Mapping of Arctic Shrubland Using the Net Anthocyanin Reflectance Index

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Introduction

- Due to increased vegetation productivity associated with recent climate change, Arctic erect shrubs are being observed in increasingly northern locations, and can be used as indicators of increasing temperatures.
- Anthocyanins are a type of pigment commonly found in shrubs that help protect the plants from solar radiation and result in red, blue, and purple colourations.
- Anthocyanin in Arctic shrubs peaks in early May or late June approximately one week after the completion of snowmelt, and has a second, smaller peak in September (Figure 1).
- The Net Anthocyanin Reflectance Index (NARI) was applied to Sentinel-2 satellite imagery and effectively mapped shrubland in the French Alps (Bayle et al., 2019).
- Utilizing NARI, this study seeks to determine if the NARI can be used to map Arctic shrubland, verifying with in-situ data.

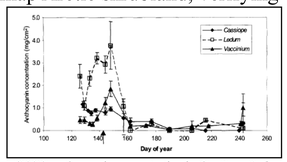
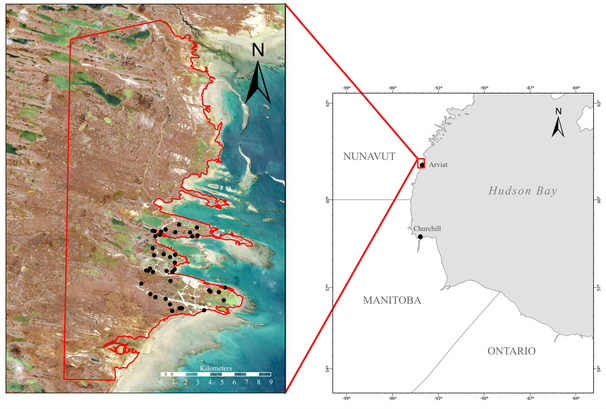


Figure 1: From Oberbaueri & Starr (2002), anthocyanin concentration in *Cassiope, Ledum,* and *Vaccinium* evergreen dwarf shrubs in the Alaskan tundra. The arrow at the 142nd day of the year indicates the completion of snowmelt.

Study Site

- The study site is encompassed by a 10 km radius around the Hamlet of Arviat, which is one of the most southerly Inuit communities in Nunavut, located approximately 200 km north of Churchill, Manitoba and 90 km north of the treeline.
- Arviat falls within Subzone E of the Circumpolar Arctic Vegetation Map and has a high diversity of vascular plants covering between 80-100% of the land.
- The Hamlet has a mean July temperature of 11.2°C and an annual average of 318 mm of precipitation, with an average 81.4 cm of snow per year.



Methods

- A total of nine Sentinel-2A and Sentinel-2B images from June, July, and September 2016 – 2018 were collected from the European Space Agency's Copernicus browser at level 2A (L2A).
  - The L2A preprocessed product includes a scene classification layer (SCL) which allowed for snow, cloud, and shadow masking as well as top of atmosphere (TOA) corrections to derive surface reflectance values.
  - To analyze the images, the Sentinel-2 band three (green: 560 nm), five (red edge: 705 nm), and SCL images were selected.

$$NARI = \frac{\left(\frac{1}{R_{green}} - \frac{1}{R_{red\text{-}edge}}\right)}{\left(\frac{1}{R_{green}} + \frac{1}{R_{red\text{-}edge}}\right)}$$

- Comparing NARI values from June and September when shrubs have increased anthocyanin content to July when anthocyanin is the lowest, "Delta" images were created highlighting the differences between the peak and low times of the year.
- In-situ data come from fieldwork in July and August of 2015 (Boulanger-Lapointe, 2017).
  - Data were collected in plots located within a 10 km radius of Arviat. Each plot was 20 m x 20 m in a homogenous stand of vegetation and had 10 random 70 x 70 cm quadrats.
  - Abundance and total cover for each site were both derived from these data.
  - Twenty-four of these plots were found to be viable for this analysis and 20 shrub species were identified in these plots.
- Extracting the Delta values from each site and comparing to the cumulative percent of shrub cover across quadrats allowed for correlation analyses.

Results

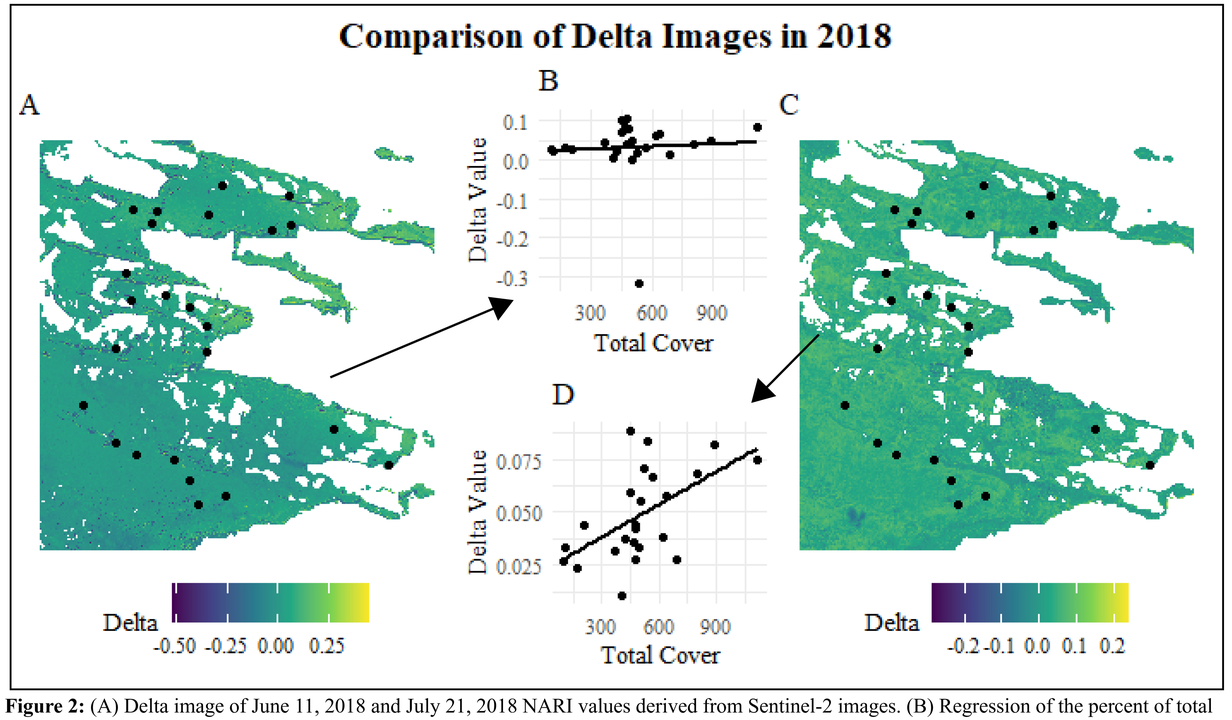


Figure 2: (A) Delta image of June 11, 2018 and July 21, 2018 NARI values derived from Sentinel-2 images. (B) Regression of the percent of total site cover by shrubs and the Delta values from image A. This period had a p-value of 0.772 with a residual standard error of 0.08168. (C) Delta image of September 14, 2018 and July 21, 2018 NARI values derived from Sentinel-2 images. (D) Regression of percent of site shrub cover and Delta Values from image C. This period had a p-value of 5.03×10^{-4} with a residual standard error of 0.0185.

Results Cont.

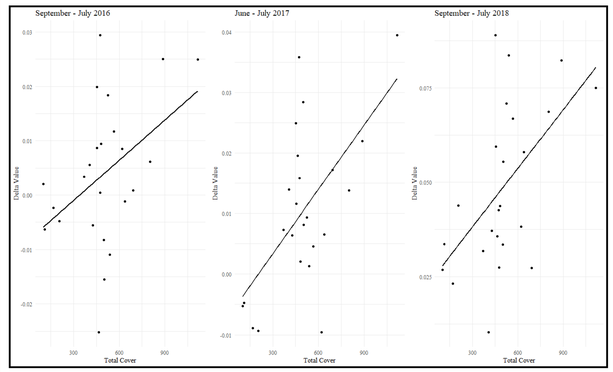


Figure 3: Regressions showing total site shrub cover and Delta values from 2016 (left) to 2018 (right) with the time periods that most successfully identified areas of shrub cover. From left to right, the p-values were 0.03593, 0.001626, and 0.000503 with residual standard errors of 0.01232, 0.01098, and 0.0185, respectively.

Discussion and Conclusion

- The period of time in which shrubland could be accurately mapped using satellite imagery varies from year to year.
- While there is a much larger peak of anthocyanin in early June after snowmelt, the models utilizing September rather than June generally had more accurate predictions.
  - This is likely due to the difficulty of obtaining cloud- and snow-free images at the time of the shorter primary peak.
- The current results suggest that NARI may be used for mapping shrubland in the Arctic, although the accuracy is heavily dependent on the availability of cloud-free images during the short temporal windows of high anthocyanin.

References

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