Landscape-Level Impacts of Mesquite Canopy Cover on Herbaceous Species Composition

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Key words: *Prosopis*, woody encroachment, mesquite, savanna

Abstract

Woody encroachment of mesquite (*Prosopis)* and acacia (*Acacia)* species into grasslands has widespread and ongoing impacts on grassland ecosystems. Changes in the herbaceous layer are associated with changes in the canopy cover of these sparse-canopied species, which do not exclude the herbaceous component, but often change species composition under the canopy relative to surrounding open areas. These effects are often differential based on productivity of the site and herbaceous species composition of the grassland. Here we investigated landscape-scale changes in the herbaceous composition resulting from changes in canopy cover of honey mesquite (*Prosopis glandulosa*) within woody-encroached areas of Texas, U.S.A. Mesquite canopy percent changes were determined from aerial photographs and related to field-based measurements of the herbaceous component. We then related our findings to similar studies in the literature within different environments to assess similarities and differences among the impacts on the herbaceous component across a range of conditions. We utilized herbaceous layer functional groups to make these comparisons across different sites. Finally, we evaluated these changes in herbaceous composition to rates of woody encroachment to assess temporal changes across the landscape and possible impacts from restoration. We found that changes in the herbaceous layer were dependent on length of time of woody encroachment, percent woody cover, and site productivity.

Introduction

Semi-arid grassland ecosystems worldwide have been encroached by woody legumes in the *Prosopis* and *Acacia* genera (Ansley et al. 2001; Sankaran et al. 2005). These sparse-canopied trees change the sub-canopy herbaceous composition and production of rangelands (Scholes and Archer 1997). Mesquite (*Prosopis*) and *Acacia* species are nitrogen-fixing, semi-arid leguminous trees and shrubs with thin, bipinnately compound leaves, deep tap roots, and shallow lateral roots. At low levels of woody canopy cover, herbaceous diversity and production may increase in an area; however, as canopy cover increases, herbaceous production and diversity often decreases (Archer 1990; Scholes 2003; Riginos et al. 2009). Changes in herbaceous diversity and production associated with woody cover are likely related to several factors including sub-canopy light limitation, soil fertility, and water status (Belsky et al. 1989).

In mesquite (*Prosopis glandulosa*) encroached areas of the Southern Great Plains of North America, herbaceous transition occurs rapidly as percent canopy cover increases across the range of 25 - 40% (Ansley et al. 2004; Ansley et al. 2013). Decreases in herbaceous production are often due to increases in C_3 grass relative to C_4 perennial grass cover (Ansley and Castellano 2006; Teague et al. 2008). Archer (1990) also conceptualized a threshold where areas rapidly transition from herbaceous-driven succession to woody species-driven succession as mesquite canopy increases, with a resulting decrease in herbaceous production. These woody-encroached grasslands and savannas are 'unstable' systems where disturbances (fire, herbivory, mechanical, or chemical treatment) are required to prevent canopy closure (Sankaran et al. 2005).

In this study we used aerial photographs (drone images) from mesquite-encroached areas to determine individual mesquite canopies, overall percent canopy cover, and location of C_3 cool-season grasses (CSG) & C_4 warm-season grasses (WSG) relative to mesquite canopies. We compared these to ground-based measurements of mesquite canopy area and herbaceous percent cover of CSG and WSG functional groups relative to mesquite canopies.

Methods and Study Site

Three areas in north-central Texas, USA were chosen based on a range of mesquite cover (15 - 50%) and the presence of CSG and WSG. Mean annual precipitation for the region is 850 mm, with highest precipitation occurring in the spring and fall. The soils are clay loams. At each site, we used a drone (DJI 4 Pro) to take aerial photographs from a height of 92 m. Aerial data was collected during the dormant season to differentiate the below-canopy herbaceous layer into live CSG and dormant WSG. Using Arc GIS 14.0, we determined individual georeferenced canopy areas, percent mesquite canopy cover, and percent cover and location of CSG and WSG relative to mesquite canopies. We used a supervised maximum likelihood method to classify CSG and WSG. Aerial images collected during the growing season, when mesquites had live foliage, were used to create circular canopy shapefiles to verify mesquite canopy locations in the classified images from the dormant season.

Ground-based measurements included mesquite canopy area and herbaceous percent cover based on the line-intercept method. Using individual mesquite trees as the center, line-intercept transects were run in random directions from the main stem in lengths that were double the canopy radius to include sub-canopy areas beneath mesquite trees and inter-canopy areas between trees. This allowed us to compare CSG and WSG coverage between sub-canopy and inter-canopy microsites. Grasses were documented to the species level and then converted to CSG and WSG functional groups to standardize results for comparisons across different sites with different species.

For analysis, we split the study sites into areas with mesquite canopy cover < 20 % (solitary trees) and areas > 40% (aggregated trees). For classified images, we used linear regression to assess the relationship between imaged-based and field-based herbaceous measurements. For line-intercept data, we used linear regression to compare relationships between mesquite canopy area and percent coverage of CSG and WSG functional groups. Sub-canopy and inter-canopy data were compared separately.

Results

Linear regression of sub-canopy cover of CSG and WSG in classified drone images versus field-based measurements indicated favourable agreement (r^2 = 0.7). Field-based measurements made in areas with < 20% mesquite cover indicated positive (r^2 = 0.8) and negative-sloping (r^2 = 0.7) log normal linear relationships for sub-canopy percent cover of CSG and WSG, respectively, with canopy area of individual mesquite trees (Fig 1). The proportion of CSG relative to WSG increased rapidly when tree canopy areas transitioned from approximately 10 m^2 (20% CSG and 60% WSG) to 40 m^2 (60% CSG and WSG 20%) per tree. Inter-canopy CSG and WSG coverage averaged 7% and 80%, respectively.

From field measurements made in areas > 40% mesquite cover, we determined no relationship between individual tree canopy area and sub-canopy CSG coverage (r^2 = .03). Regardless of individual mesquite canopy size, CSG comprised a high percentage of both the sub-canopy (88%) and inter-canopy (83%) microsites.

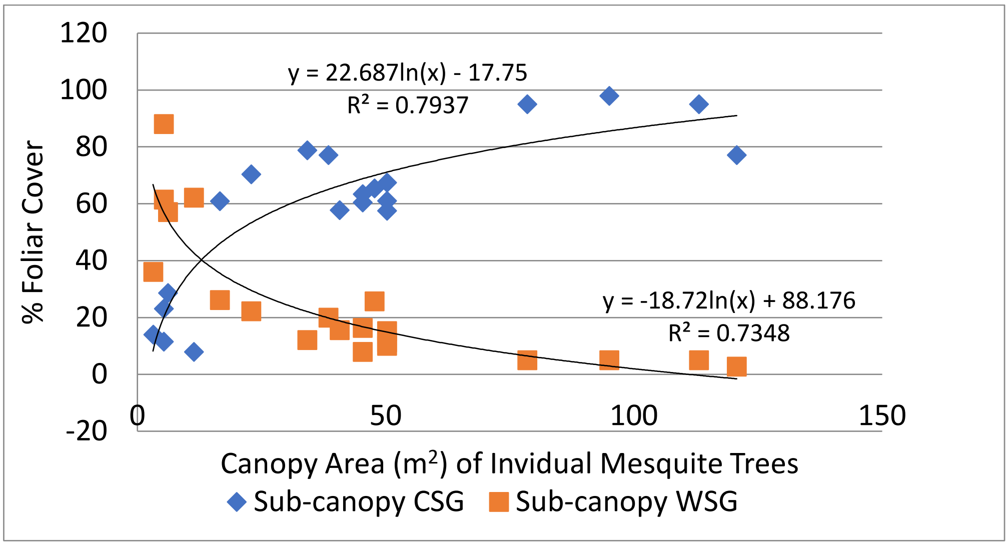

Figure 1. Percent cover of cool-season (CSG) and warm-season grasses (WSG) in the sub-canopy herbaceous layer relative to canopy areas of individual mesquite trees.

Discussion

Based on aerial photos and field measurements, mesquite trees aggregate on the landscape, in addition to occurring as solitary, randomly distributed trees. In sites where mesquite coverage was < 20%, trees were mostly solitary and randomly distributed. In areas where mesquite coverage was > 40%, trees were more aggregated on the landscape. Other studies have described woody encroachment as a progression from solitary trees to aggregates that eventually coalesce into woodlands, mediated by rainfall (Archer 1988). Ansley et al. (2001) found that mesquite cover increased on average 2.2 % per year in a moderately-productive clay loam site, with mesquite encroachment possibly becoming self-limiting at some point past > 60% canopy cover.

At the landscape scale, Ansley et al. (2013) found that in mesquite-encroached areas of North America, a threshold exists between 25 - 40% woody canopy cover where the herbaceous transition from WSG to CSG occurs rapidly. In this study, we determined that a transition from sub-canopy WSG to CSG occurs at the individual tree level based on size of tree (canopy area). This change occurs rapidly until the canopy area of individual trees reaches 40 - 50 m^2. The transition from sub-canopy WSG to CSG occurs more slowly after that point. This transition at the individual tree level drives change at the landscape scale, and along with tree aggregation, further speeds the transition to CSG. Our findings indicate that mesquite tree cover > 40% is closely aggregated, and there is not enough inter-canopy space to allow WSG to persist across the landscape.

These effects are often differential based on productivity of the site and species composition of the grassland. Our findings were from moderately-productive sites with adequate rainfall, where encroaching trees aggregate and greatly decrease native WSG to CSG ratios. This generally lowers total herbaceous production of the site, but may spread production across the year given increased CSG (Ansley et al.2004; Teague et al. 2008). In semi-arid, low-productivity sites where CSGs rarely occur, sparse-canopied leguminous trees may increase sub-canopy herbaceous productivity of WSG relative to open, inter-canopy areas through N-fixation and improved water status (Belsky et al. 1989; Kahi et al. 2009).

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