Project
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A Functional Perspective of Circumpolar Arctic Tundra Dynamics and Herbivory

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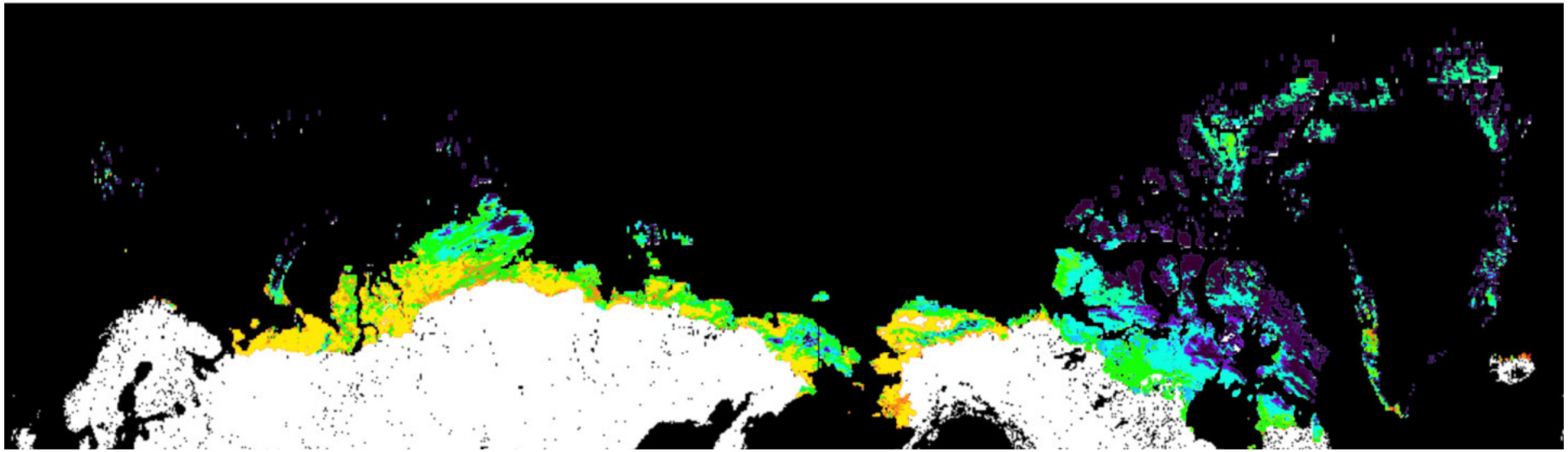


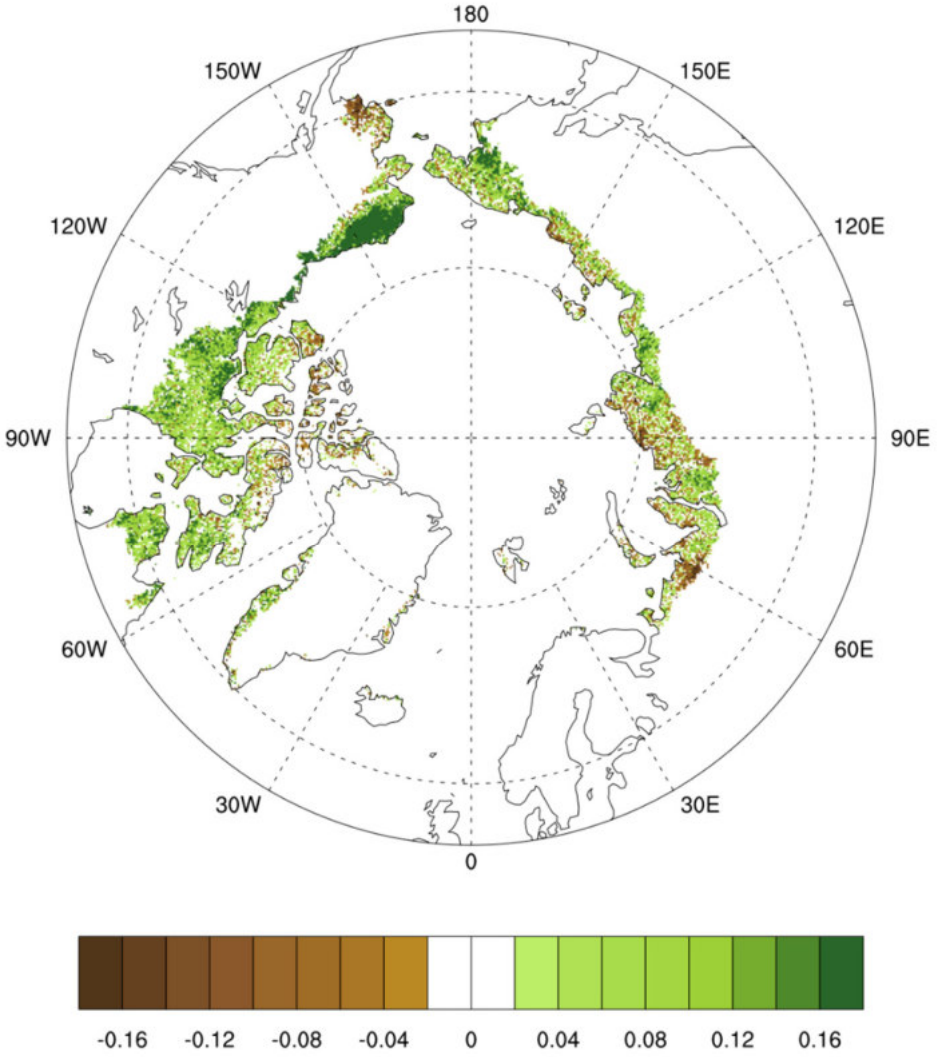
PART I – Effects of grazing on circumpolar tundra vegetation productivity

Arctic tundra vegetation has been highly dynamic over the course of the recent satellite record (since 1982).

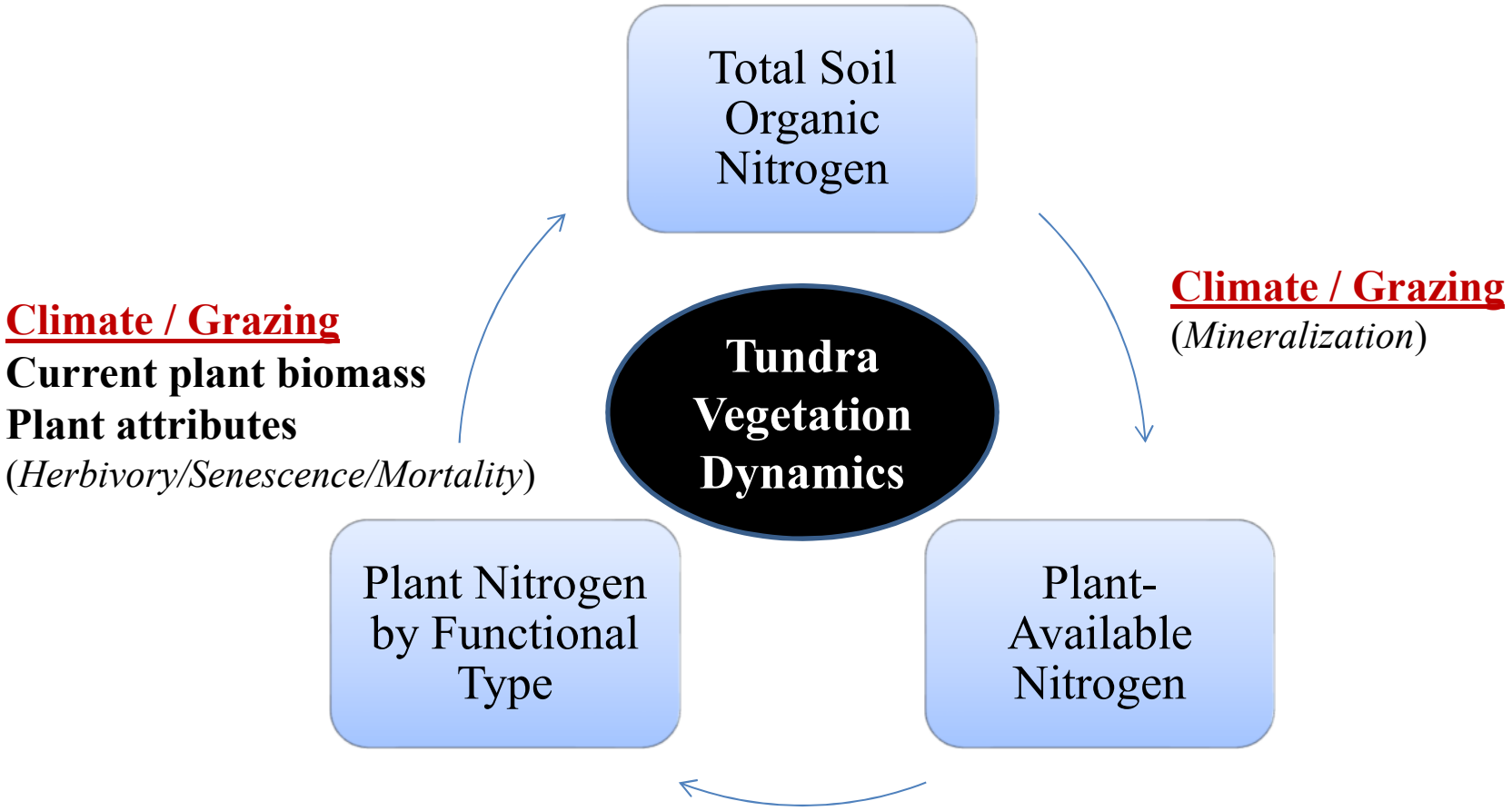
Whereas the general pattern has been one of **“greening,”** in other words increases in vegetation abundance and productivity, the dynamics have been highly heterogeneous over space and time, including regions and periods of tundra **“browning,”** decreases in vegetation abundance and productivity.

How much has grazing influenced these patterns and dynamics?

Change in Maximum Annual Normalized Difference Vegetation Index (NDVI) (1982-2016)

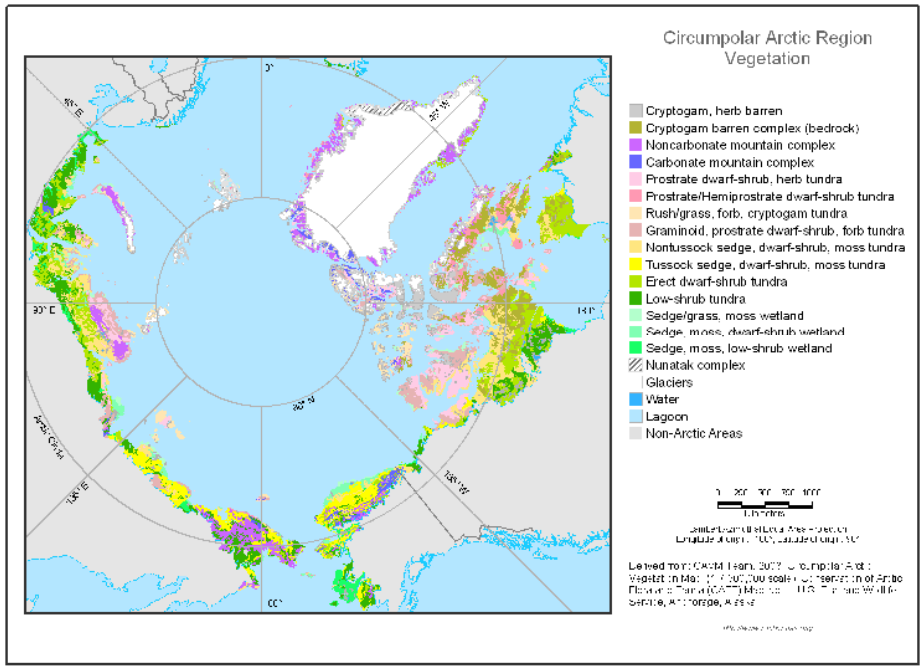


ArcVeg – Arctic Tundra Vegetation Dynamics Model



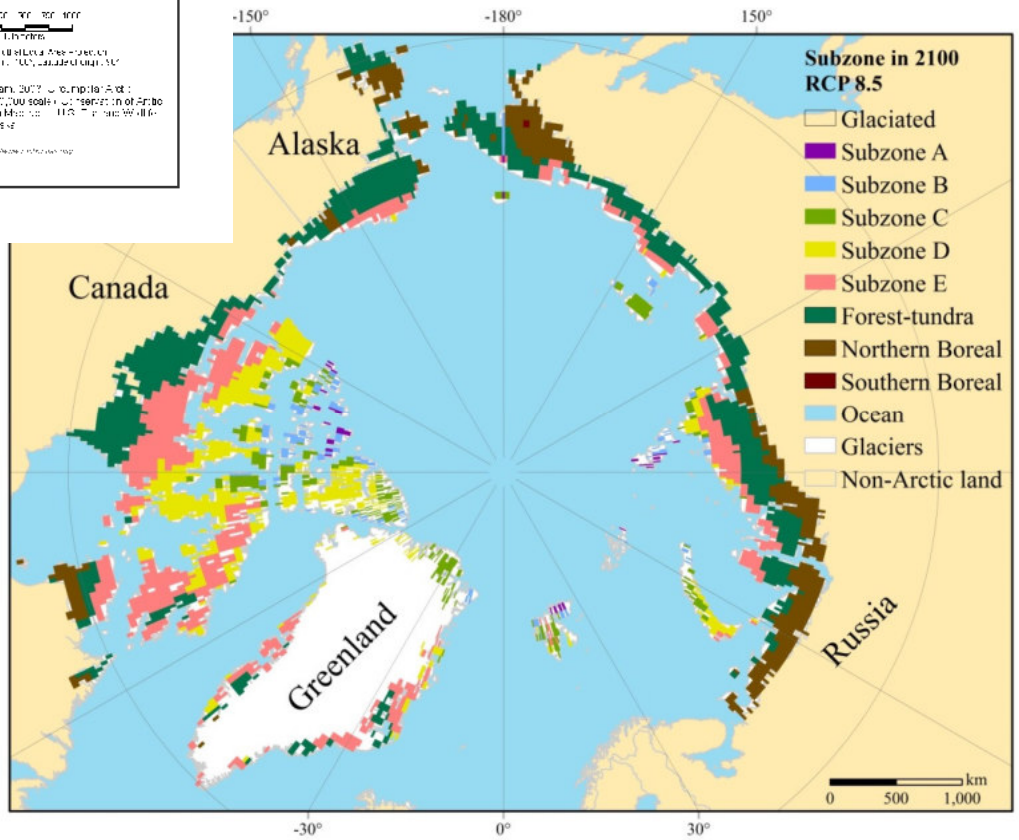
Epstein et al. (2000, 2001, 2004, 2007)
Yu et al. (2009, 2011, 2017)

ArcVeg has 12 Plant Functional Types (PFTs).
Grazing is selective in ArcVeg.



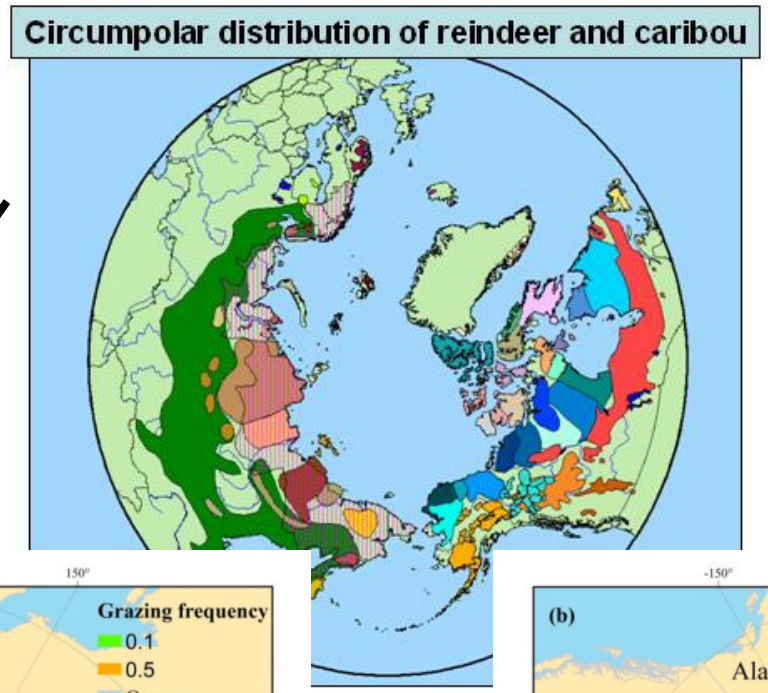
MODEL INPUT DATASETS

Current and projected distribution of the **tundra bioclimate subzones** from the Circumpolar Arctic Vegetation Map (CAVM)



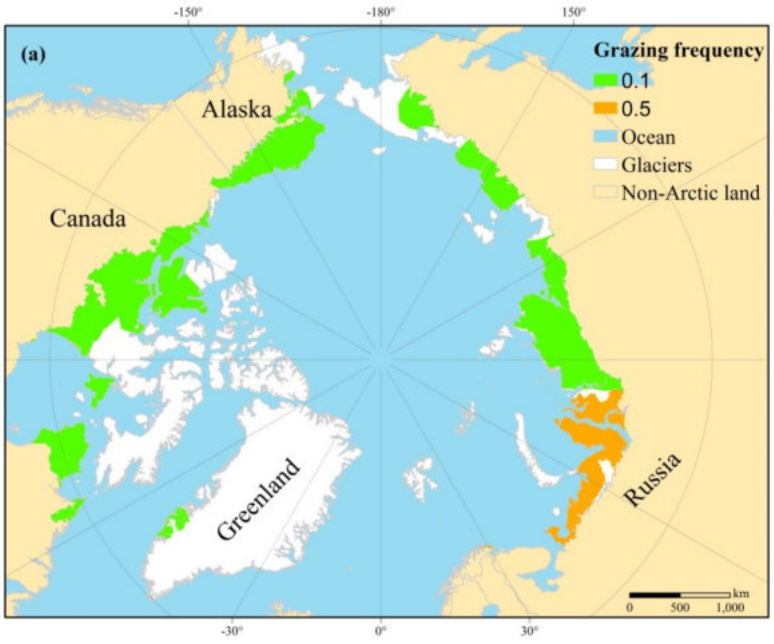
CAVM (2003)

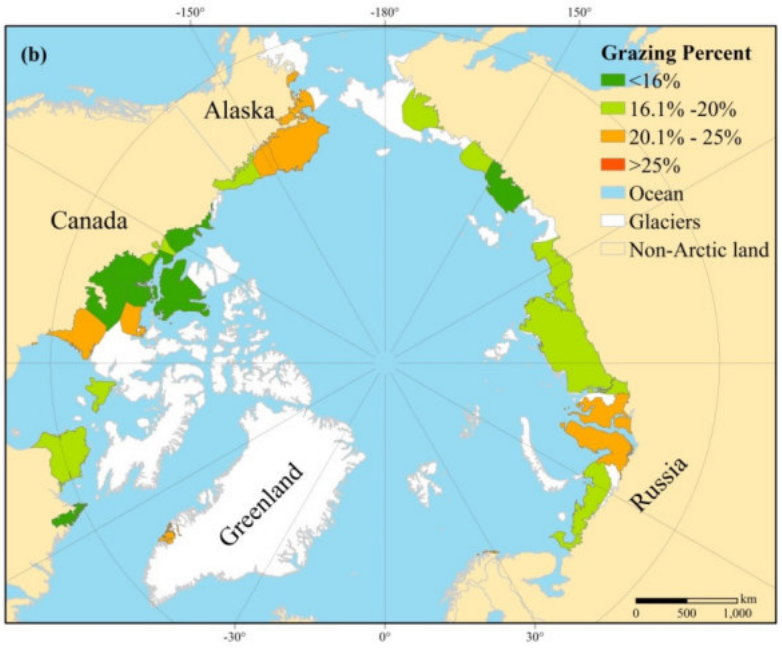
Reindeer and caribou distribution data from the CircumArctic Rangifer Monitoring and Assessment (CARMA) Network



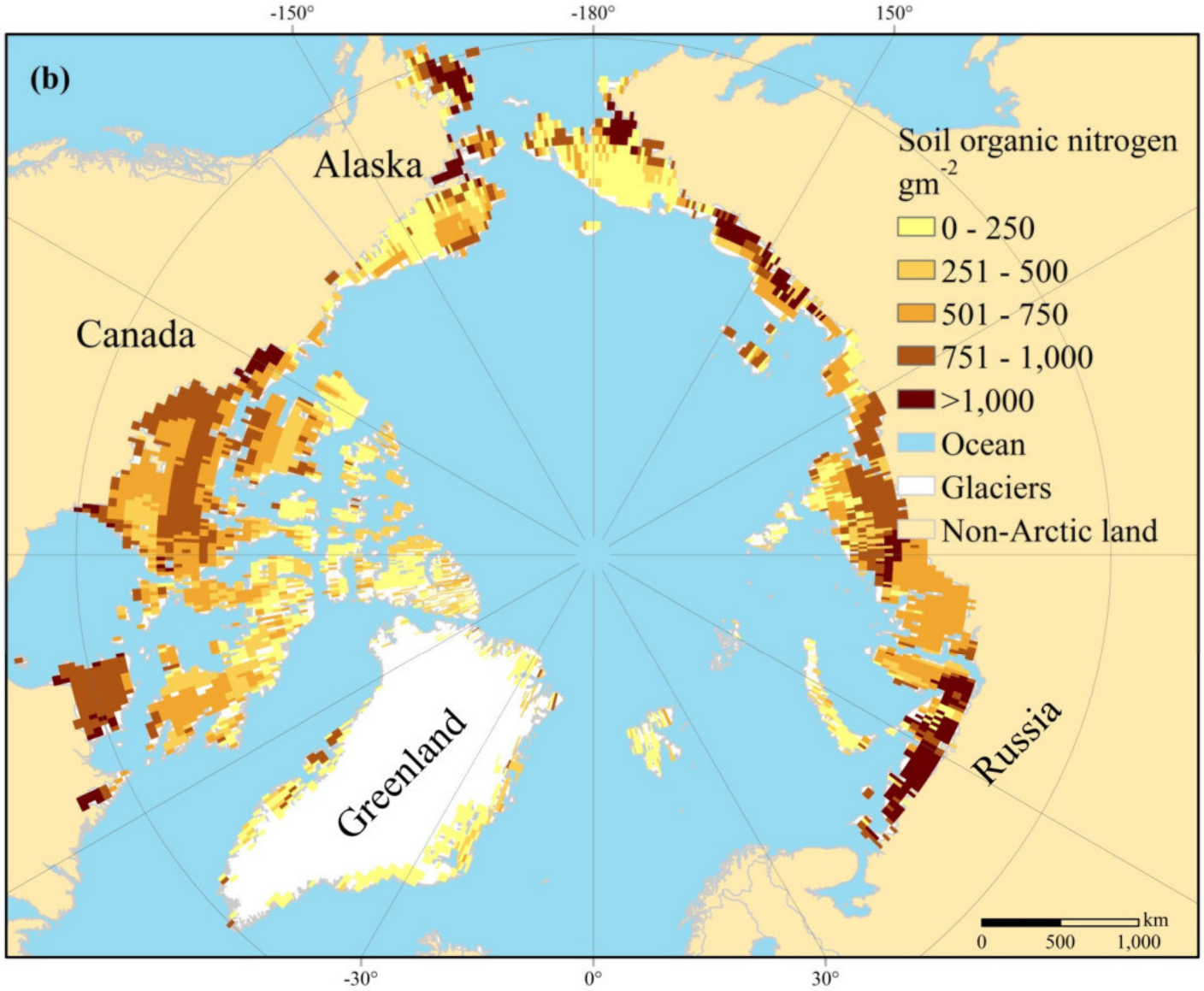
Grazing Frequency

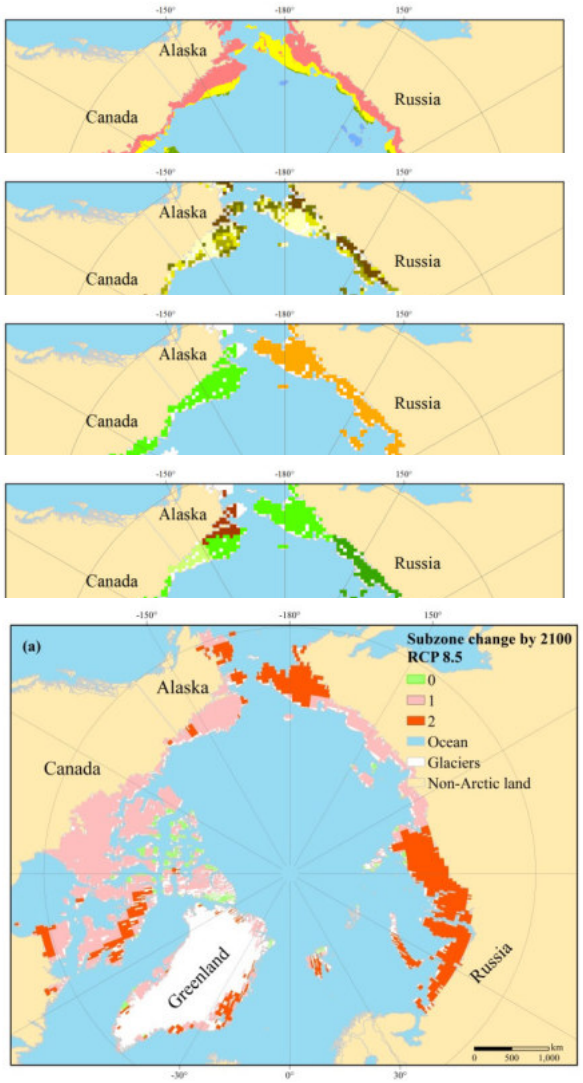
Grazing Intensity



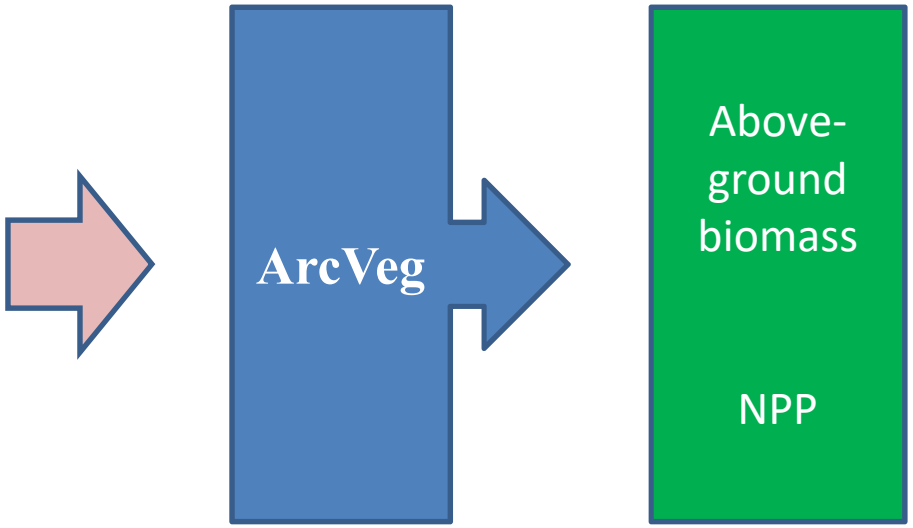


There are currently no circumpolar datasets for **soil nitrogen**, so we used output from the Terrestrial Ecosystem Model (TEM) (e.g. Hayes et al. 2011, 2014)





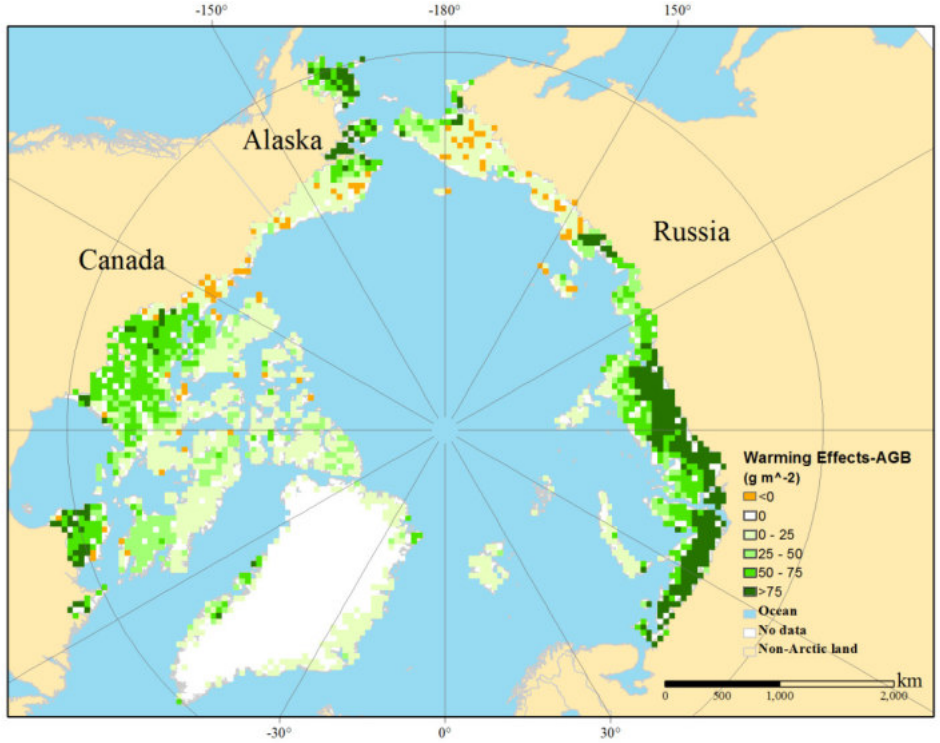
ArcVeg simulations with four different climate/grazing scenarios, evaluating isolated and combined effects of climate change and herbivory on vegetation productivity.



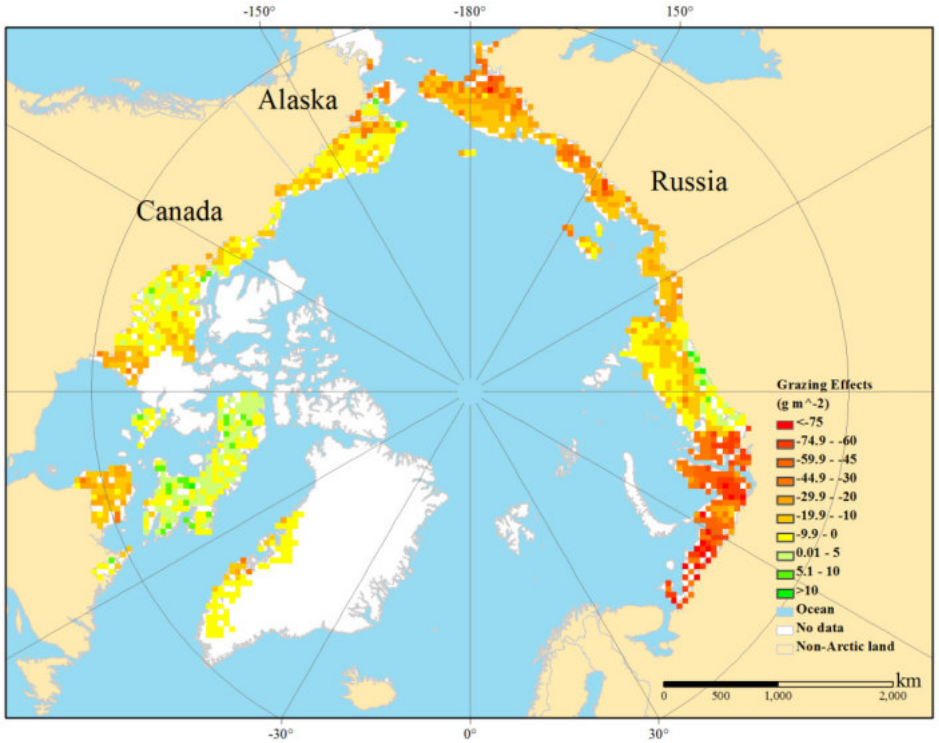
Simulation scenarios	Climate	Herbivory
Control	Before climate warming	No herbivory
Herbivory effects	Before climate warming	Current herbivory regimes
Warming effects	Projected climate warming	No herbivory
Coupled/combined effects	Projected climate warming	Current herbivory regimes

Climate and Herbivory Effects on Aboveground Tundra Biomass

Projected temperature-related change



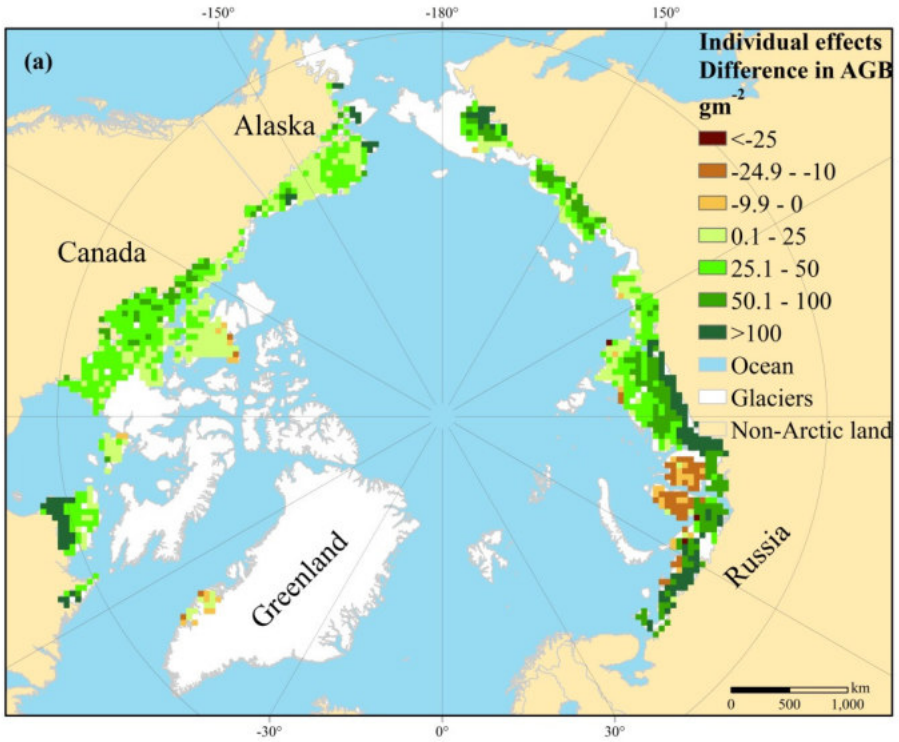
Simulated herbivory-related change



- Climate change projections are largely for increased tundra aboveground biomass/productivity.
- Grazing reduces aboveground tundra biomass/productivity, particularly in western Siberian tundra.

Individual effects of climate and herbivory

Simple difference between climate and grazing caused biomass change



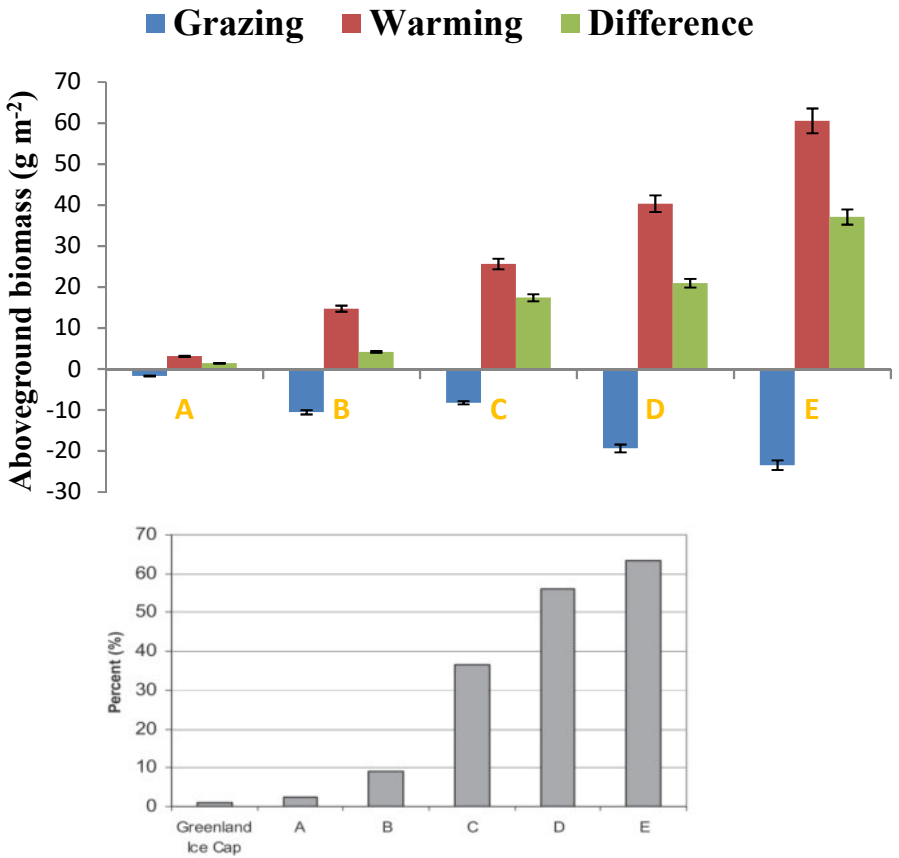


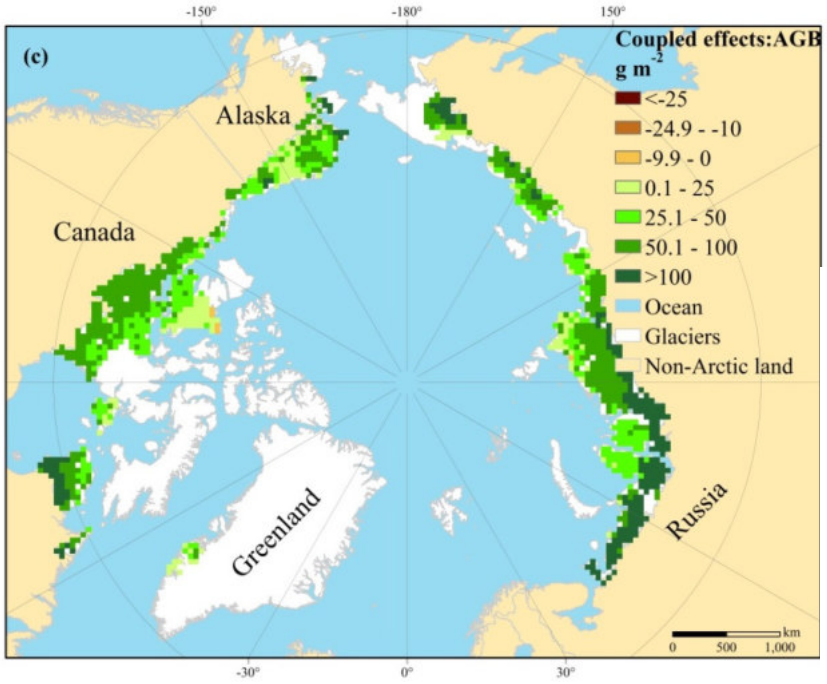
Figure 4. Per cent of subzone pixels with significant ($p < 0.05$) positive trend.

Epstein et al. (2012)

- **Most of the biomass changes are in the three southernmost subzones**
- **Very little change in subzones A (2.1%) and B (6.4%)**

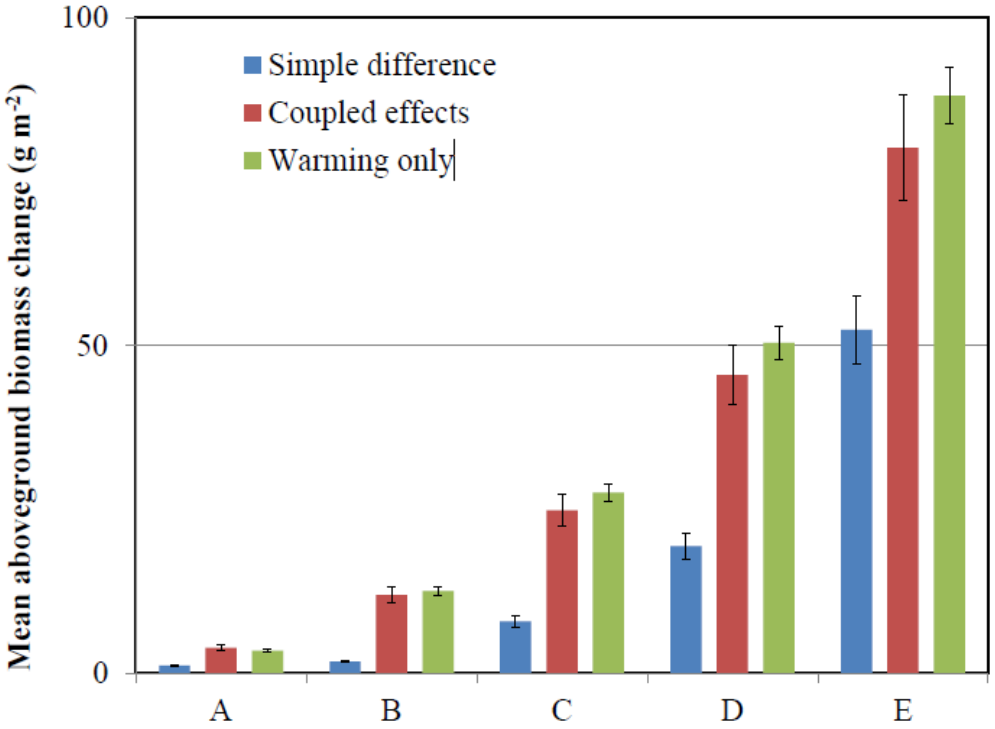
Coupled effects of climate and herbivory

Coupled effects of climate and herbivory caused change



- On average, grazing is constraining the “greening” of the arctic tundra by approximately 5% (greater in areas with dense herds)

- Coupled effects diminish the individual effects of herbivory, indicating vegetation resilience



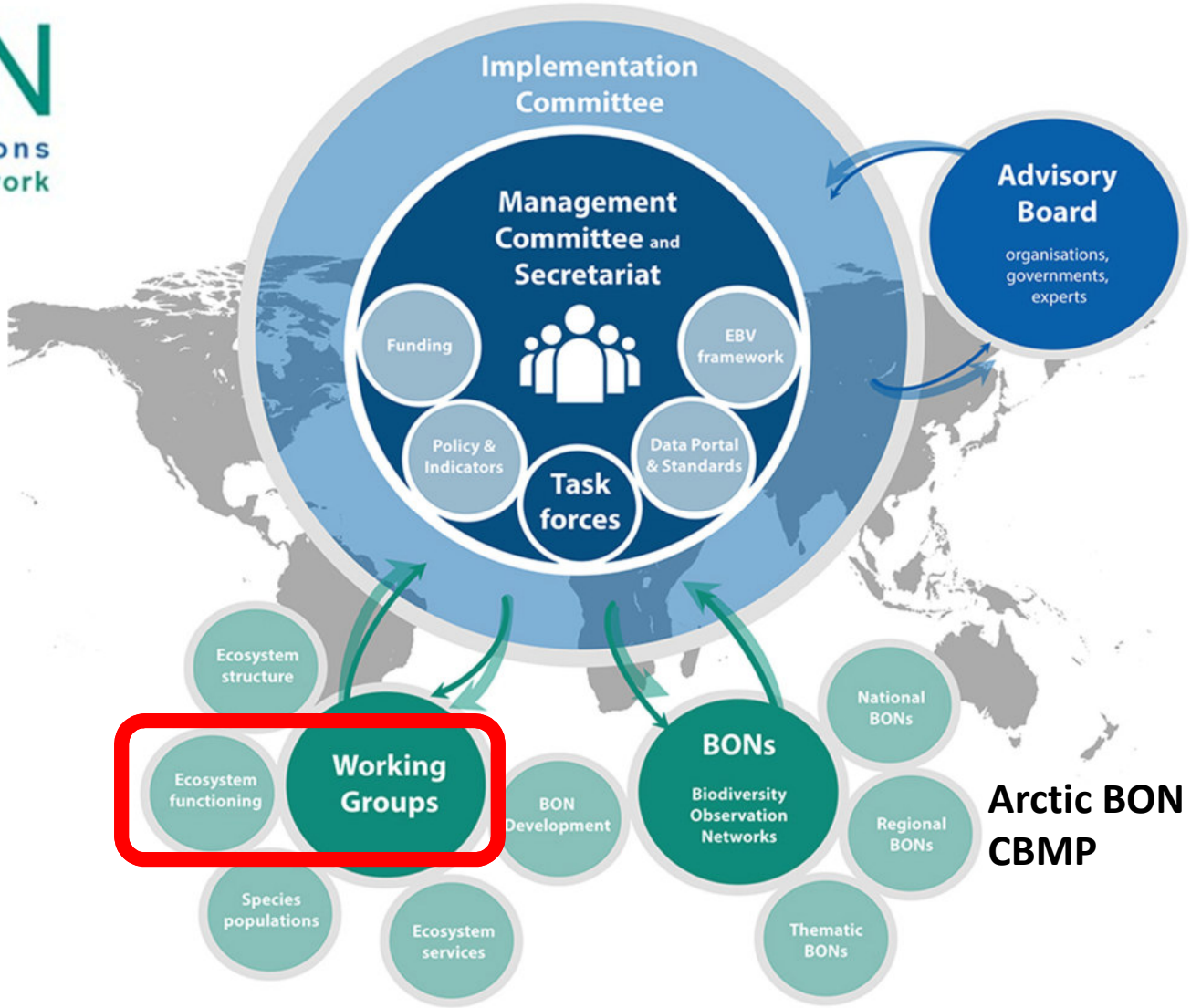
Yu et al. (2017)

Part II – Ecosystem Functional Diversity and Herbivory

New NASA Ecological Forecasting / Biodiversity project supporting the GEO-BON Work Programme (don't expect results yet)

GEO BON
Group on Earth Observations
Biodiversity Observation Network

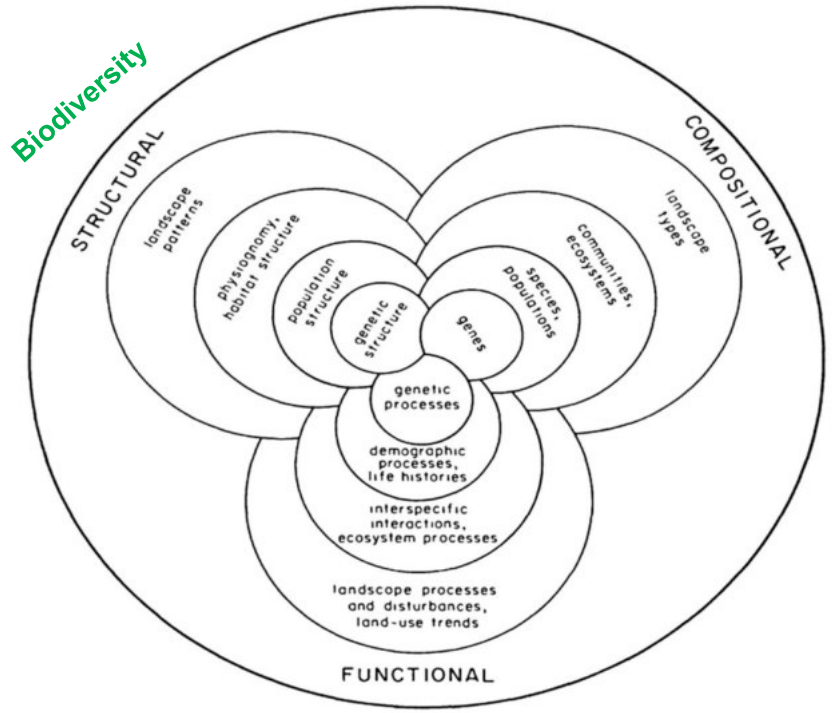
A global system of harmonized observations is needed to inform scientists and policy-makers



Arctic BON
CBMP

Project Background

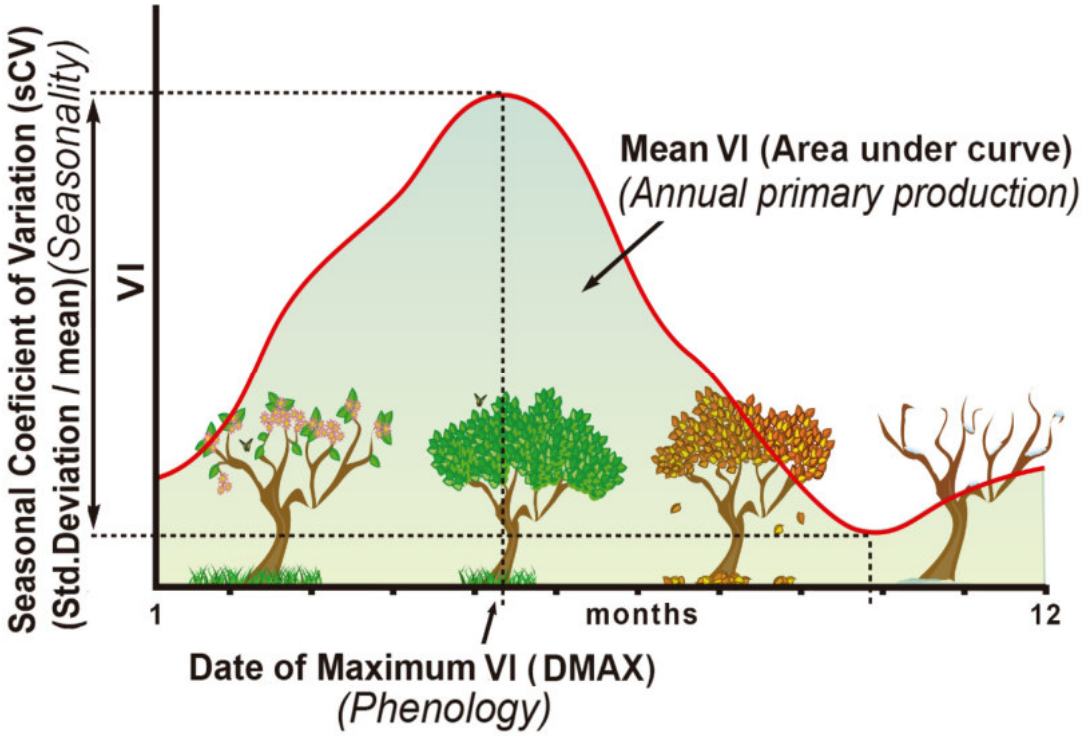
- Biodiversity hierarchy can be assessed along three dimensions: composition, structure, and **function** (Noss, 1990)
- Primary production (carbon cycling) dynamics are integrative descriptors of ecosystem function and an **Essential Biodiversity Variable** candidate of GEO-BON (Pereira et al., 2013; Skidmore et al., 2015)
- **Ecosystem Functional Diversity** based on dynamics of primary productivity can be assessed by means of **Ecosystem Functional Types (EFTs)**, patches of the land surface that process energy and matter in similar ways and potentially show coordinated responses to environmental factors (Valentini,1999; Paruelo et al. 2001).
- Our goals is to develop an **Ecosystem Functional Diversity** set of products for the **Circumpolar Arctic**



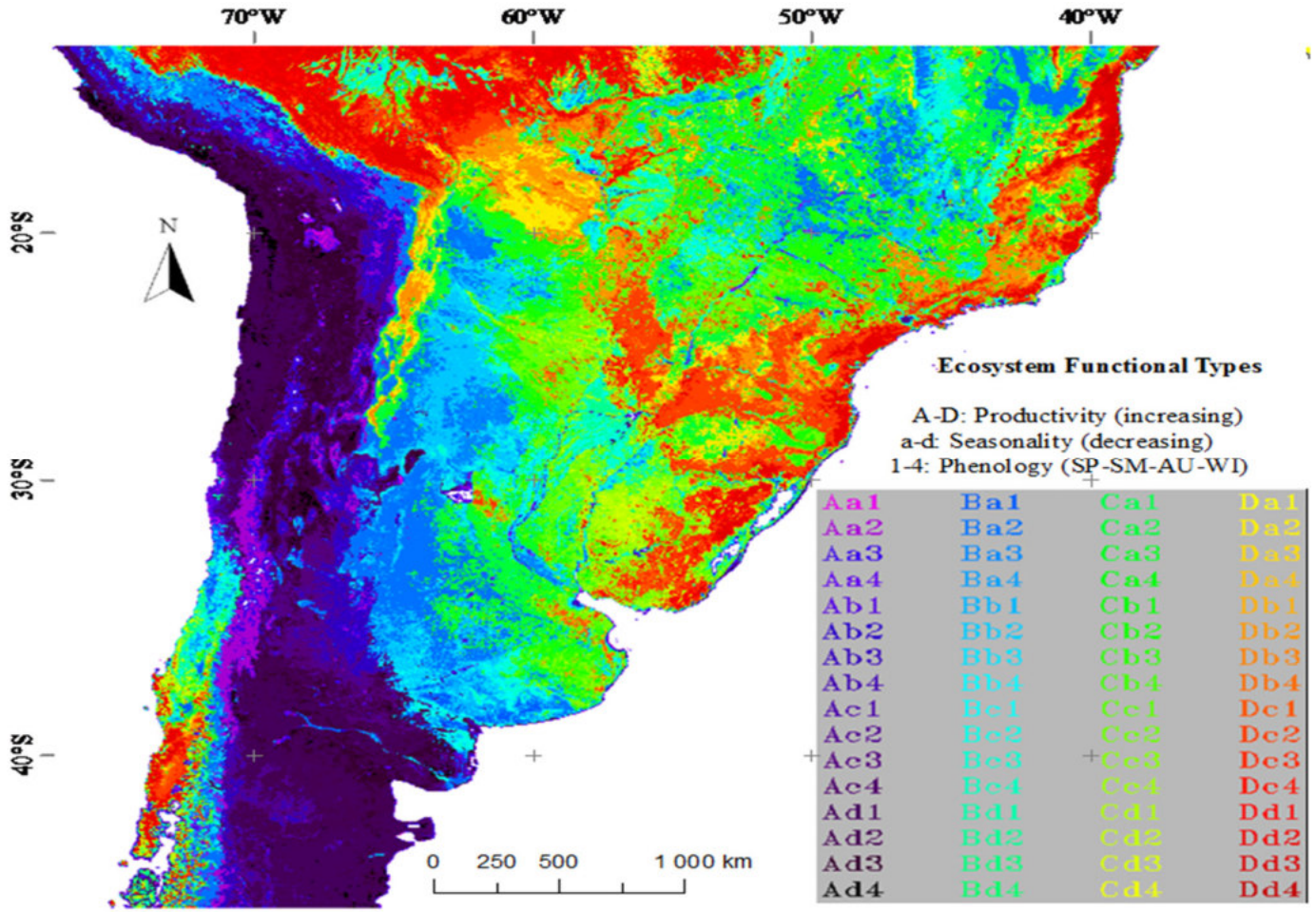
Ecosystem Functional Types derived from spectral vegetation indices (contributing to a set of Functional Biodiversity variables)

- **EFTs**: Patches of the land-surface with similar dynamics of matter and/or energy exchanges between the biota and the physical environment (Paruelo et al. 2001, Alcaraz-Segura et al. 2006).

- One example is to identify EFTs from **functional attributes of the seasonal curve of a spectral vegetation index (e.g. NDVI, EVI)**:



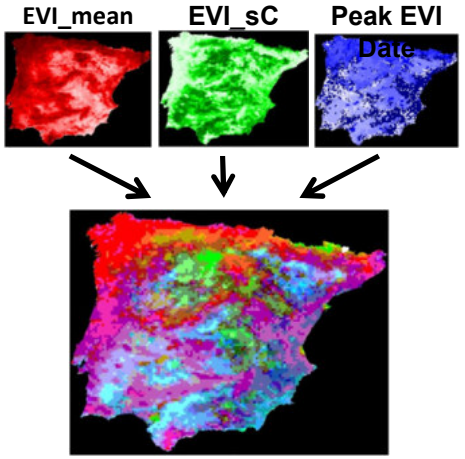
As an example, if we have three attributes of a seasonal NDVI curve, and bin the values of each attribute into quartiles, we will have maximum of 64 EFTs – some combinations may not exist.



Alcaraz-Segura et al. (2013)

- **Not a completely new idea**
- **EFTs denote areas of functional similarity**
- **Agnostic to vegetation composition or structure**

Developing Functional Diversity Variables

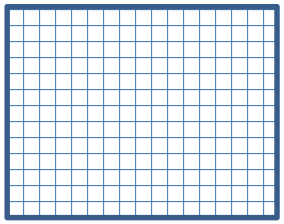


EFTs: ecosystems with similar exchanges of matter and energy

Each RS pixel is classified as a single EFT

Coarser-resolution spatial analysis

Grouping contiguous pixels (upscaling) provides the data for functional diversity variables

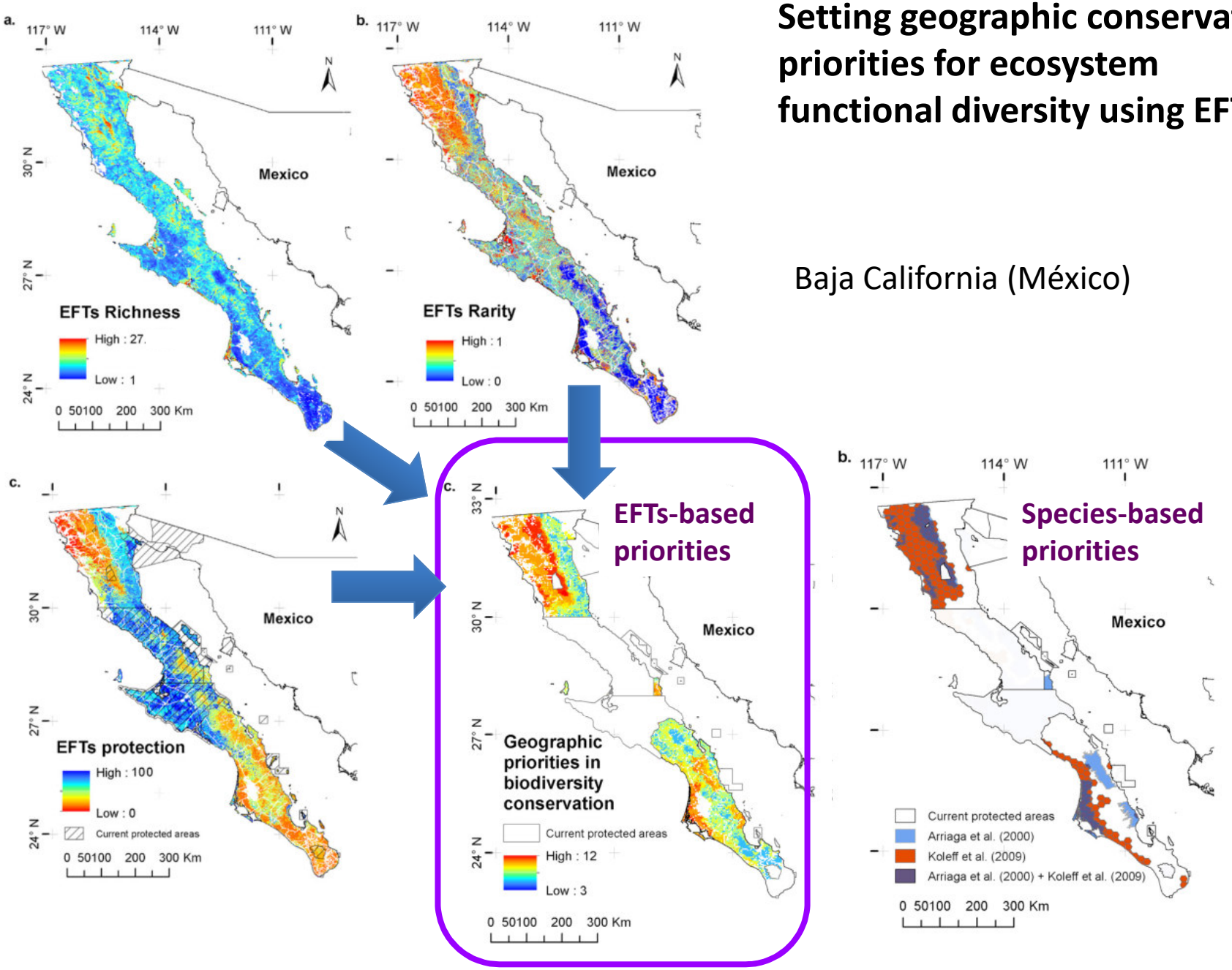


Ecosystem Functional Diversity

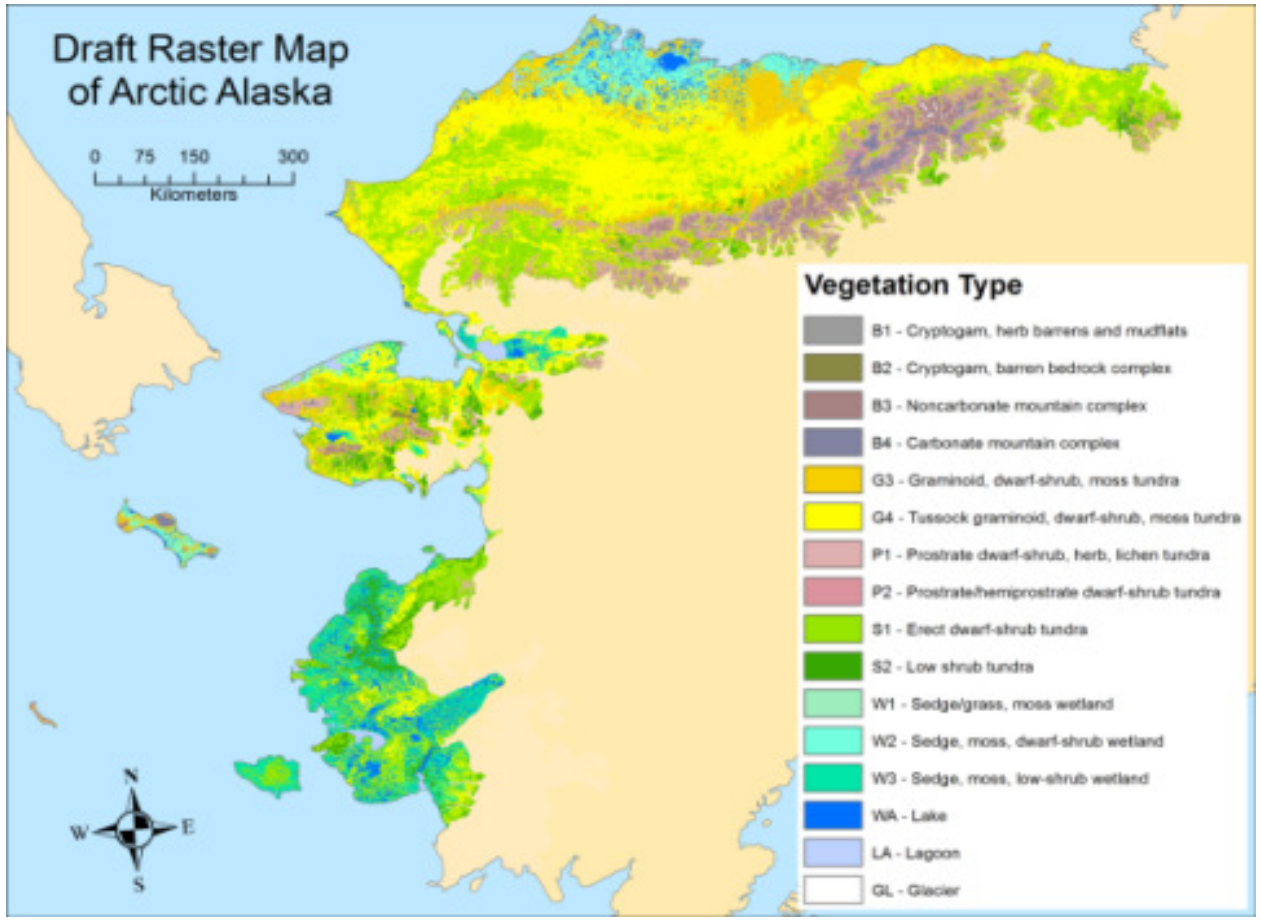
EFT Richness, Dominance, Rarity
Composition, Diversity (Shannon-Wiener etc.)

Setting geographic conservation priorities for ecosystem functional diversity using EFTs

Baja California (México)

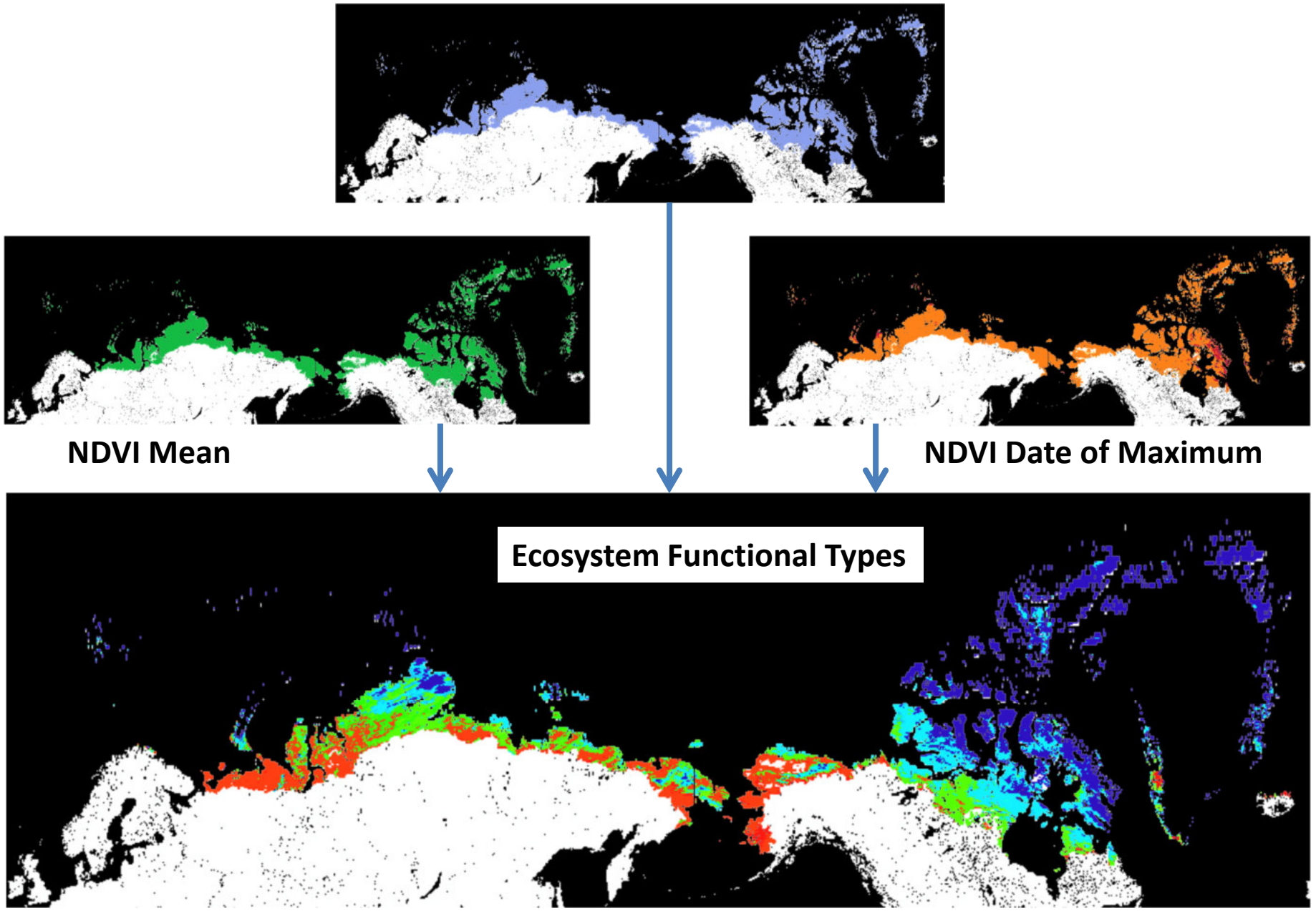


Using the new raster version of the Circumpolar Arctic Vegetation Map (CAVM), we can…

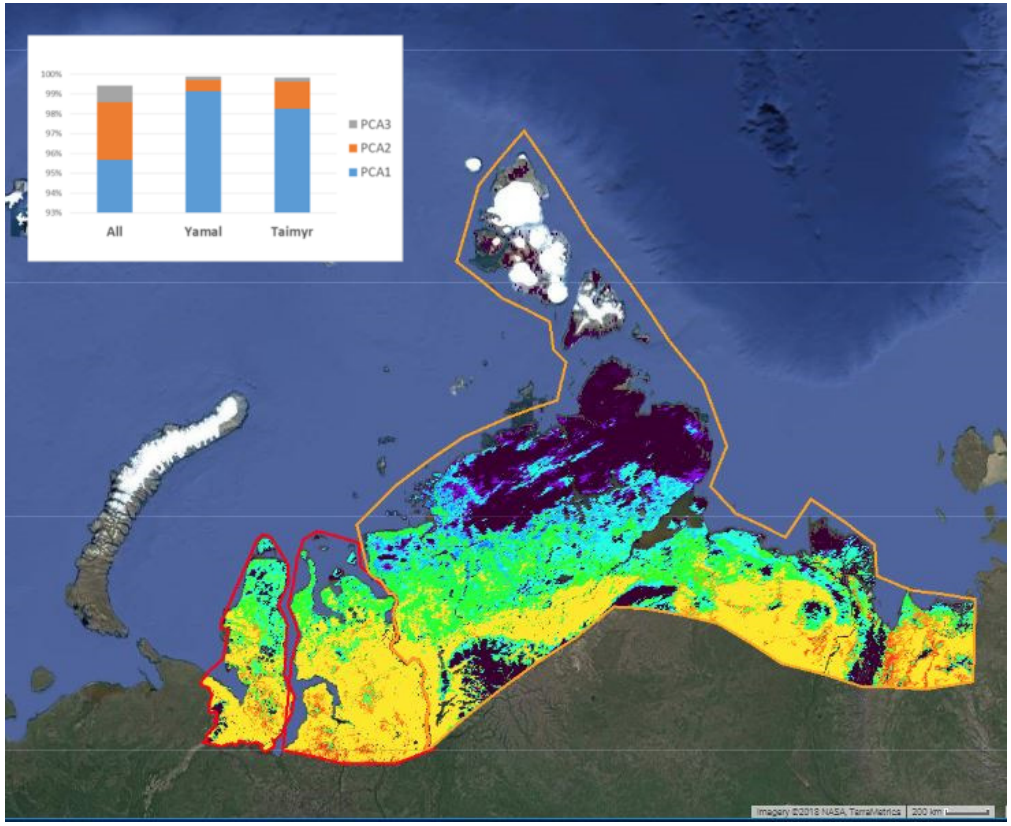


1) Identify the functional diversity within vegetation types
2) Identify different vegetation types that may be functioning similarly.

Circumpolar Arctic Example



EFT maps of the Yamal and Taimyr Peninsulas (managed vs. wild *Rangifer* herds)



- PC1 related to June-August NDVI magnitude; PC2 related to NDVI seasonality
- Greater EFT diversity on the Taimyr compared to the Yamal

Work in Progress – Future Questions

1) **What are the effects of Ecosystem Functional Type distribution and diversity on patterns of herbivory?**
2) **How does herbivory in turn alter EFT distribution and diversity?**