

# Circumpolar Arctic vegetation classification, mapping, and transects: a framework for Arctic change monitoring and analysis

Donald A. Walker<sup>1</sup>, Martha K. Reynolds<sup>1</sup>, Amy L. Breen<sup>2</sup>, Lisa A. Druckenmiller<sup>1</sup>, Jozef Štíbík<sup>3</sup>, Howard E. Epstein<sup>4</sup>, Uma S. Bhatt<sup>5</sup>, Gabriela Schaeppman-Strub<sup>6</sup> and the Circumpolar Vegetation Group\*

<sup>1</sup> Alaska Geobotany Center, Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK, USA; <sup>2</sup> International Arctic Research Center and Alaska Geobotany Center, Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, AK, USA;

<sup>3</sup> Plant Science and Biodiversity Centre, Slovak Academy of Sciences, Institute of Botany, Department of Geobotany, Bratislava, Slovakia; <sup>4</sup> Department of Environmental Sciences, University of Virginia, Charlottesville, VA, USA;

<sup>5</sup> Geophysical Institute and Department of Atmospheric Science, University of Alaska Fairbanks, Fairbanks, AK, USA; <sup>6</sup> Department of Evolutionary Biology and Environmental Studies, University of Zurich, Switzerland

## Why a circumpolar framework?

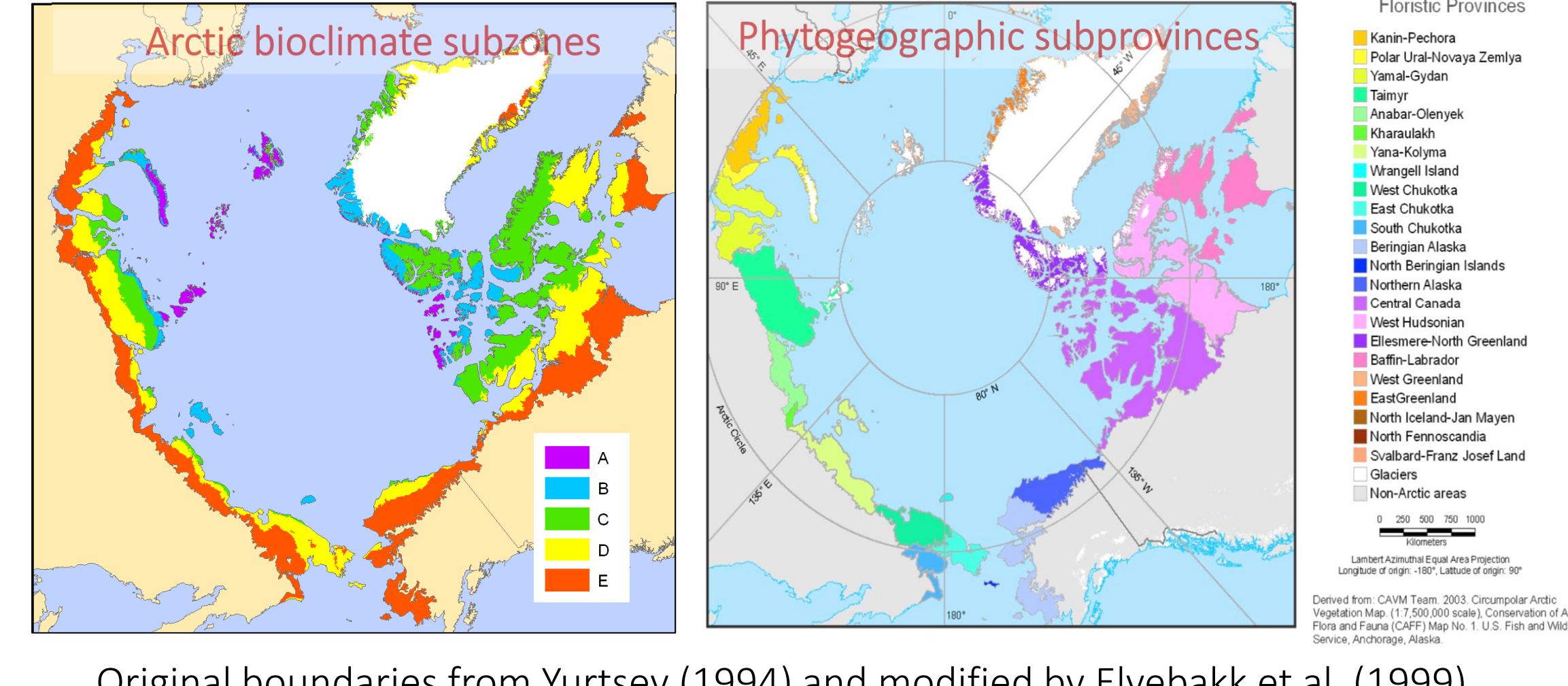
A circumpolar framework of arctic tundra vegetation is needed for a wide variety of purposes including studying, monitoring, and modeling present, past, and future arctic terrestrial ecosystems. Several IASC and CAFF sponsored initiatives aim to provide such a framework. Here we present a new raster version of the Circumpolar Arctic Vegetation Map, an update on the Arctic Vegetation Archive and Classification, and two arctic transects that traverse the full bioclimate gradient in North America and Eurasia.

## A floristic foundation



Boris Yurtsev

The foundation for a circumpolar vegetation framework was laid by Boris Yurtsev (1994) and other Russian geobotanists, who defined circumpolar north-south Arctic bioclimate subzones, based on vegetation structure, floristic, and summer-temperature criteria. East-west phytogeographic subprovinces were based on floristic distribution patterns. Modifications of Yurtsev's boundaries were used to develop the Pan Arctic Flora (PAF) (Elven et al. 2011), the Circumpolar Arctic Vegetation Map (CAVM Team 2003), and the 2013 Arctic Biodiversity Assessment of vascular plants, mosses, and fungi (Daniëls et al. 2013; Dahlberg and Bültman 2013).



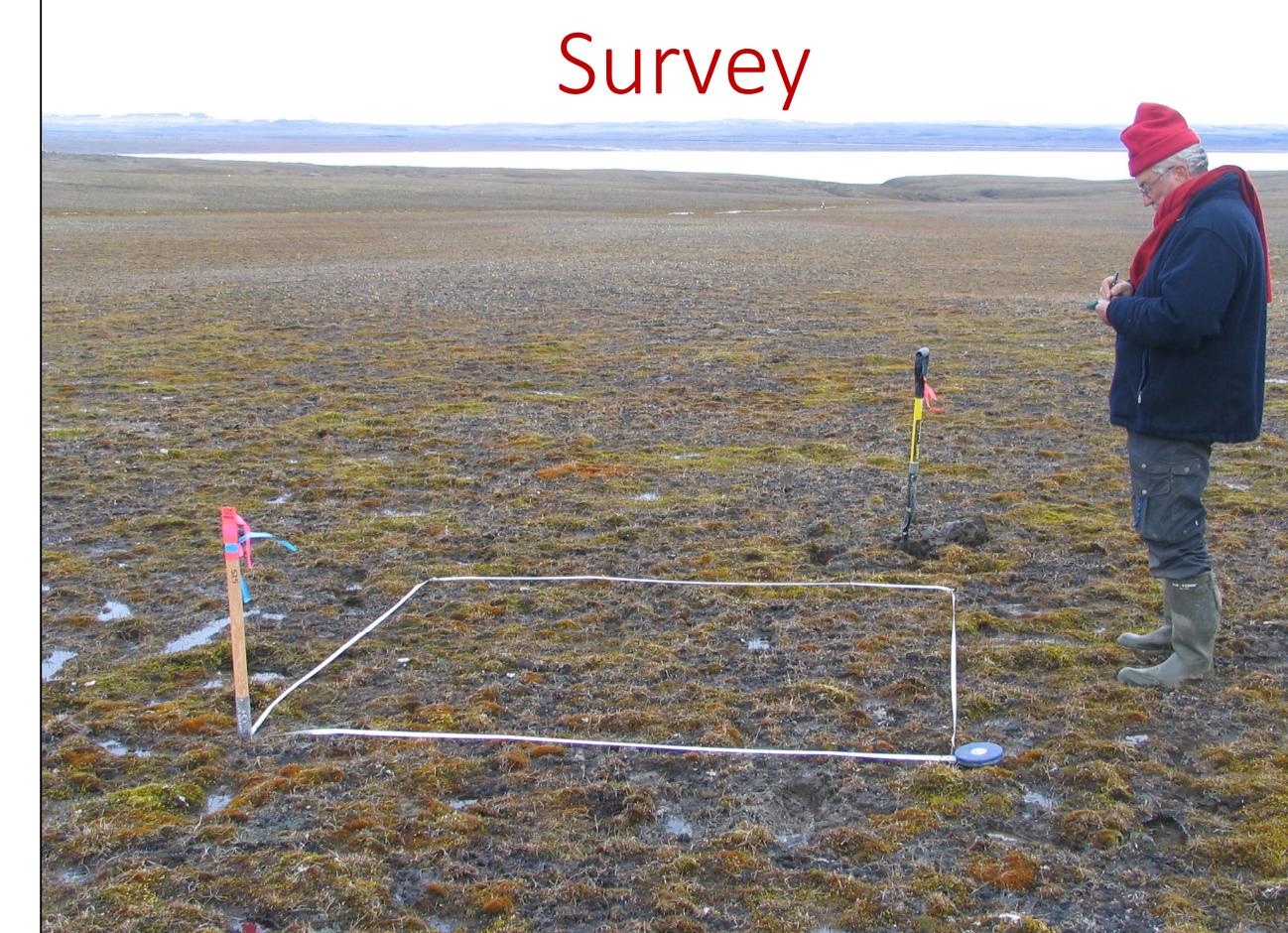
Original boundaries from Yurtsev (1994) and modified by Elvebakken et al. (1999).

## Toward a standardized hierarchical approach for plot surveys, archives, classification, and maps

**Survey:** At least 31,000 vegetation-plot surveys represent an historical legacy of ground-based vegetation and environment observations (Walker et al. 2018).

**Archive:** The data are spread across most of Yurtsev's floristic subprovinces (map at right), and are now being assessed for quality and processed for inclusion in a circumpolar Arctic Vegetation Archive (AVA).

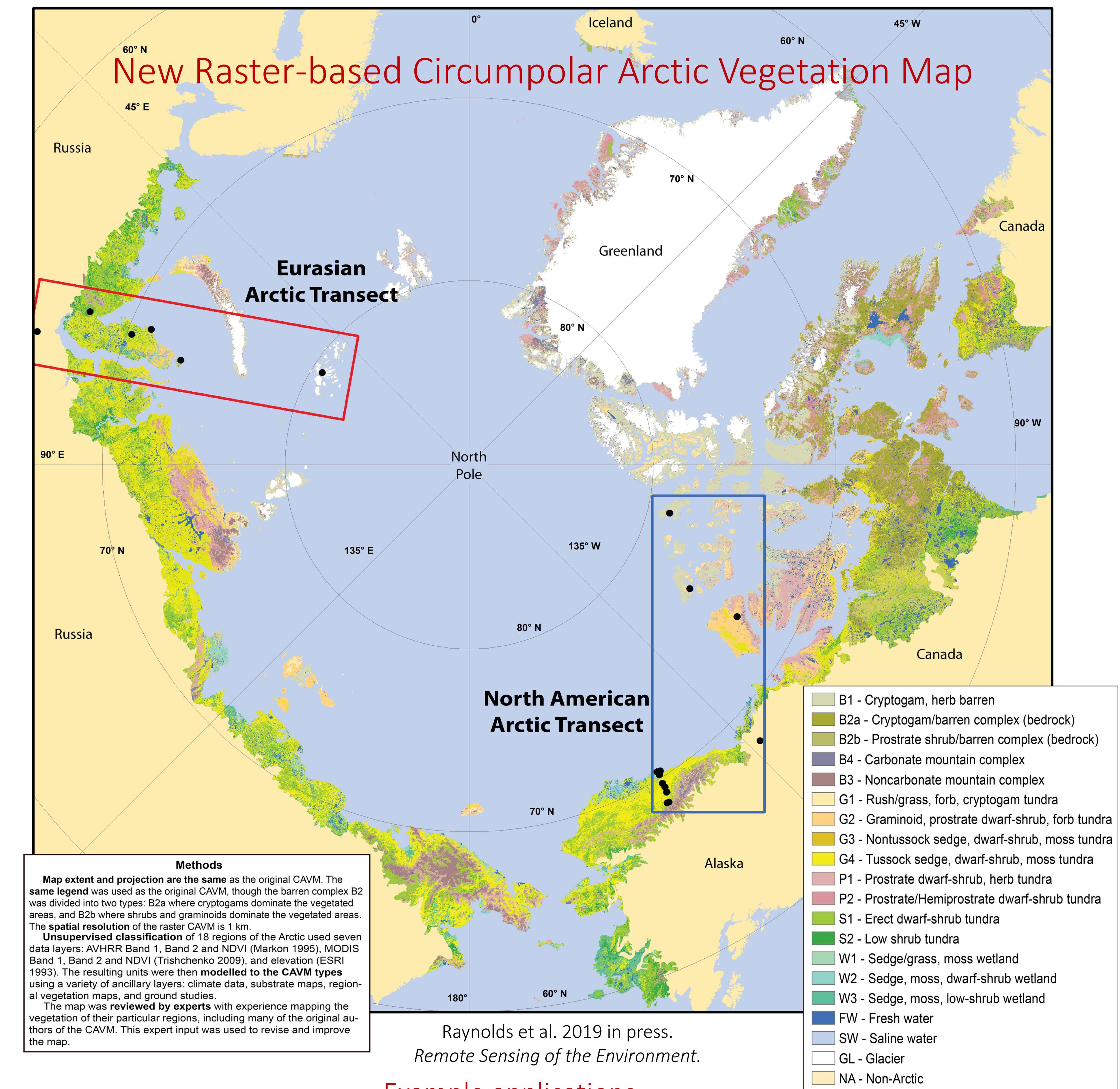
**Classification:** A circumpolar arctic vegetation classification (AVC) was first proposed 27 years ago (M.D. Walker et al. 1994) and is now feasible because of advances in the storage and analysis of massive vegetation datasets (Hennekens et al. 2001, Tichý 2002, De Cáceres 2015). Classification of plots into recognizable vegetation units uses numerical clustering analysis, table analysis (Braun-Blanquet 1928; Tichý 2002), and the European Vegetation Classification organized by typical plant community habitats (Mucina et al. 2016). Crosswalks to the US and Canadian vegetation classification approaches are being developed (Faber-Langendoen et al. 2018, Mackenzie et al. 2013).



Fred Daniëls surveying 2-m x 2-m wet-tundra plot on Ellef Ringnes Island, Canada.



Circumpolar distribution of approximately 31,000 vegetation plots by phytogeographic subprovince.



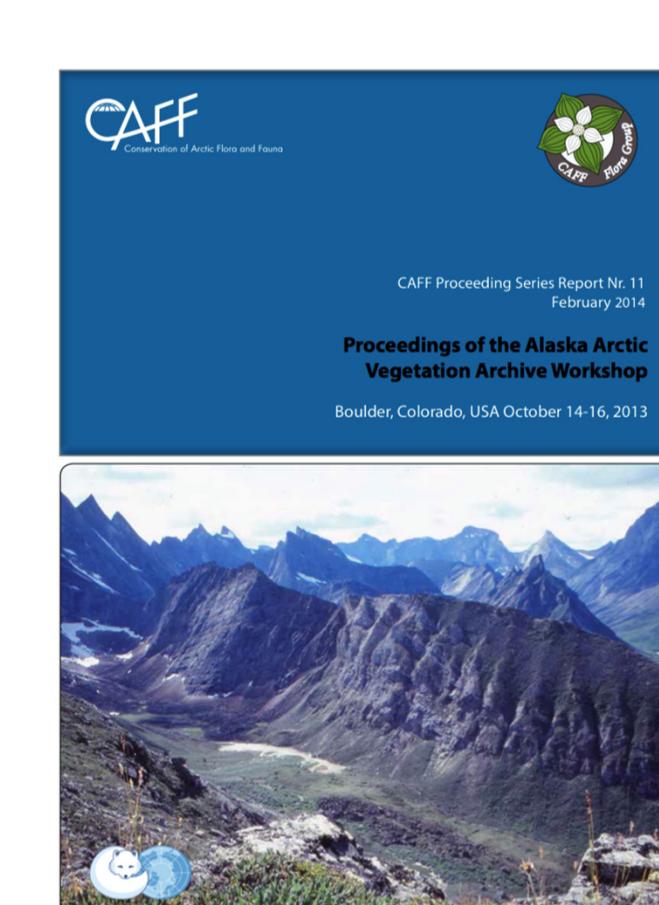
Raynolds et al. 2019 in press.  
Remote Sensing of the Environment.

**Mapping:** The AVC is being used to develop map legends that can be applied at multiple scales. Hierarchical series of maps with consistent legends and coloring schemes, such as that developed for the Arctic Long-Term Ecological Research site at Toolik Lake, Alaska, are used for numerous remote-sensing, monitoring, and modeling applications.

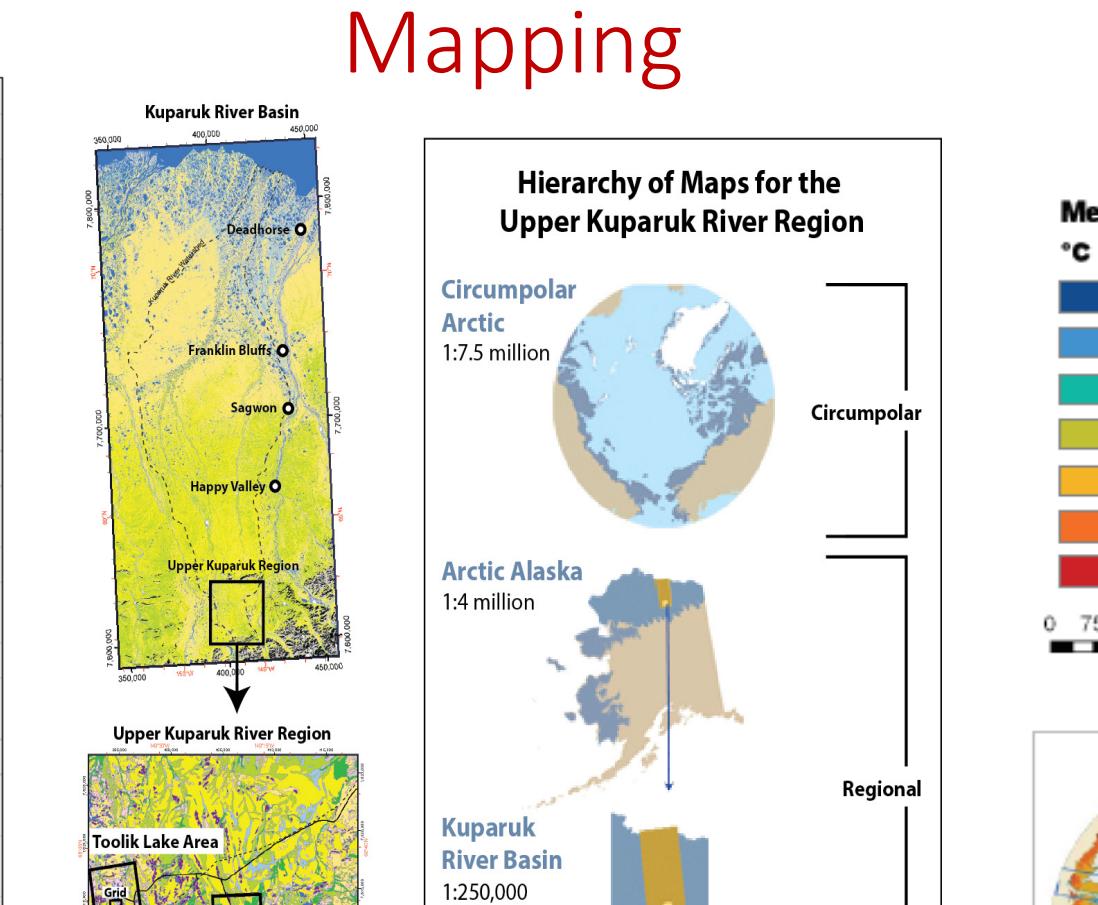
### Applications:

➤ **Arctic transects:** The survey methods, archiving, and classification approaches have been applied along two 1700-km transects that traverse all five Arctic bioclimate subzones in North America and Eurasia (Walker et al. 2011, 2019) (see raster-based circumpolar map).

➤ **Circumpolar analyses:** Analysis of vegetation-related phenomena at circumpolar scales is needed for documenting, monitoring, analysis, and prediction of terrestrial ecosystem changes. Examples include analysis of circumpolar pattern of biomass (Raynolds et al. 2008), analysis of patterns and change of greenness, as indicated by the Normalized Difference Vegetation Index (NDVI) (Bhatt et al. 2010, Epstein et al. 2019), circumpolar assessment of Arctic plant and fungi biodiversity (Daniëls et al. 2013, Dahlberg & Bültman 2013), and predictions of change (Pearson et al. 2013).

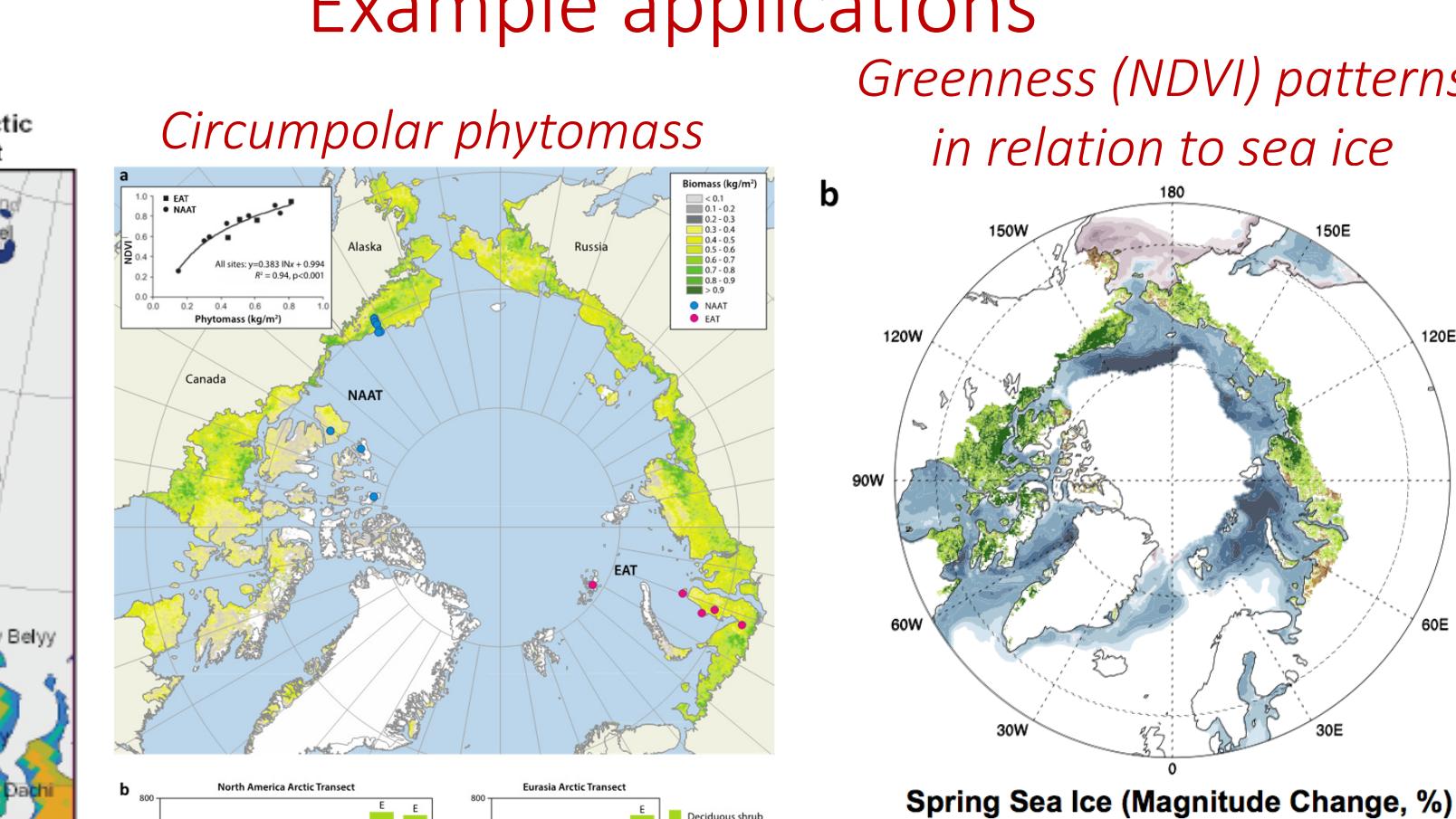
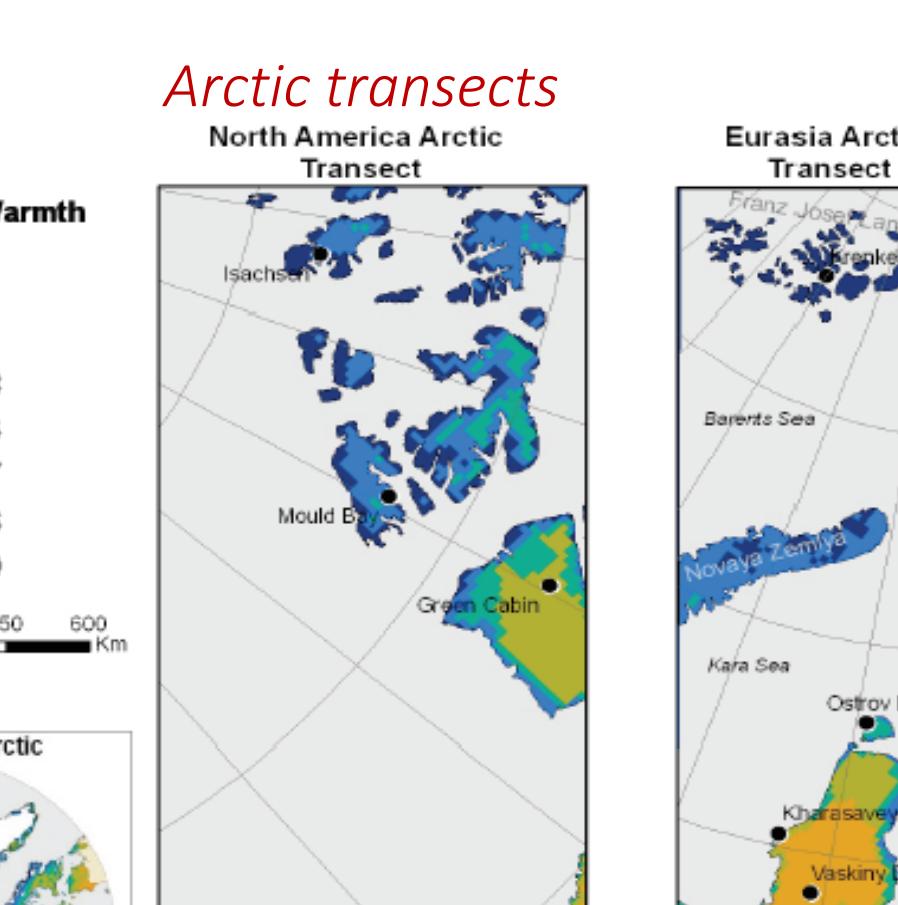


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

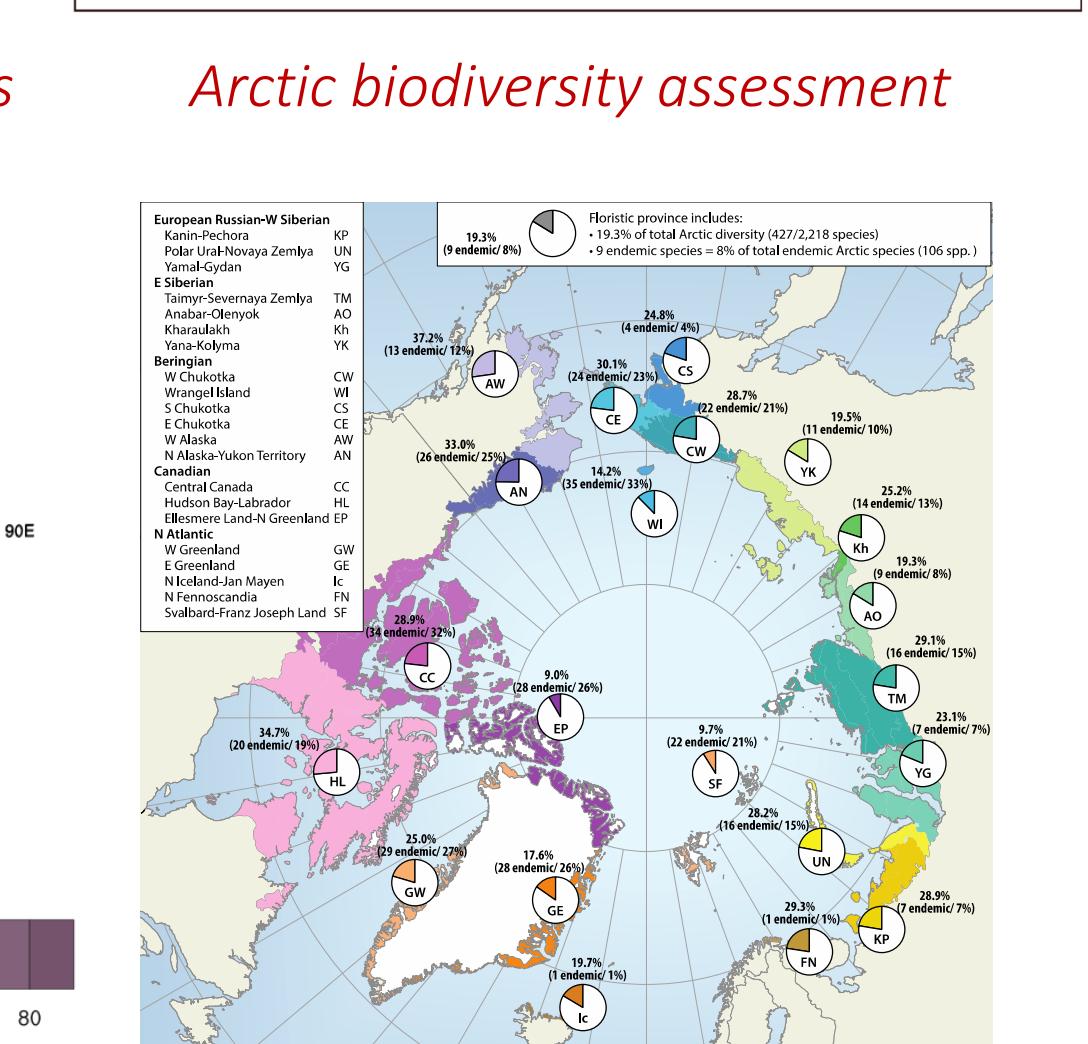


Waker et al. (2011, 2019)

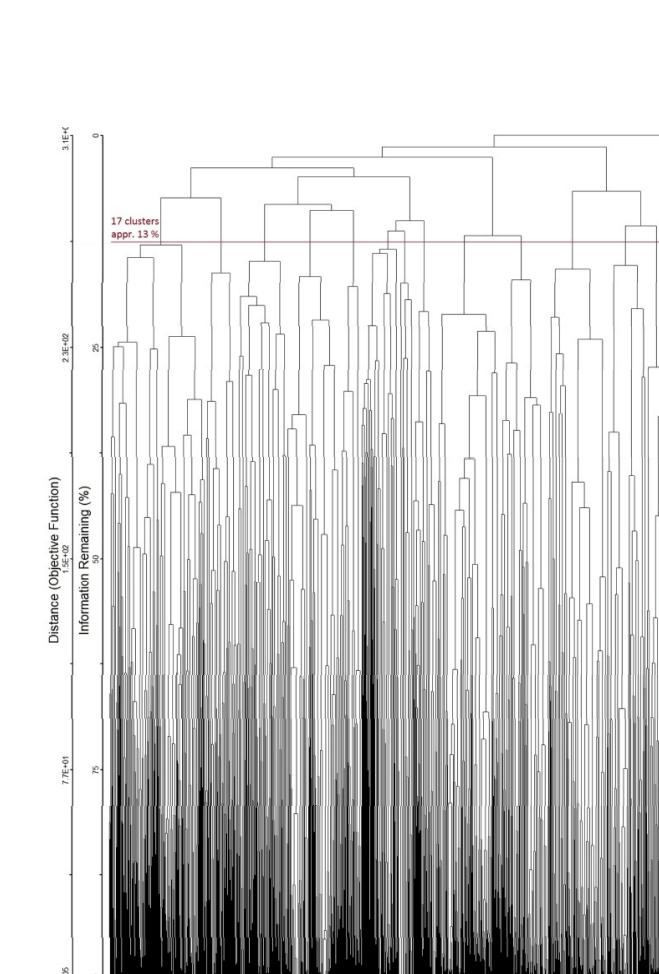
### Mapping



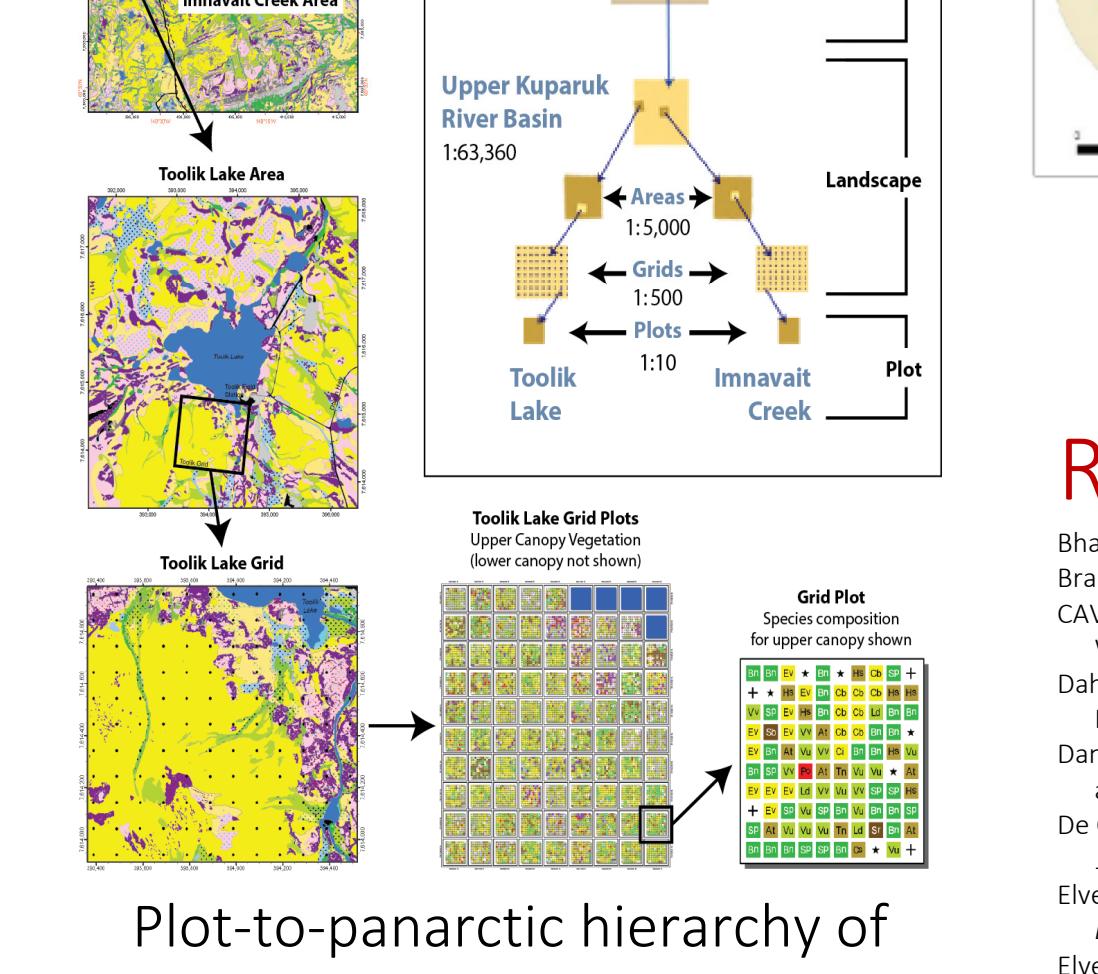
### Example applications



Daniëls et al. (2013)

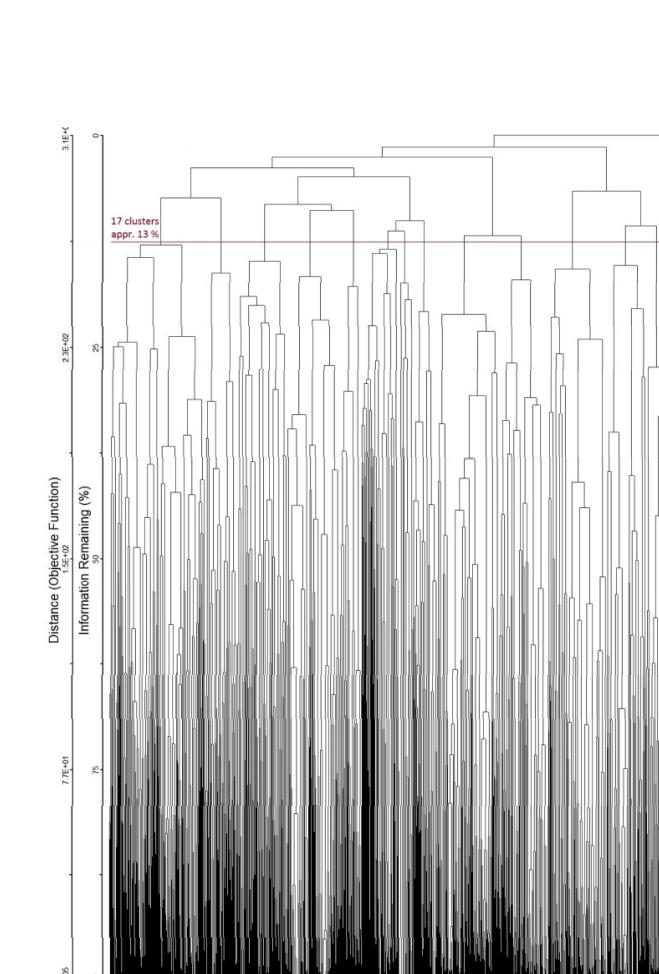


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

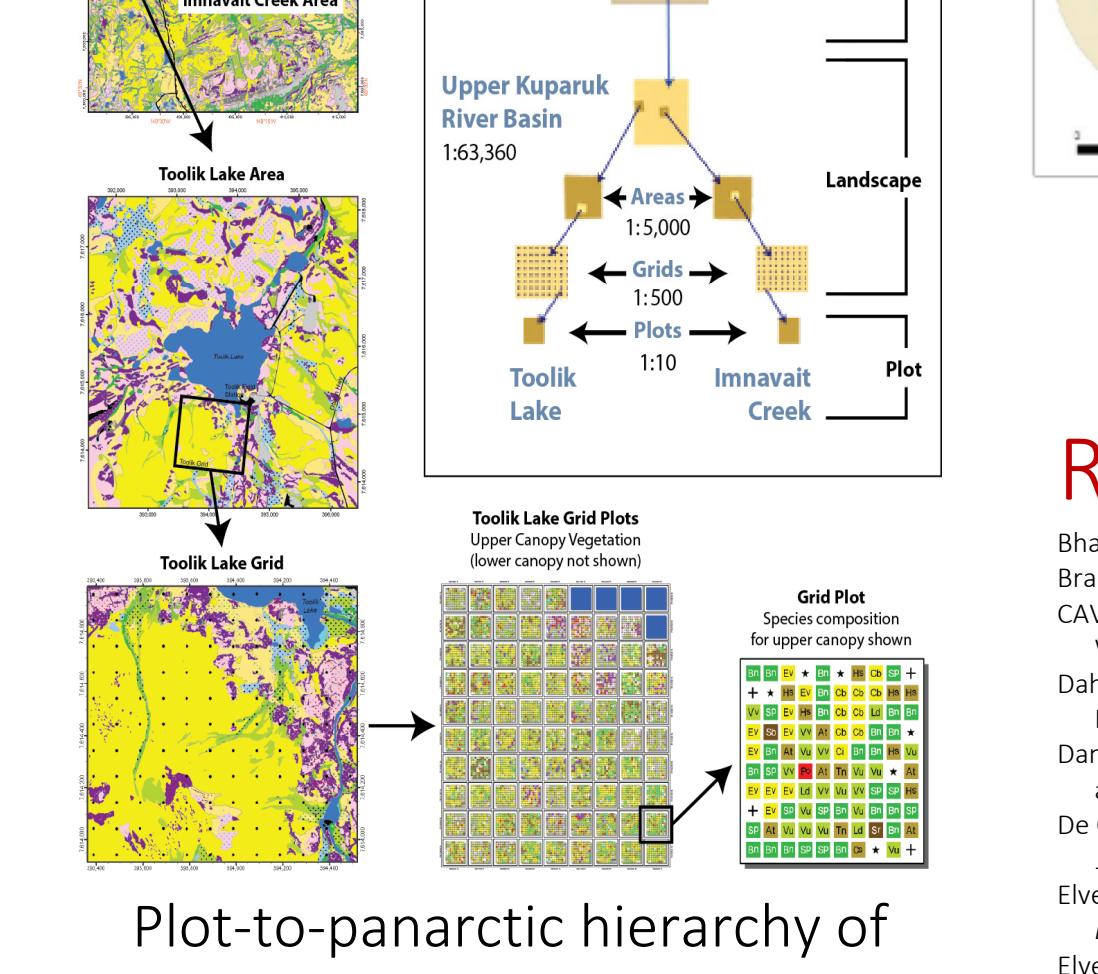


Waker et al. (2011, 2019)

### Classification

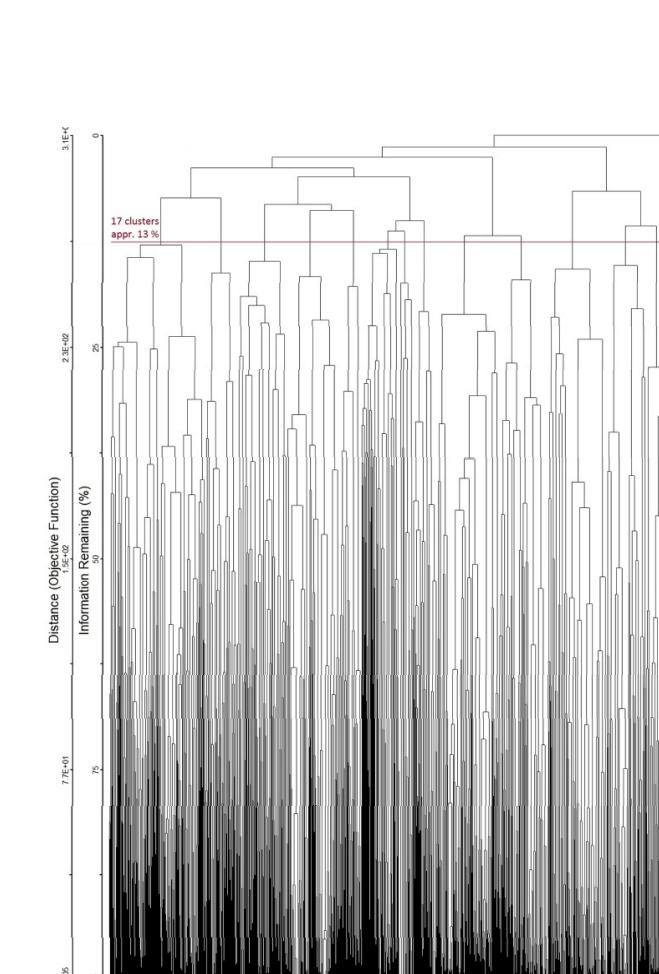


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

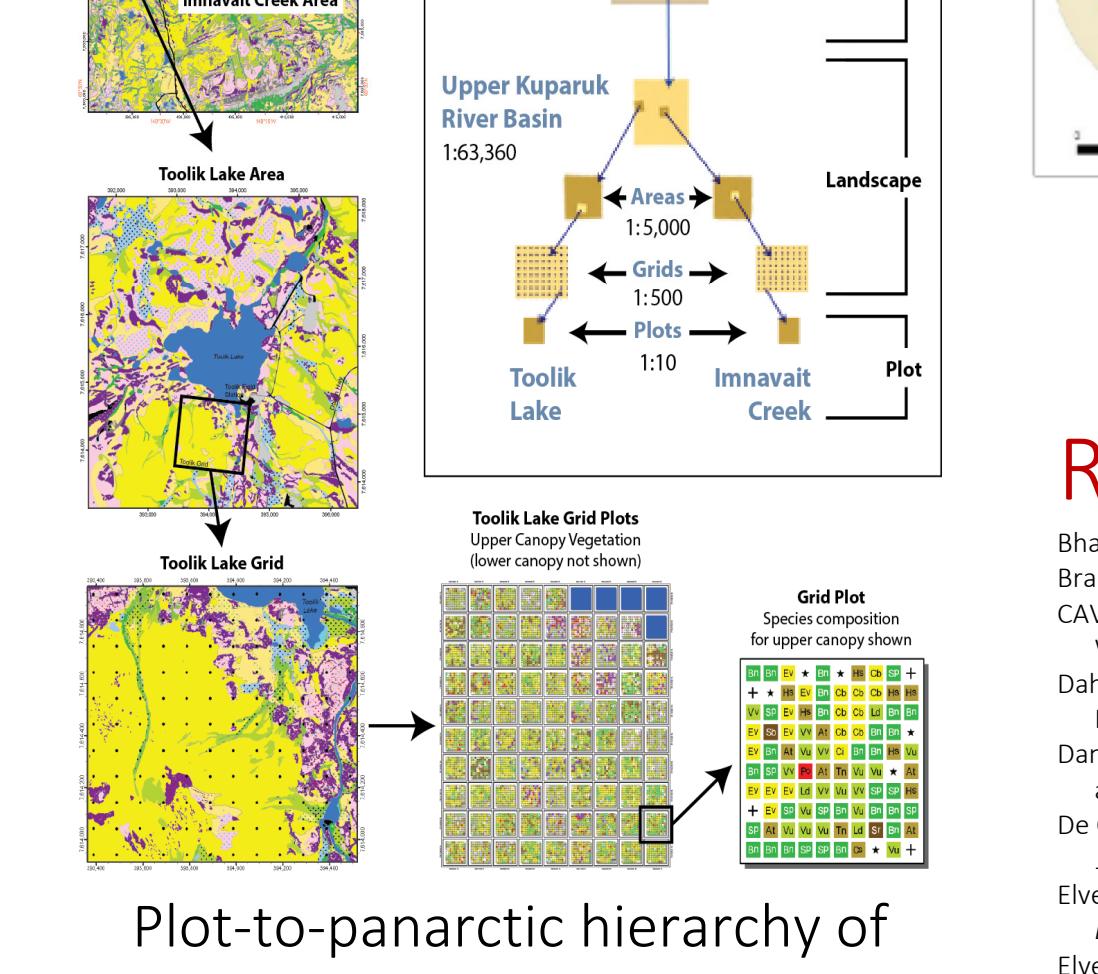


Waker et al. (2011, 2019)

### Classification

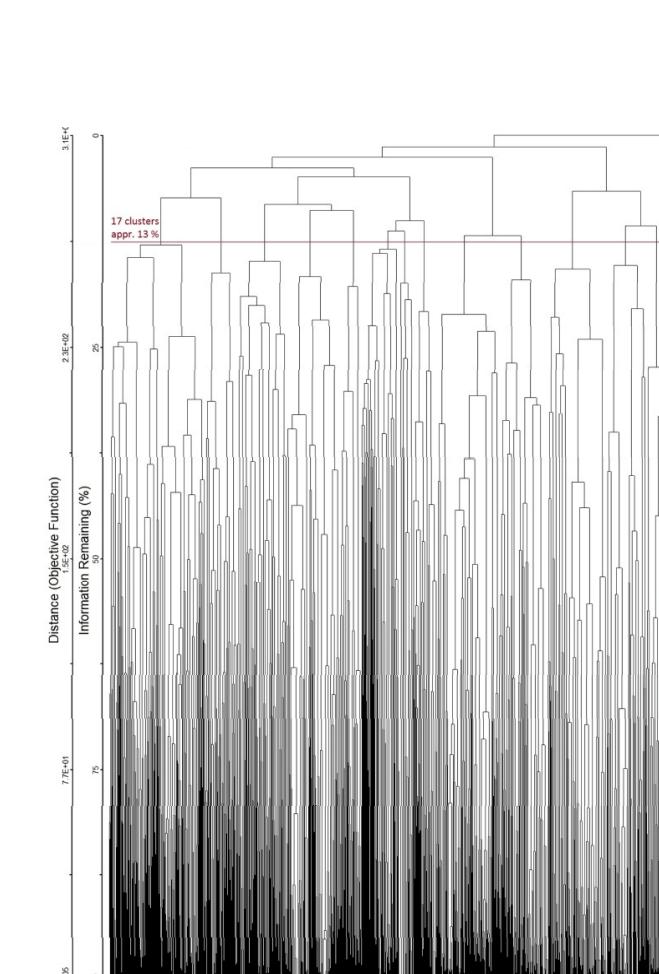


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

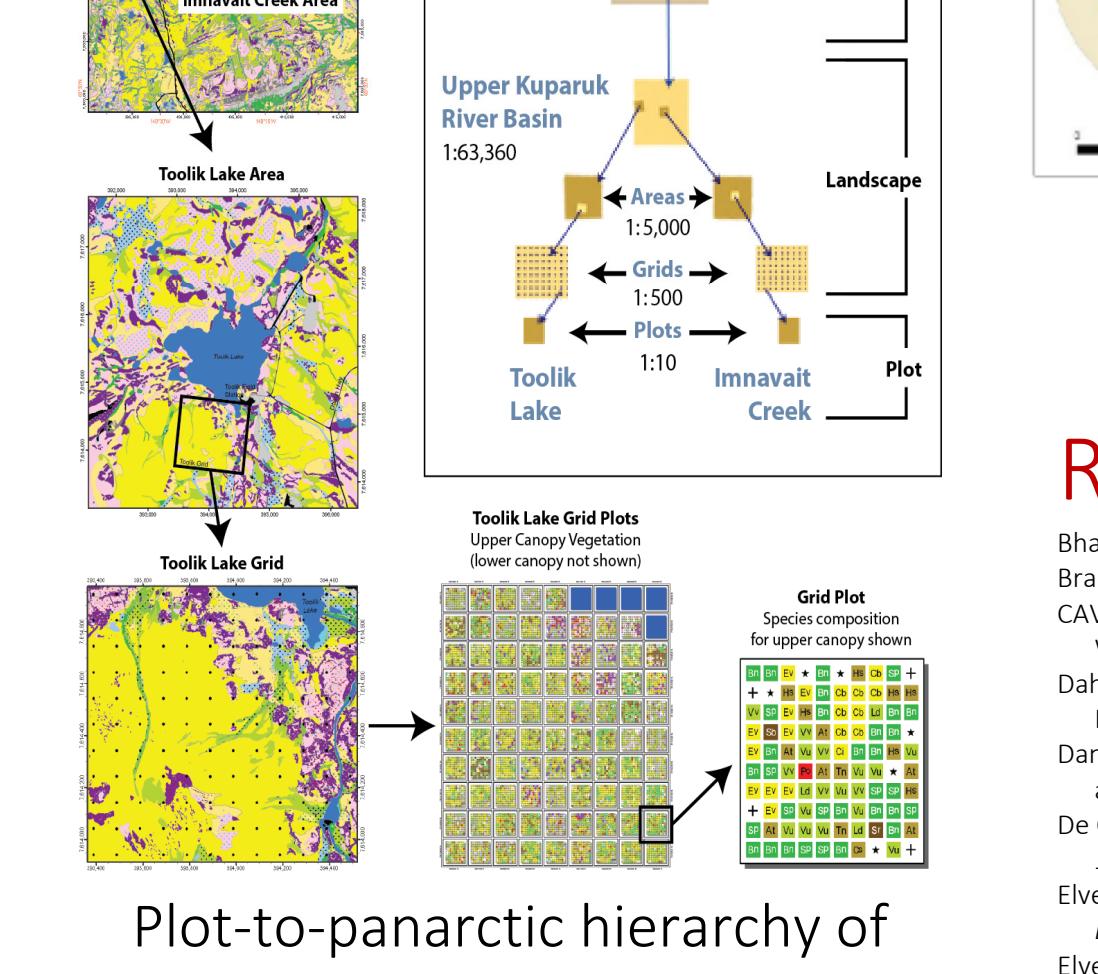


Waker et al. (2011, 2019)

### Classification

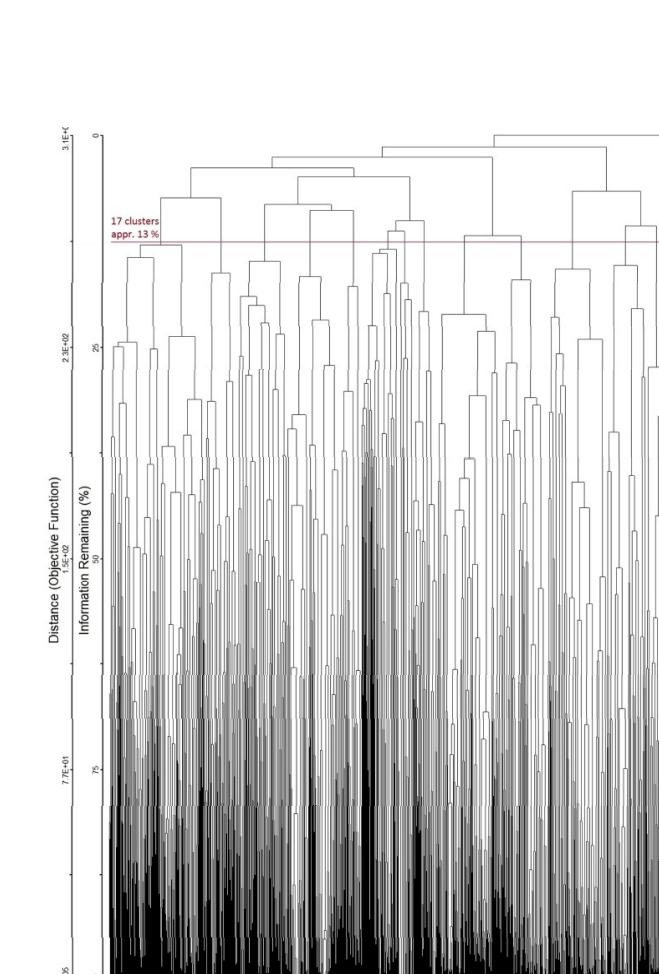


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

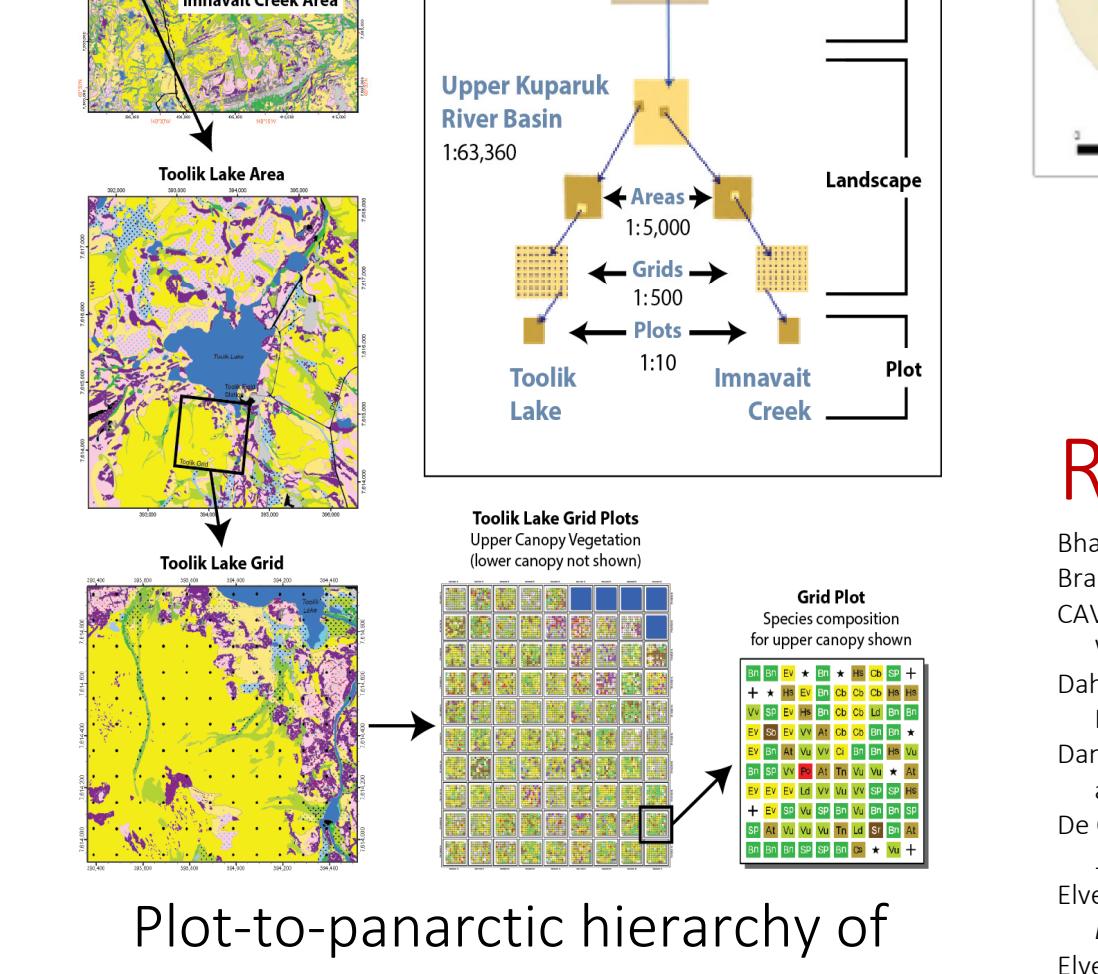


Waker et al. (2011, 2019)

### Classification

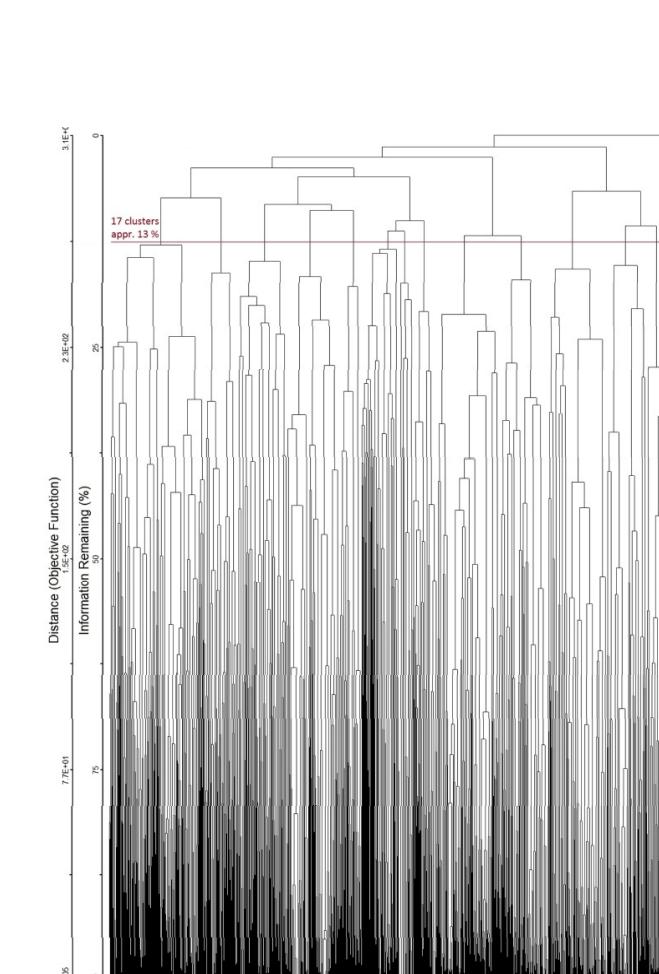


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

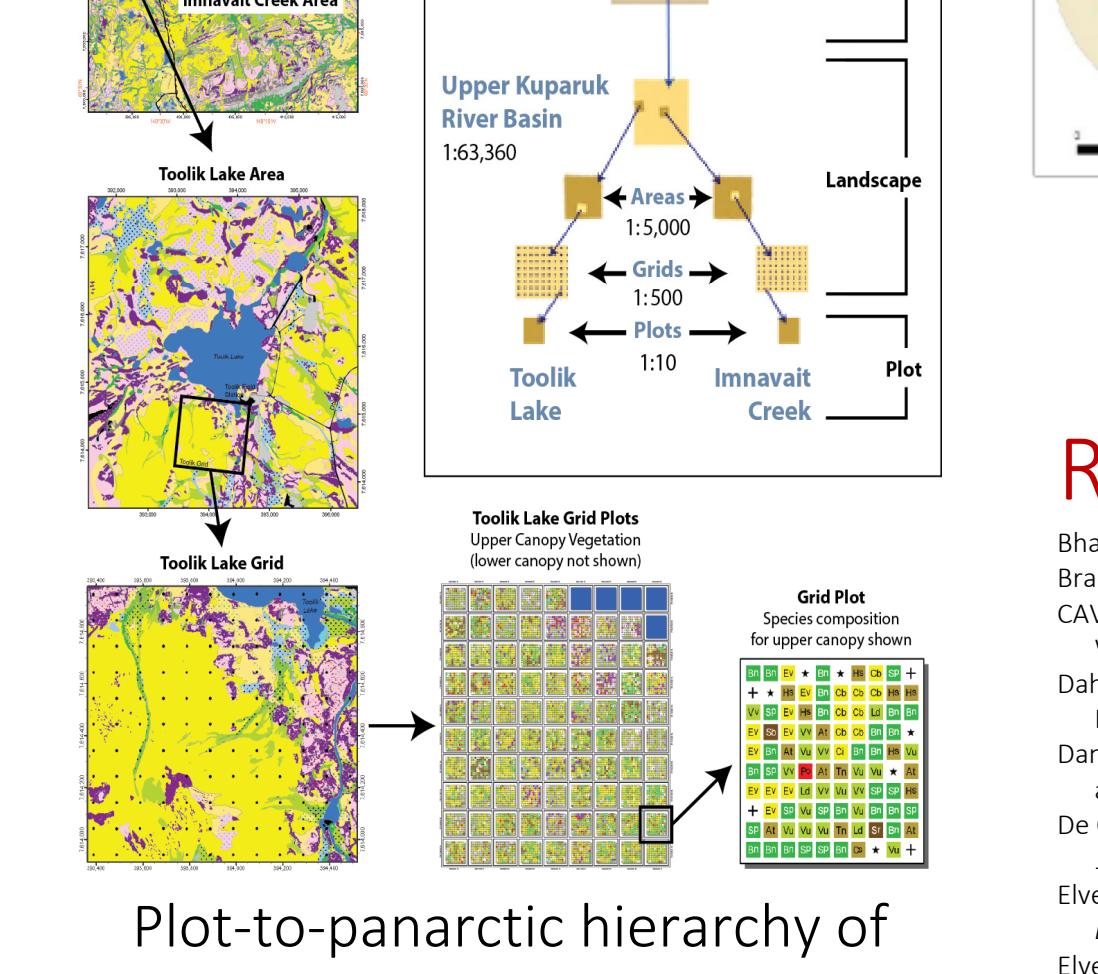


Waker et al. (2011, 2019)

### Classification

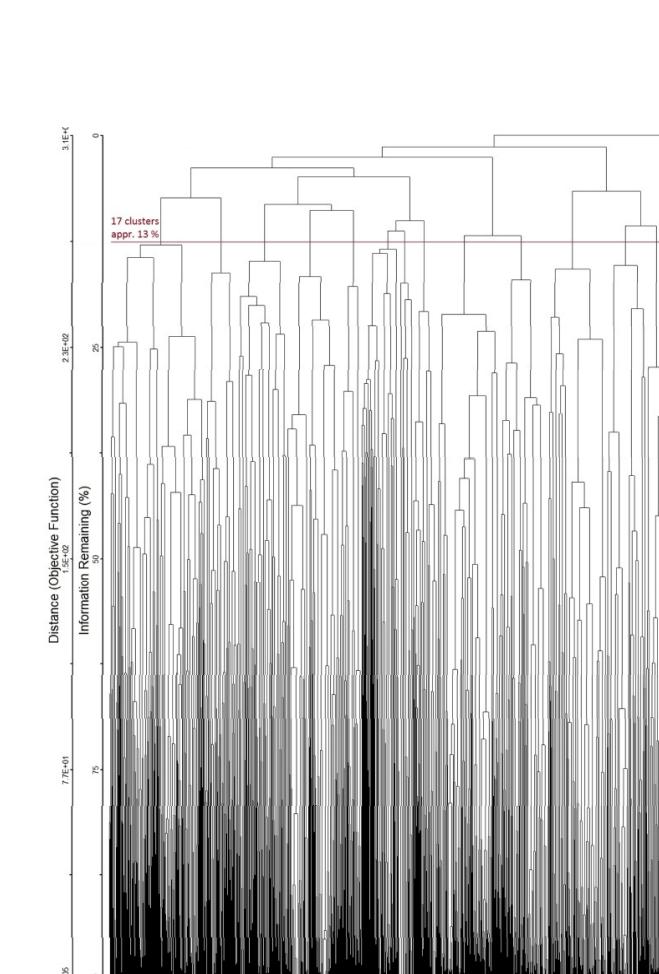


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

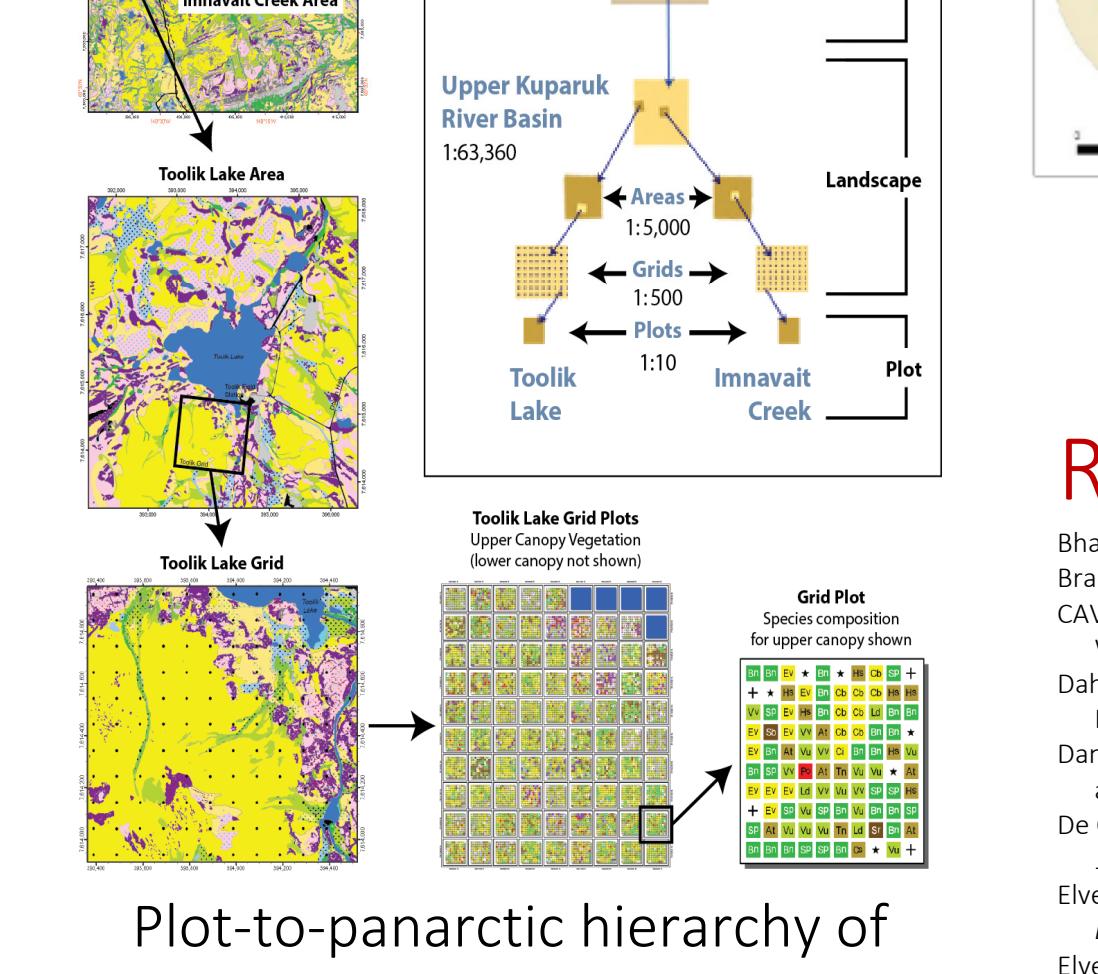


Waker et al. (2011, 2019)

### Classification

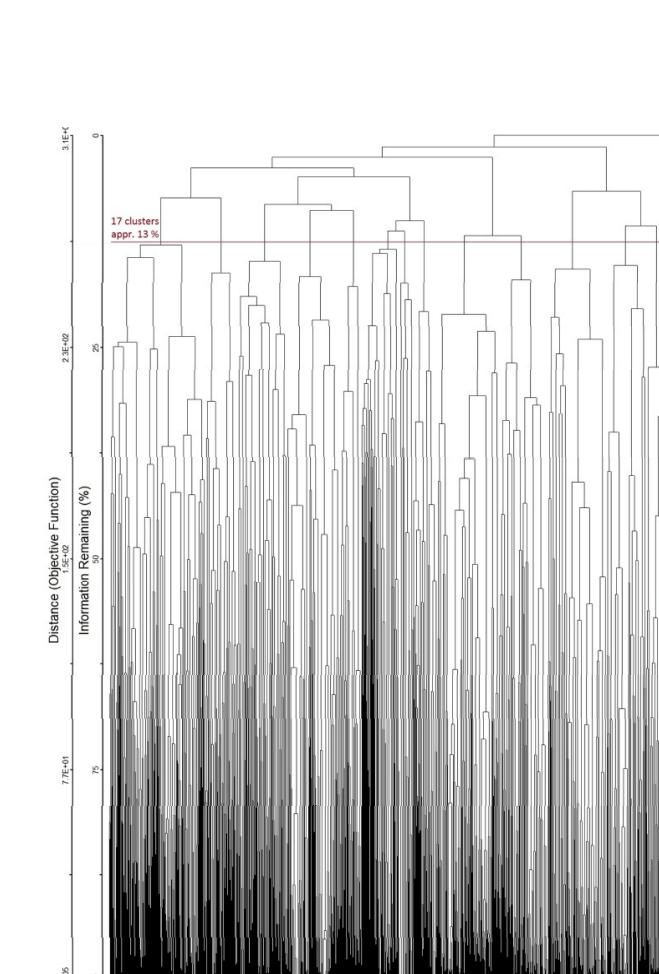


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

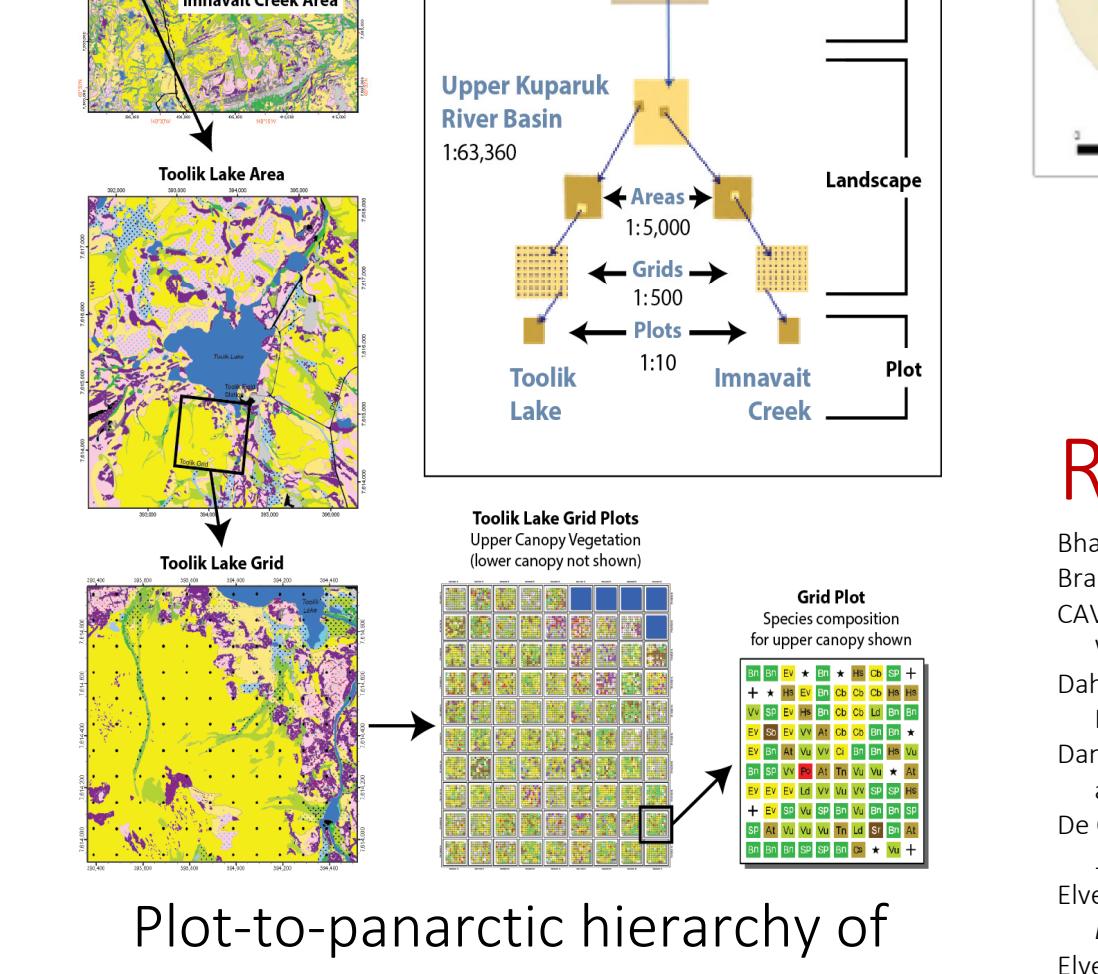


Waker et al. (2011, 2019)

### Classification

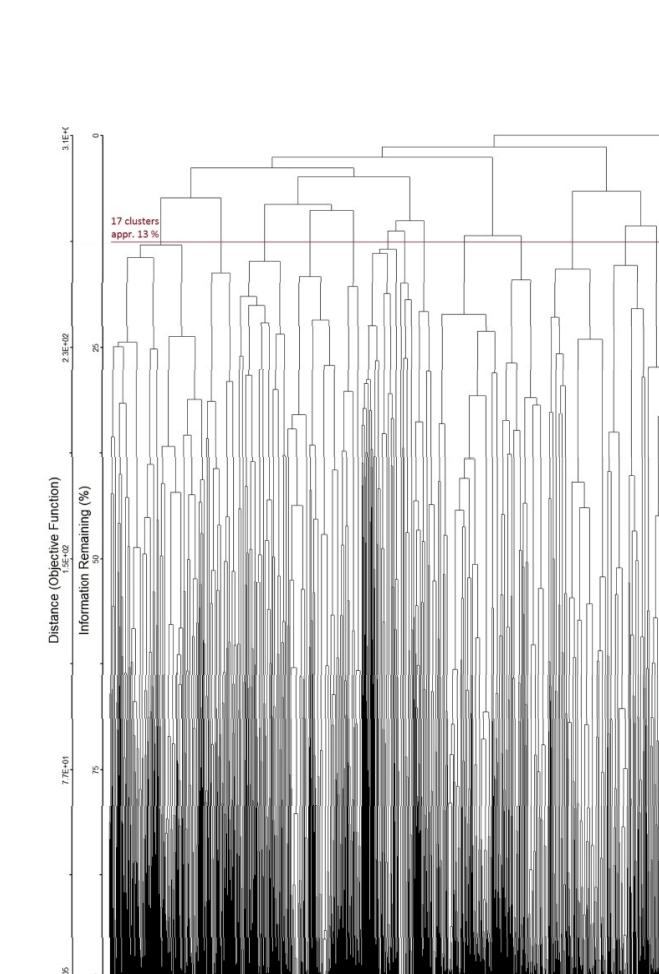


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

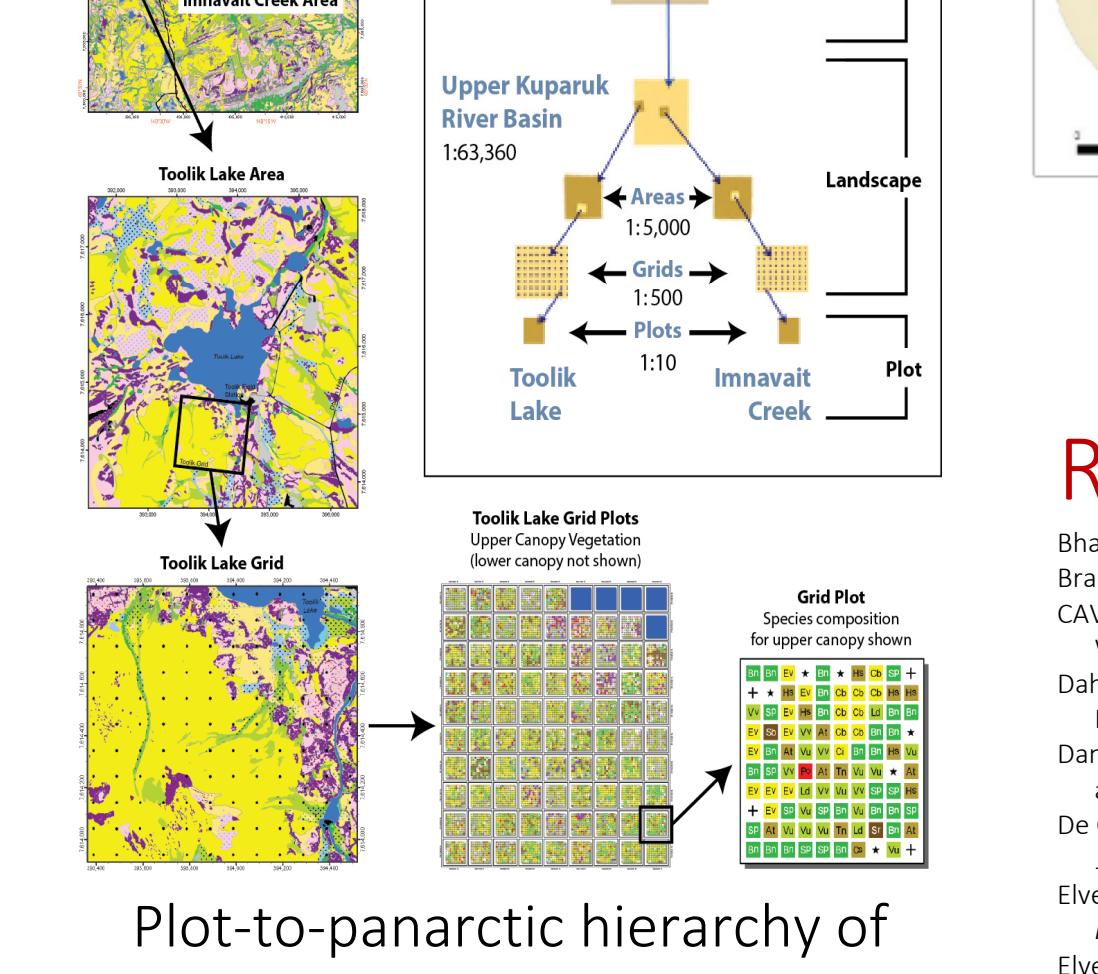


Waker et al. (2011, 2019)

### Classification

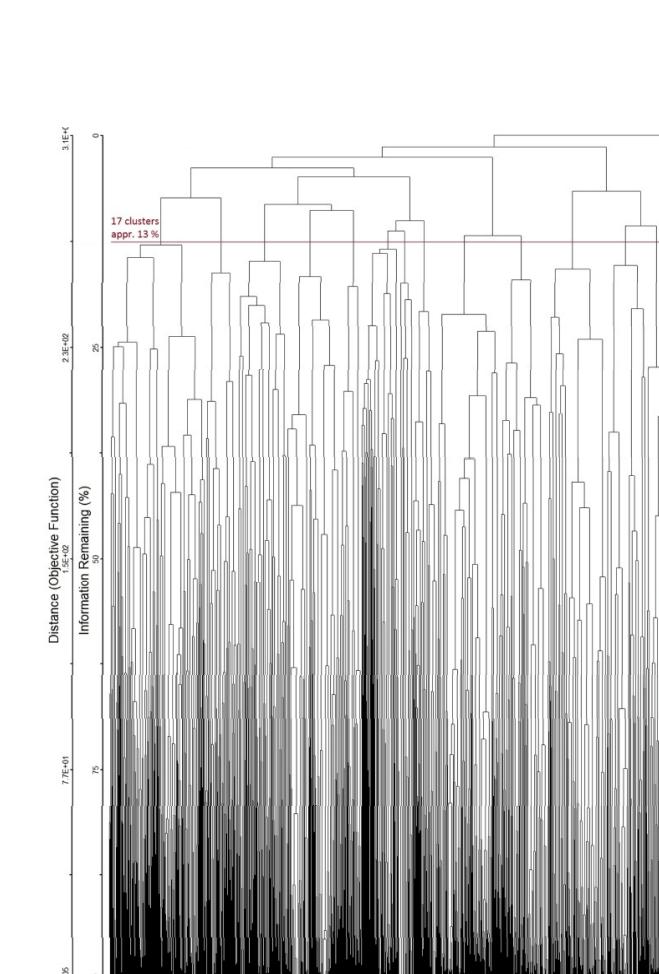


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

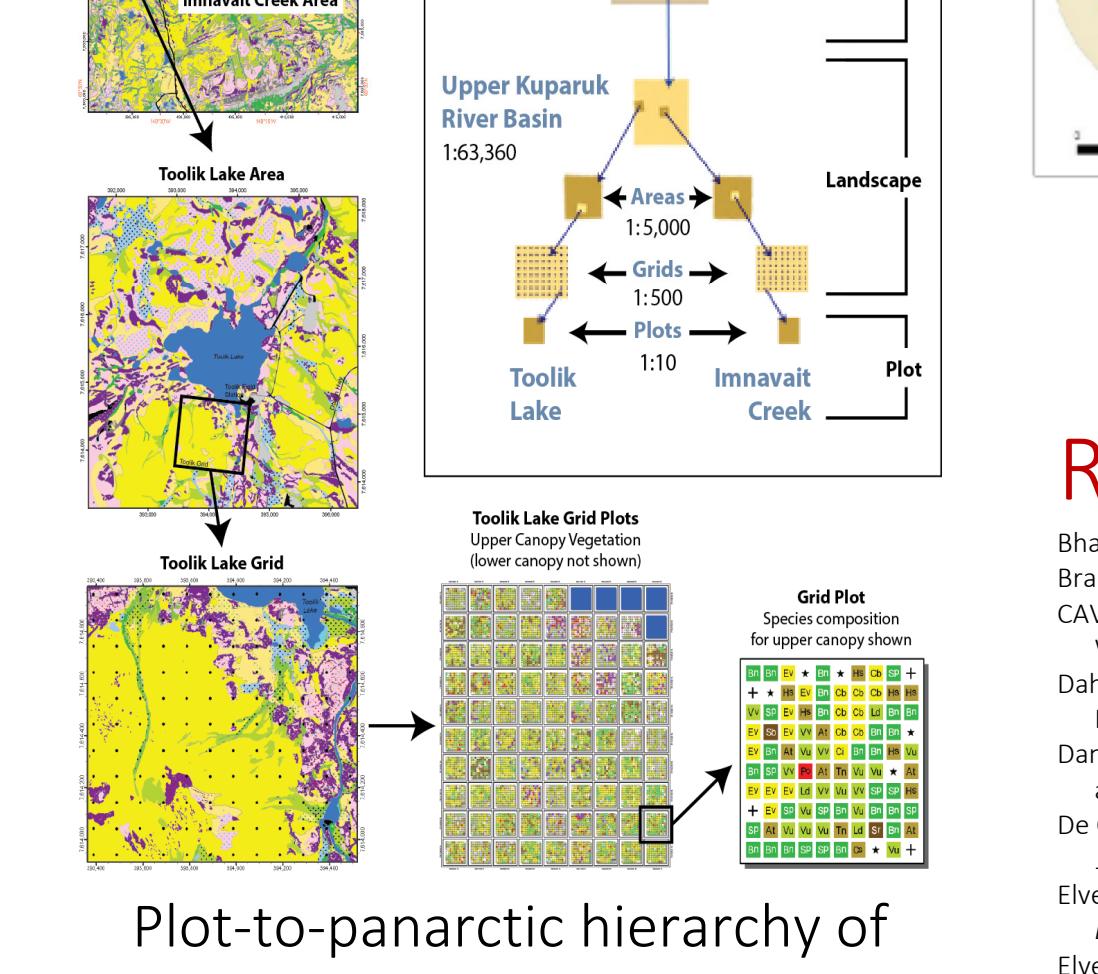


Waker et al. (2011, 2019)

### Classification

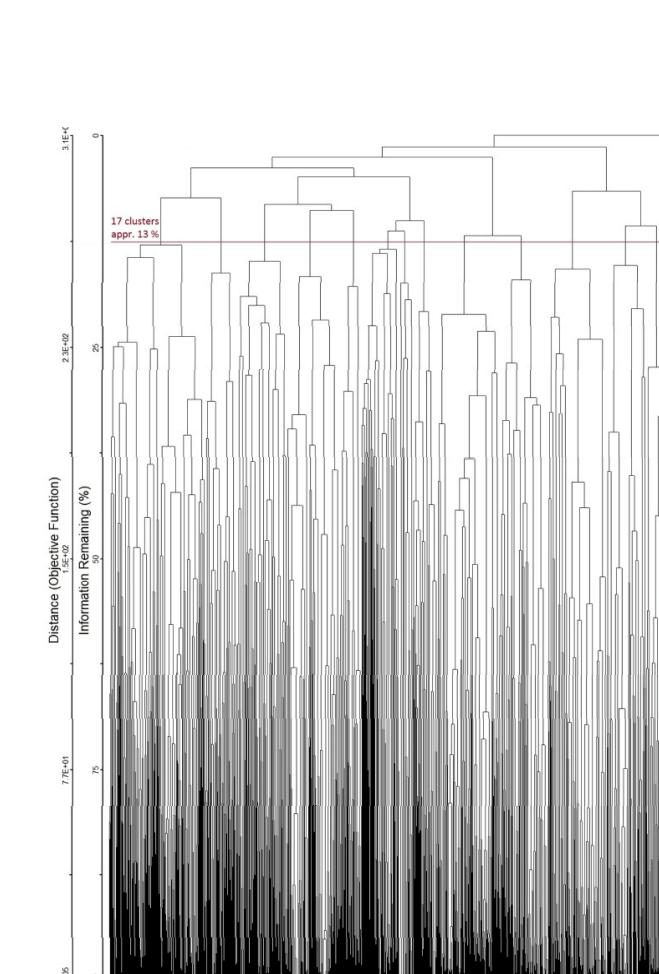


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

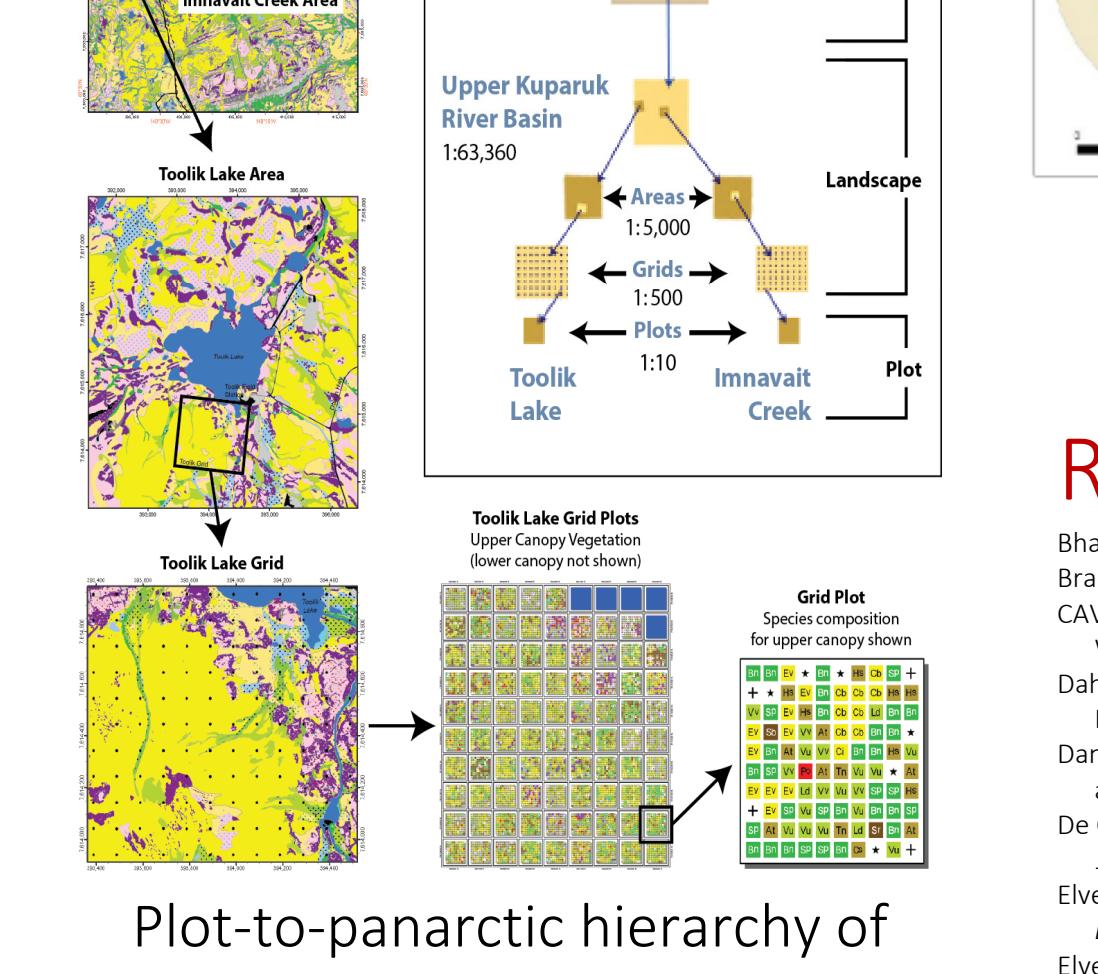


Waker et al. (2011, 2019)

### Classification

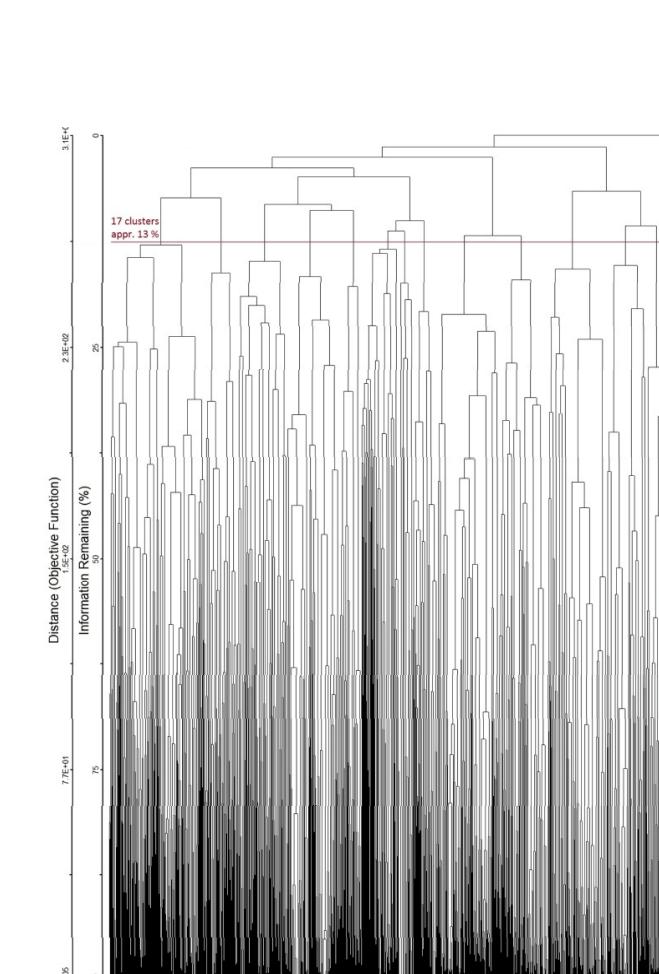


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

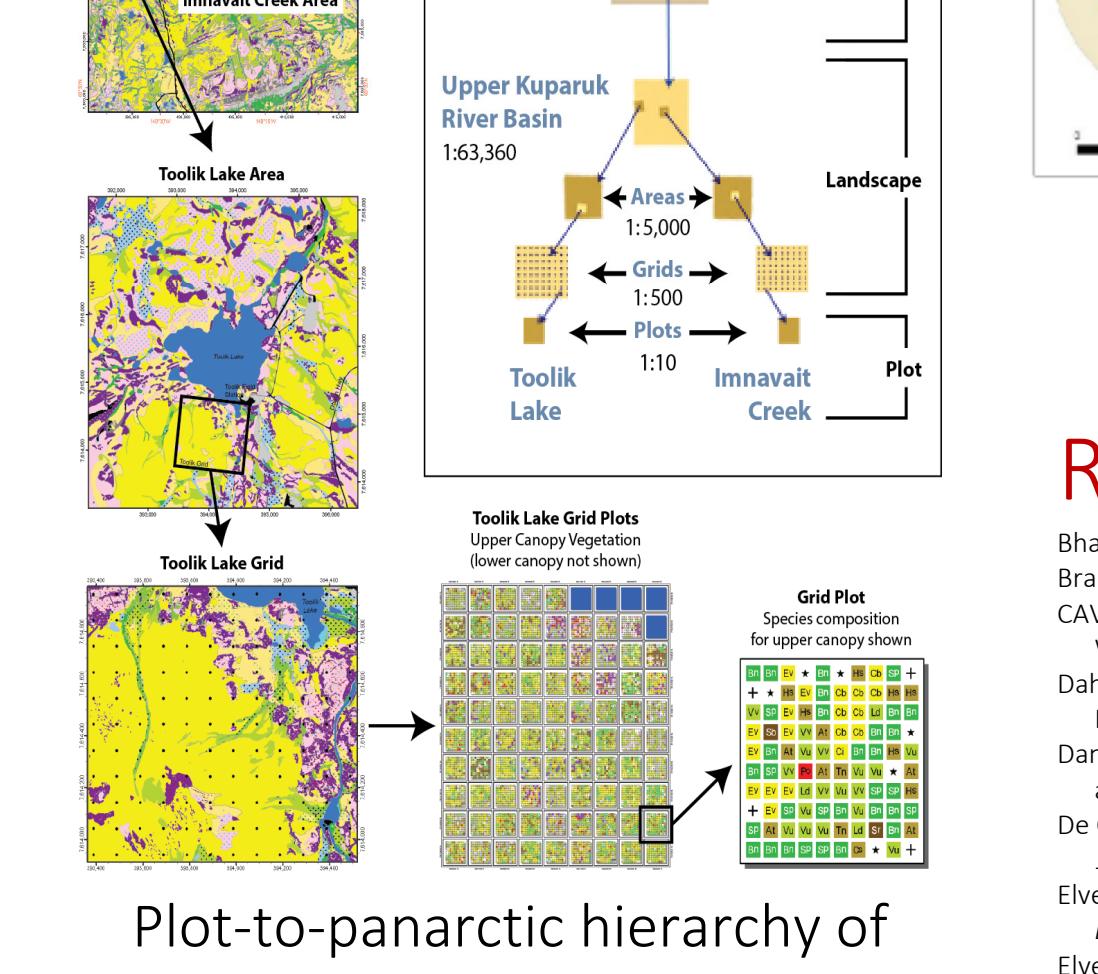


Waker et al. (2011, 2019)

### Classification

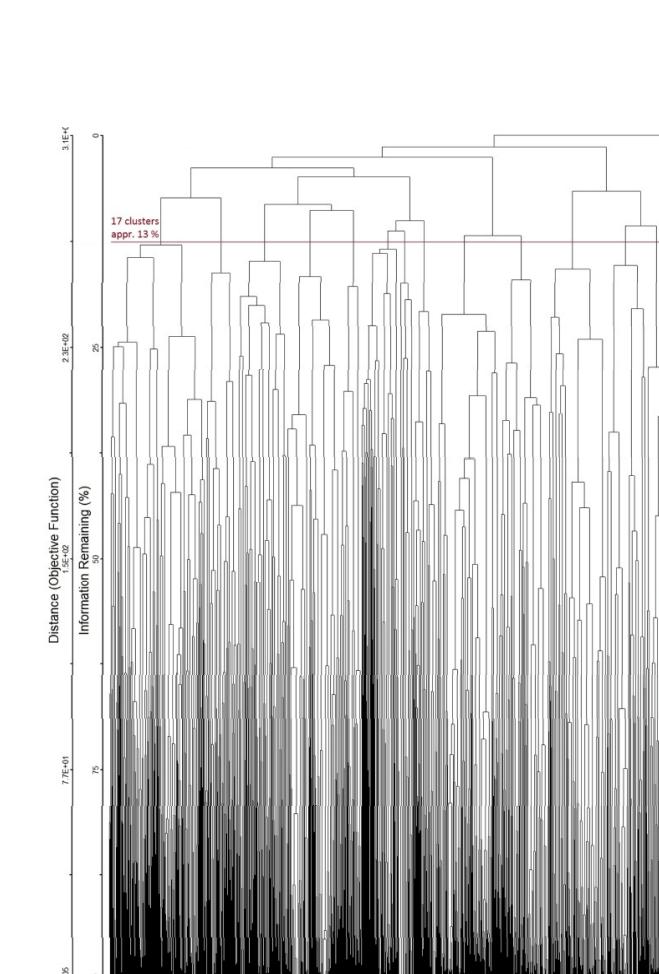


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

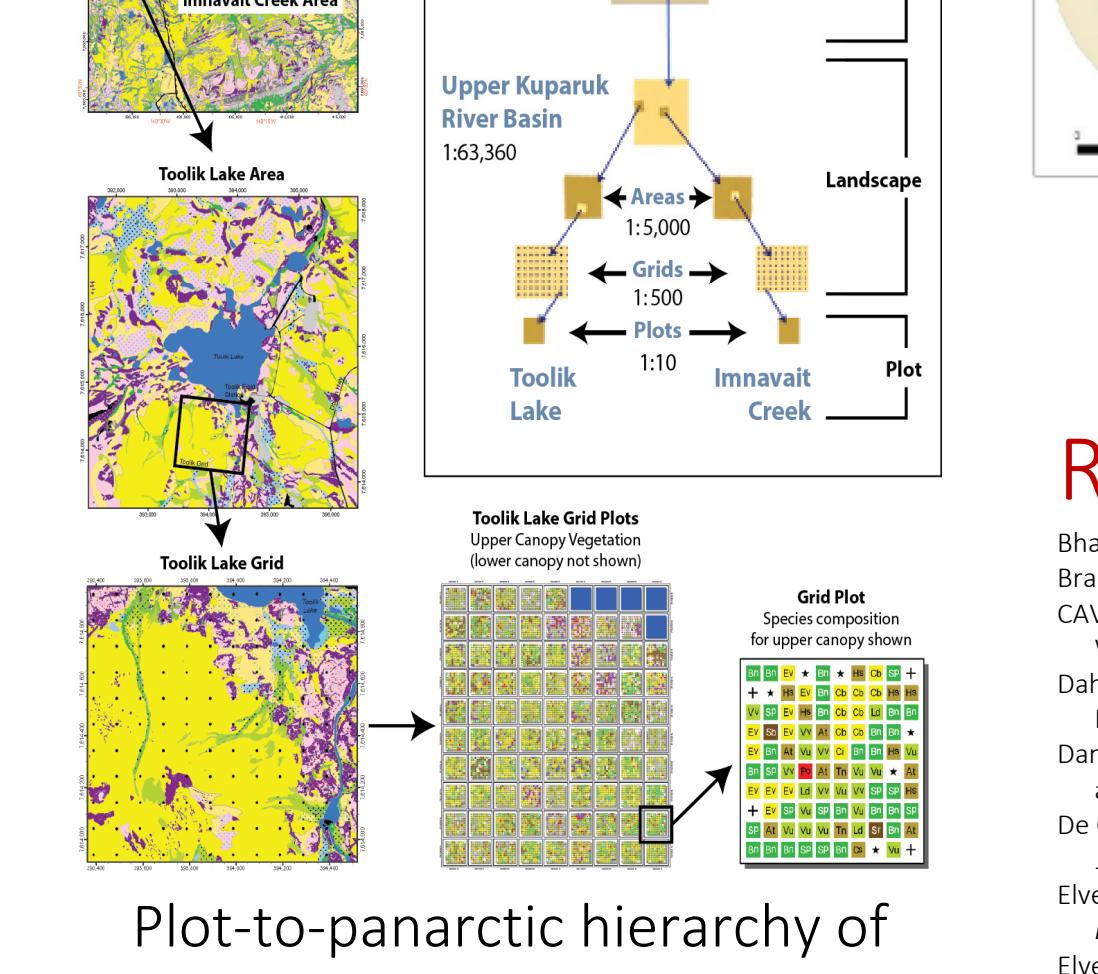


Waker et al. (2011, 2019)

### Classification

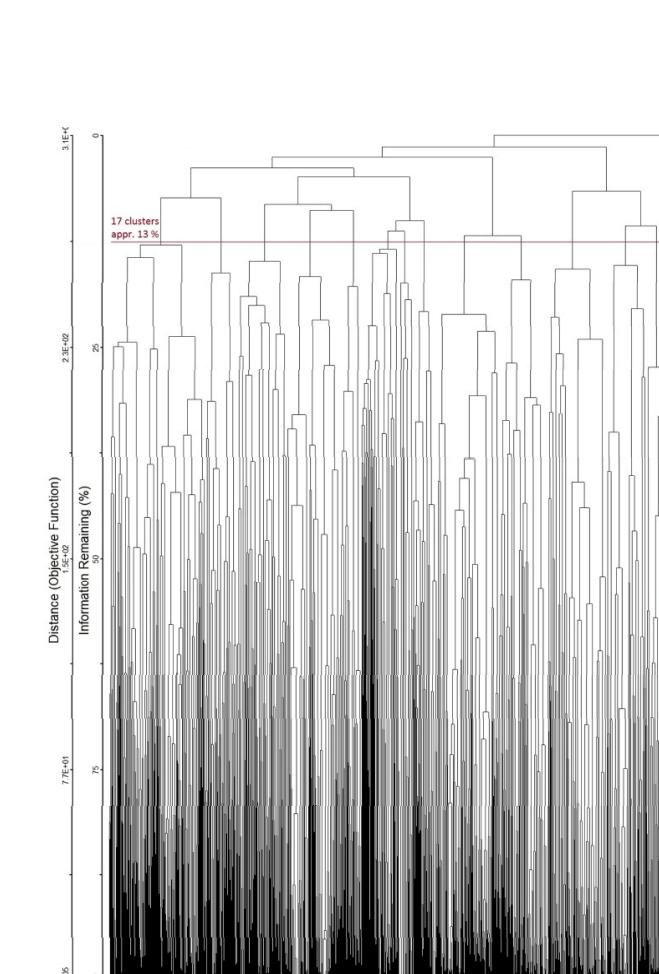


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

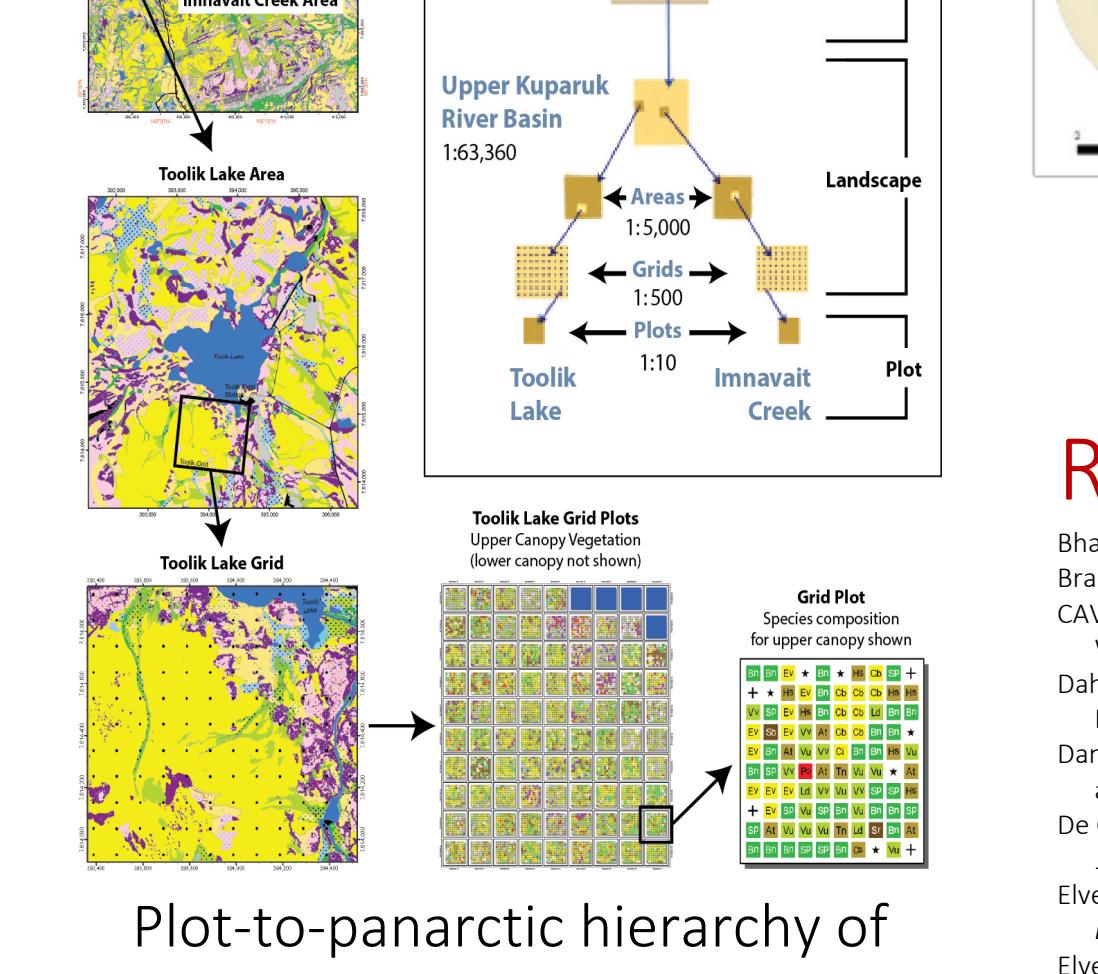


Waker et al. (2011, 2019)

### Classification

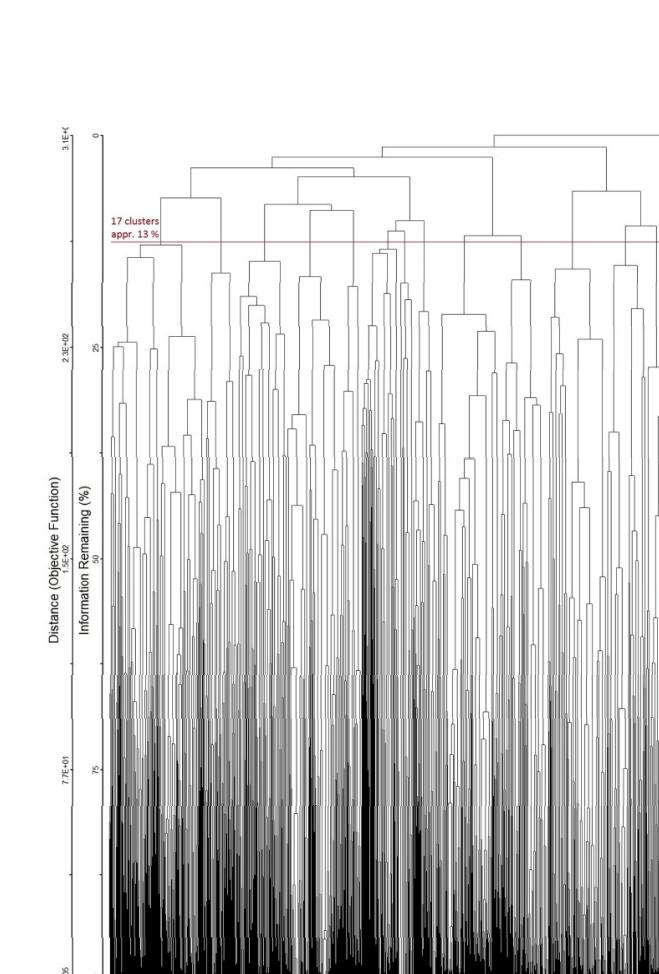


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

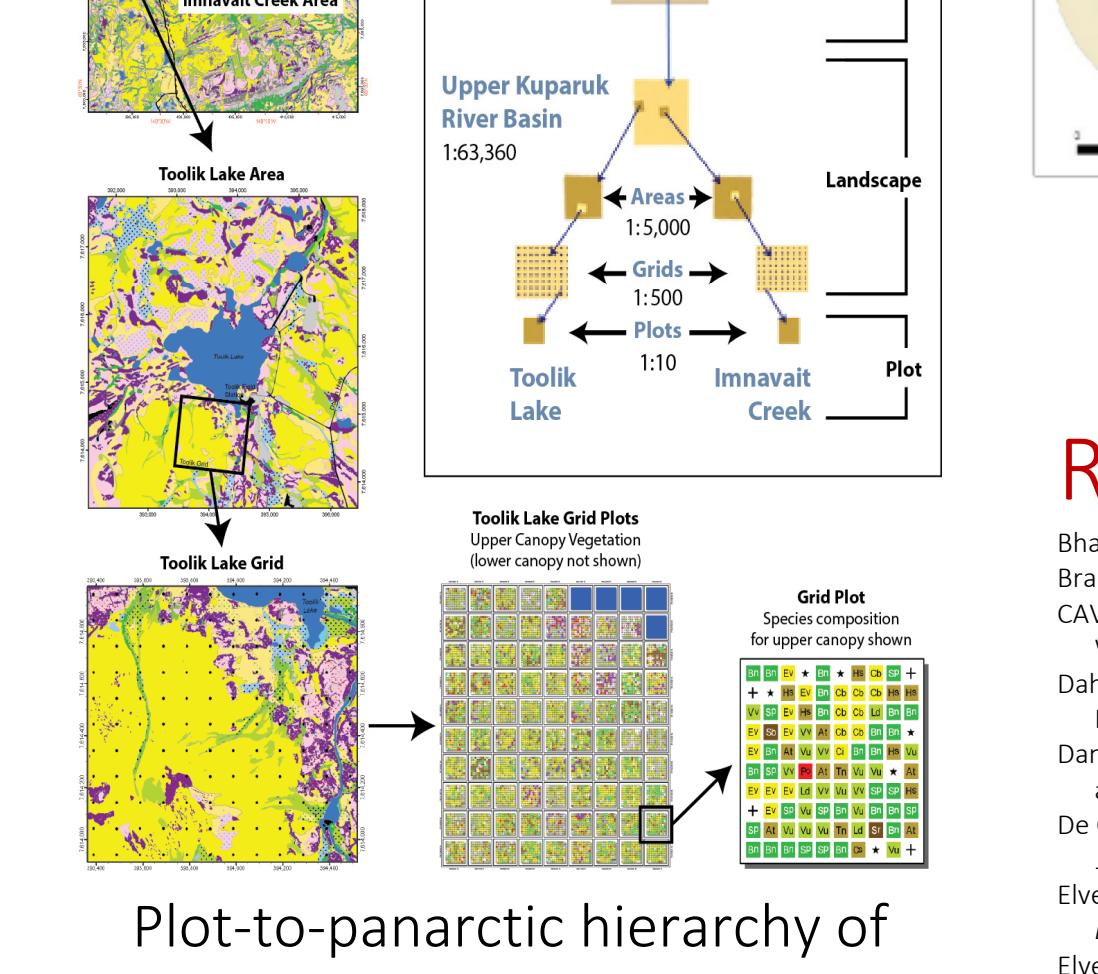


Waker et al. (2011, 2019)

### Classification

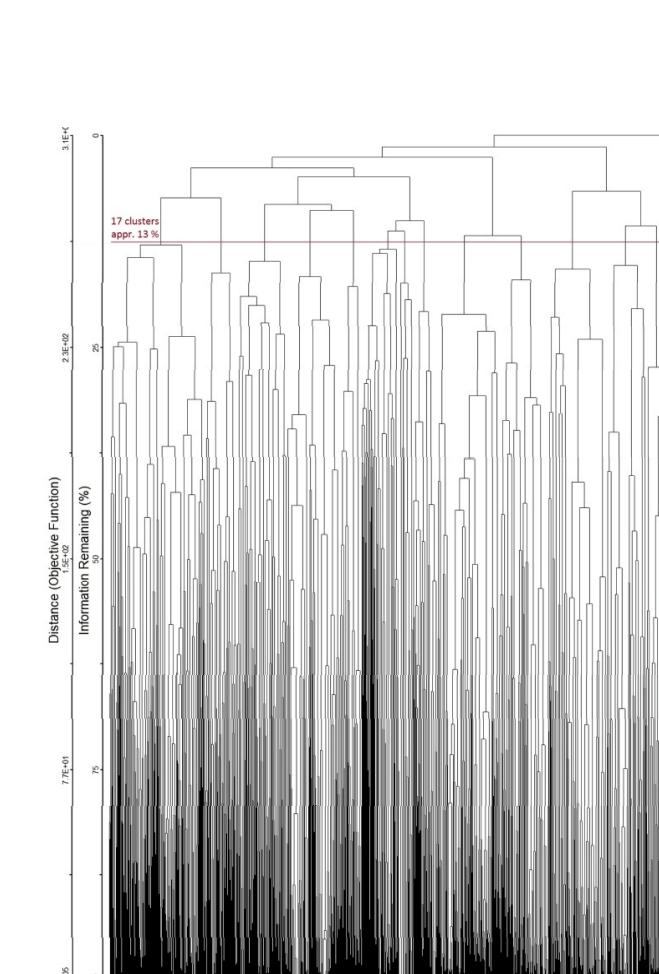


Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>

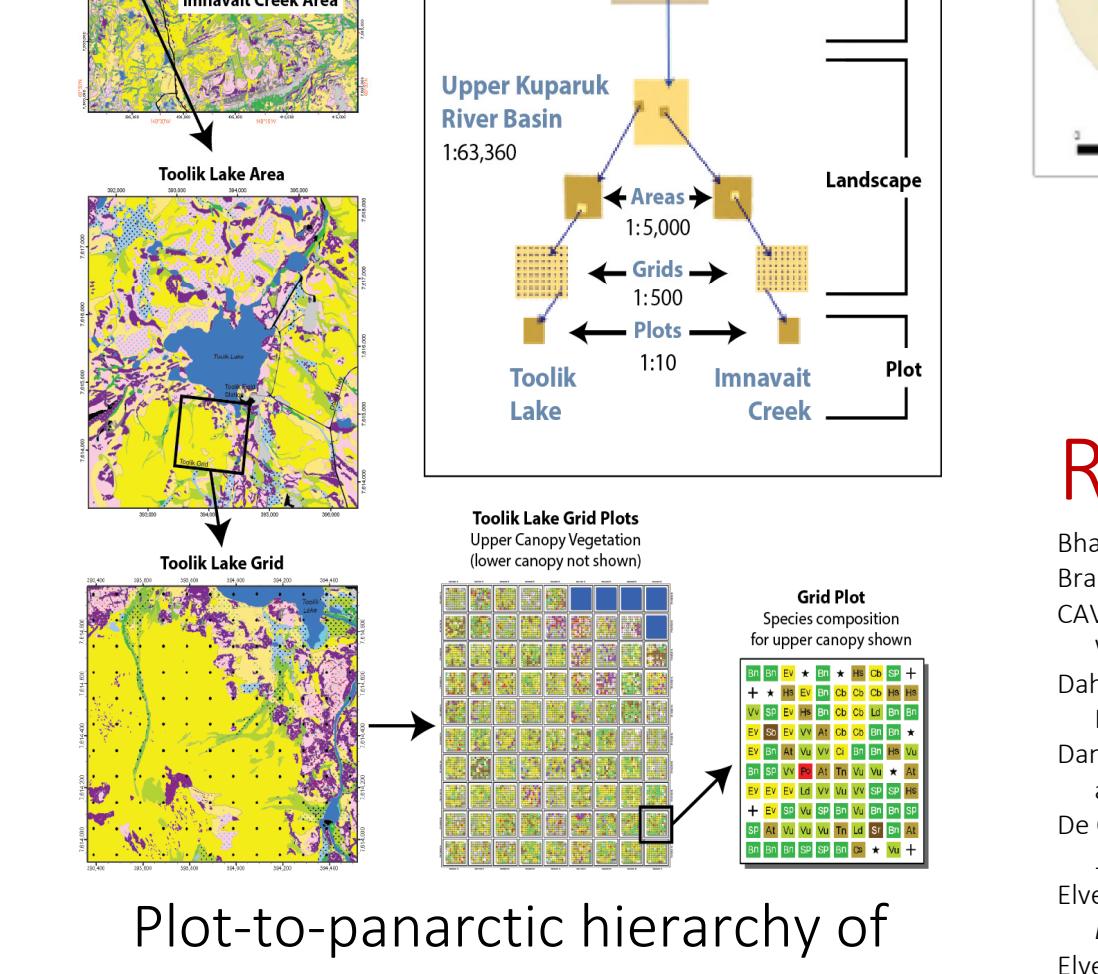


Waker et al. (2011, 2019)

### Classification



Information as of 2016-17-05; further details and future updates available from <http://www.givd.info/ID/NA-014>



Waker et al. (2011, 2019)

### Classification</h3