Topo-edaphic Constraints on Woody Plant Cover Change in a Semi-Arid Grassland

Scott Jones[1,2] and Steve Archer[1,3]

[1]University of Arizona, [2]Arid Lands Resource Sciences, [3]School of Natural Resources and the Environment

Contact: scottajones@email.arizona.edu

THE UNIVERSITY OF ARIZONA.
Graduate Interdisciplinary Program in Arid Lands Resource Sciences

COLLEGE OF AGRICULTURE & LIFE SCIENCES
School of Natural Resources & the Environment

Introduction

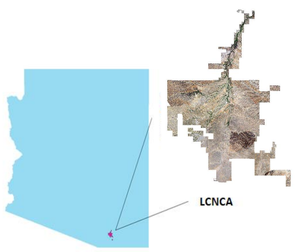
- The proliferation of woody plants in grassland has occurred globally over the past century.
- This vegetation change impacts ecosystem function and the provision of a variety of ecosystem services. [1]
- Drivers of the encroachment process are varied, complex and subject to constraints related to soils and topography, but are not fully understood.
- Accordingly, spatial-temporal dynamics of the encroachment process are difficult to predict.
- The 'carrying capacity' (maximum potential shrub cover) of topoedaphic units within a climate zone are not known.
- Knowledge of 'shrub carrying capacity' and rates, dynamics and patterns of the shrub encroachment process across topo-edaphically diverse landscapes could be used by managers to:
  - Identify areas most at-risk for vegetation change
  - Prioritize when and where to employ brush management to achieve desired conservation objectives. [2]

Figure 1. Repeat photography (1937, 1951. 2018) showing velvet mesquite encroachment at the Santa Rita Experimental Site ~ 13 km from the LCNCA study site (SRER Repeat Photography Archive, Station 127).

Study Site

Las Cienegas National Conservation Area (LCNCA), Southern Arizona

- ~18,200 ha (~45,000 acres) of State and Federal (BLM) lands
- Supports five of rarest habitat types in the American Southwest
- Managed as "working landscapes"
- Active brush management program



Objectives

- Quantify rates/patterns of shrub cover change from 1936 to 2017 across LCNCA.
- Assess the rate and extent of shrub cover change on ecosites within the LCNCA.
- Analyze the influence of topoedaphic variables (elevation, slope inclination, soil texture, soil moisture and slope aspect) on the rates of shrub encroachment

References

1. Archer, S.R., Predick, K.I. 2014. An ecosystem services perspective on brush management: research priorities for competing land-use objectives.
2. Ansley, R.J., Wu, X.B., Kamp, B.A. 2001. Observations: long term increases in mesquite canopy cover in North Texas savanna. Journal of Range Management 54: 171-176
3. Koenker, R., P. Ng, and S. Portnoy. 1994. Quantile smoothing splines. Biometrika 81:673–680.
4. Wu, X. B., and S. R. Archer (2005), Scale-dependent influence of topography-based hydrologic features on vegetation patterns in savanna landscapes, Landscape Ecol., 20, 733– 742.
5. Naito AT, Cairns D. 2011. Relationships between arctic shrub dynamics and topographically-derived hydrologic characteristics. Environ Res Lett 6(4):045506.

WESTERN SARE Sustainable Agriculture Research & Education

Results

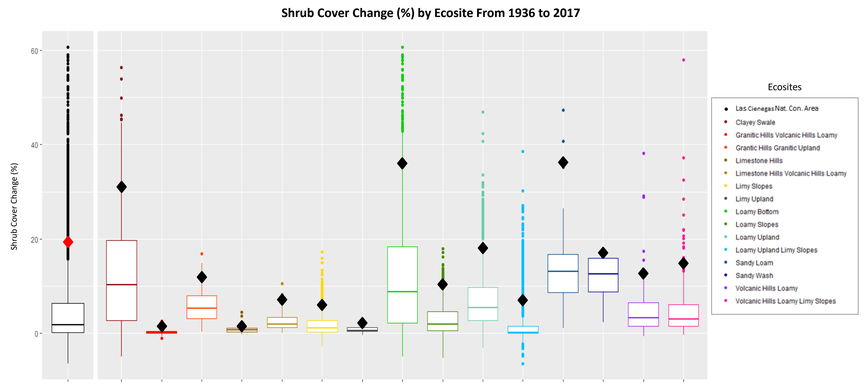


Figure 2: Box and whisker plots of shrub cover change (%) by ecosite. The center, bottom, and top of boxes denote median, 25th- and 75th-percentiles; diamonds are the 95th percentile. The 95th percentile shrub cover for the entire study site was 20% but ranged from 2% on limestone hills ecosites to 37% loamy bottoms ecosites.

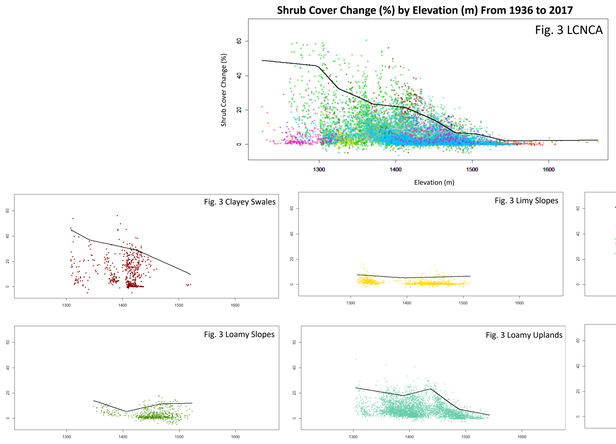


Figure 3: Shrub cover change (%) vs. elevation (m) on selected ecosites. Data points color coded by ecosites (see Fig. 2 key). Black line denotes 95th quantile regression line and maximum shrub cover change. Highest potential shrub cover change occurred at lower elevations and steadily declined as elevation increased. Near 1530 m shrub cover change was ~ 0%.

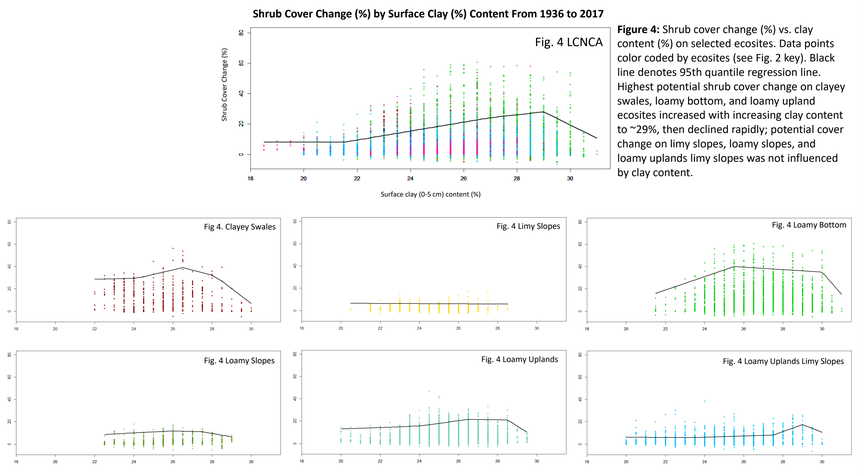


Figure 4: Shrub cover change (%) vs. clay content (%) on selected ecosites. Data points color coded by ecosites (see Fig. 2 key). Black line denotes 95th quantile regression line. Highest potential shrub cover change on clayey swales, loamy bottom, and loamy upland ecosites increased with increasing clay content to ~29%, then declined rapidly; potential cover change on limy slopes, loamy slopes, and loamy uplands limy slopes was not influenced by clay content.

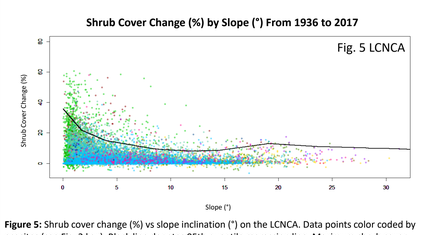


Figure 5: Shrub cover change (%) vs slope inclination (°) on the LCNCA. Data points color coded by ecosites (see Fig. 2 key). Black line denotes 95th quantile regression line. Maximum shrub cover change decreased as slope inclination increased to 5°, then levelled out.

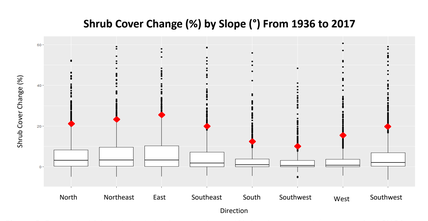


Figure 6: Box and whisker plots of shrub cover change (%) by slope aspect for the entire LCNCA. Center, bottom, and top of boxes denote the median, the 25th- and the 75th-percentile; diamonds the 95th percentile. Potential shrub cover change ranged from 10% (Southwest facing slopes) to 25% (East facing). Five of the six major ecosites followed this pattern; clayey swales exhibited no relationship between maximum shrub cover change and aspect (data not shown).

Methods

Classification of shrub cover change from 1936-2017:

- Aerial imagery (B&W) from 1936, 1975, and 2017 (1:24,000) were georeferenced and resampled to a common resolution of 1-m 2.
- Iterative self-organizing (ISO) unsupervised classification in ArcGIS was used to quantify shrub cover.
- Accuracy assessment was ≥ 80%.

Shrub cover change variation on ecosites

- Spatially explicit shrub cover change between 1936 and 2017 was assessed for 1-ha grid cells.
- Ecosite maps were obtained from the Natural Resource Conservation Service (NRCS).
- Mean and the 95th percentile of shrub cover change was calculated for each ecosite and for the entire LCNCA.
- Cells in riparian corridors and on sites receiving past brush management were excluded from change analysis.
- Mean and the 95th percentile of shrub cover change was calculated for each ecosite and for the entire LCNCA.

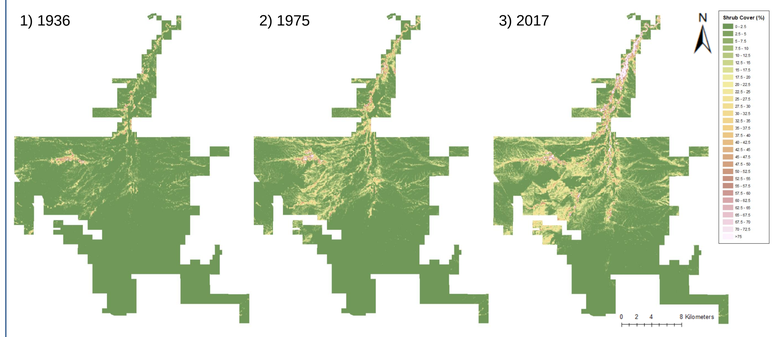


Figure 7. Shrub cover (%) on the ~18,200 ha (45,000 acre) LCNCA site..

Shrub over change variation by topoedaphic variables

- Cell-specific variables quantified included: elevation, slope inclination, slope aspect, surface clay content, and a topographic wetness index (proxy for soil moisture).
- Upper (95th percentile) boundaries for cover or cover change across the LCNCA and on the six largest ecosites were defined using additive, non-parametric quantile regression. [3] These boundaries are taken to represent the maximum potential shrub cover and shrub cover change.

Discussion/Next Steps

Discussion:

- LCNCA has undergone shrub encroachment but rates varied substantially by ecosite.
- Topoedaphic variables influencing cover change potential varied by ecosite.
- Contrary to expectations [4,5], the topographic wetness index did not appear to influence shrub cover change potential (data not shown).

Next Steps:

- Account for interactions between topoedaphic variables (e.g. slope inclination x aspect)
- Expand analyses on clay content effects to include greater depths.
- Assess effects of 'depth to restrictive barriers" (e.g. caliche, bedrock, argillic horizons)
- Quantify rate and extent of shrub re-establishment on ecosites receiving brush management.

Acknowledgements

This project was supported, in part, by the Western Sustainable Agriculture Research and Education (SARE) (GW17-024) and USDA-NIFA Agroecosystems (2015-67019-23314) programs. We thank Kyle Hartfield for guidance with GIS and spatial analysis, and Austin Rutherford and Katie Predick for assistance with statistical analysis.