Using remotely-sensed hyperspectral data to help understand vegetation cover change at Utqiaġvik, AK

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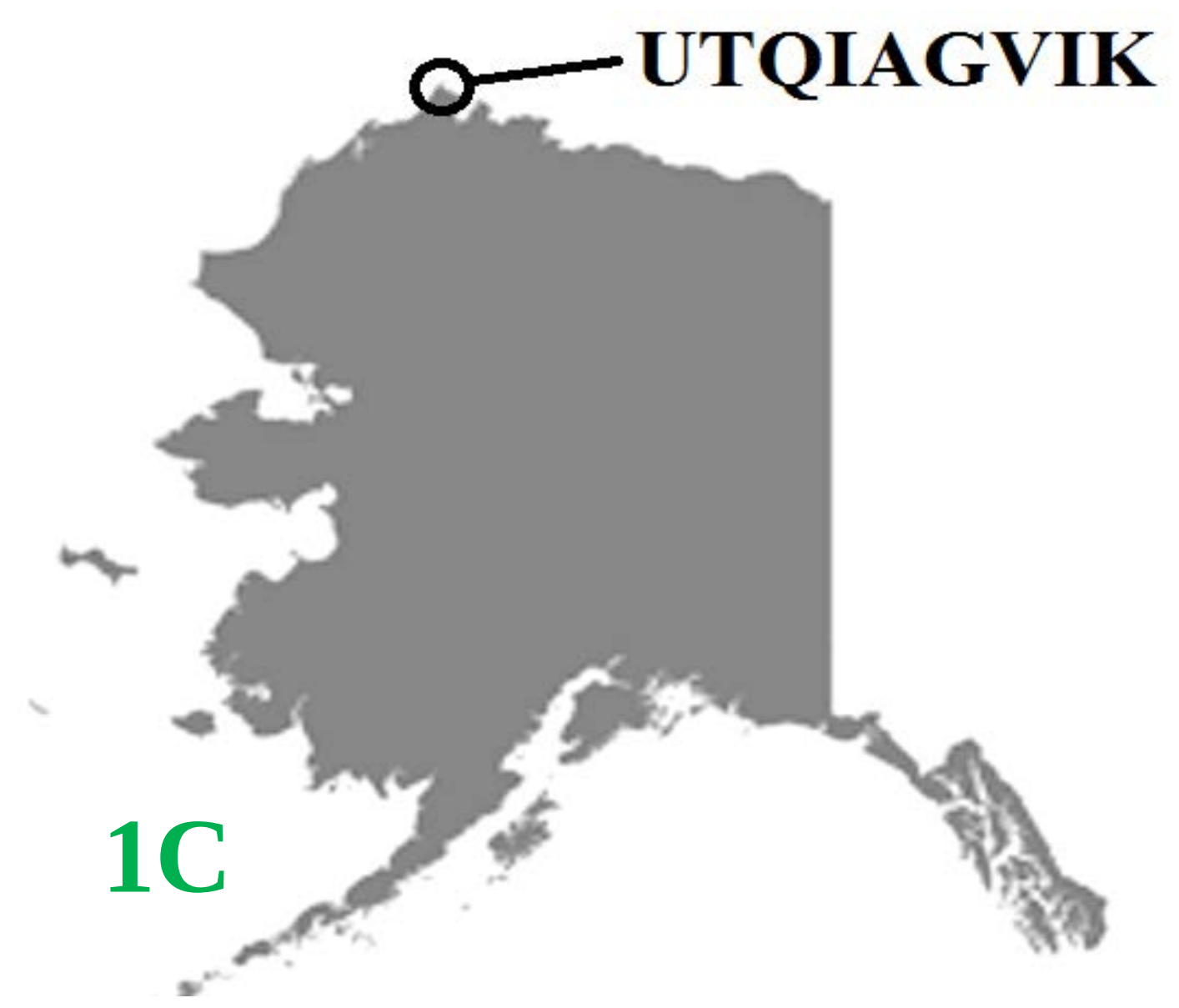
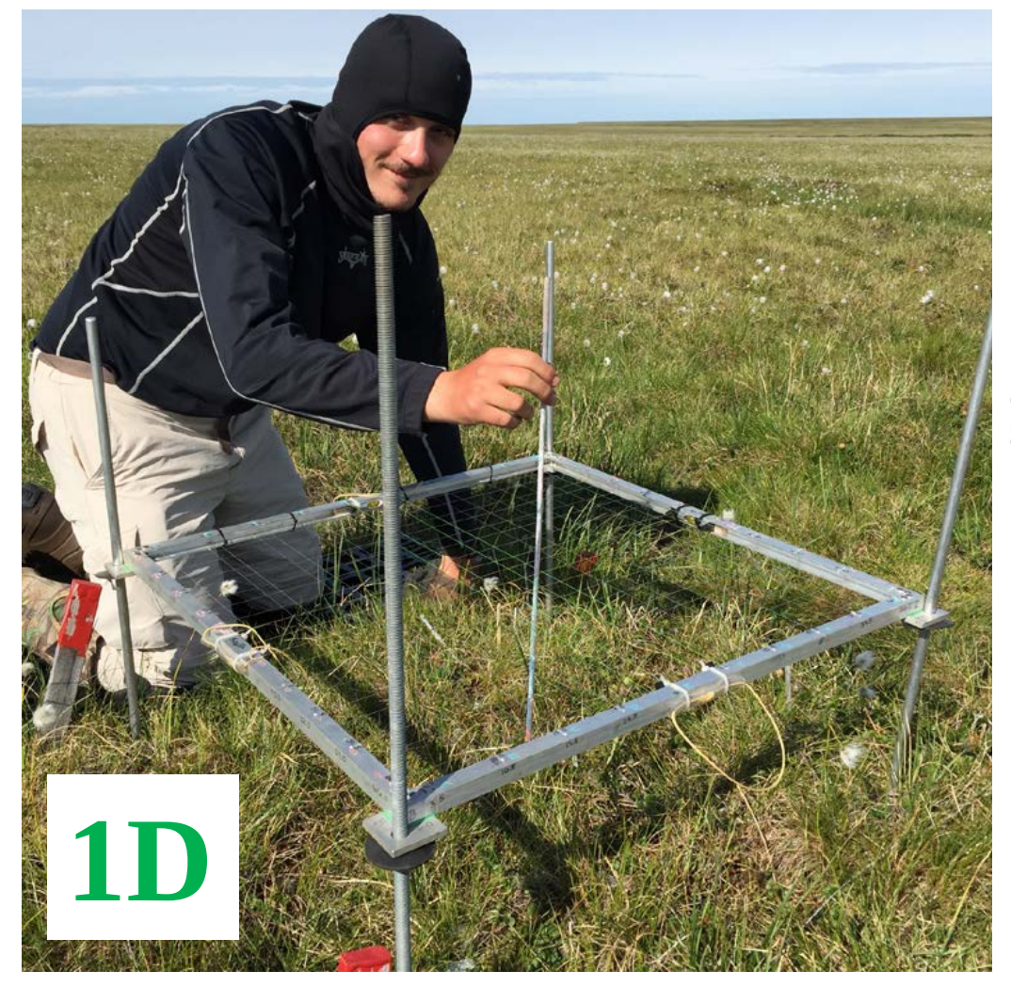
Introduction

A rapidly warming climate is affecting vegetative growth and reproduction on a global scale, especially in highly vulnerable, arctic plant communities (IPCC, 2013). Although remote-sensing technology is becoming an increasingly precise method of tracking landscape-level vegetation change, gaps still exist in our understanding of tundra structure without the consideration of on-the-ground measurements (Epstein et al., 2012). This study links vegetation field data with remotely-sensed hyperspectral data. Graminoids and lichens are especially responsive to a warming climate (Hollister et al., 2015). Thus, we examine the change in graminoid and lichen cover in Utqiaġvik, AK from 1995 to 2017 relative to 2017 hyperspectral data. Changes in vegetation cover over time can be explained through influence from NDII and MSI indices. We make predictions about the future movement and change in plant species by creating and mapping a linear regression model of Utqiaġvik, Alaska.

Methods

The research site was established in 1995 in Utqiaġvik, Alaska, in a dry health community located along a historic beach ridge (**Fig. 1A-1C**). The site contains forty-eight, one-square-meter plots. Twenty-four plots are experimentally warmed 1°C to 3 °C from June through August *via* open-top chambers (**Fig. 1B**). Twenty-four plots are controls. Cover data was collected *via* point-intercept method from 1995 to 2017 (**Fig. 1D-1E**). Hyperspectral data was collected through the National Ecological Observatory Network (NEON) Airborne Observation Platform (AOP) in August 2017. Data was extracted through ArcGIS, normalized, and patterns were established via Pearson's Correlation test (**Table 1**). Stepwise linear multiple regression was implemented in R software, identifying key predictors of vegetation cover change. The model was selected based on optimal r-value and AKAIKE Information Criterion. ArcGIS was utilized to create a predictive, visual model.





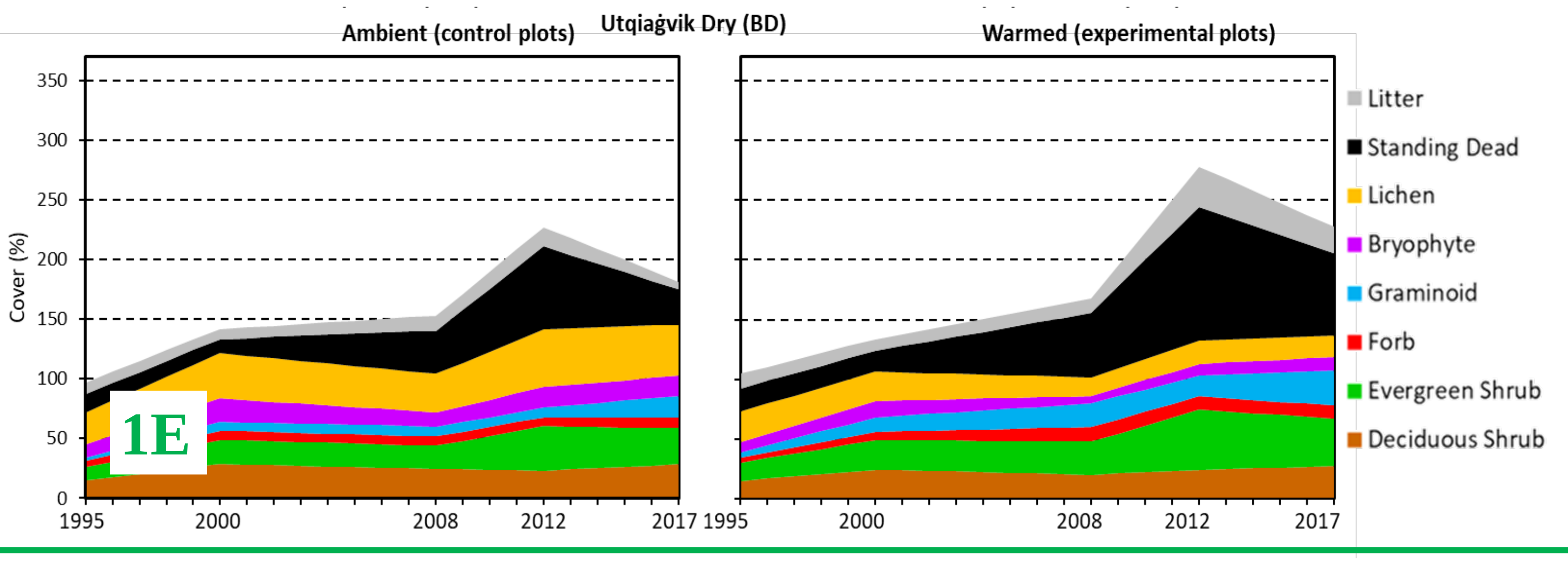


Fig. 1A: 48 control and experimental plots are located along three boardwalks at the site. **Fig. 1B:** Open-top chambers are placed over experimental plots at the site to simulate warming effects. **Fig. 1C:** Location of study site at Utqiaġvik (formerly Barrow), Alaska. **Fig. 1D:** Point-intercept method of data collection. **Fig. 1E:** Change in cover over time at the site for control and experimental plots (elsewhere referred to as the Utqiaġvik Dry or BD site).

Table 1. Pearson's correlation test reveals correlations between vegetative cover change and normalized hyperspectral variables, including aspect, slope, fractional photosynthetically active radiation (fPAR), enhanced vegetation index (EVI), photochemical reflectance index (PRI), soil adjusted vegetation index (SAVI), moisture stress index (MSI), normalized difference infrared index (NDII), normalized difference water index (NDWI), normalized difference multi-band drought index (NDMI), and water band index (WBI). Correlations with P-values less than 0.05 are denoted with an asterisk.

Taxa	Aspect	Slope	fPAR	EVI	PRI	SAVI	MSI	NDII	NDWI	NDMI	WBI
Graminoid	- 0.3996*	- 0.3612*	0.0910	- 0.0158	0.0370	0.0784	- 0.4706*	0.5853*	0.4417*	0.2107	0.4469*
Lichen	0.0495	- 0.0363	0.2019	0.1848	- 0.3903*	0.2158	- 0.0716	- 0.0646	- 0.0653	0.0895	- 0.1310

Results and Discussion

Statistical analysis of the change in graminoid cover, change in lichen cover, and remotely-sensed hyperspectral data revealed correlations between vegetative cover, aspect, slope, and moisture indices (**Table 1**). Linear regression revealed that Moisture Stress Index (MSI) and Normalized Difference Infrared Index (NDII) are the best predictors of graminoid cover change in experimentally warmed conditions at the site. No significant predictors were established for lichen cover change. The derived linear multiple regression model is $\sqrt[2]{\text{Cover Change in Graminoids}} = 109.15*(\text{NDII}) + 50.06*(\text{MSI}) + (-\ 43.06)$ with $r^2 = 0.59$, $p < 0.05$, AIC = 91.6.

NDII quantifies soil moisture and assesses the water content of different vegetation types. MSI determines water stress through assessment of canopy water content. This preliminary model suggests that a strong relationship exists between vegetative water content, soil moisture, and graminoid cover change (**Fig. 2A**). This suggests that local plant communities at Utqiaġvik may undergo substantial change in the future if soil moisture parameters shift.

It is surprising that Normalized Difference Vegetation Index (NDVI), a metric frequently used to assess the quantity and distribution of green vegetation in the Arctic, was not present in the predictive model. However, NDVI exhibits a high sensitivity to cloud cover. The cloud cover in **Fig. 2B** may generate error and interfere with true hyperspectral values. Despite this limitation, our findings suggest that field-based and remote-sensed data can help understand the complexities of changing vegetation in response to climate change.

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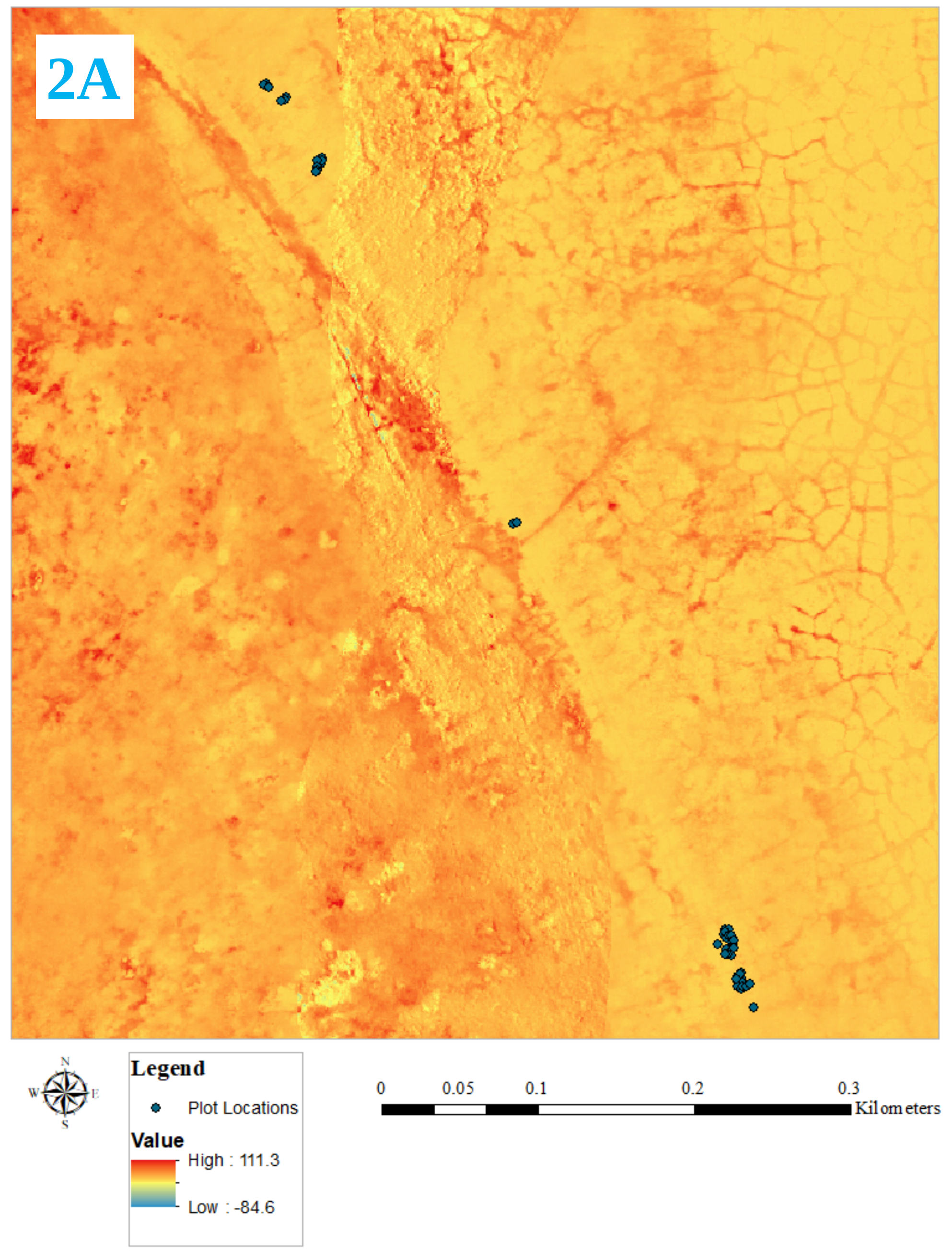
References

Epstein, H.E., M.K. Raynolds, D.A. Walker, U.S. Bhatt, C.J. Tucker, & J.E. Pinzon. (2012). Dynamics of aboveground phytomass of the circumpolar Arctic tundra during the past three decades. *Environmental Research Letters*, *7*(1), 015506.

Hollister, R.D., J.L. May, K.S. Kremers, C.E. Tweedie, S.F. Oberbauer, J.A. Liebig, T.F. Botting, et al. 2015. Warming experiments elucidate the drivers of observed directional changes in tundra vegetation. *Ecology and Evolution* **5**: 1881–1895.

IPCC. 2013. Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.



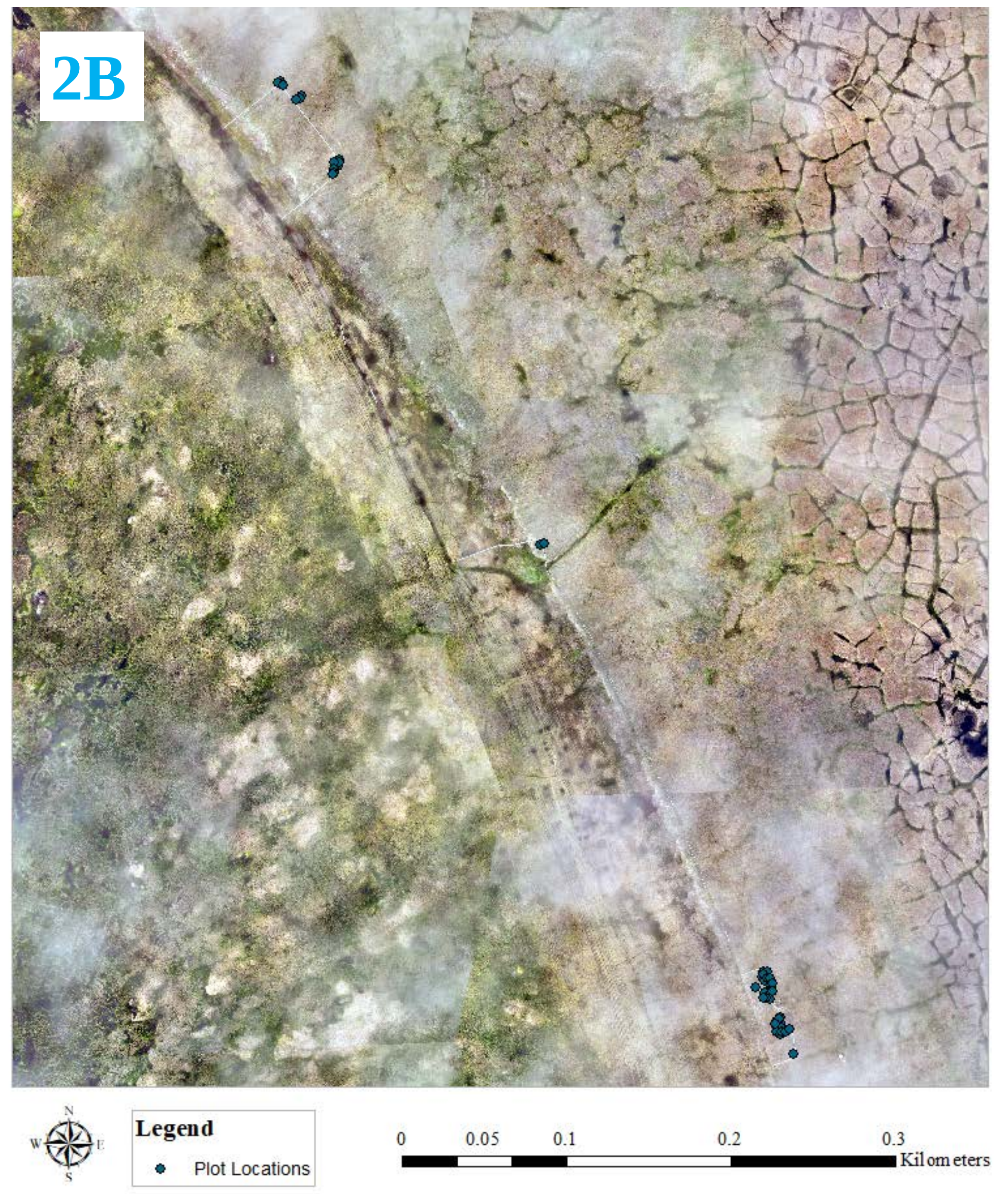


Fig. 2A: The multiple linear regression model is mapped onto the Utqiaġvik site and extrapolated to local surroundings in order to identify plant communities that are expected to respond the most to regional warming. The areas shaded in red are expected to increase in graminoid cover, areas in yellow are not expected to change. **Fig. 2B:** An aerial image of the Utqiaġvik site, which exhibits less than 10% of cloud cover over the forty-eight plots.