# Spatio-temporal vegetation patterns across UNESCO World Heritage site Kujataa, Greenland using NASA MODIS - 2000-2023


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Figure 1: South Greenland farm

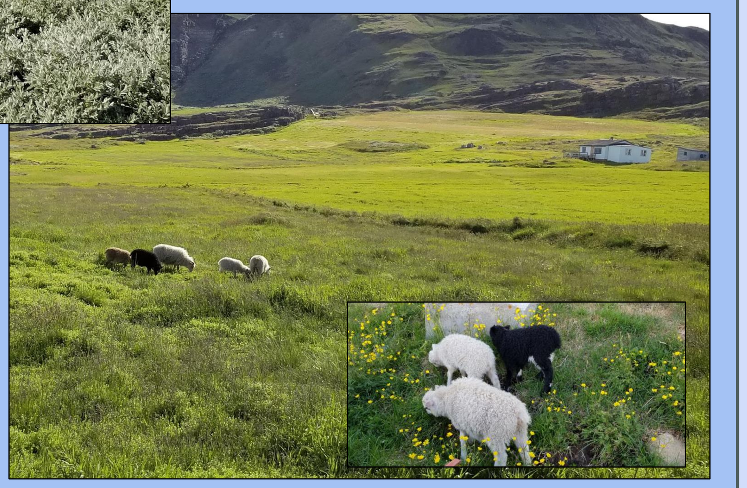


Figure 2: Sheep grazing in lowland pasture

Figure 4: Hvalsey Church site

## Introduction and Study Area

The pace and intensity of climate shifts across the Arctic have local and global implications (IPCC, 2019; Myers-Smith et al. 2020; Moon et al. 2021). Residents of remote Arctic regions dependent on the natural resource base and local economic conditions must rapidly adapt to changes influencing their livelihoods. Monitoring environmental shifts and developmental changes across the Arctic will be crucial to anticipating vulnerabilities and reducing risk for local populations.

In one such remote sub-Arctic community, residents of the Kujataa region of south Greenland engage in pastoralism and sheep herding, much like the Norse Greenlanders did in this region from the 10th to the mid 15th centuries (Fig.1, 2 & 3). The region's UNESCO World Heritage designation is based on unique farming traditions and the intermittent human settlement history that dates to these Norse communities during Europe's climatic Medieval Warm Period (MWP) (Vésteinsson, 2016). Norse archaeological sites are found throughout the region and are a stark reminder of the fragility of this landscape (Fig. 4 & 5).

Sheep farms are distributed across this vast fjord region and include managed pasture-land and cultivated fields in lowland valley areas. Kujataa's farmers report shifts to the region's environmental conditions and precipitation regimes in more recent years. Unusual rainfall patterns during summer months have resulted in sub-optimal pasture conditions and consequentially lowered lamb production (Field notes, 2019).

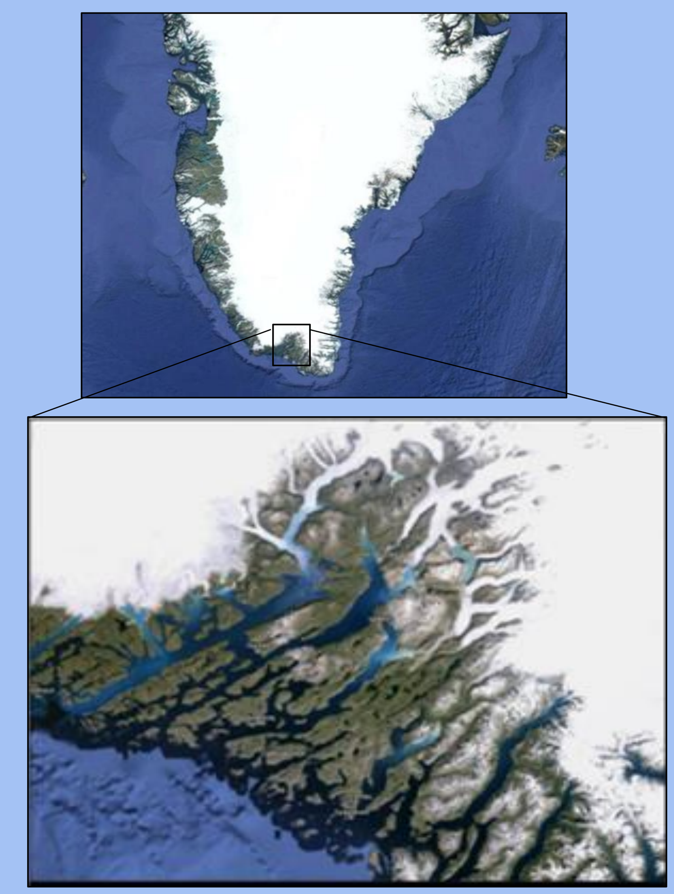


Figure 3: South Greenland, Google Earth

Figure 5: Ruins at Qassiarsuk (Brattahlid)

## MODIS Normalized Difference Vegetation Index (NDVI) 2000 - 2023

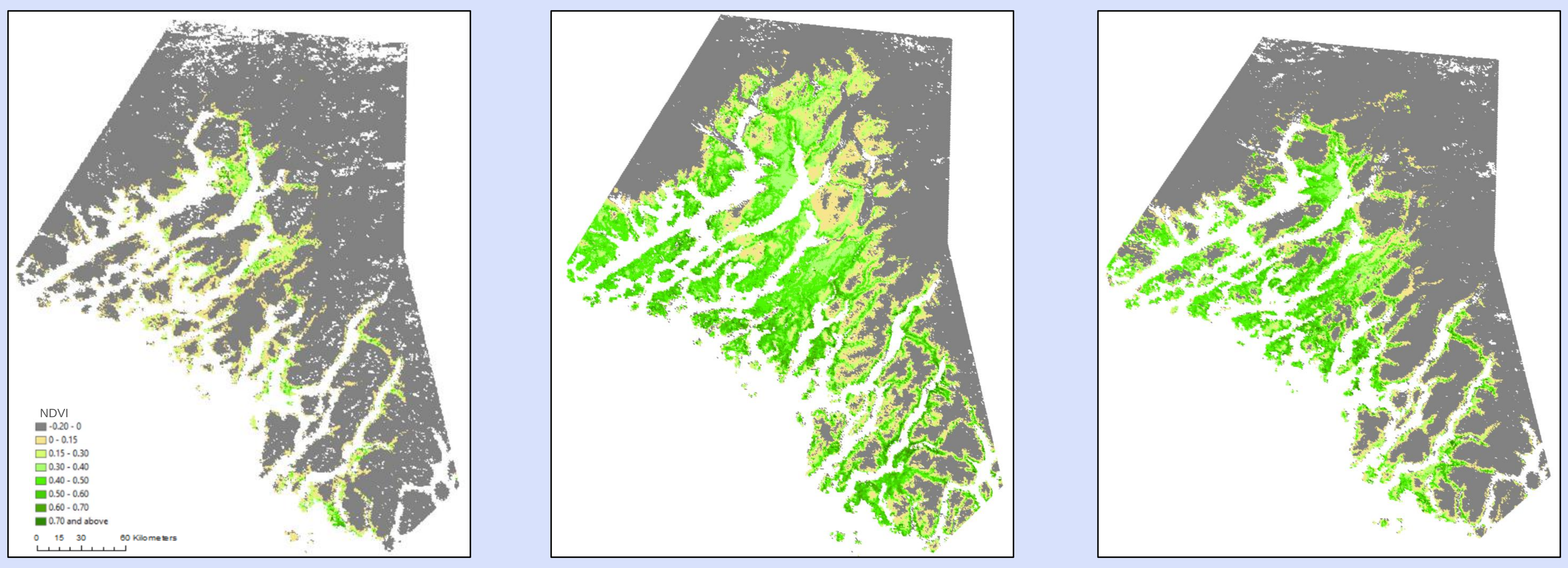


Figure 6: MODIS MOD13Q1 NDVI May, July, and September 2000

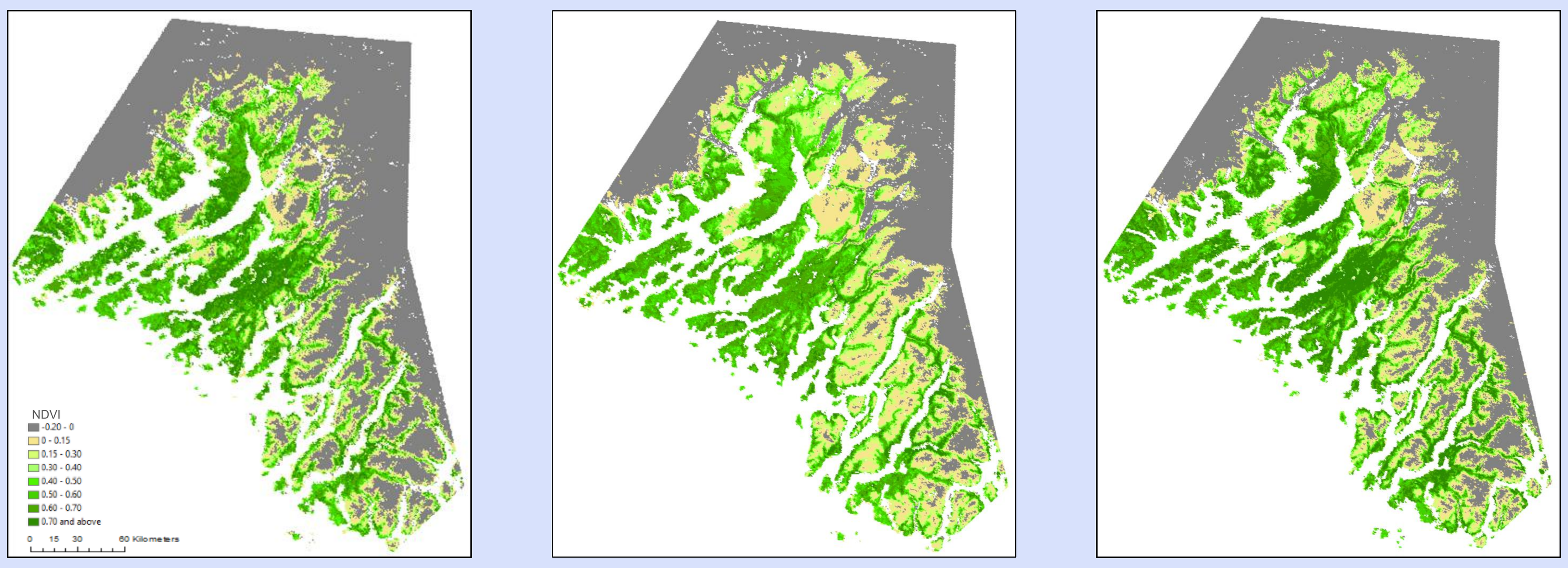


Figure 7: MODIS MOD13Q1 NDVI May, July, and September 2010

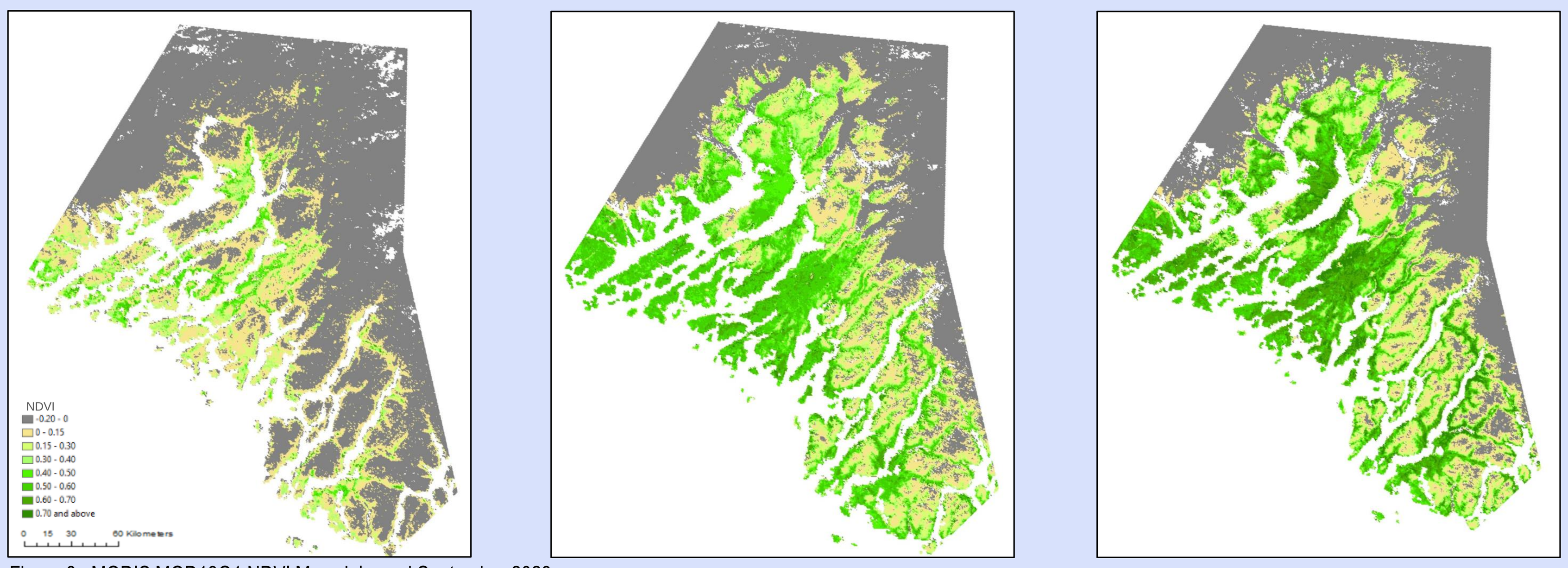
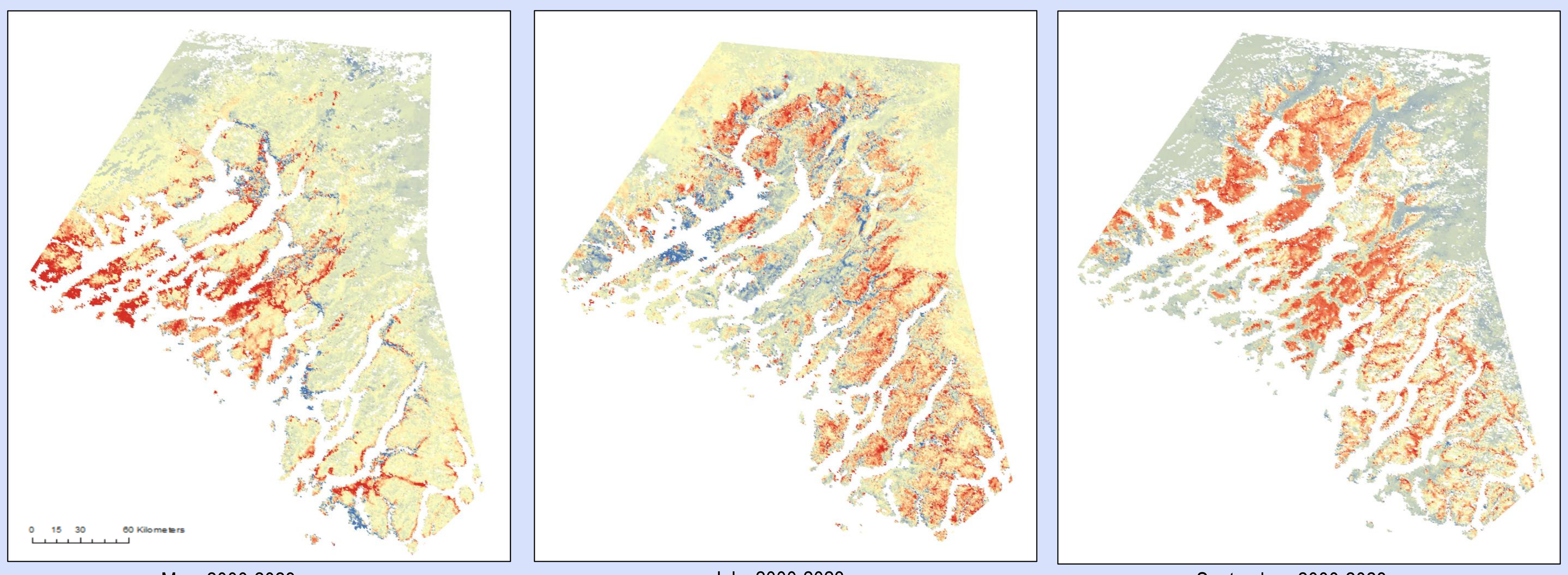


Figure 8: MODIS MOD13Q1 NDVI May, July, and September 2023

NDVI values above (Fig. 6, 7, & 8) for select years, represented in shades of green, measure the amount and vigor of vegetation presence, with more intense vegetation shown in darker shades of green.

## NDVI Raster Calculator to Visualize Change



May: 2000-2023 | July: 2000-2023 | September: 2000-2023

Figure 9: Raster Calculator Subtraction for May, July and September. 2000-2023

The Raster calculator function above displays areas in Red when NDVI values were higher in 2023 versus 2000 and areas in Blue when NDVI values were lower in 2023 versus 2000, showing areas of change between the two years.

## Data and Methods

To understand these changing environmental conditions, we employ NASA MODIS data to document spatio-temporal patterns in vegetation coverage over the past two decades. NASA Terra's Moderate Resolution Imaging Spectro-radiometer (MODIS) Vegetation Indices data, which are a sixteen-day average satellite data product at 250 meter (m) spatial resolution, are used for this study (Didan, 2015). Early (May), mid/peak (July) and late (September) season data for 2000-2020 provide us a synoptic view of vegetation shifts during the summer growing season. We also use temperature and precipitation data to complement our MODIS analysis. MODIS NDVI (Normalized Difference Vegetation Index) data are mapped and graphically represented to observe spatial patterns and quantify variability in the geographic coverage of vegetation presence. To visually assess spatial patterns of change we engage in a raster calculator function to assess shifts in NDVI.

## Analysis and Observations

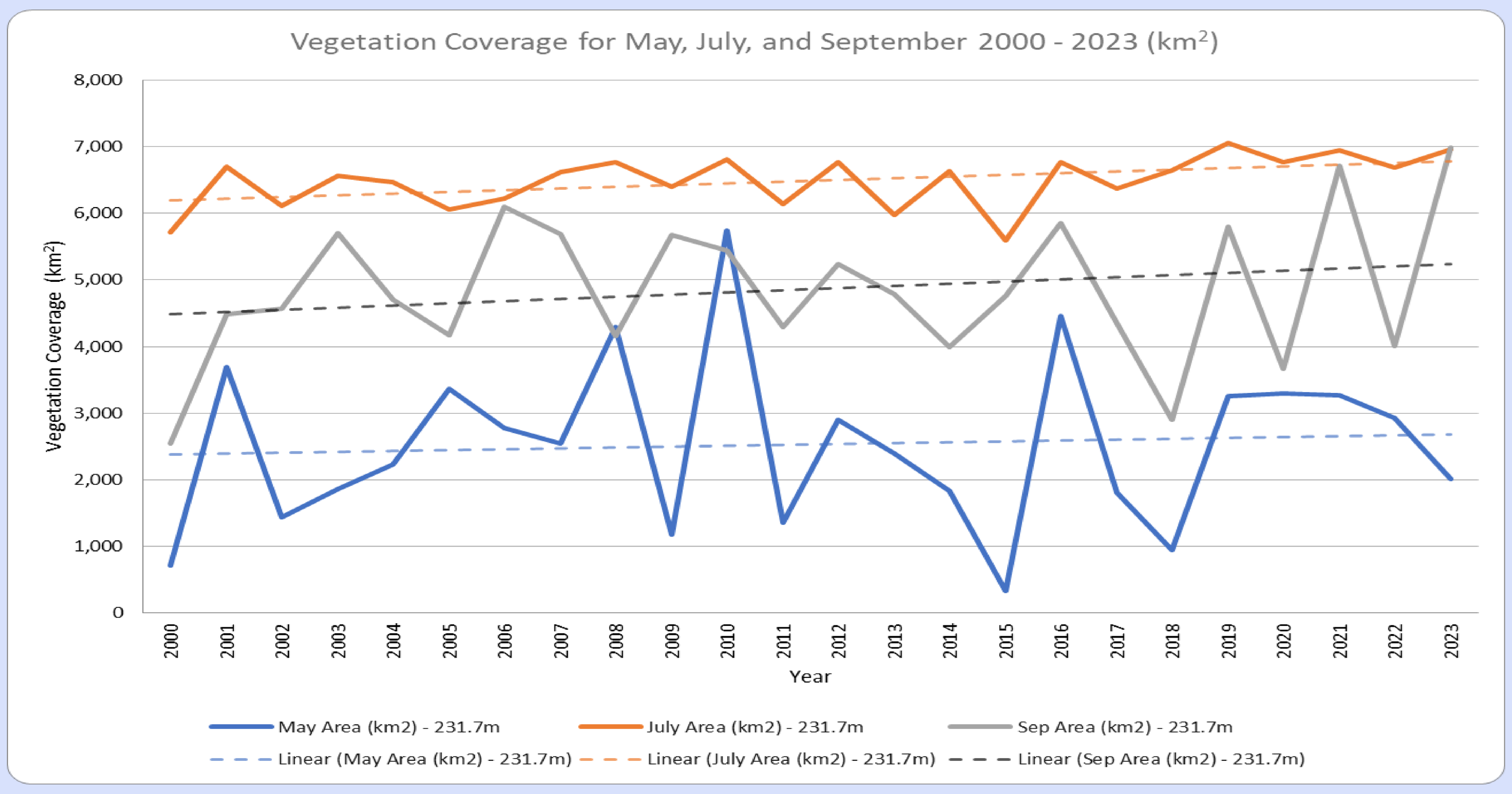



Figure 10: Vegetation Coverage from NDVI data in $km^2$, Kujataa

Figure 10 above graphically displays the geographic coverage of vegetation presence as sensed by NDVI and MODIS data over the study period 2000-2023 during the early, mid and late growing season.

- We observe significant early season variability in spatial extent and intensity of vegetation and this mirrors average monthly temperature and precipitation data.
- Mid/peak growing season data indicate relative stability in terms of spatial coverage, however, one observes an increase in spatial extent of vegetation coverage along glacial forelands and ice cap edges from 2017.
- The late season pattern from September shows the most dramatic expansion of coverage & intensity with an upward trend over the past two decades.

## Conclusions and Future Directions

Our analysis indicates considerable annual and seasonal variability in coverage and NDVI intensity over the past two decades. This is likely to persist and will be exacerbated by shifts in temperature and precipitation regimes. The geographic expansion of vegetation observed from the late season indicate that the growing season may be lengthening, especially at the tail end. If this persists and intensifies, it will undoubtedly influence sheep herding and farming practices across the region. Our work on this project has also included surveying and interviewing local farmers on their lived experiences and sharing data with them. We solicit their input to understand how climate shifts impact their livelihoods and economic wellbeing, including farm production, output & shifts in land utilization practices.

## References


Didan, K. 2015. *MOD13Q1 MODIS/Terra Vegetation Indices 16-Day L3 Global 250m SIN Grid V006* [NDVI]. NASA EOSDIS Land Processes DAAC. Accessed 2022-05-29 from https://doi.org/10.5067/MODIS/MOD13Q1.006

Moon, T. A., M. L. Druckenmiller, and R. L. Thoman, Eds. (2021). Arctic Report Card 2021. https://doi.org/10.25923/5s0f-5163.

Myers-Smith, I.H., Kerby, J.T., Phoenix, G.K. et al. Complexity revealed in the greening of the Arctic. Nat. Climate Chang. 10, 106–117 (2020). https://doi.org/10.1038/s41558-019-0688-1

Vésteinsson, O., Andreasen, A., Bisgaard, I., Høegh, K., Kristoffersen, B., Jochimsen, A., Ledger, P., Lynge, P., Madsen, C., Myrup, M., Nyegaard, G., and Sørensen, H. (2016). Kujataa – a subarctic farming landscape in Greenland: A nomination to UNESCO´s World Heritage List.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