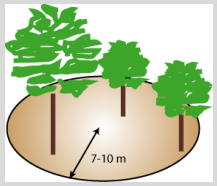
Reese and Olsson, 2011. Remote Sensing of Environment 115:1387-1400

Background – sample based national inventories

NFI

- field visits >10,000 plots per year
- much data on forest, ground cover...
- plots revisited on a 5 to10 year cycle

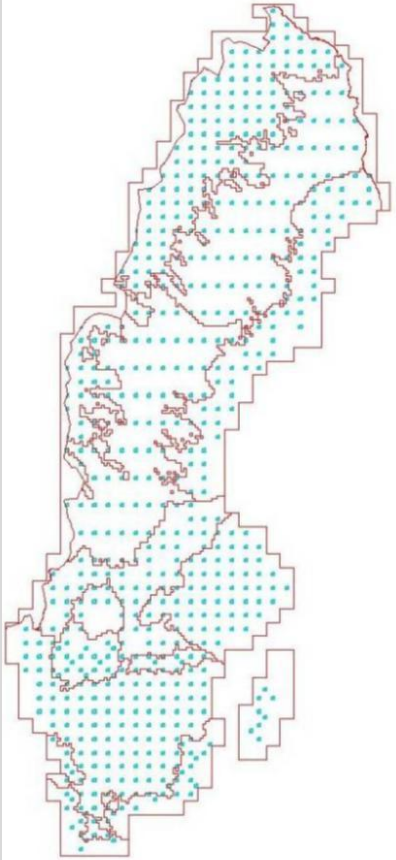


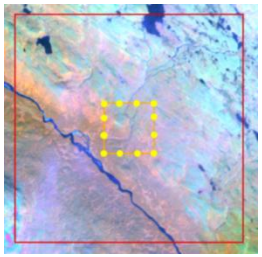


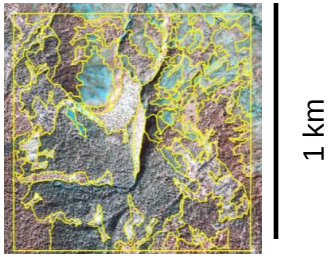
NILS & THUF/MOTH

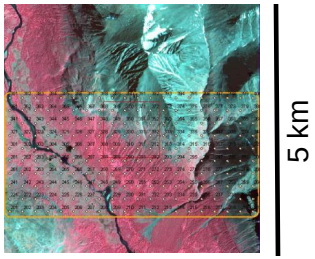
- 631 5×5 km squares
- 12 field plots in inner 1x1 km square
- photo-interpretation of 1x1 km
- all land cover types

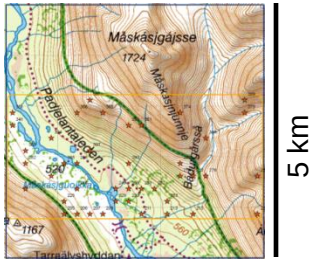
MOTH project:
- 200 points photo-interpreted in 2×5 km in NILS squares
- field visit to plots of interest



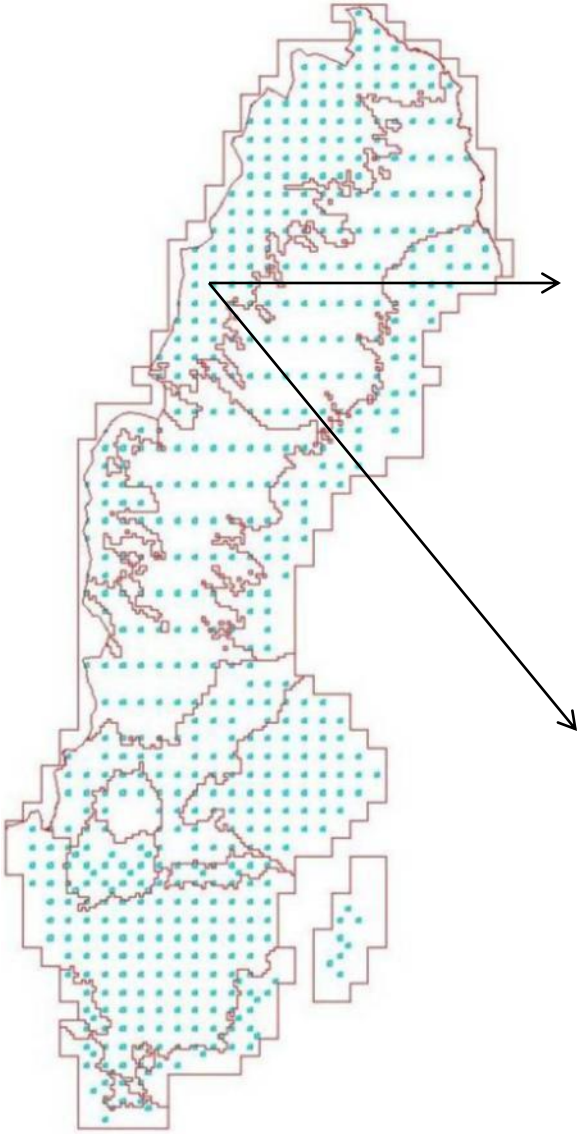




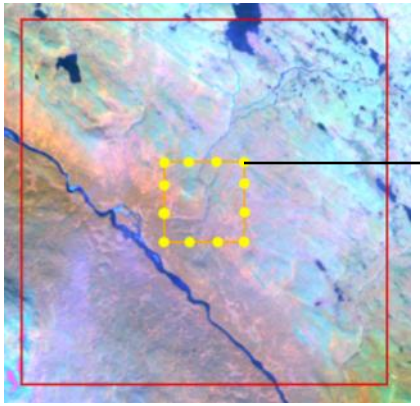




Background – National Inventory of Landscapes in Sweden (NILS)

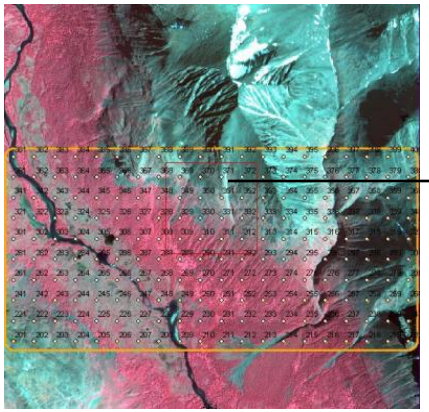


<u>NILS</u>
631 5×5 km tracts
C-IR 1:30,000 aerial photos



5 km

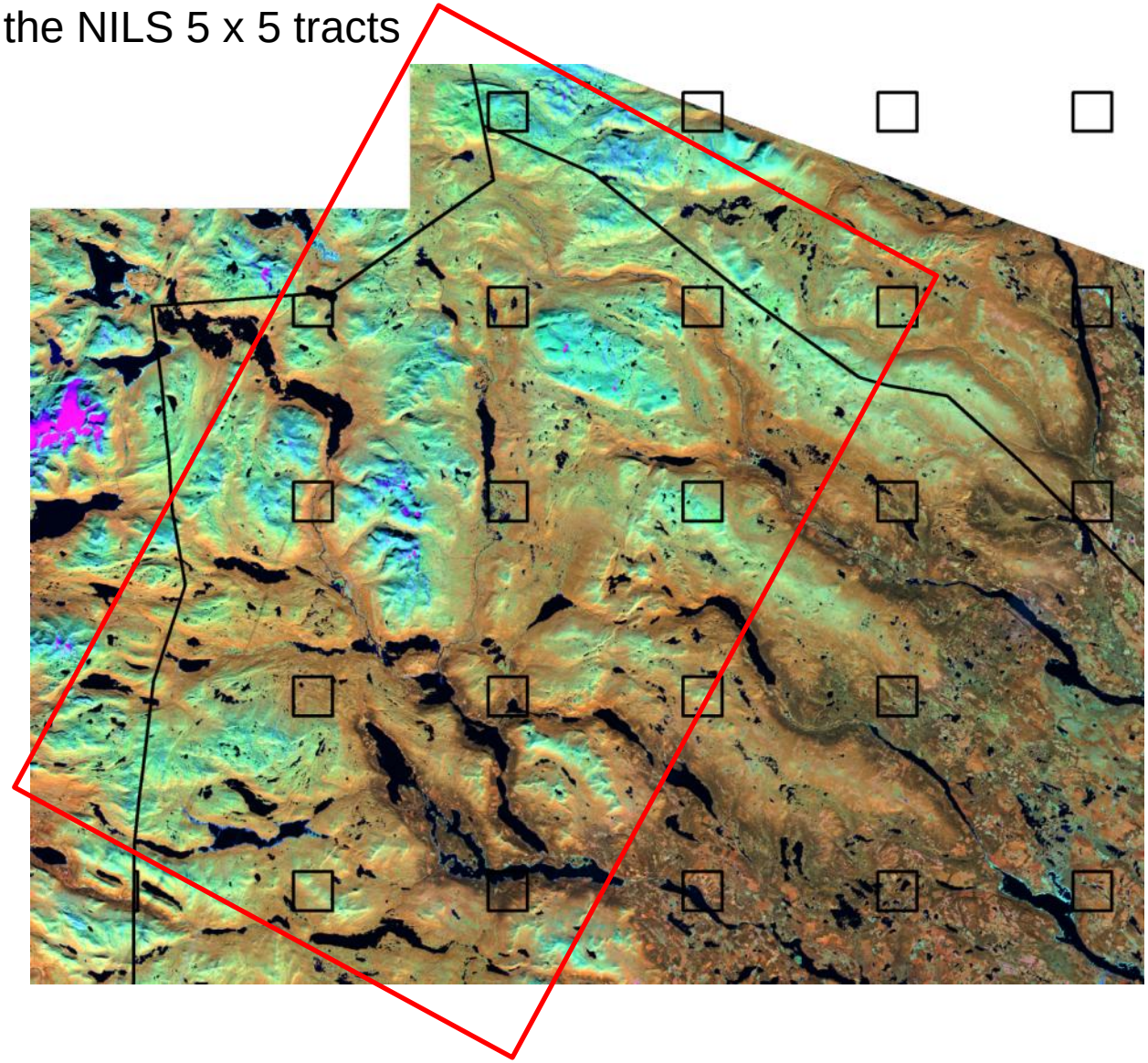
Inner 1x1 km has 12 field-inventoried plots



EU MOTH project photo-interprets 200 plots in each NILS tract

Training data

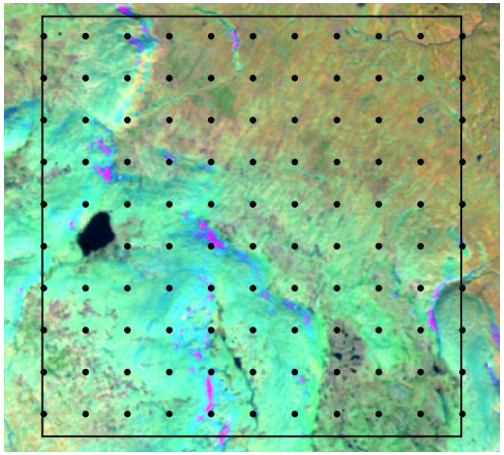
Doubled the NILS 5 x 5 tracts



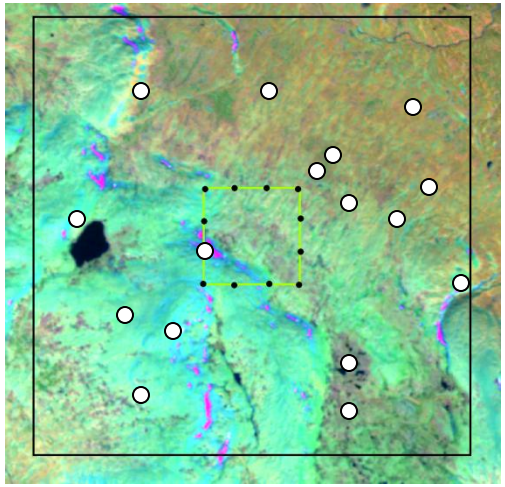
Training data

Doubled the NILS 5 x 5 tracts

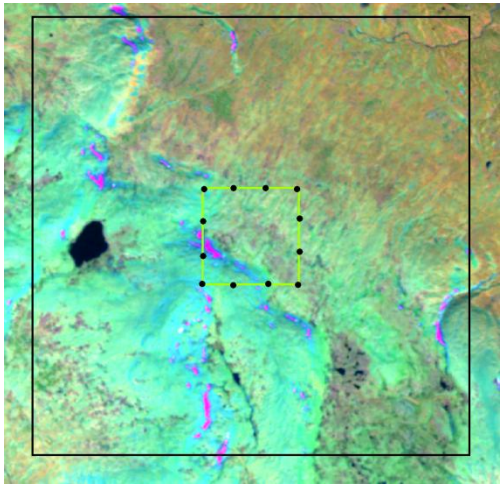
110 plots
Systematic



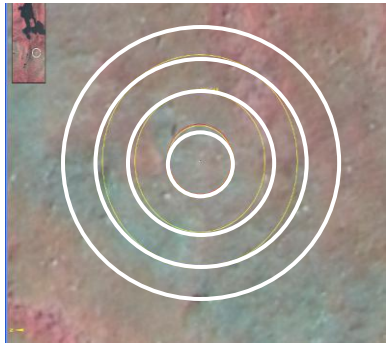
20
polygons



NILS field plots

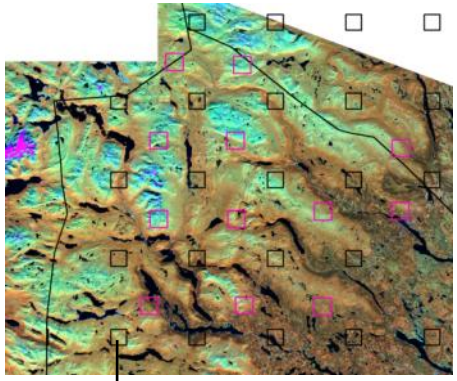


Interpretation of all vegetation types present (%) at center point, 5, 10, 20 and 30 m radii

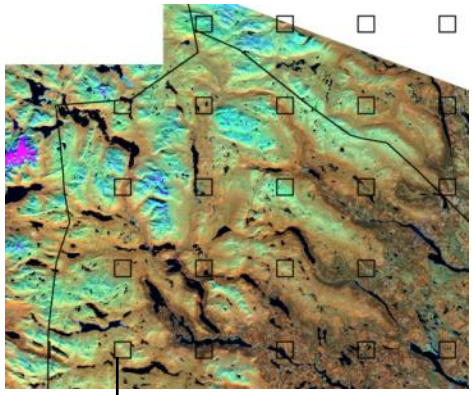


Training data

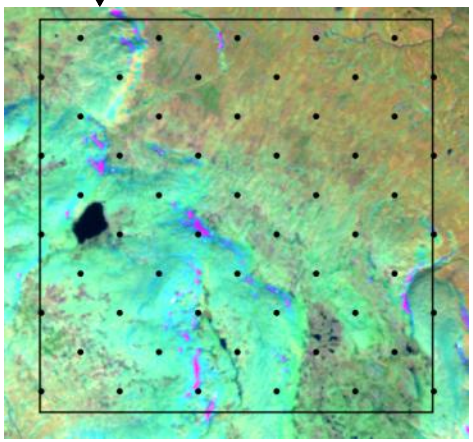
2 x NILS (N=2331)



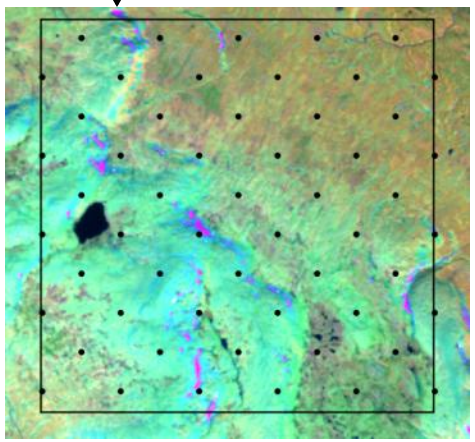
1 x NILS (N=1368)



2 x NILS 50% (N=1165)



1 x NILS 50% (N=684)



	Nr plots after quality control for alpine only
2xNILS	803
2xNILS50	436
1xNILS	532
1xNILS50	268
Subjective	200
NILS Field	89

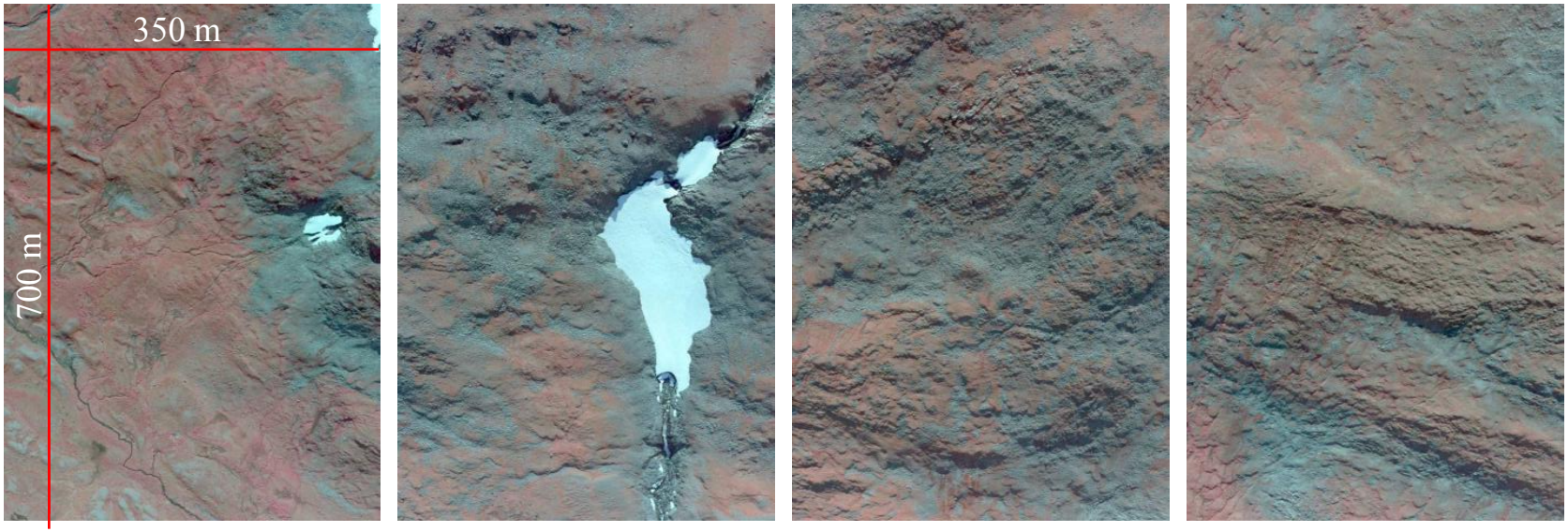
Accuracy Assessment Data

<u>Evaluation data</u>

- Seven 1 x 10 km areas, 17 non-overlapping photos per area

- Multi-scale photo-interpretation of high resolution (1:2000) CIR photos.

- Systematic sample of 5 m, 10 m, and 30 m plots (*n* = 666)



Results

Highest accuracy using SPOT + Elevation with RF and all training data

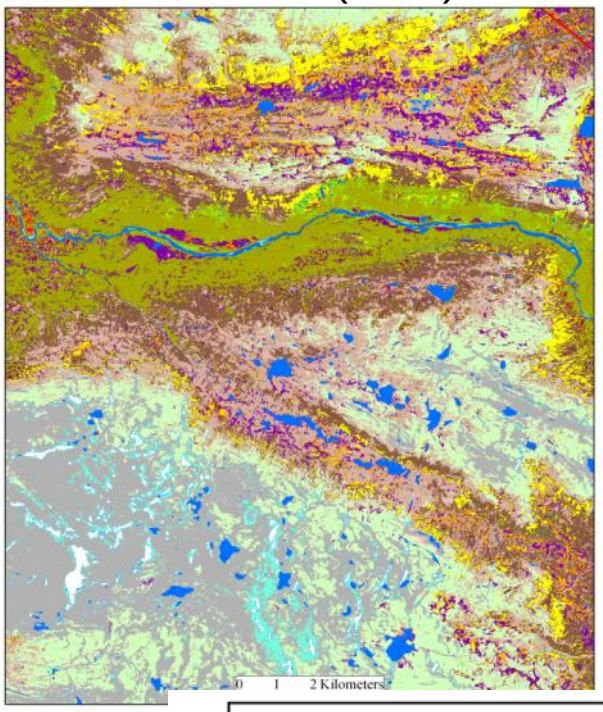
Overall accuracy (pixel-level):

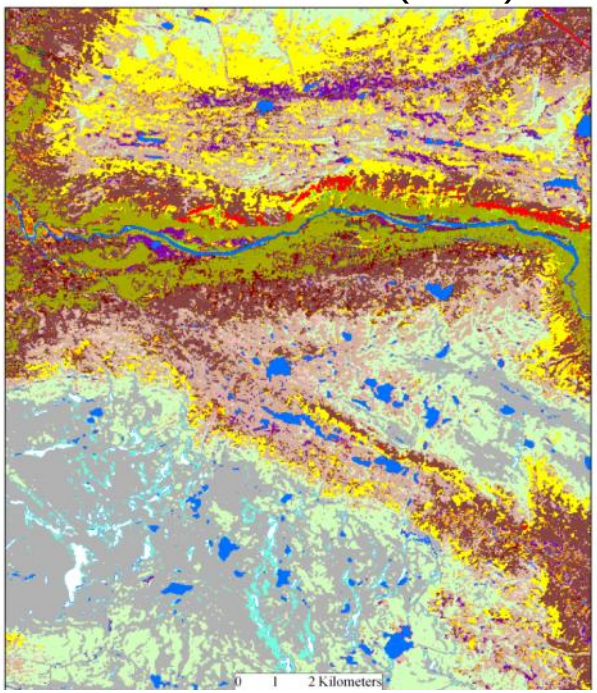
88% (alpine + subalpine)

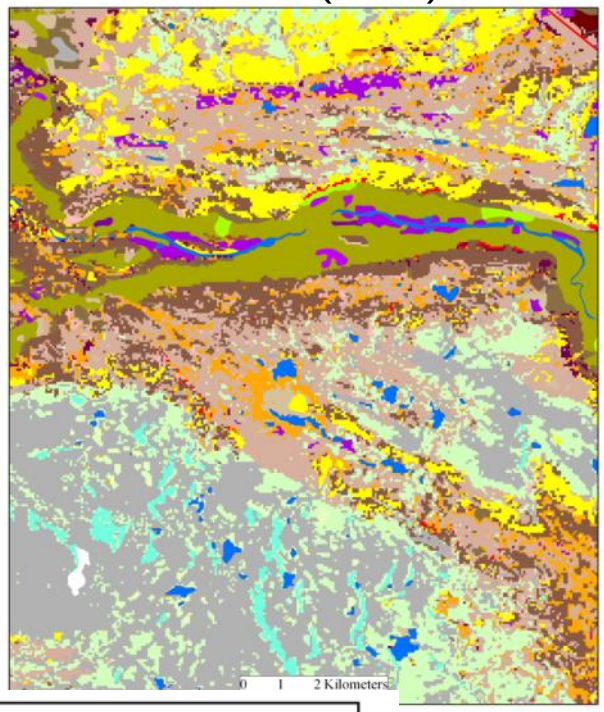
73% (alpine classes)
SPOT 5 (10 m)

63% (alpine classes)
Landsat 5 TM (25 m)

47% (alpine classes)
AWiFS (60 m)







Bare rock
Extrem. dry heath
Dry heath
Mesic heath
Wet heath
Short alpine meadow
Grass heath
Tall alpine meadow
Mire
Alpine willow
Coniferous forest
Mountain birch (with shrub)
Mountain birch (with forbs)
Snow/Ice
Snow bed vegetation
Water
Shadow/Cloud

Results

Results

Overall accuracy (%) for the alpine vegetation classification, for the Random Forest (RF) with and without DEM derivatives and Quadratic Discriminant Analysis (QDA) without DEM derivatives

	SPOT			Landsat			AWIFS		
	RF w/DEM	RF	QDA	RF w/DEM	RF	QDA	RF w/DEM	RF	QDA
2xNILS	72.9	64.0	60.7	62.7	58.5	61.5	46.5	36.4	38.9
2xNILS50	67.0	--	60.3	61.1	--	61.1	--[2]	--[2]	--[2]
1xNILS	64.9	--	56.5	59.4	--	60.3	--[2]	--[2]	--[2]
1xNILS50	63.6	--	54.4	59.4	--	59.2	--[2]	--[2]	--[2]
Field data	--[1]	--[1]	--[1]	--[1]	--[1]	--[1]	51.2	…	22.3
Subjective	69.9	62.3	60.3	56.5	53.2	60.3	45.9	33.4	33.9

Results

Results

Elevation data increased accuracy of classification by ~9%

In particular:

- elevation to help separate grass heath and dry heath
- wetness index to identify willow

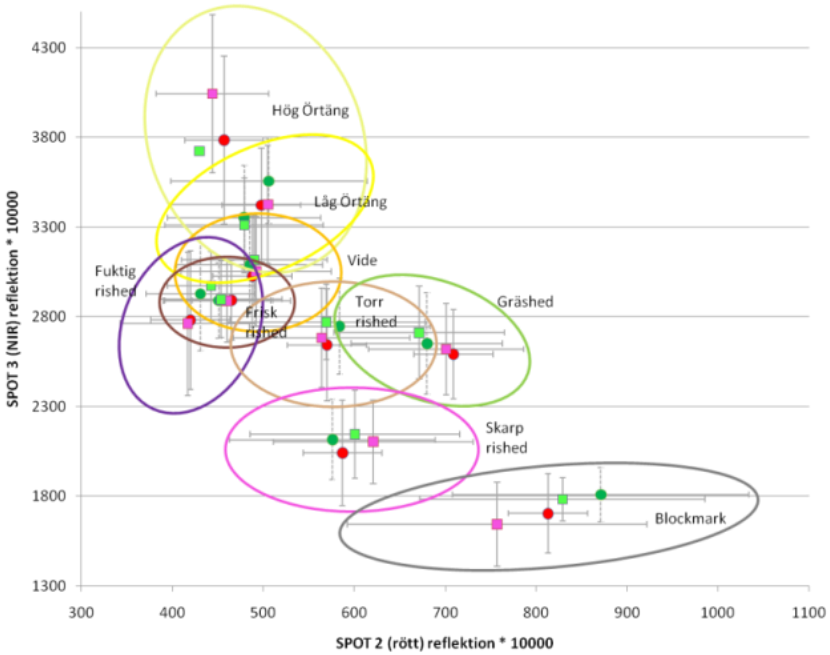
Results

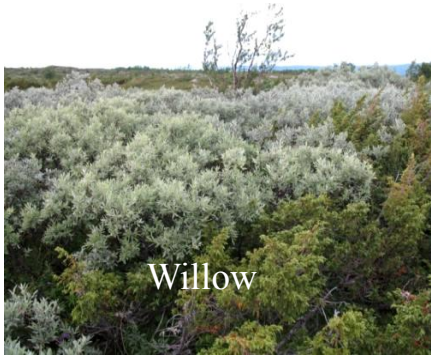
Accuracy for individual classes (SPOT, RF)

Class	Accuracy (pixel level)
Bare rock	76%
Dry heath (torr rished)	73%
Mesic heath (frisk rished)	80%
Grass heath (gräshed)	93%
Willow (vide)	31%
Alpine meadow (örtäng)	50%
Mountain birch	88%

Willow classification most difficult due to:
- spectral similarity with other types
- definition of willow type (> 50% willow)

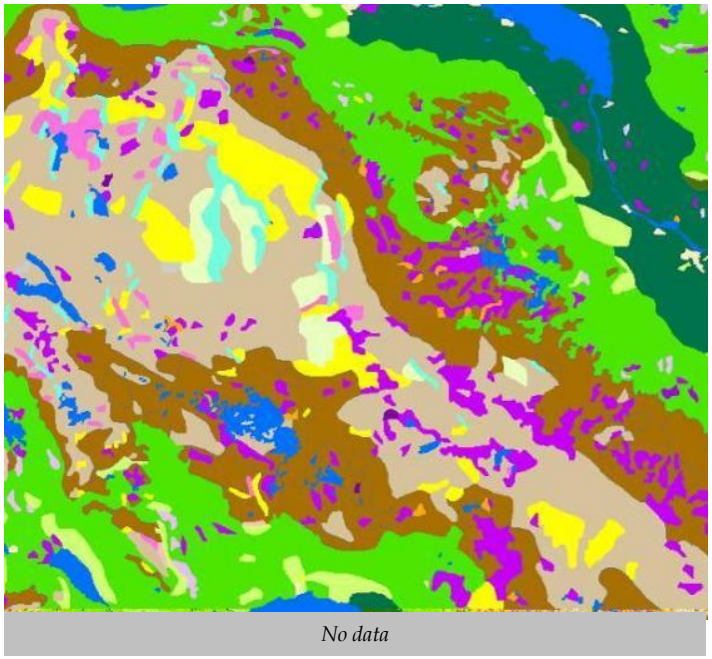
Spectral overlap between classes



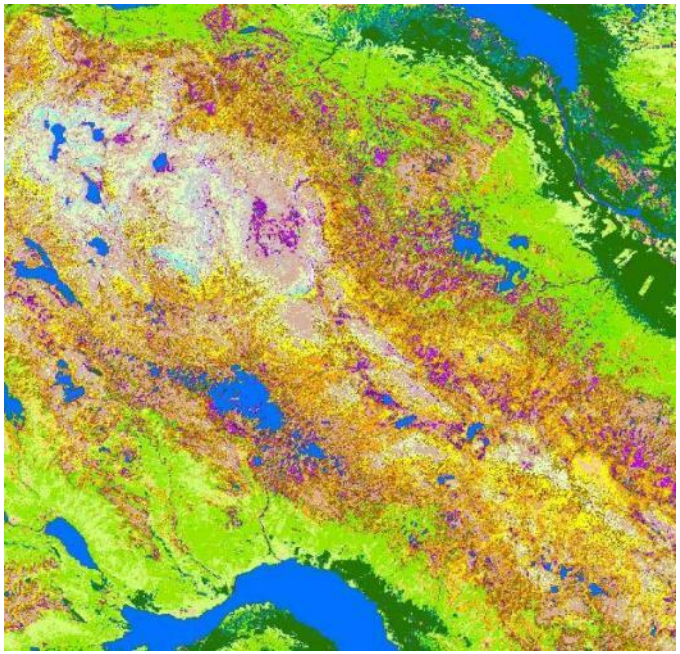


Full coverage vegetation maps with 10 m pixel size

Air photo interpreated Mountain Vegetation Map

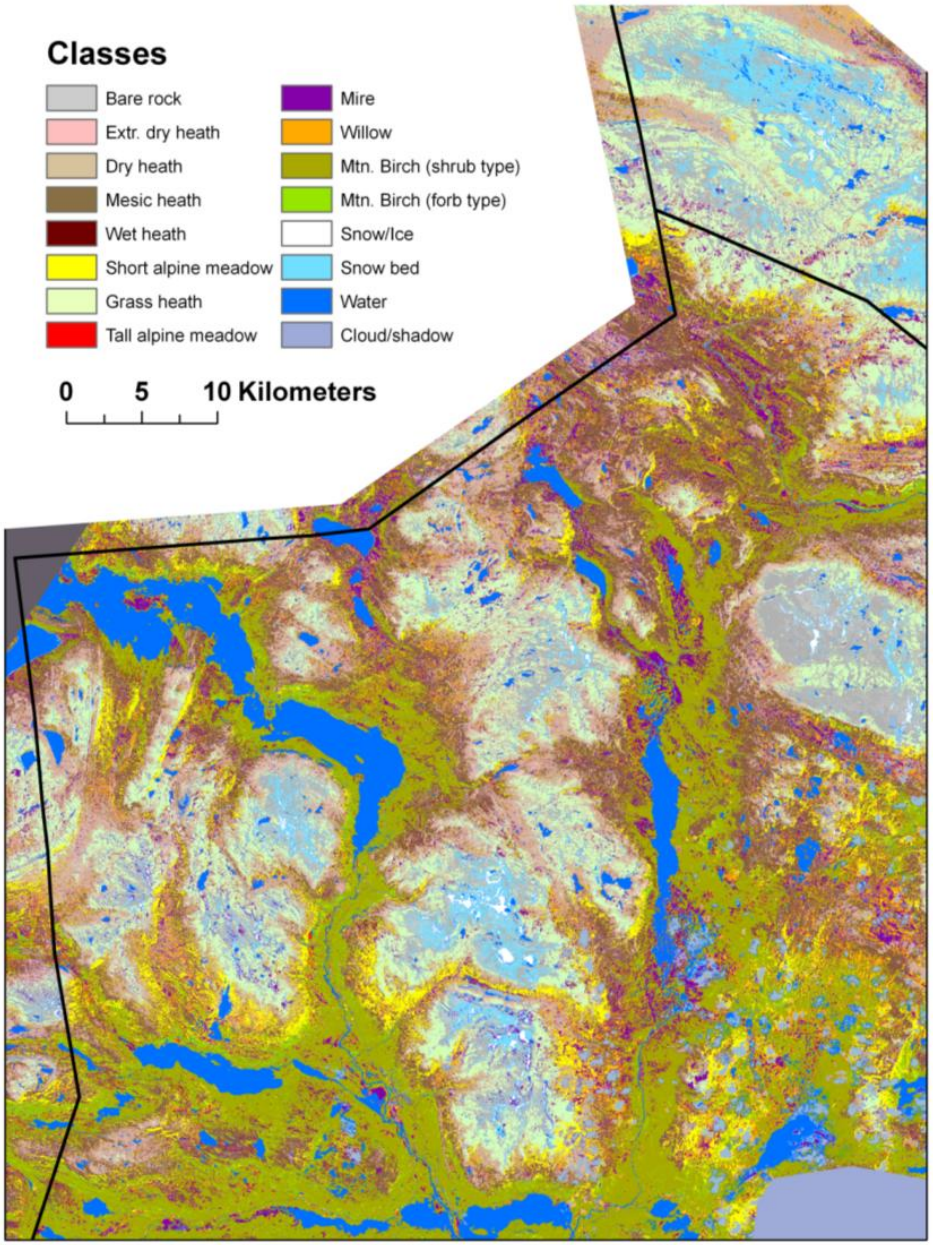


Classification from SPOT data



Bare rock	Short alpine meadow	Coniferous forest	Water
Extrem. dry heath	Grass heath	Mountain birch (with shrub)	Shadow/Cloud
Dry heath	Tall alpine meadow	Mountain birch (with forbs)	
Mesic heath	Mire	Snow/Ice	
Wet heath	Alpine willow	Snow bed vegetation	

Now being tested as a method for mapping mountain area



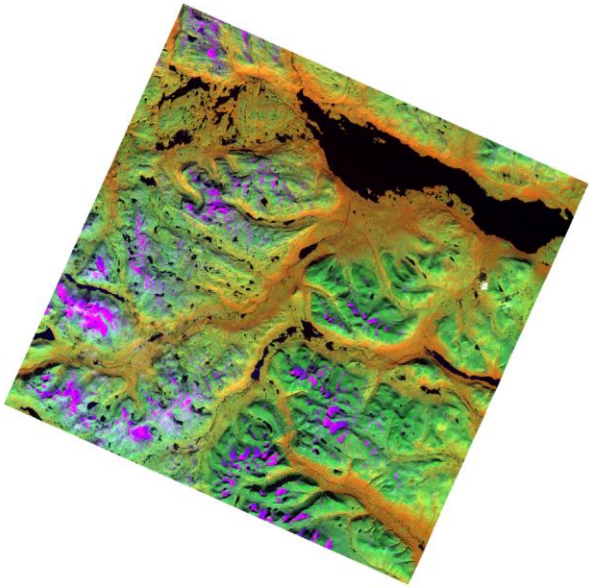
Varying training data set size for supervised classification of alpine vegetation

Conclusions

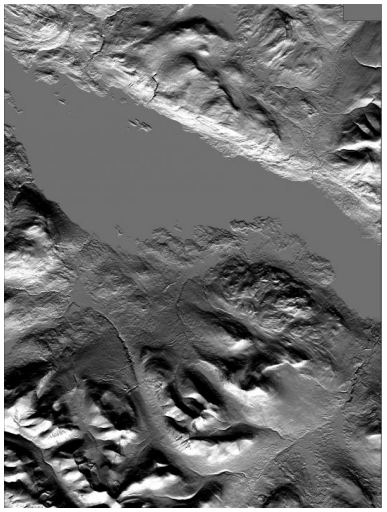
- SPOT data (10m pixel) was the best choice for detailed alpine vegetation classification
- Elevation derivatives increased map accuracy
- Random Forests classification gave better results than QDA
- Larger training data sets gave higher accuracy in general.
- NILS field data were too few for use with single SPOT or Landsat images … but for larger scenes areas like AWiFS or Sentinel-2 (300 km wide) they may be useful
- Role of subjectively collected data needs to be considered (faster, cheaper)
- Ballpark suggestion of ~ 40 to 60 samples per class + extra 30% to account for clouds, data quality problems

Future Directions

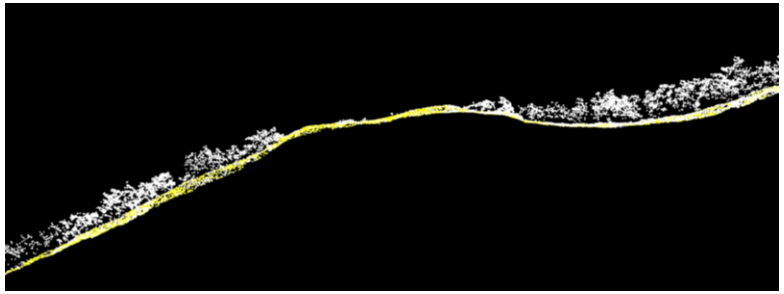
Sentinel-2 + Laser DEM + Laser DSM

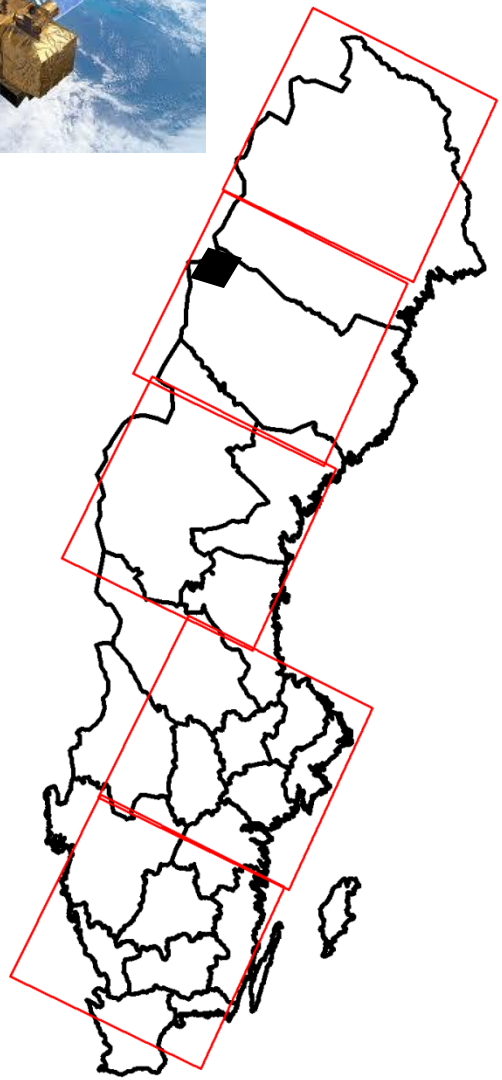


Elevation, slope, etc



Vegetation height and density





Thank you!

Questions?