Use of extremely high resolution images to upscale carbon fluxes and stocks

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Study questions and rationale, 1

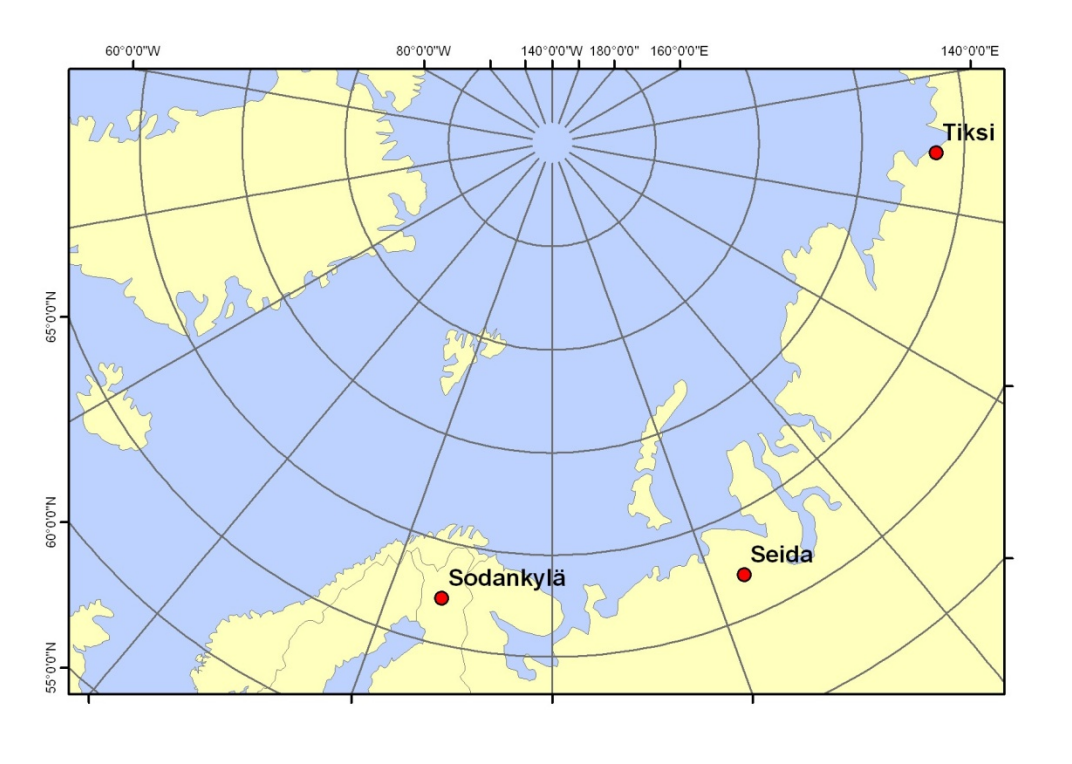
- When aim is to understand the regional carbon and nitrogen dynamics, spatial information about vegetation and soil properties is needed
- Generally, GHG fluxes varies in relation to weather, water table, plant properties and soil properties
- These variables also change during the growing season
- To predict GHG fluxes, the most essential variables needed are
  - **LAI** (leaf area index)
  - vegetation type
  - some soil active layer properties

Study questions and rationale, 2

- Our aim is to create vegetation and soil data sets which can be used, when flux measurements are modelled and regionalised for measurement region (1 -2 km^2) and by taking into account spatial and seasonal variability
- What is the appropriate spatial scale/resolution for such classifications in Arctic regions, where different vegetation communities occur in a spatially very heterogenous way?
  - Different peatland types (bog/fen) separation is essential!
- How different vegetation and soil properties can be predicted and regionalised to larger regions by satellite image data, to make site specific flux measurement results comparable to coarse resolution (hundreds or thousands of km^2) Ecosystem Model results?

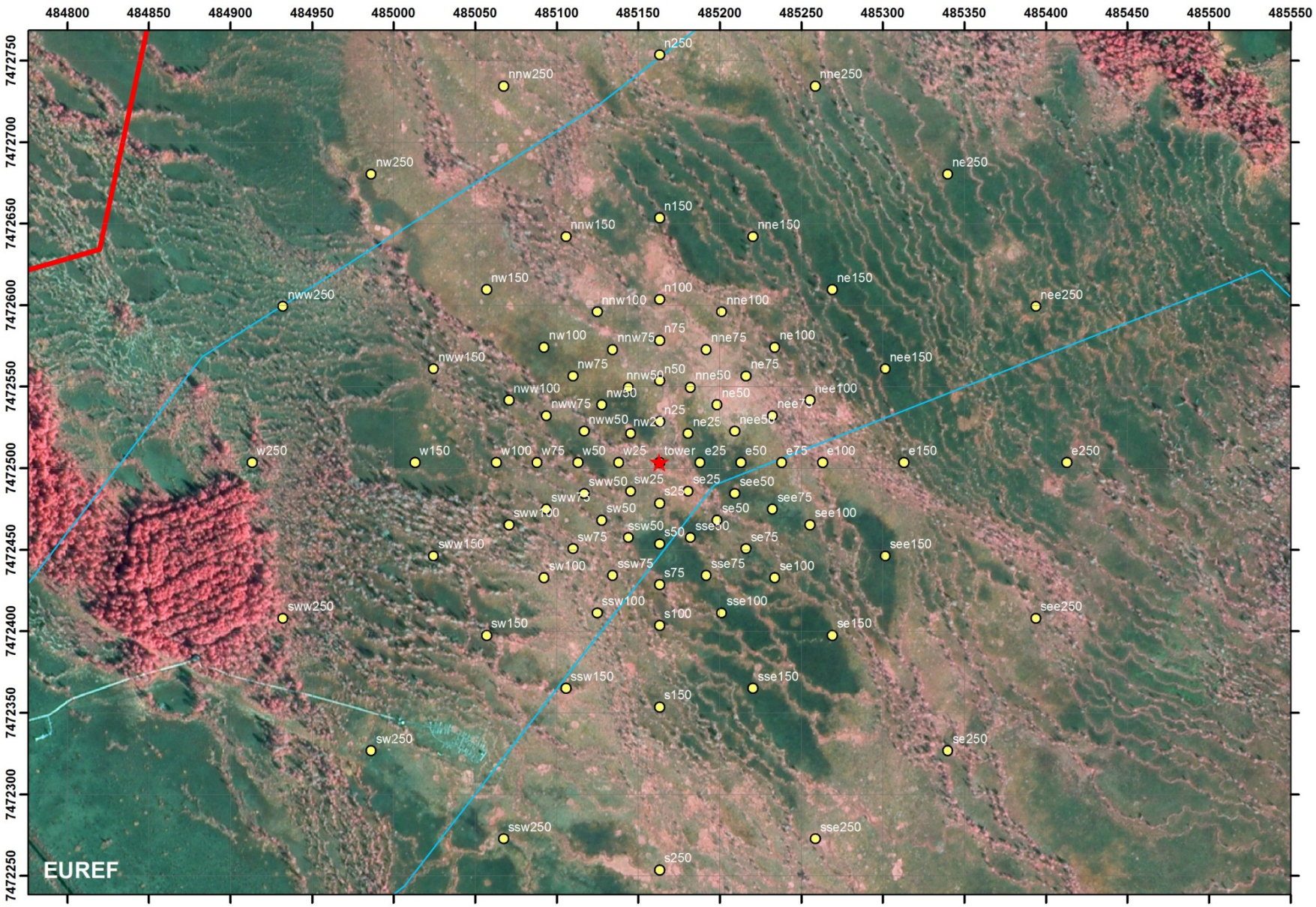
Study areas

- Tiksi, middle tundra, CH_4 and CO_2 flux measurements by eddy flux tower have been done since 2010, and chamber measurements in several years
- Seida, southernmost tundra, some flux studies since 2008
- Sodankylä, northern boreal, CH4 and CO2 flux measurements have been done since 2013, chamber measurements in 2014



Sodankylä flux tower & one chamber area

Sodankylä measurement area



Sodankylä work in 2014

- Land cover data by functional groups / main species in the start-, middle-, in the end of growing season, 60 plots (each 3 0.5 x 0.5 m sub-plots + 5 m radius general estimate)
- Weekly phenological measurements of 10 main species
- Biomass & LAI samples from 60 plots in middle/peak season by plant species / main functional groups
- Weekly chamber CO_2 & CH_4 flux measurements from 6 different peatlnd types, 2 replicates each
- Soil samples from 60 plots
- Land cover, biomass, LAI & soil properties will be regionalised for the whole peatland, including also seasonal variation

Tiksi measurement area

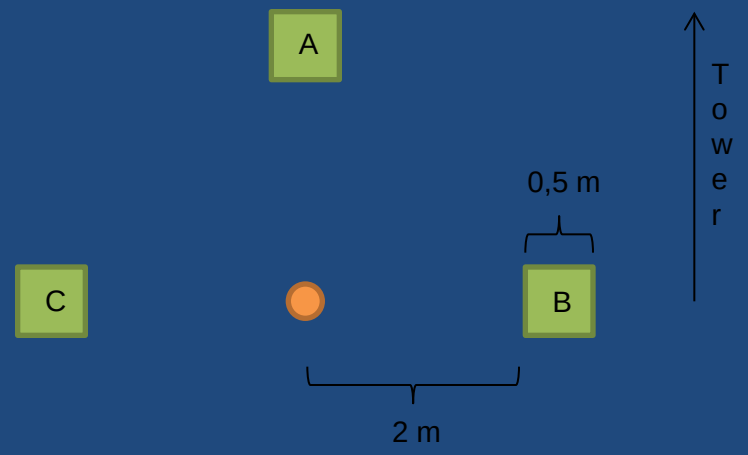
Tiksi work in 2014

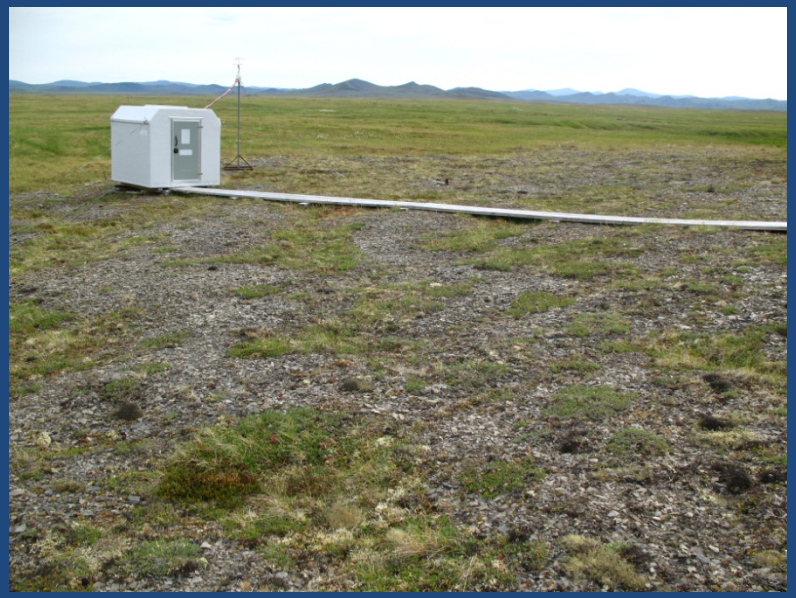
- Land cover data by functional groups / main species in the start-, middle-, in the end of growing season, 100 plots (each 3 0.5 x 0.5 m sub-plots + 5 m radius general estimate)
- Weekly phenological measurements of 8 main species
- Biomass & LAI samples from 100 plots in middle/peak season by plant species / main functional groups
- Weekly chamber CO_2 & CH_4 flux measurements from 9 different land cover types
- Soil samples from 100 plots
- Land cover, biomass, LAI & soil properties will be regionalised for the whole peatland, including also seasonal variation

Field data collected in 2012

- We established 5 or 6 sample plots to 8 different cardinal points (N, E, S, W, NE, SE, SW, NW) in late July 2012
  - Distances from the tower 25, 50, 75, 100, 150 and 250 m
- Also 8 additional sample plots between the cardinal points
  - Distance 150 m
- Altogether 52 sample plots with three sub-plots

Sampling design:





Coverage and height of different plant functional types (N=58)

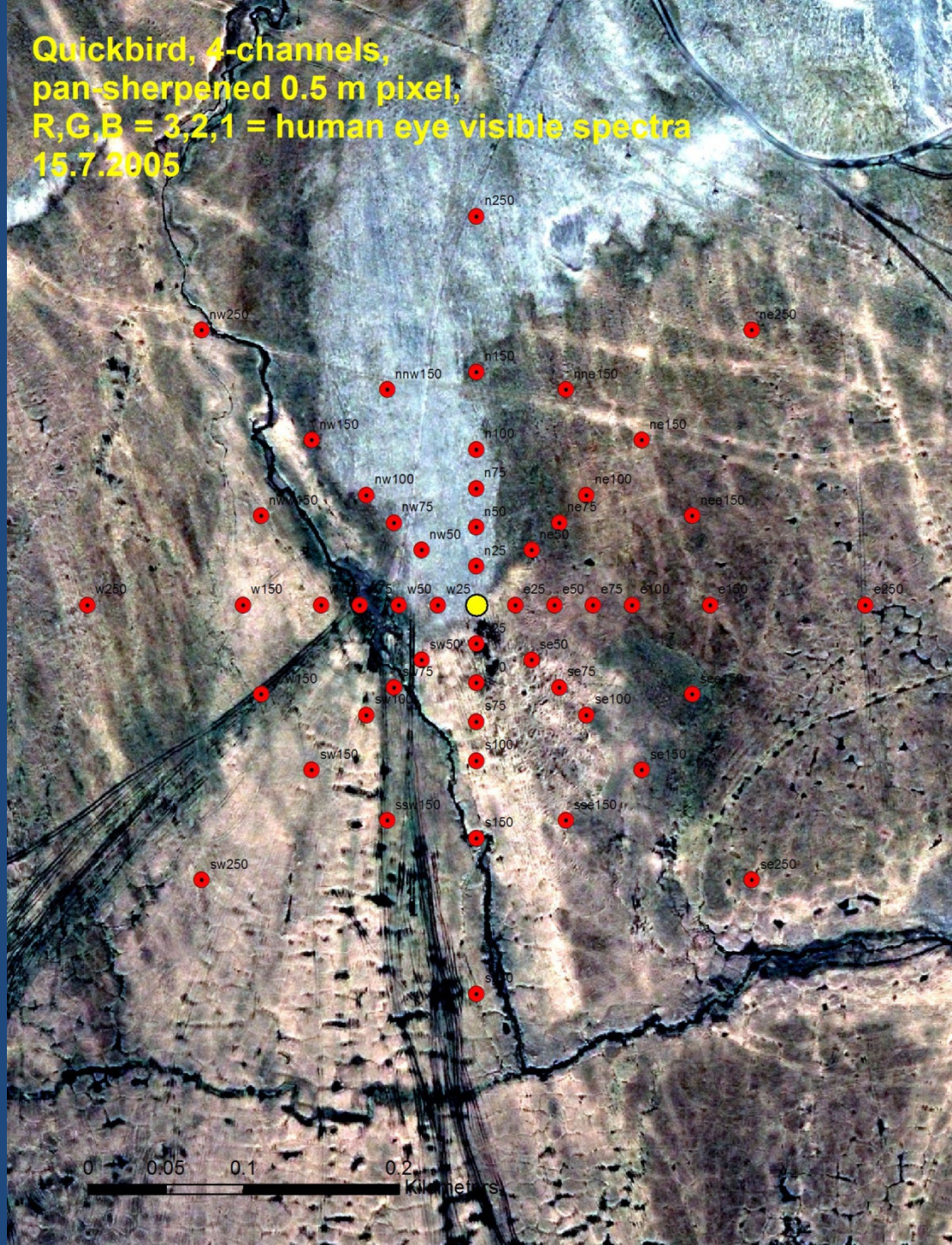
Plant species list (N=58)

LAI (N=34)

Depth of active layer (N=29)
Water content (N=29)
Bulk density (N=29)
Organic matter % (N=29)

Location of the field study plots & satellite data

- Two high resolution satellite images: Quickbird (15.7.2005: 4 channels, pansharpened to 0.5 m) and WorldView-2 (12.8.2012: 8 channels in 2 m, panchromatic 0.5 m)
- Some Landsat images (25 m pixel size)
- Digital elevation model in 25 m pixel size



Results: Vegetation classes

1. PEATLANDS
 1.1 Fen
  1.1.1 Dry fen
  1.1.2 Wet fen
 1.2 Bog

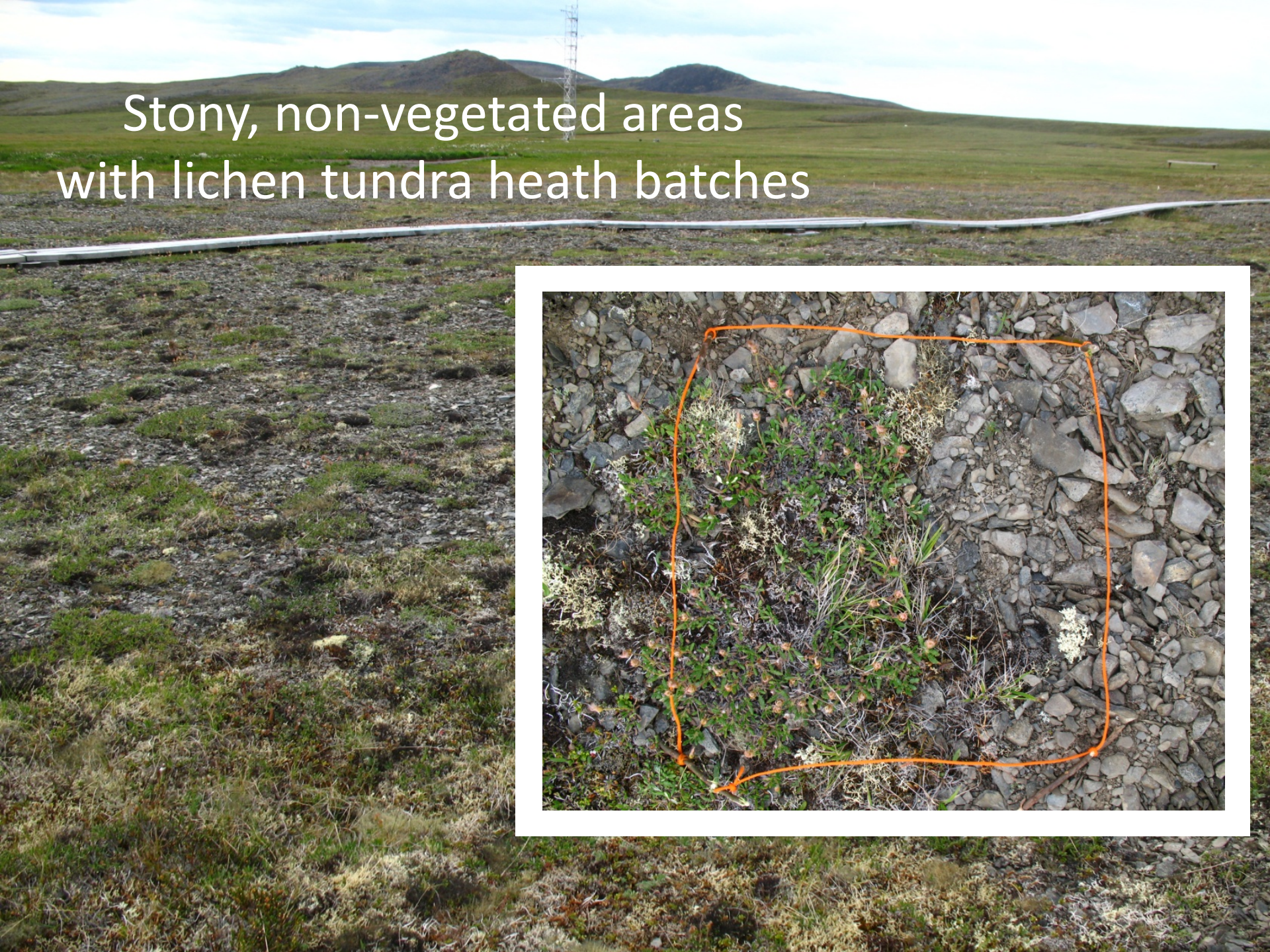
2. MOORLANDS /HEATHS
 2.1 Tundra heath
  2.1.1 Lichen tundra heath
  2.1.2 Shrub-moss tundra heath
  2.1.3 Dwarf birch tundra heath
 2.2 Tussock tundra

3. MEADOWS
 3.1 Grass meadow
 3.2 Willow meadow

4. STONY, NON-VEGETATED AREAS

5. WATER

Stony, non-vegetated areas with lichen tundra heath batches



Shrub-moss tundra heath

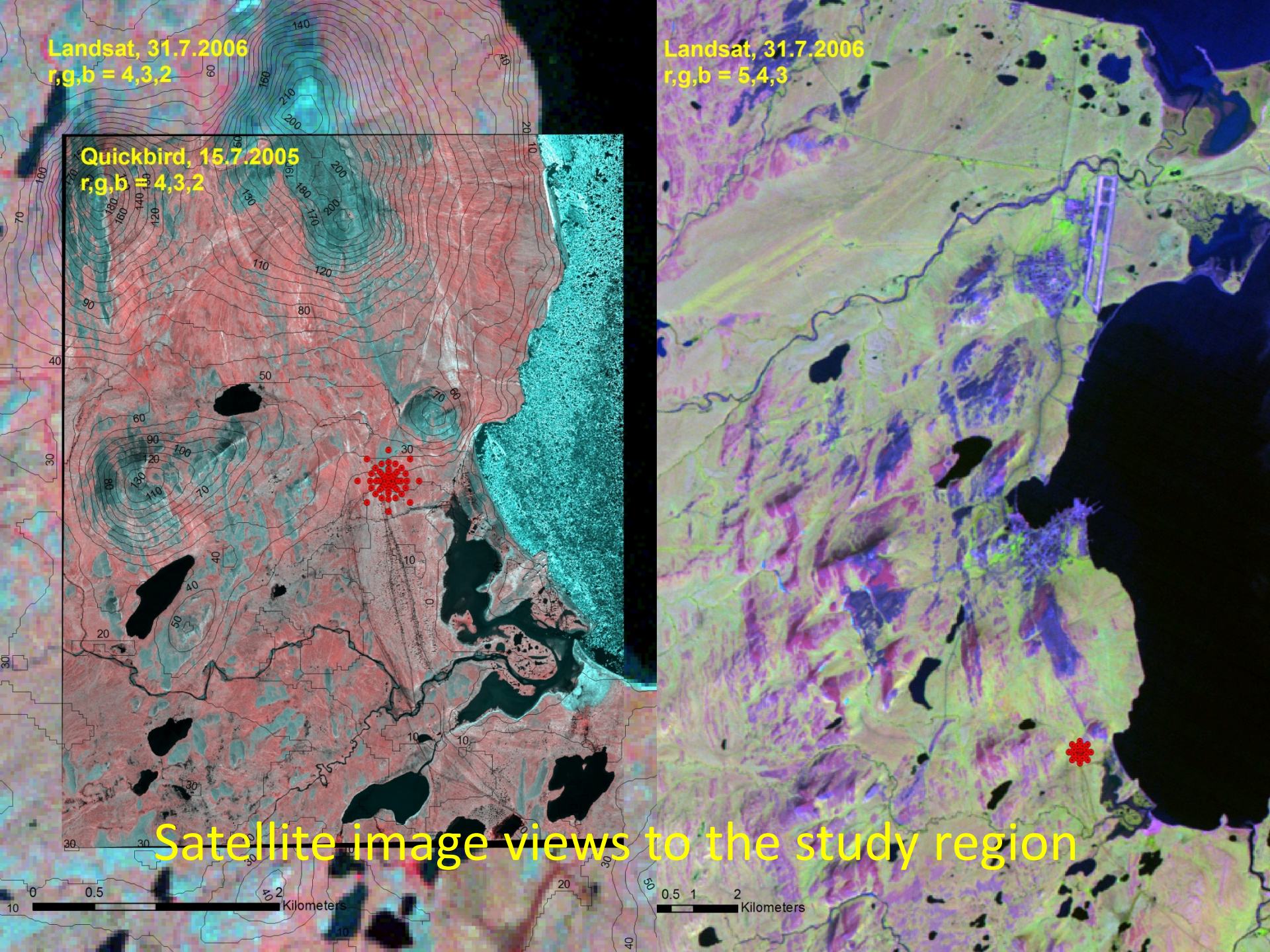
Bogs

Fens

Tussock tundra

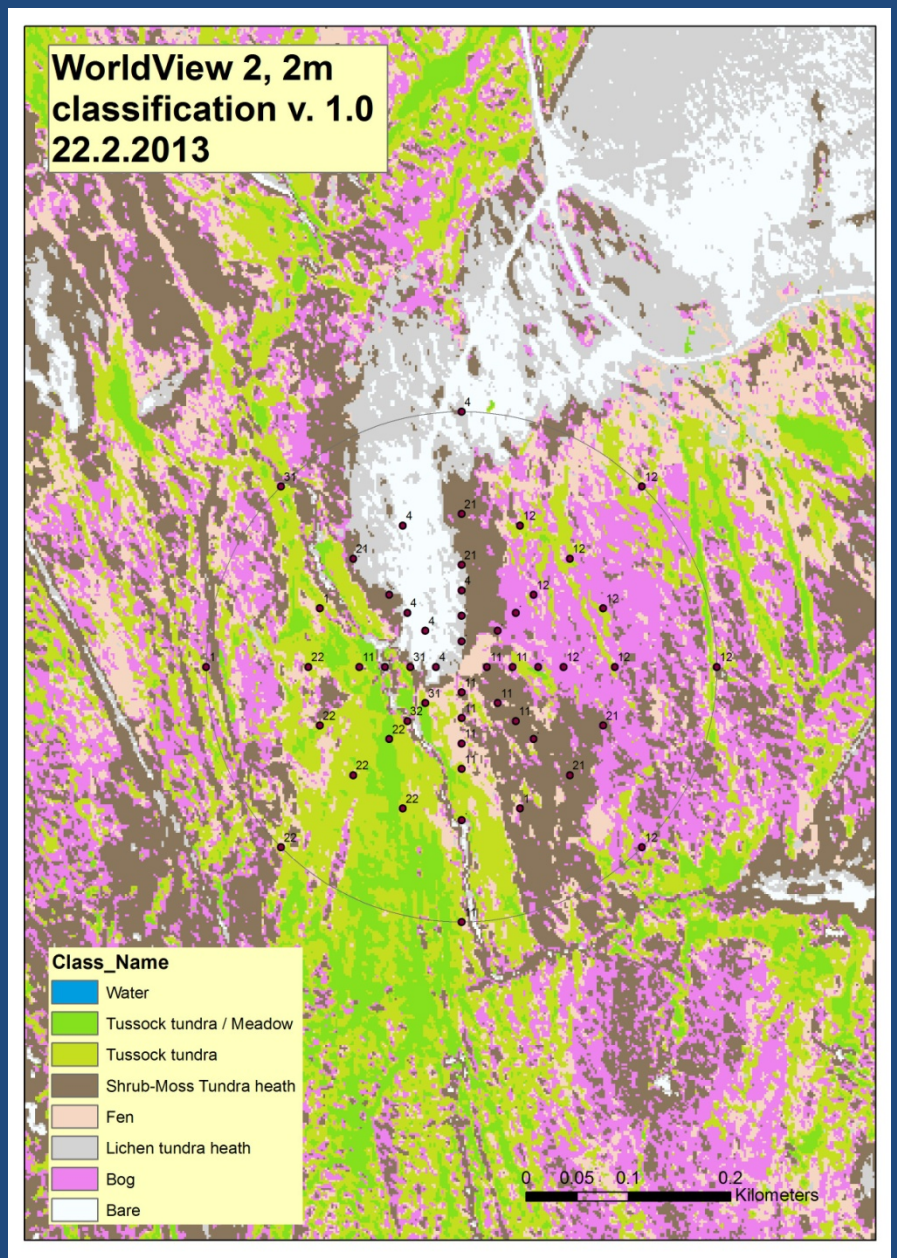
Grass meadow

Biomass & LAI samples

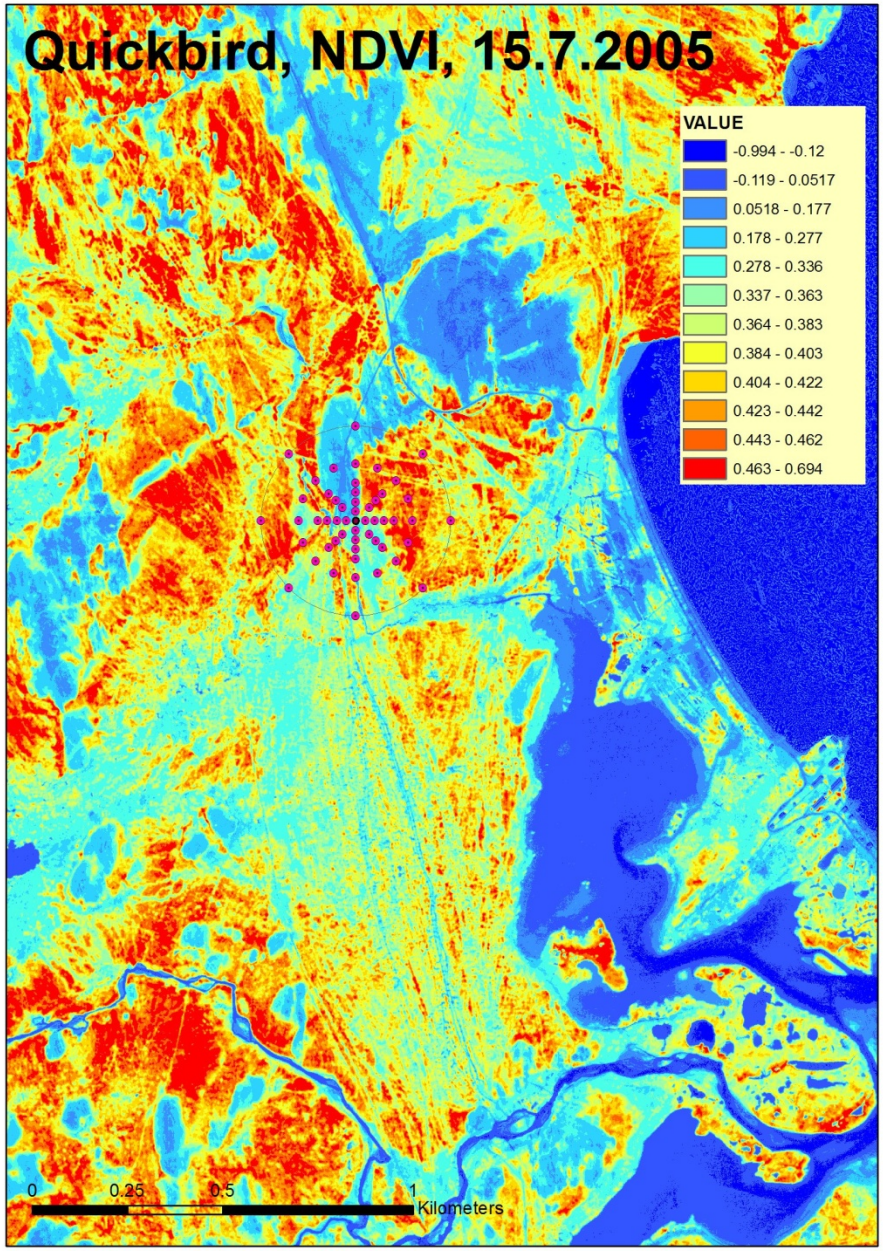


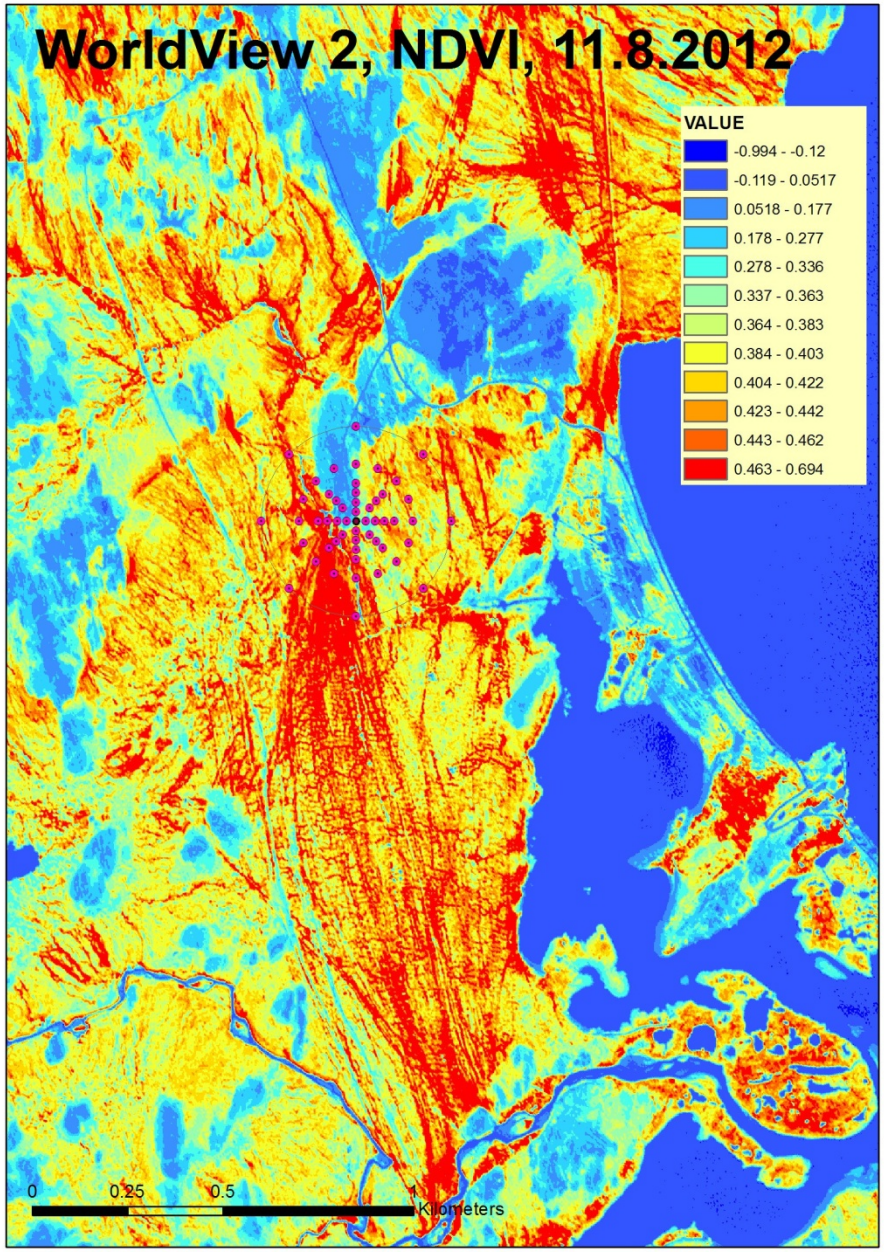
Satellite image views to the study region

Preliminary land cover classification



NDVI maps

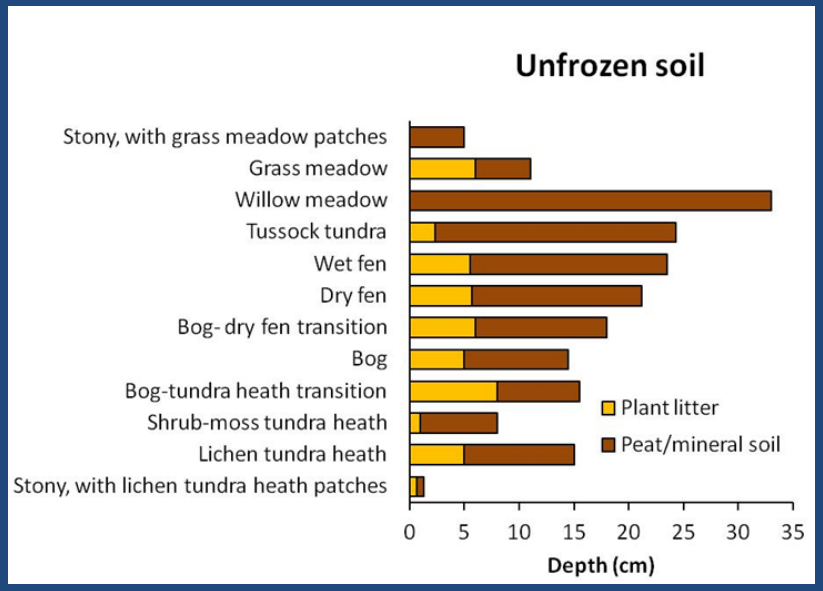

Quickbird, NDVI, 15.7.2005
VALUE
-0.994 - -0.12
-0.119 - 0.0517
0.0518 - 0.177
0.178 - 0.277
0.278 - 0.336
0.337 - 0.363
0.364 - 0.383
0.384 - 0.403
0.404 - 0.422
0.423 - 0.442
0.443 - 0.462
0.463 - 0.694
0
0.25
0.5
1
Kilometers

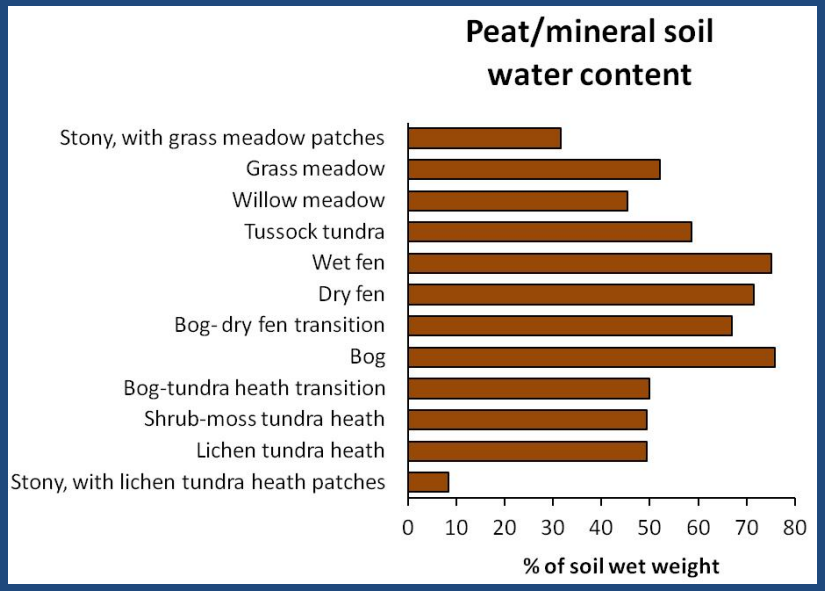

WorldView 2, NDVI, 11.8.2012
VALUE
-0.994 - -0.12
-0.119 - 0.0517
0.0518 - 0.177
0.178 - 0.277
0.278 - 0.336
0.337 - 0.363
0.364 - 0.383
0.384 - 0.403
0.404 - 0.422
0.423 - 0.442
0.443 - 0.462
0.463 - 0.694
0
0.25
0.5
1
Kilometers

Some results: Vegetation properties

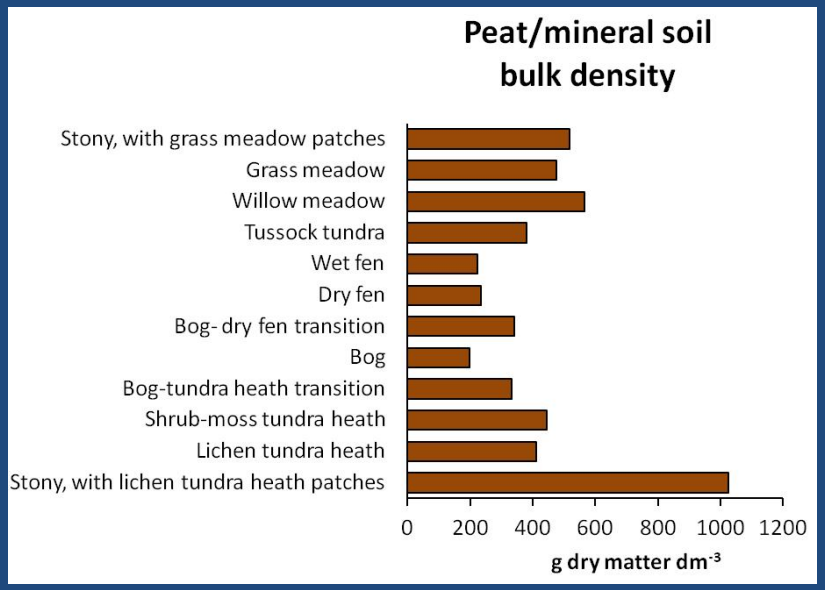
	Fieldplots / %	LAI	Tot plant cover
1. PEATLANDS	39.70 %	0.540	100 %
1.1 Fen	22.70 %	0.373	86 %
1.1.1 Dry fen	18.90 %	0.425	91 %
1.1.2 Wet fen	3.80 %	0.270	64 %
1.2 Bog	17.00 %	0.685	118 %
2. MOORLANDS / HEATHS	24.40 %	0.600	102 %
2.1 Tundra heath	13.10 %	0.540	98 %
2.1.1 Lichen tundra heath	5.60 %	0.420	68 %
2.1.2 Shrub-moss tundra heath	6.70 %	0.670	120 %
2.2 Tussock tundra	11.30 %	1.103	76 %
3. MEADOWS	5.70 %	0.650	89 %
3.1 Grass meadow	3.80 %	0.620	98 %
3.2 Willow meadow	1.90 %	0.690	81 %
4. STONY, NON-VEGETATED AREAS	17.00 %	0.230	44 %
5. WATER	1.90 %	0.000	0 %

Results: Soils, 1

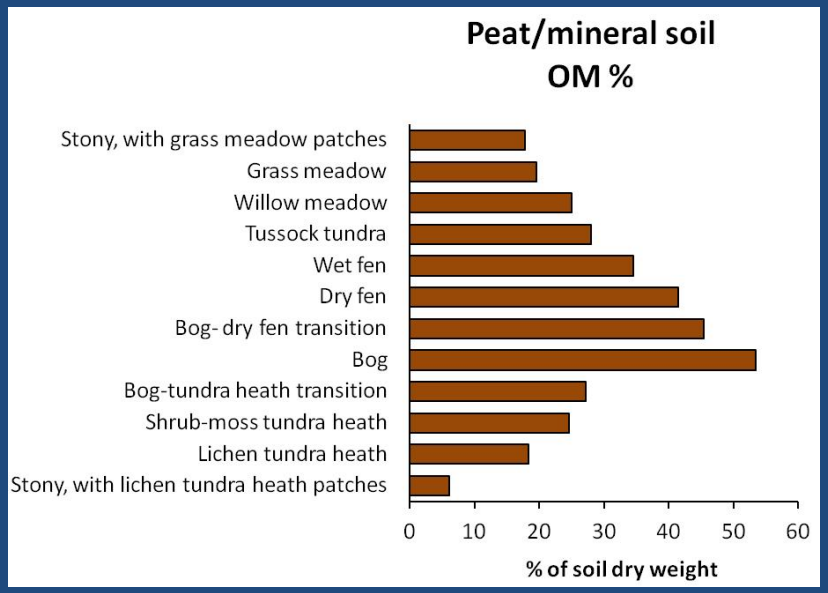


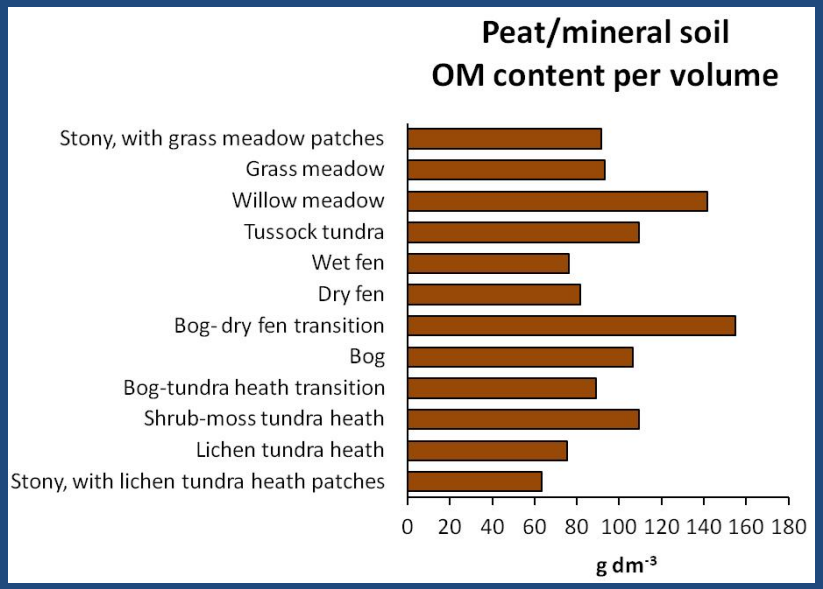


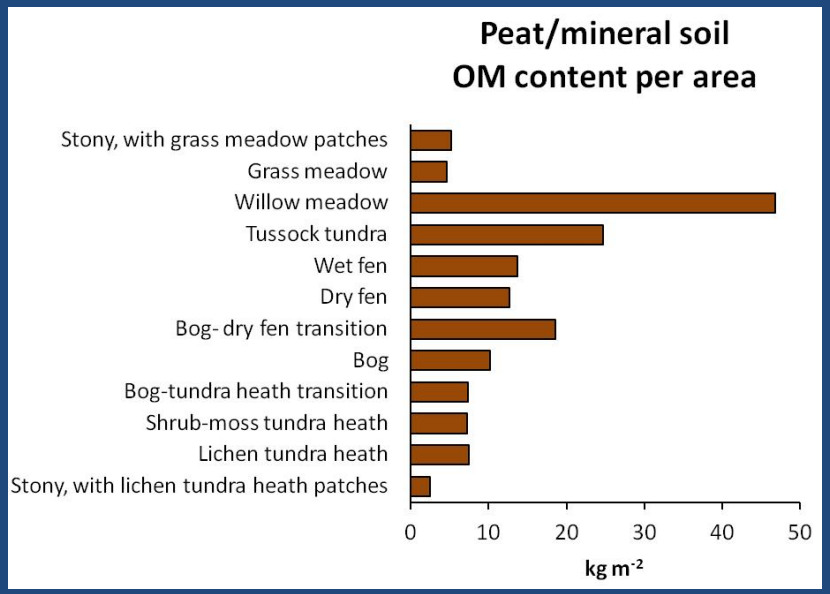
- Depth of the unfrozen layer varies between vegetation types
- Peat soils have highest water content & smallest bulk density, in stony soils it's the opposite



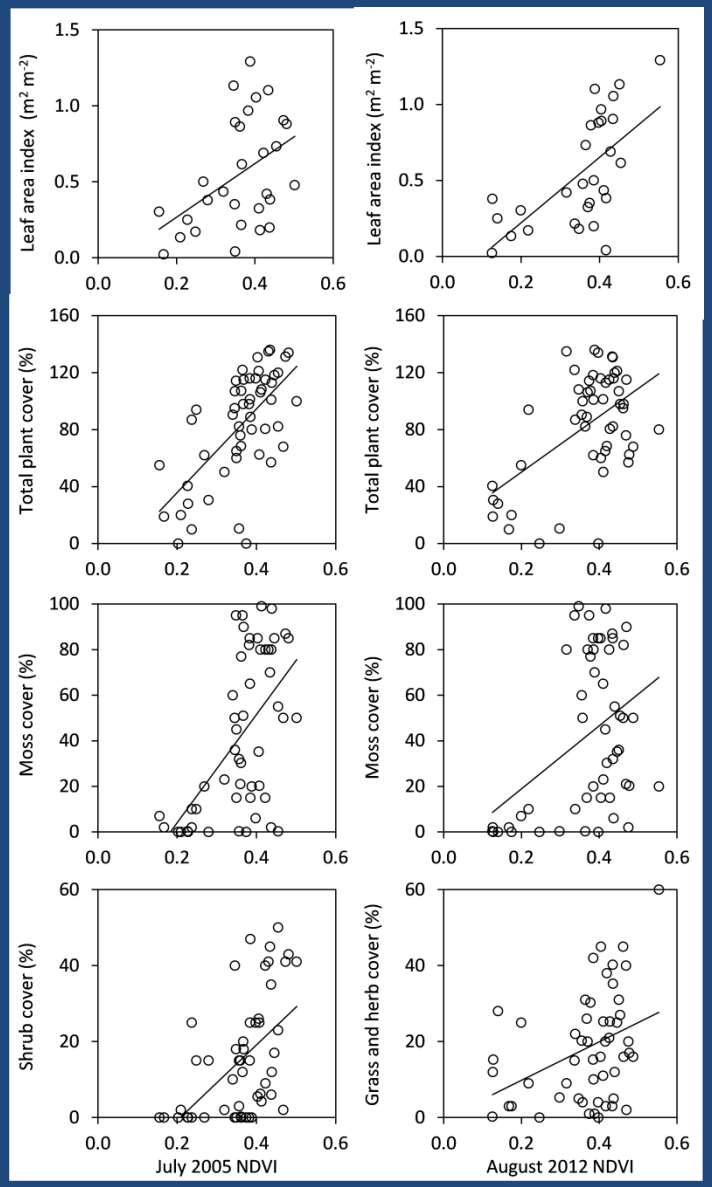
Results: Soils, 2

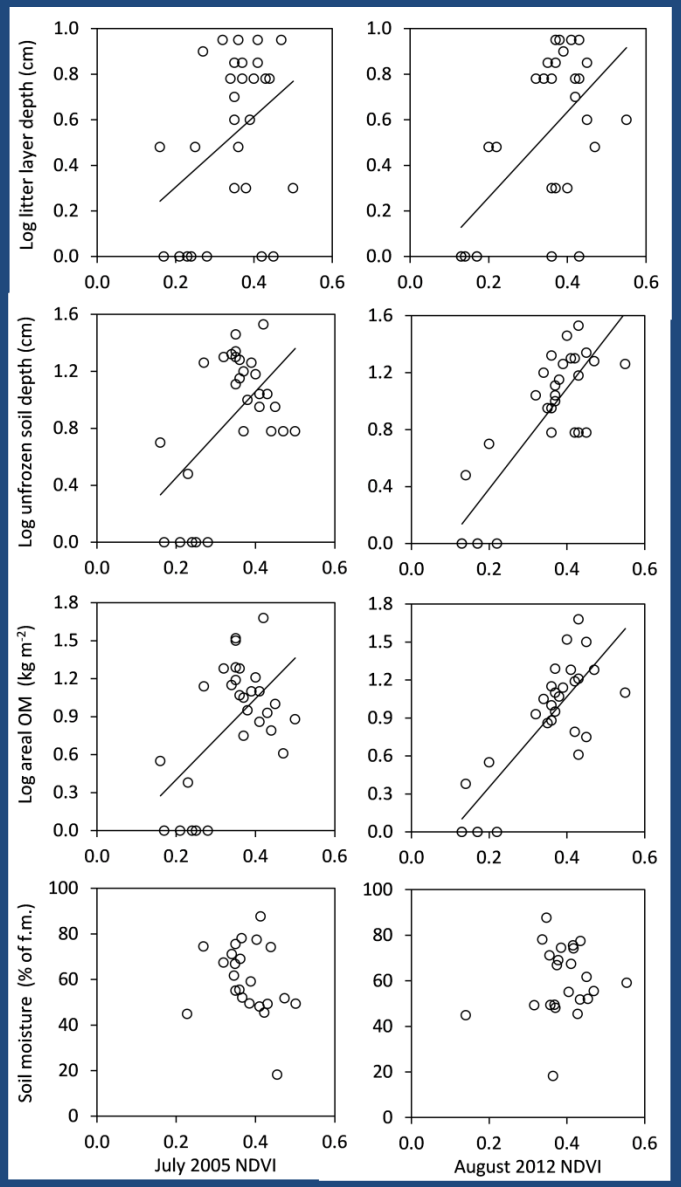






Vegetation and soil properties predicted by satellite image data



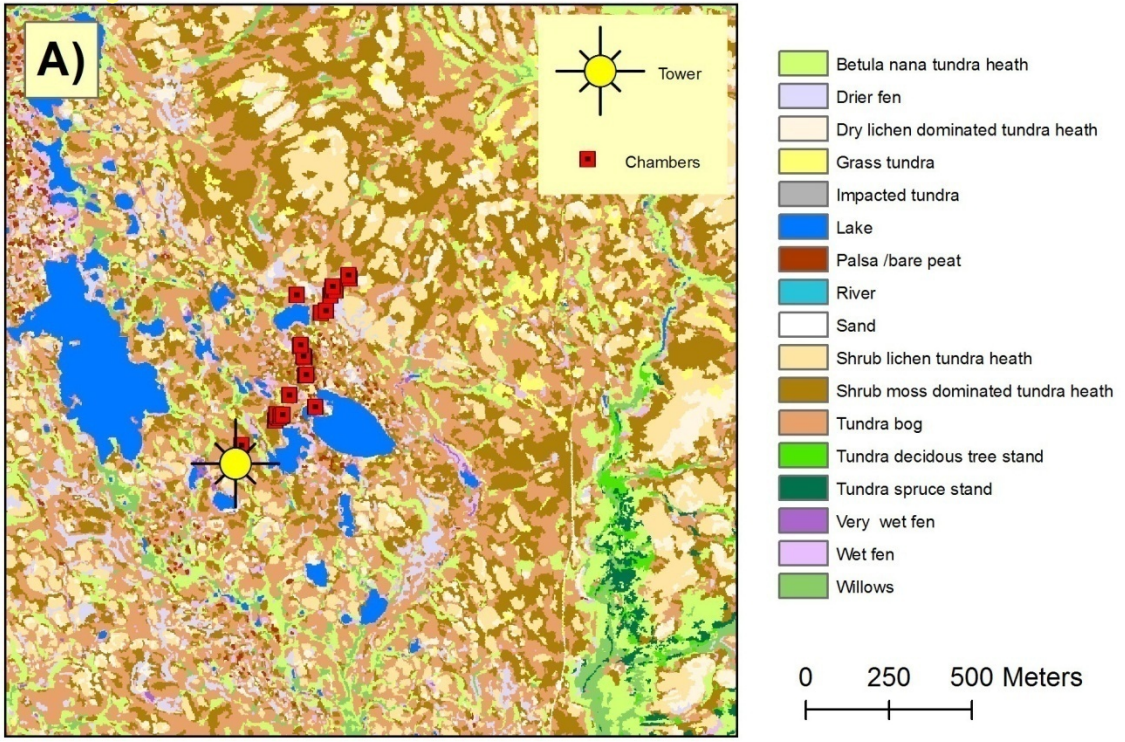


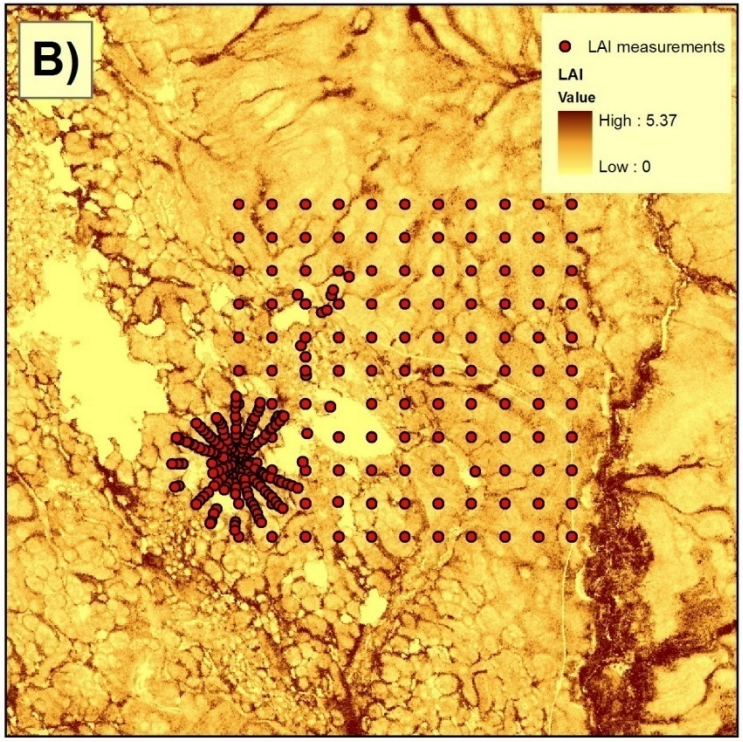
Main results from Tiksi 2012 data

- Typically, segmentation techniques are needed when these kinds of extremely high resolution images are classified, but due to lowness of the vegetation causing lack of shadow effects, it seems that even pixel based methods can be used
- Satellite image based NDVI (Normalized Difference Vegetation Index) explains spatial variation in LAI, total plant cover and moss cover
- Variation in NDVI based 2005 image explains better the variation in shrub cover and the variation in NDVI based on 2012 image explains especially the variation in grass and herb cover
- When soil properties are analysed, it seems that spatial variation in soil organic matter content and depth of unfrozen soil can be well predicted using satellite image data

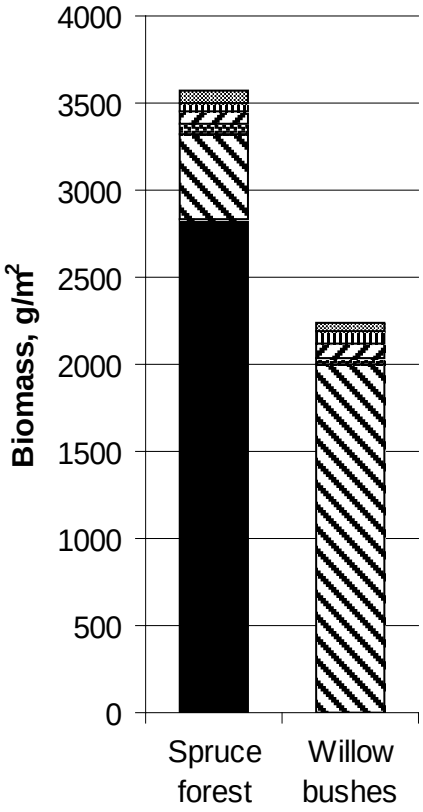
Another study: Tundra flux upscaling in Seida

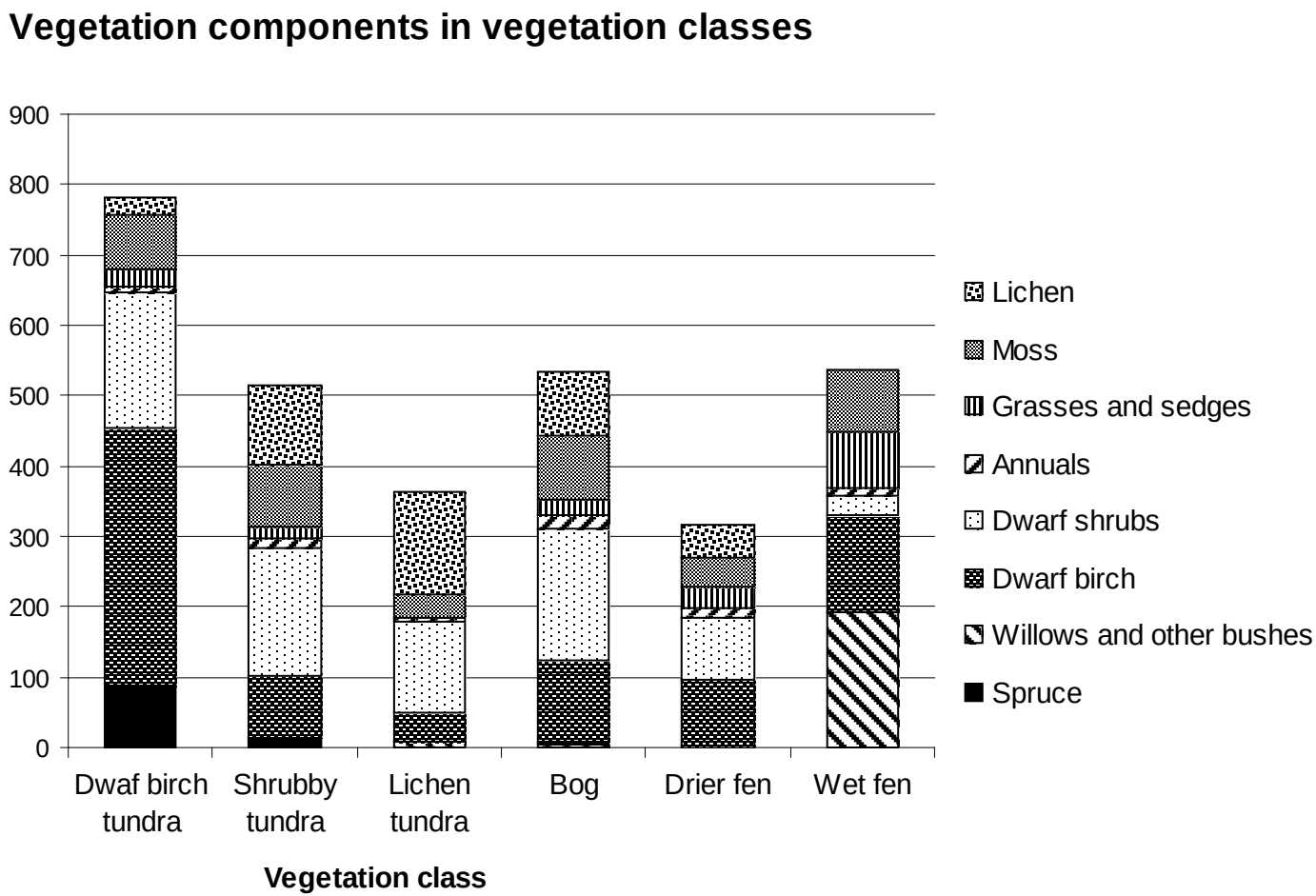
- Carbon gas dynamics was measured at the microsite chamber level and by Eddy tower covariance measurements
- Land cover classifications and field measured an regionalised LAI data is used to calculate the total regional carbon stocks and fluxes
- See more: Marushchak, ME, Kiepe, I, Biasi, C., Elsakov, V. Friborg, T., Johansson, T., Soegaard, H., Virtanen, T. and Martikainen, PJ 2013. Carbon dioxide balance of subarctic tundra from plot to regional scales. Biogeosciences, 10: 437–452



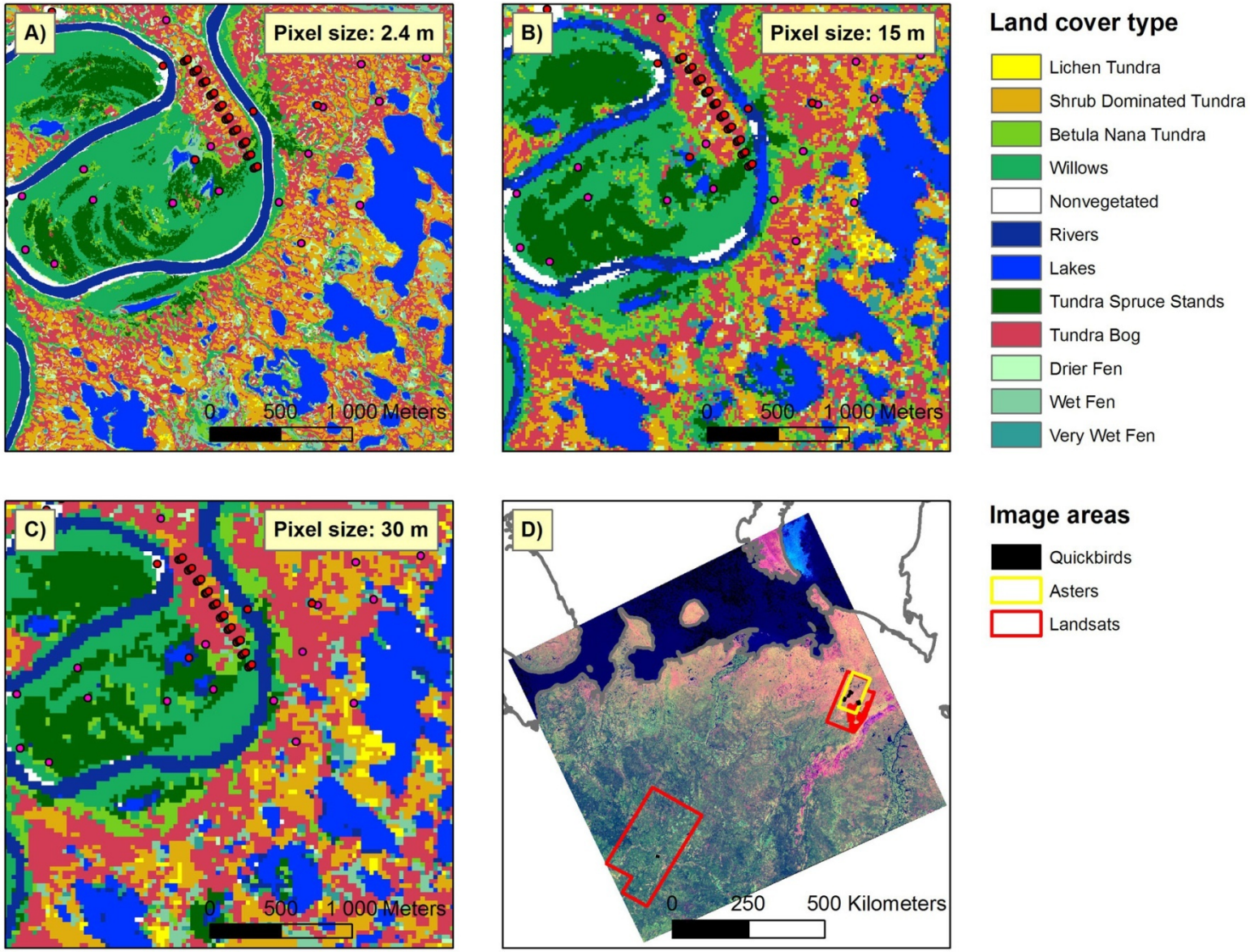


Plot level data, biomasses from Seida 2007-8

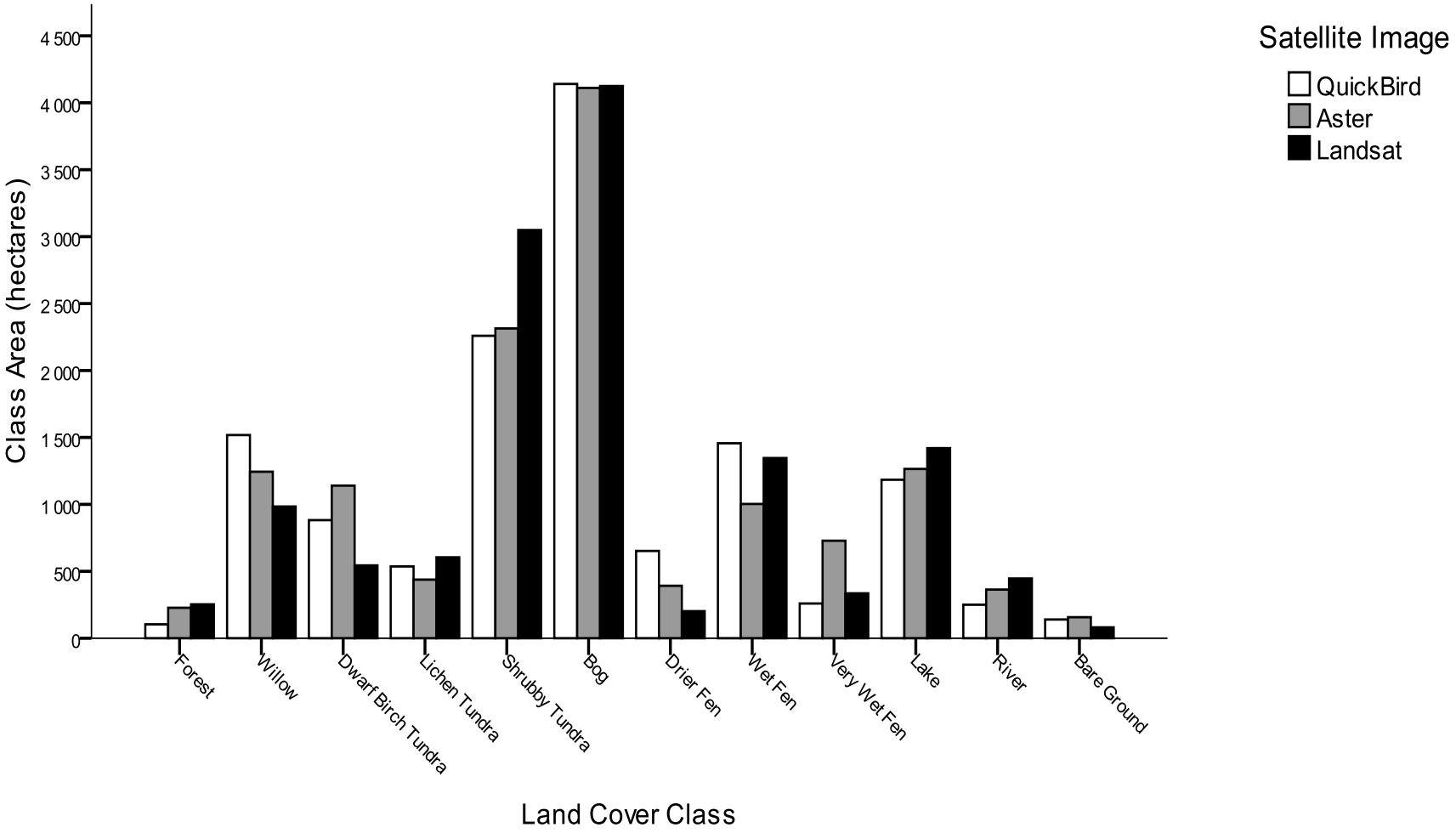




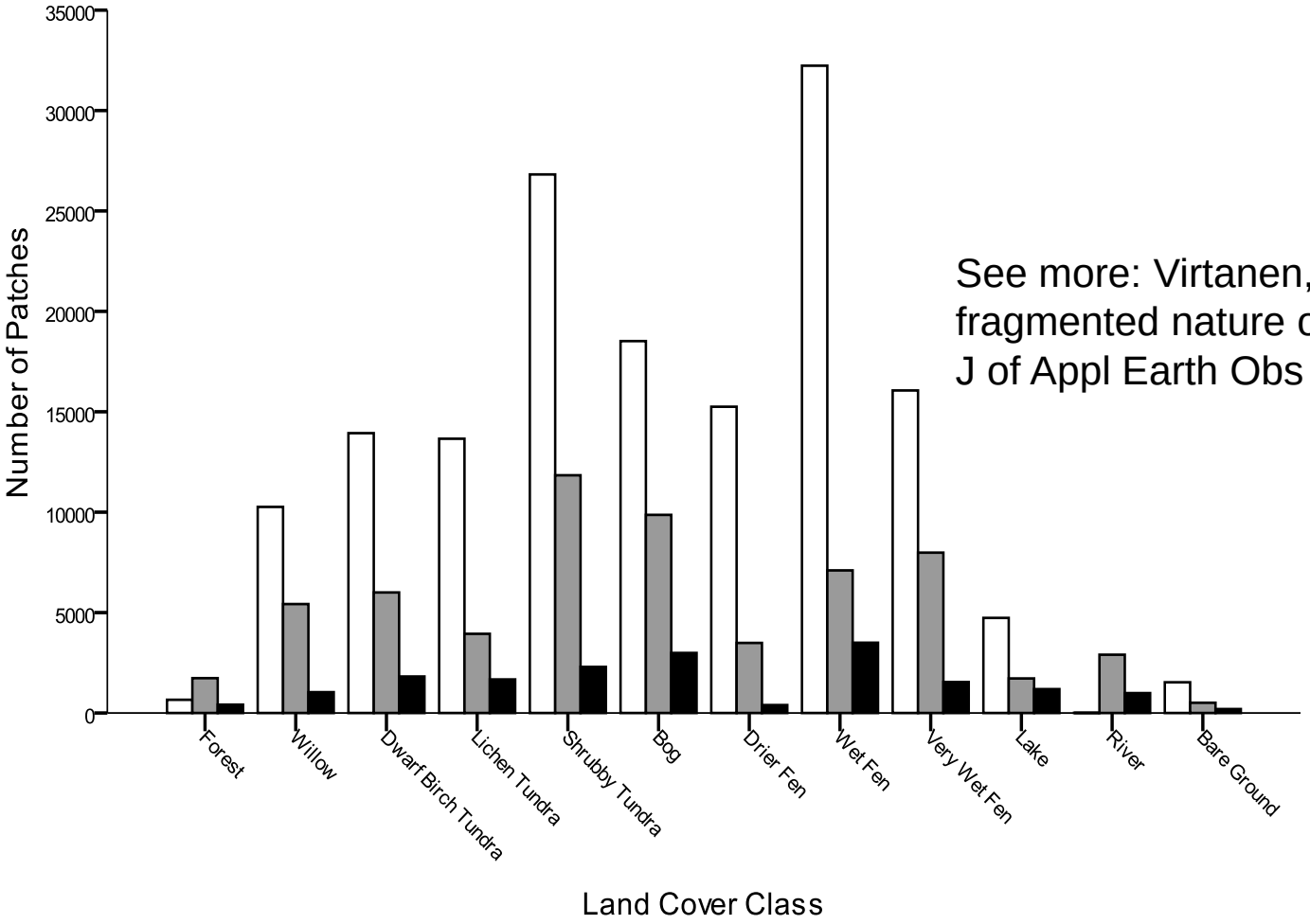
Resolution & spatial coverage of the classifications



Class coverages in Rogovaya sites



Number of vegetation patches within Rogovaya sites



See more: Virtanen, T., Ek, M. 2014. The fragmented nature of tundra landscape. Int J of Appl Earth Obs and Geoinf 27: 4–12.

Conclusions

- When goal is to create accurate models for regional GHG-fluxes in Arctic ecosystems, very detailed land cover and plant community data is needed.
- It seems that this kind of data can be produced for measurement “footprint areas” in a usable accuracy
- Satellite image data is also needed, when these results are compared to large scale Ecosystem Model results

Thanks for your attention!