Remotely sensed vegetation dynamics along Sky Island woody plant gradients: barometers of climate change and variability

Jennifer E. Davison[1,2], Willem J. D. van Leeuwen[1,3], David D. Breshears[2,4,5]
[1]Office of Arid Lands Studies, [2]School of Natural Resources, [3]Department of Geography and Regional Development, [4]Institute for the Study of Planet Earth, [5]Department of Ecology and Evolutionary Biology
University of Arizona, Tucson Arizona
davisonj@email.arizona.edu

The University of Arizona. School of Natural Resources. College of Agriculture and Life Sciences
USDA United States Department of Agriculture
Cooperative State Research, Education, and Extension Service
Office of Arid Lands Studies
Arizona Remote Sensing Center

Background:

- Landscape-scale phenology employs remote sensing to track the growth cycles and productivity of ecosystems' dominant plants.
- The dominant, often woody plants of a community moderate ecosystem structure, functions, and habitat potential.
- Woody plant cover increases with elevation along Sky Islands, prominent features in the Southwest. These biodiverse, ecotone-dense gradients are highly sensitive to environmental change.

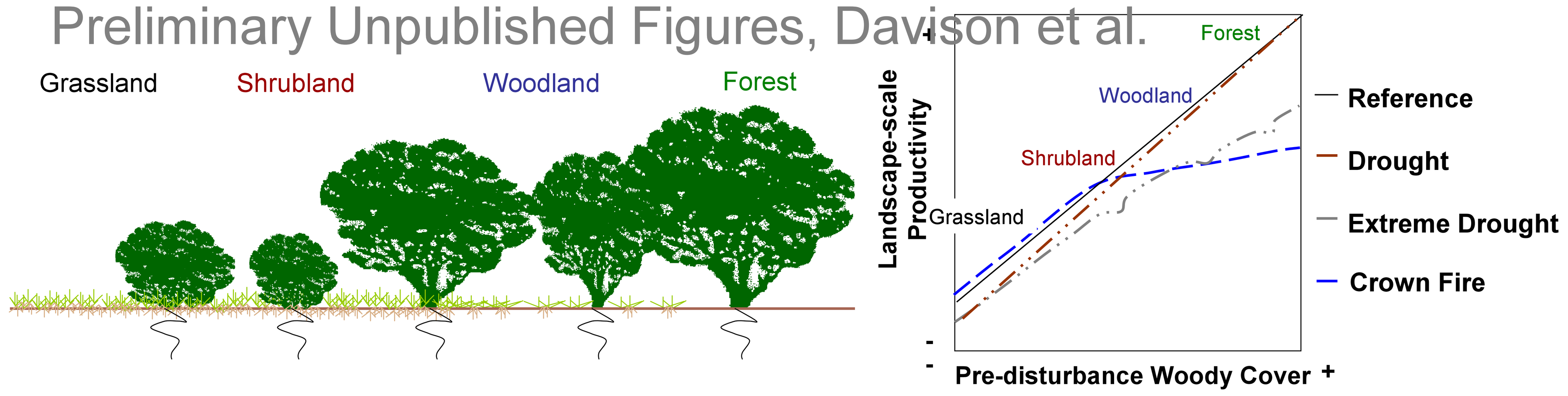
Knowledge Gap:

- Although elevation gradients are often studied for their responses to climate and other disturbances, woody plant cover as an indicator of ecosystem function is only implicitly considered in patterns of bioclimatic interactions, despite its being a key characteristic of such gradients.

Objectives

- Relate **spatial patterns** of landscape-scale vegetation phenology and productivity to woody plant cover and other environmental parameters, across a Sky Island elevation gradient
- Evaluate **temporal variation** in vegetation dynamics with relation to climate variation
- Examine **trends** in vegetation dynamics and climate from 2001 through 2007 for insights into how climate change might affect Sky Island vegetation communities

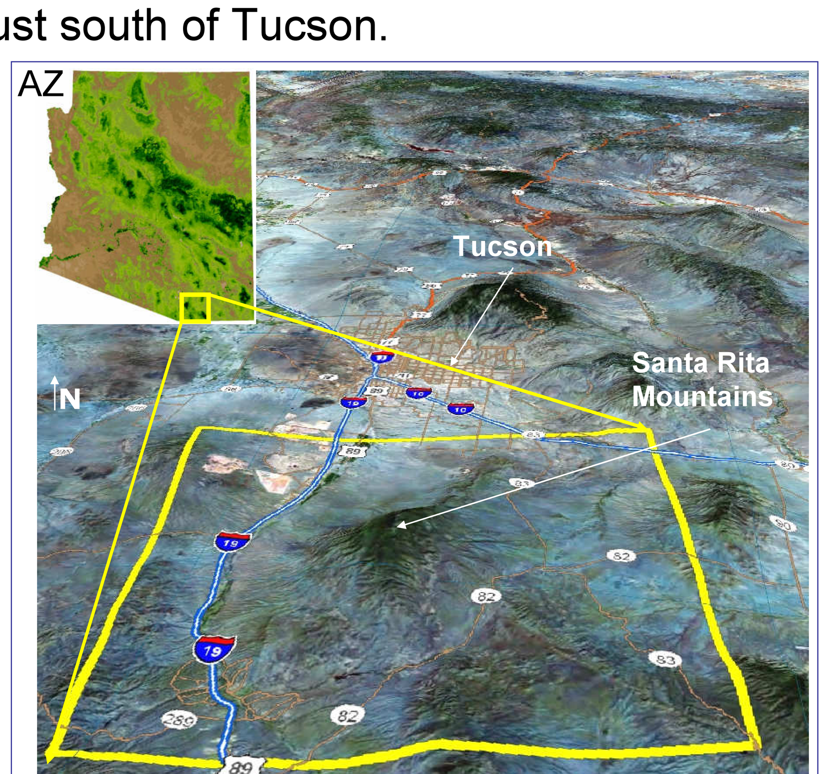
Preliminary Unpublished Figures, Davison et al.

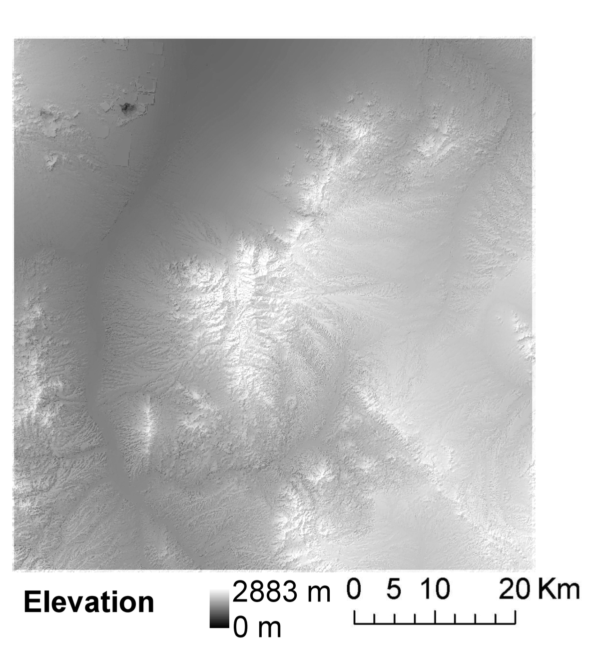


Most vegetation communities can be seen as existing along a continuum of woody plant cover. With deeper roots, long-lived plant structures and greater productivity, woody plants modify their environment in general and predictable ways. Examination of landscape-scale vegetation dynamics with respect to woody plant cover might provide insights into ecosystems worldwide and how they interact with disturbance events such as fire and drought.

Study Area:

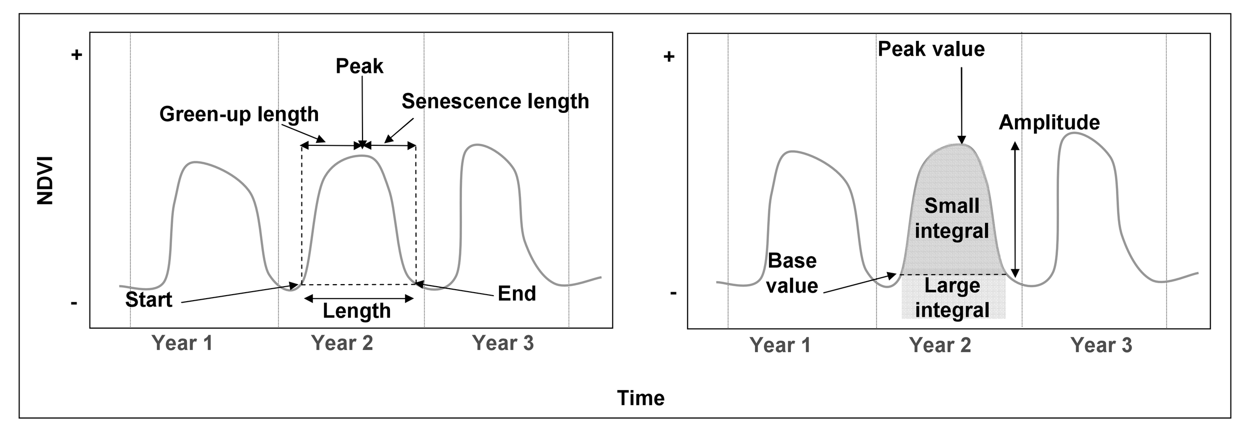
- A 4,400 km^2 area encompassing the Santa Rita Mountains, a Sky Island just south of Tucson.

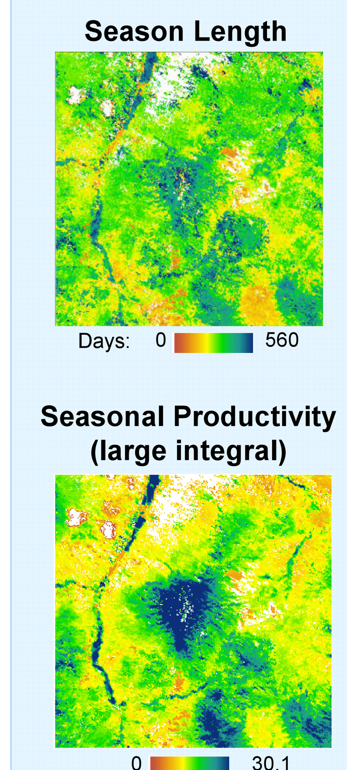




Data Used:

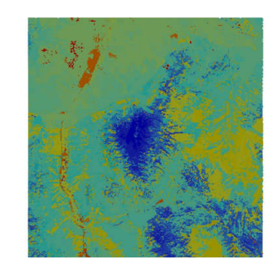
- **Response variables** were derived from MODIS (Moderate Resolution Imaging Spectroradiometer) NDVI:
  - 250 m spatial resolution
  - 16-day temporal resolution (23 periods per year)
  - 2000-2008
- TIMESAT time-series analysis software was used to derive phenological metrics from NDVI data for seasons 2001-2007:



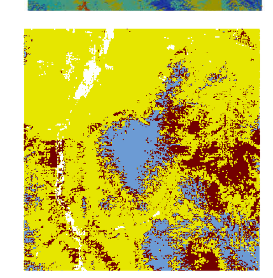


These metrics from 2003 show spatial patterns similar to the elevation of the Sky Island

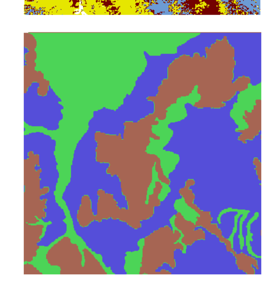
- **Explanatory variables**:
  - Percent woody plant cover



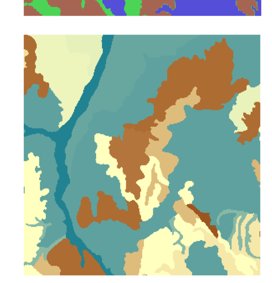
  - Plant functional type
    - Trees, shrubs, herbaceous



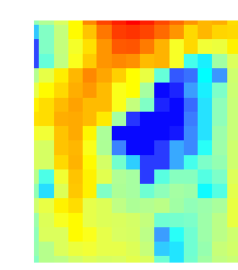
  - Soil hydrologic group
    - a categorical variable describing soil texture and depth



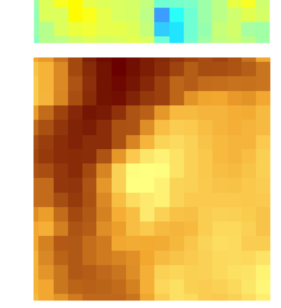
  - Plant available water



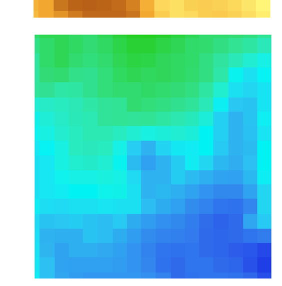
  - Precipitation
    - Annual
    - Winter
    - Summer



  - Maximum temperature
    - Annual
    - Summer



  - Minimum temperature
    - Annual
    - Winter
    - February



Statistical Analysis:

- **Spatial analysis**:
  - Mean values of climate and vegetation dynamics data were used to assess spatial patterns
  - Recursive partitioning was applied to assess which environmental parameters accounted for the most variation across space for each metric of vegetation dynamics
- **Temporal analysis**:
  - Results of the spatial analysis were used to account for spatial patterns in a step-wise multiple regression framework
  - A subset of data were analyzed that represented vegetation dynamics and climate from 2001 through 2007
- **Trend analysis**:
  - For each climate and vegetation dynamics metric the data were regressed over the temporal extent of the study, and the slopes that were shown to be significant were analyzed

Related Literature:

Beckage, B., Osborne, B., Gavin, D. G., Pucko, C., Siccama, T. & Perkins, T. (2008) A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. *Proceedings of the National Academy of Sciences of the United States of America*, **105**, 4197-4202.

Breshears, D. D. (2006) The grassland-forest continuum: trends in ecosystem properties for woody plant mosaics? *Frontiers in Ecology and the Environment*, **4**, 96-104.

Jönsson, P. & Eklundh, L. (2004) TIMESAT - a program for analyzing time-series of satellite sensor data. *Computers & Geosciences*, **30**, 833-845.

Results:

- Spatial variation:
  - Each metric showed a unique relationship to the environment
  - Woody plant cover and functional type were important in many metrics:
  - Productivity metrics were more strongly related to the environmental parameters in the model than were phenology metrics

Metric	X_1	X_2	X_3	X_4	R^2
Season start	Functional Type	Plant avail. H_20 (-)	Annual max T (-)	Annual min T (+)	0.185
Green-up length	Woody cover (+)	Functional Type	Plant avail. H_20 (+)	Annual max T (-)	0.109
Senescence length	Functional Type	Plant avail. H_20 (+)	Annual min T (+)	Summer max T (-)	0.319
Season length	Functional Type	Plant avail. H_20 (-)	Woody cover (+)	Annual min T (+)	0.304
Base NDVI	Functional Type	Woody cover (+)	Plant avail. H_20 (+)	Summer max T (-)	0.614
Peak NDVI	Summer max T (-)	Summer ppt (+)	Functional Type	Plant avail. H_2O (+)	0.495
Season amplitude	Annual min T (-)	Annual ppt (+)	Summer ppt (+)	Summer max T (-)	0.395
Season dynamics	Summer max T (-)	Woody cover (+)	Functional Type	Annual min T (+)	0.417
Season productivity	Functional Type	Woody cover (+)	Annual ppt (+)	Plant avail. H_20 (-)	0.581

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- Temporal variation:
  - Minimum temperature and precipitation explained variation in most metrics:
  - Productivity metrics were more strongly explained than phenology metrics

Metric	β_1	β_2	β_3	β_4	$AdjR^2$
Season start	Feb. min. T (+)	Winter min. T (-)	Winter ppt (-)		0.160
Greenup length	Summer ppt (+)				0.047
Senescence length	Annual ppt (+)	Summer ppt (+)			0.128
Season length	Annual ppt (+)	Summer ppt (-)	Annual min. T (-)		0.202
Base NDVI	Annual ppt (+)	Winter ppt (+)	Winter min. T (-)		0.604
Peak NDVI	Summer ppt (+)	Summer max. T (-)	Woody cover (+)		0.462
Season amplitude	Summer max. T (-)	Functional type	Summer ppt (+)	Annual min. T (+)	0.418
Season dynamics	Annual ppt (+)	Summer max. T (-)	Feb. min. T (+)		0.349
Season productivity	Annual ppt (+)	Feb. min. T (-)			0.450

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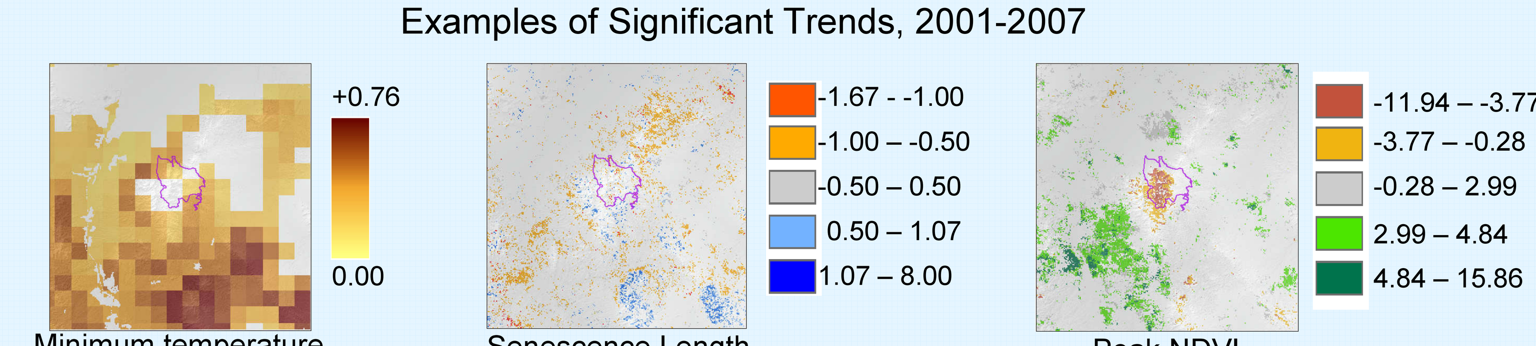
- Trends in vegetation and climate:
  - Trends in vegetation dynamics from 2001 to 2007 showed unique spatial patterns along the Sky Island gradient
  - The study site also showed an increase in minimum temperature

Examples of Significant Trends, 2001-2007



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*the pink polygon represents the Florida Fire of 2005

Conclusions:

- Our results identify some key phenological dynamics in Sky Islands for which the spatiotemporal patterns may be pertinent to other gradients and landscapes.
- Importantly, explicitly considering the type and abundance of woody plants aided in modeling these patterns.
- The patterns documented – and the underlying role of woody plant cover – offers promise for developing a more comprehensive remote-sensing approach to using Sky Islands as barometers of change.