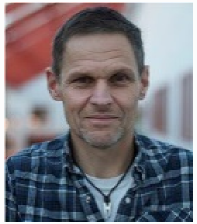
Multi-scale remote sensing observations of a palsa in degradation phase

HEATHER REESE, MATS OLVMO, SOFIA THORSSON, BJÖRN HOLMER

DEPARTMENT OF EARTH SCIENCES, UNIVERSITY OF GOTHENBURG, SWEDEN (HTTPS://GVC.GU.SE)

Table of contents

Aerial photo and climate variable analysis is published in

Olvmo M, Holmer B, Thorsson S, Reese H and Lindberg F,. 2020. Sub-arctic palsa mire degradation and the role of climatic drivers in the largest coherent palsa complex in Sweden (Vissátvuopmi), 1955-2016. Scientific Reports, 10(1). https://doi.org/10.1038/s41598-020-65719-1

RESEARCH QUESTIONS

What is the annual degradation rate of palsas in the study area from 1955 to present, and what are the primary climate drivers of palsa degradation?

Can we use drone-based photogrammetry to detect changes in individual palsas?

Can changes seen in the high spatial resolution data from drones and aerial photographs be detected using medium resolution satellite data such as Sentinel-2?

STUDY AREA

Vissátvuopmi palsa mire
Sweden’s largest coherent palsa complex (ca 275 ha)

A palsa is a raised mound with peat and mineral soil with ice lenses, forming in wetland areas in the sporadic permafrost zone. In Vissátvuopmi they range from a few decimeters to 5 m tall.

Foto Björn Holmer August 2016

STUDY AREA

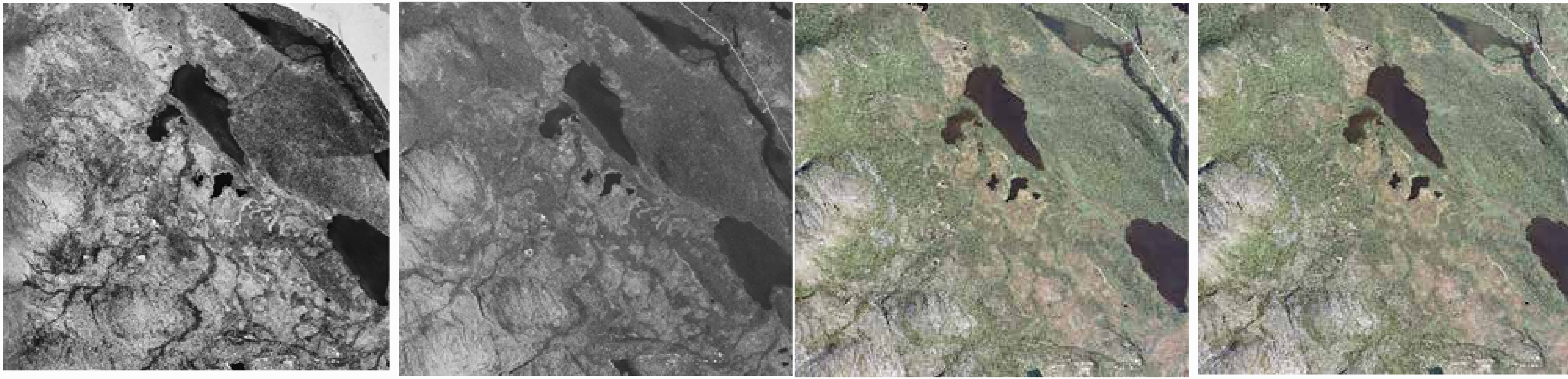
The area has mainly palsa plateaus with low heights

but it also has Ridge palsas (this one 5m tall)

and a Dome palsa (this one 4m tall)

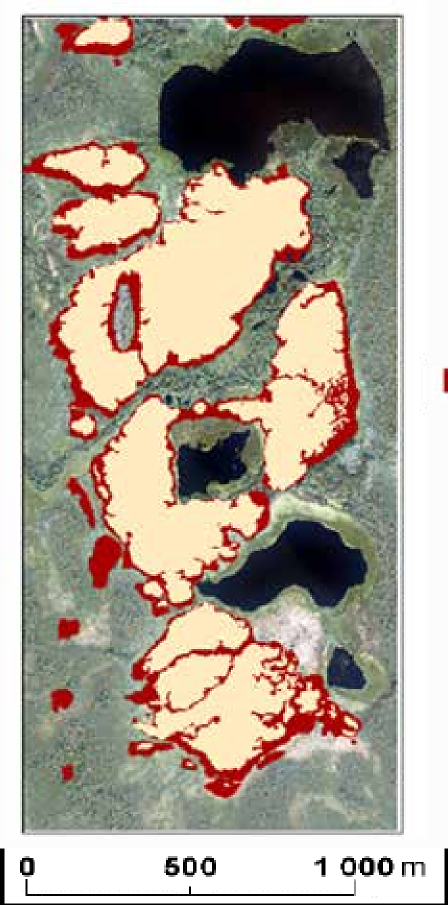
AERIAL PHOTOS - METHODS

We did manual delineation of palsa borders using 5-6 available years of aerial photos from 1955-2016 (0.5m pixels)



1955 1963 1983 1994 2010 2016

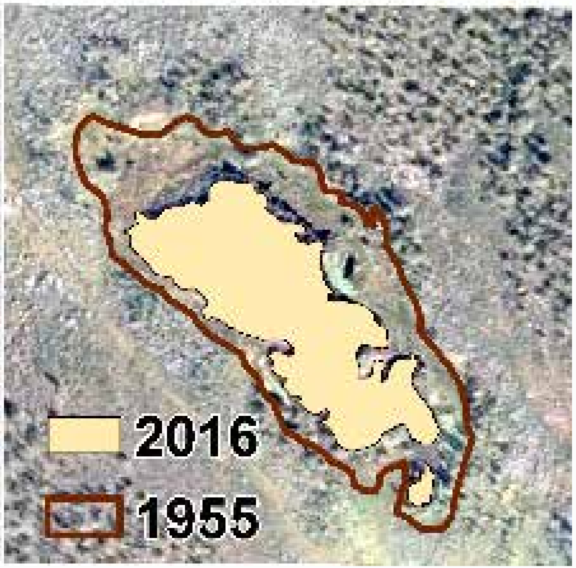
AERIAL PHOTOS - RESULTS



In the palsa plateau, 30% of the palsas have degraded from 1955-2016, going from 70 ha to 49 ha

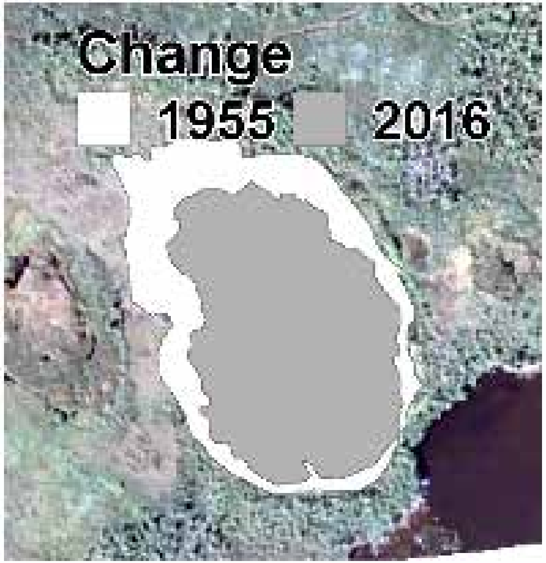
On the Ridge palsa, 54% area had degraded from 1955-2016

200 m



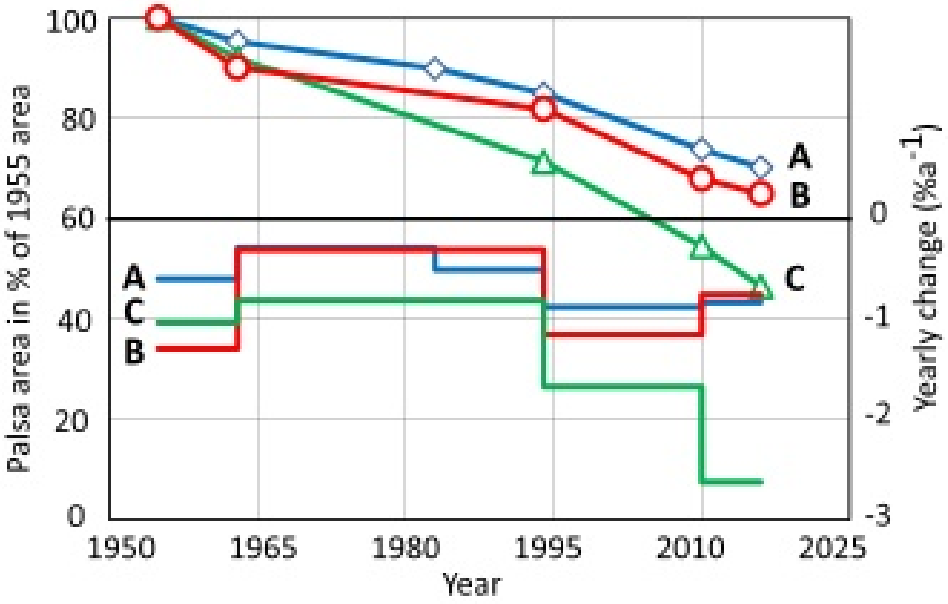
On the Dome palsa, 35% area had degraded from 1955-2016

300 m



AERIAL PHOTOS & CLIMATE DATA ANALYSIS- RESULTS

Palsa lateral changes and change rate over time

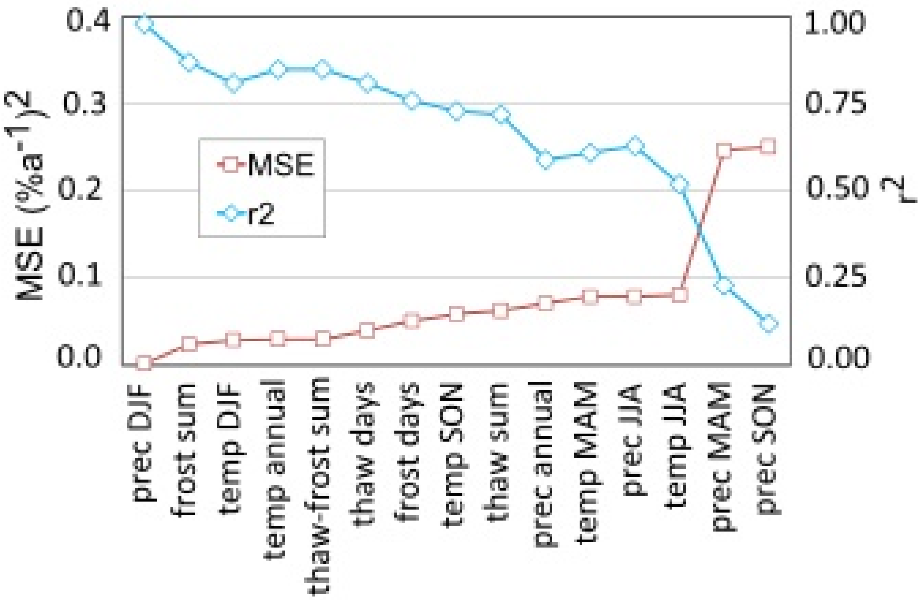


Olvmo et al. (2020)

- *There has been a continuous decrease of palsa area since 1955*
- *Rate of lateral degradation varies between observation years*
- *Lowest average annual decay rate observed 1963 -1994 and highest 1994 – 2010 (slightly lower than 2010-2016)*
- *Dome palsa (Area B) and Ridge palsa (Area C) had higher decay rate than Plateau palsa (Area A)*

AERIAL PHOTOS & CLIMATE DATA ANALYSIS- RESULTS

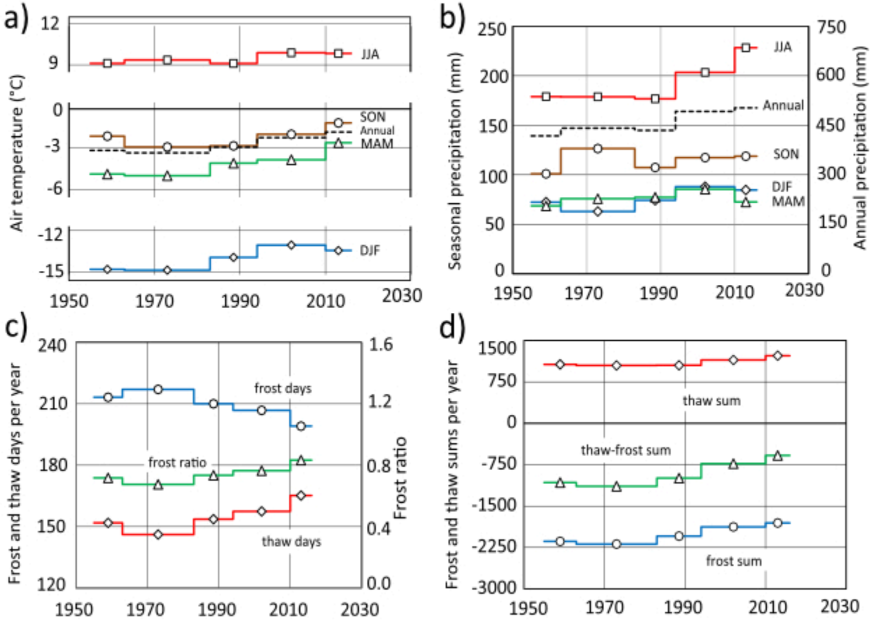
The role of different climate drivers on lateral palsa decay



Olvmo et al. (2020)

- *Winter precipitation, frost sum & winter temperature models have the lowest MSE and highest explained variance (r^2) in regression models to explain palsa decay rates*
- *Wetter, shorter and warmer winters are the main causes for the change in lateral-palsa extent.*
- *Changes in summer conditions, i.e. increased air temperatures and precipitation also have an impact on the decay rates.*

Climate variations and change between 1955 and 2016



Olvmo et al. (2020)

Meteorological data (Karesuando)

Annual and seasonal:

- Air temperature
- Precipitation
- Frost and thaw days (mean daily air temperature below/above 0 °C)
- Frost and thaw sums (accumulated daily temperatures below/above 0 °C)

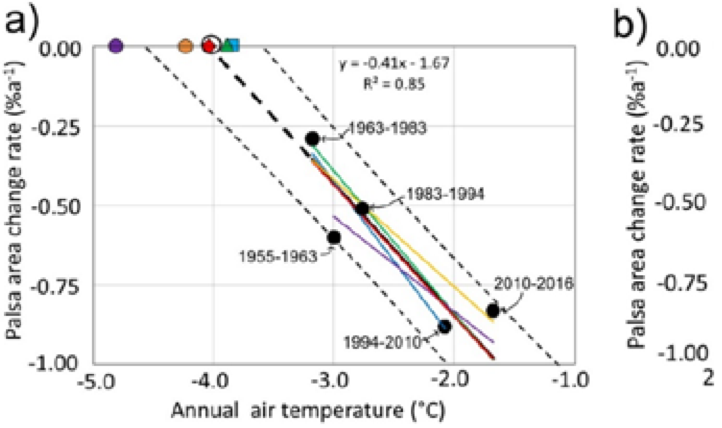
Ø *During the first half of the study period there are small changes in the climate*

Ø *Shift in the heat balance towards a warmer, longer and moister thawing season*

- enhanced downward heat flux and melting of permafrost.

Ø *The winter has also become warmer and moister*

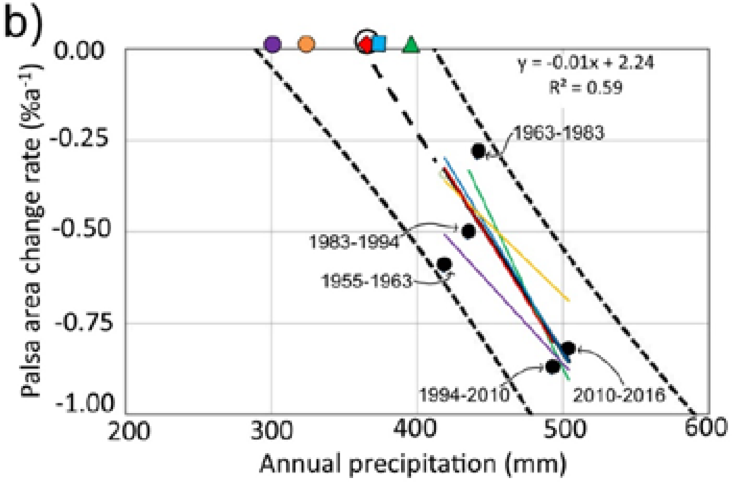
- increased snowfall and snow depth (enhanced insulation)

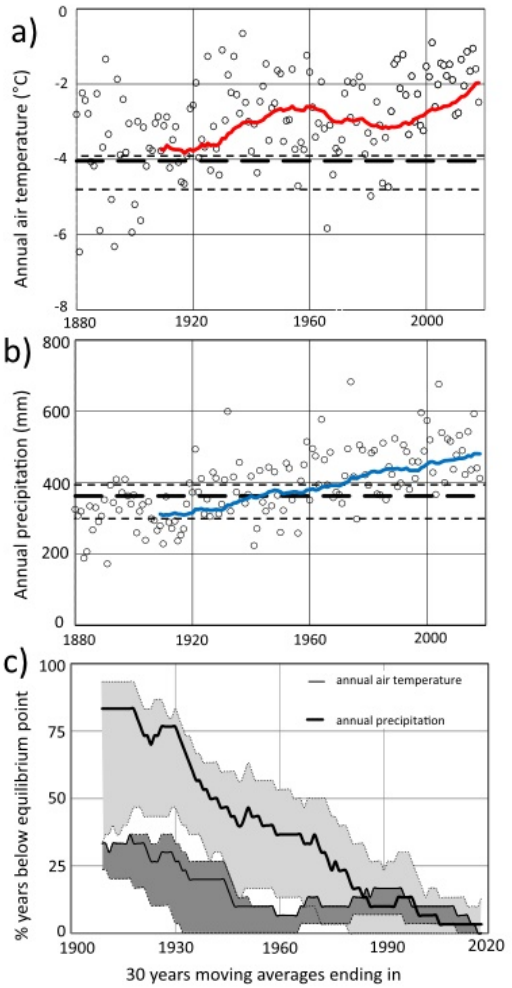


Estimated “equilibrium points”

Equilibrium point: the value of a certain climate driver for which annual freezing and thawing of a palsa is assumed to be in balance, i.e., when the average annual decay rate is zero.

***Annual air temperature**: -4.0 °C*





Olvmo et al. (2020)

Climate conditions for palsa formation and existence from 1880 and onward

- *Palsas have been in a degradation phase since the early 20th century*
  - *confirmed by signs of palsa decay (large number of thermokarst lakes) in the aerial photographs from 1955*
  - *explain the difference in previously reported temperature equilibrium points*

- *The decay rates have been amplified since the 50-60s, in particular over the most recent decades*
  - *combined effect of adverse air temperature and precipitation conditions.*

- *In this study area, conditions for new palsa formation and existence no longer exist.*

  Over the last 30 years (1987-2016):

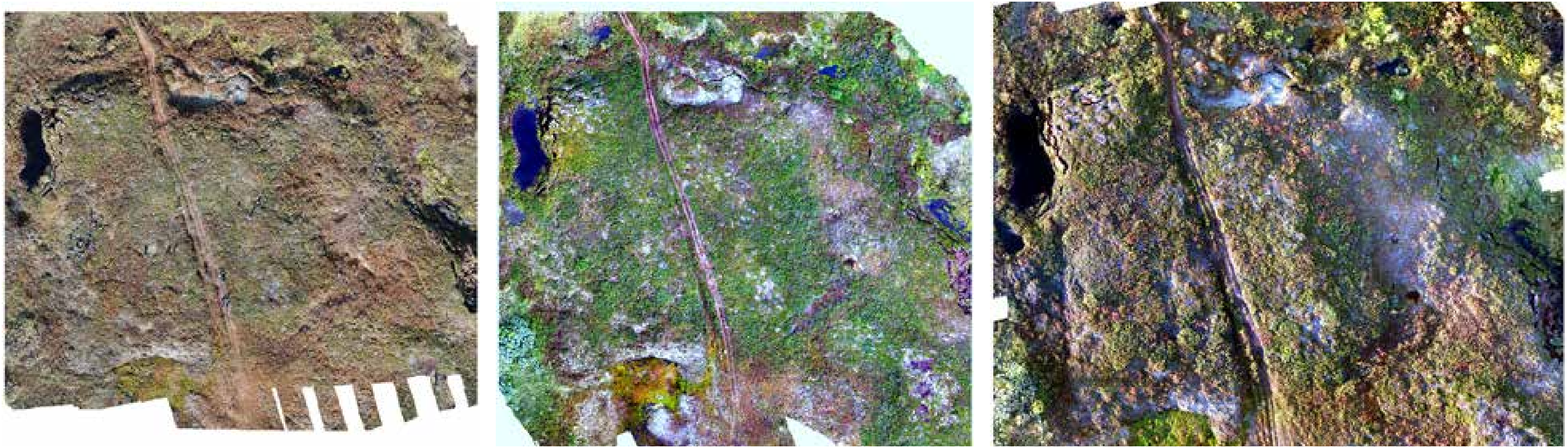
  °C (anomaly of +1.9 °C)

  Annual precipitation was 481 mm (anomaly of +118 mm)

a) Annual air temperature and 30 years moving average compared to the equilibrium point (hatched line)
b) Annual precipitation and 30 years moving average compared the equilibrium point (hatched line)
c) Frequencies of years below the air temperature and precipitation equilibrium points.

A Phantom 4 and Matrice 210 drone with an RGB camera was used to create orthophoto mosaics and 3D digital surface models over the Dome and Ridge palsas

Look at the film in the material to see the 3D model of the Dome palsa



Sept 2018 Sept 2019 Sept 2020

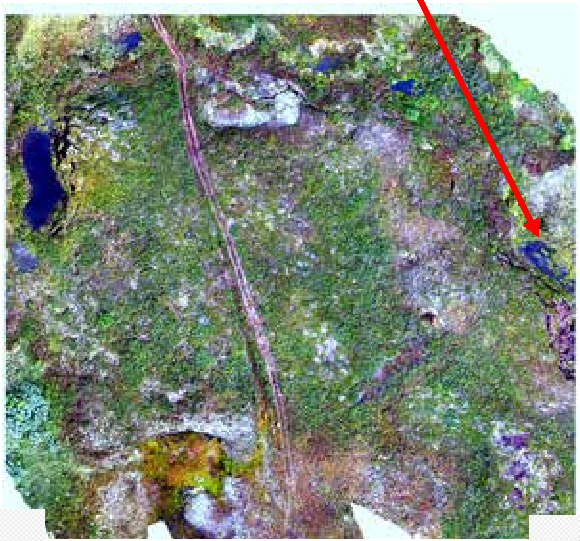
Large area subsiding, and an apparent rapid change in vegetation (Betula nana apparently died back in 2020, exposing lichen field layer)

This leads to the question, ***can we see this change in vegetation using multi-temporal Sentinel-2 data ??***

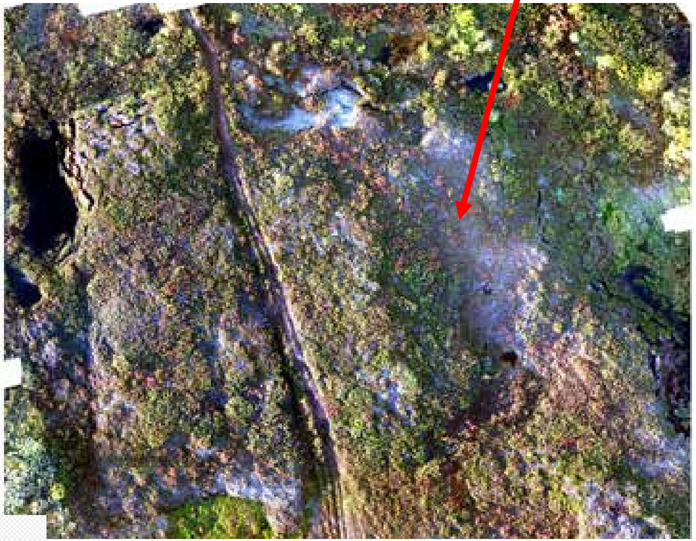
Pond formed at NW corner in 2018
Lateral erosion increases each year

On western edge, lateral erosion that occurred between 2016-2018 increases with each year

Sept 6 2018

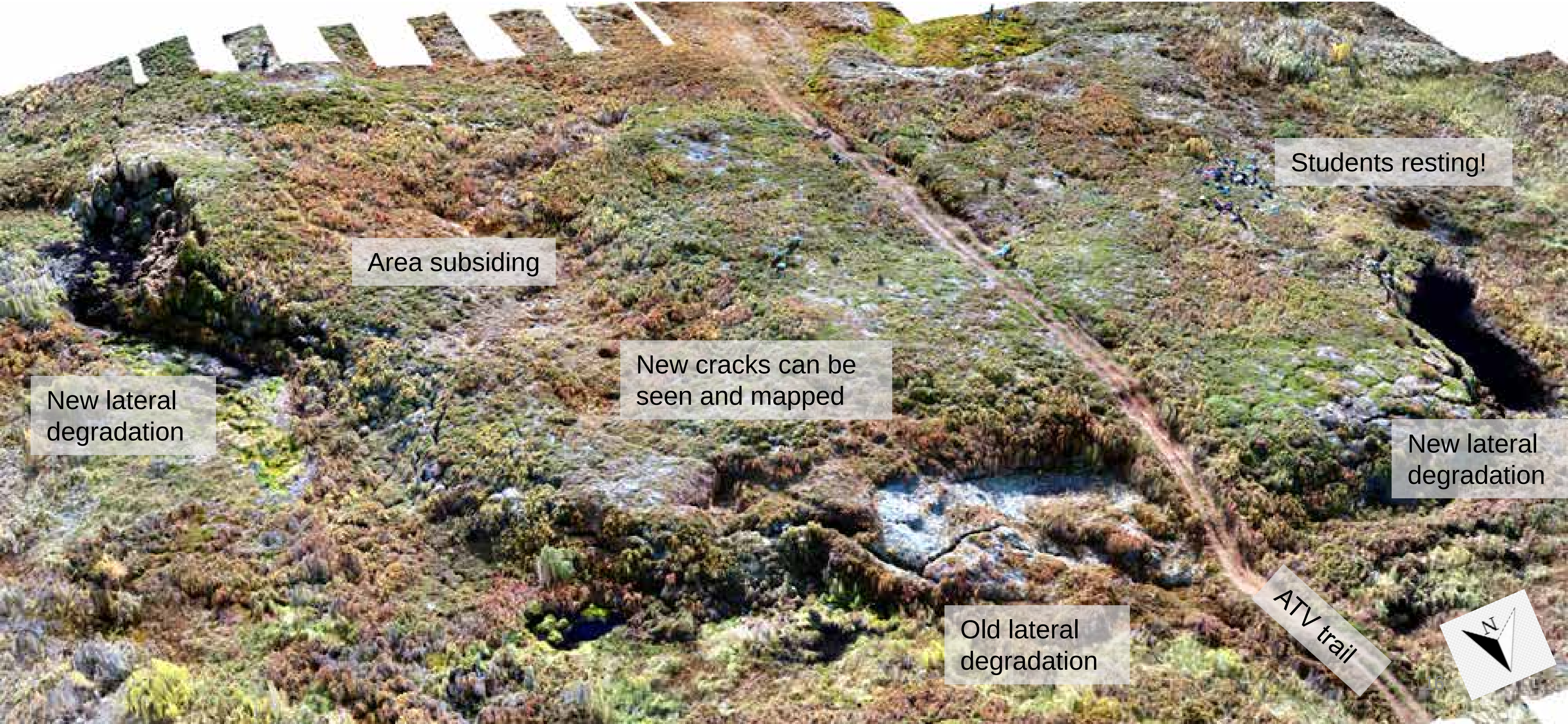


Aug 12 2019



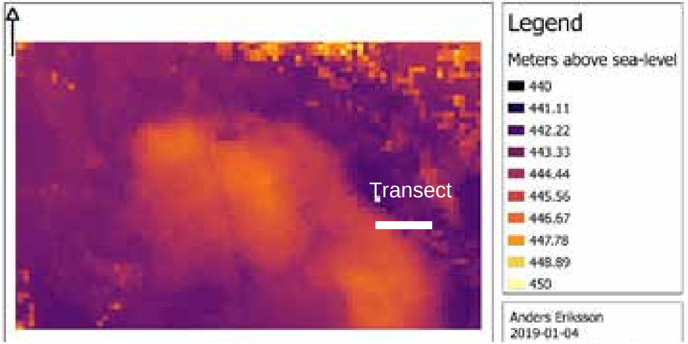
Sept 2 2020

Working with drone photogrammetry gives us 3D models of the palsa, allowing us to measure elevation changes over time



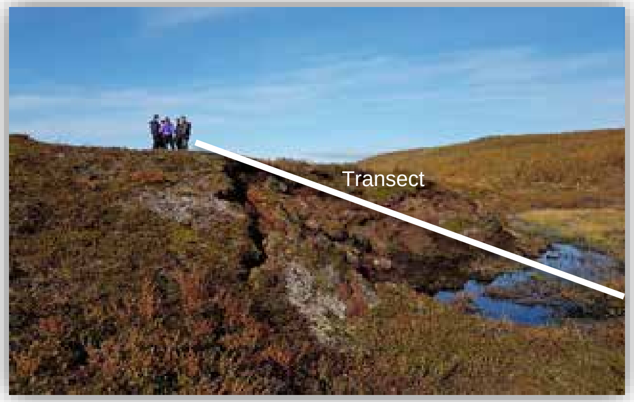
COMPARING DRONE AND LIDAR DERIVED HEIGHTS

2010 Lidar DSM

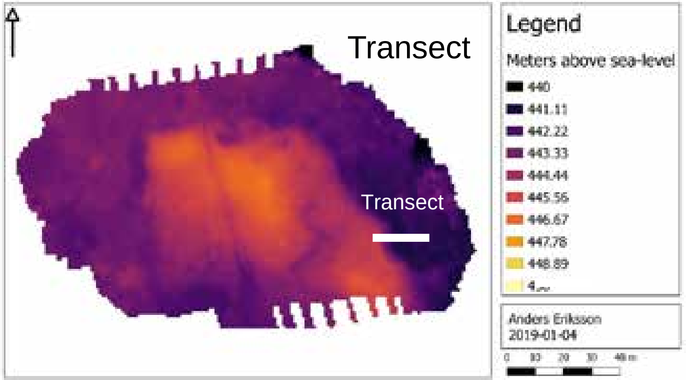


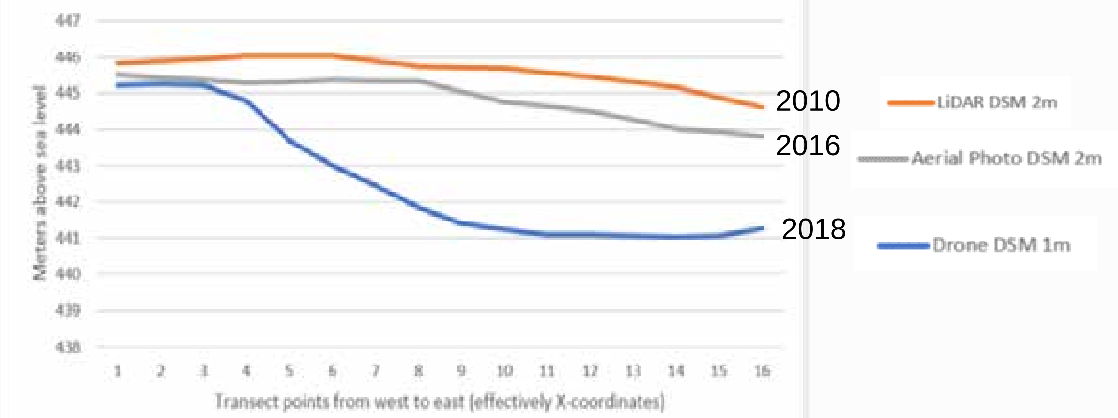
Comparison of elevation from Lidar data (2010) and photogrammetric models from 2016 and 2018

The transect below shows the erosion where 4 m of the palsa degraded



2018 Drone DSM





Can we see this vegetation change in 10 m Sentinel-2 data?

Sentinel-2 was launched 2015 and has 10 m pixels for B,G,R & NIR bands.

Currently an image is available every 1-2 days, providing time series and higher probability of acquiring cloud-free images.

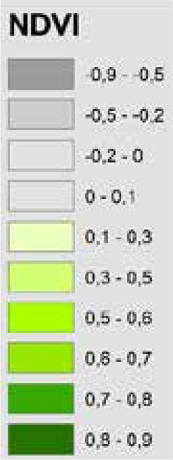
07/25/2017

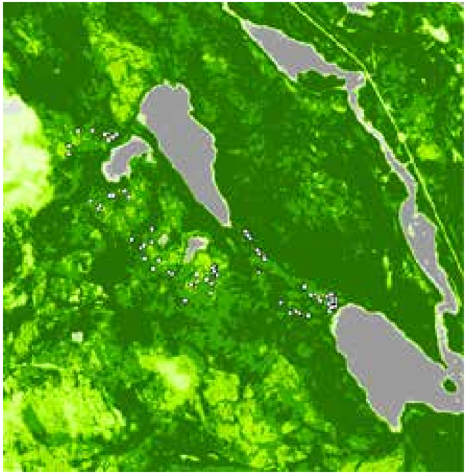
07/29/2018

07/30/2019

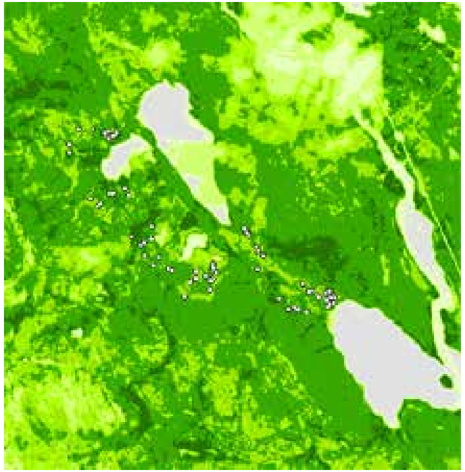
07/06/2020

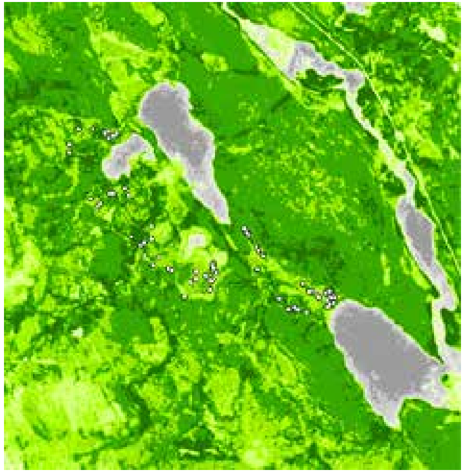
NDVI calculated and points sampled in the categories “no change between 2017-2020”; “potential degradation 2017-2020”; “degradation between 2017-2020”

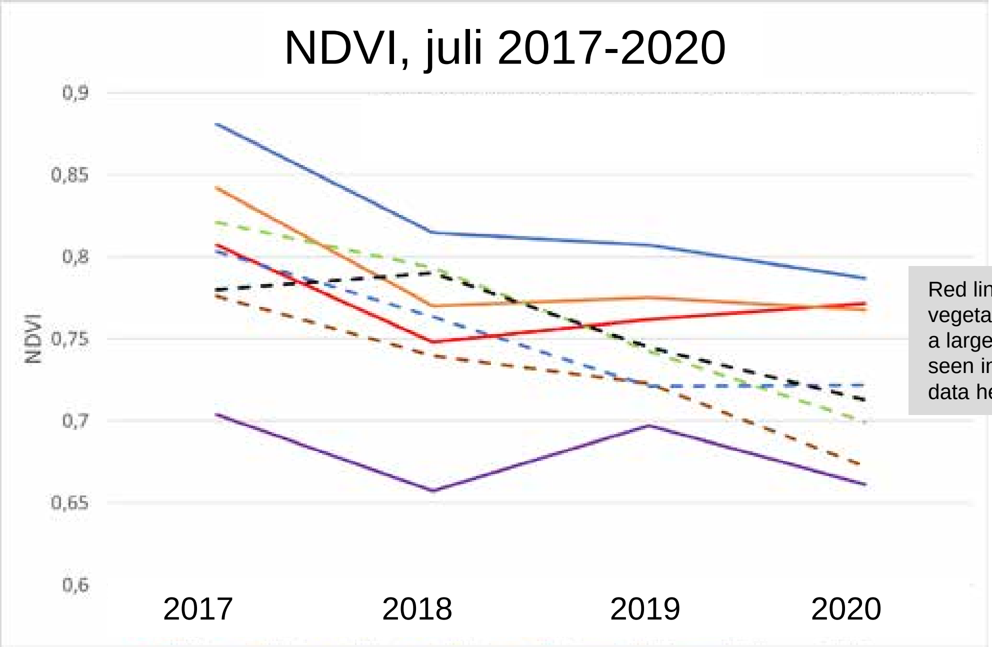



07/25/2017


07/29/2018


07/30/2019


07/06/2020



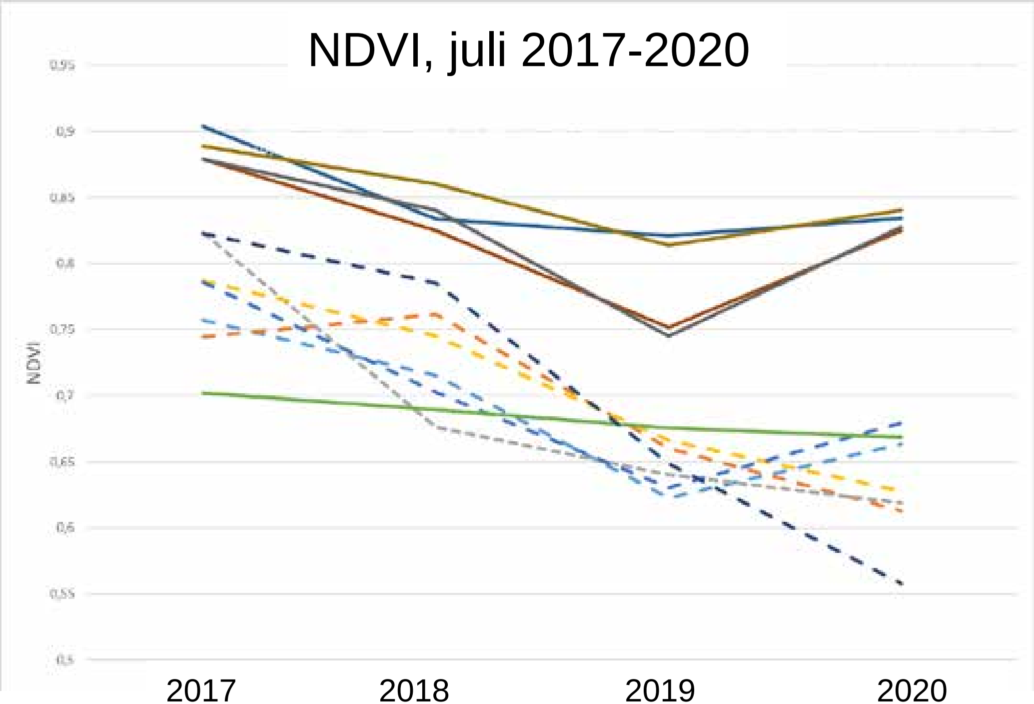
Sample point colors correspond to line colors

Red line was area of vegetation change…but a large change is not seen in the Sentinel-2 data here

___ Palsa not visibly degrading

- - - Palsa visibly degrading

Note the downward trend of NDVI for degrading/degraded areas



2010

2016

___ Palsa not visibly degrading

- - - Palsa visibly degrading

Q: Can changes seen in the high spatial resolution data from drones and aerial photographs be detected using medium resolution satellite data such as Sentinel-2?

- The Sentinel-2 data are detecting areas of palsa degradation where lateral erosion has occurred, vegetation has degraded, and where there is shadowing and water (e.g., fissures, and/or thermokarst ponds)

- Sentinel-2 didn’t detect a change in NDVI where the drone data indicated a change in vegetation, so we will re-check in the field (in 2021) to see whether the *Betula nana* still is in this area.

- It’s likely that the effects of the extremely warm summer of 2018 can be seen in the downward trend of NDVI for some areas on the palsas.

Thanks!

I’m happy to chat about drones, satellites and palsas

Web: https://gvc.gu.se

Twitter: @RRs4es