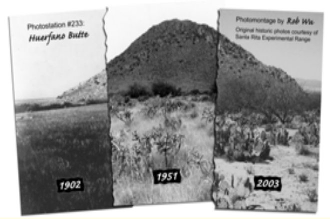

How much are we missing? Field validation of historic aerial photography

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Problem:

- Historic aerial photography is often used to derive base-line conditions for vegetation cover in studies quantifying land cover change.
- Spatially-explicit data of sufficient quality are rarely available to retrospectively validate estimates of vegetation cover and determine detection limits for early aerial photography.

Research Questions:

(1) What are detection limits of 1936 aerial photography (i.e., smallest reliably discernable canopy for dominant woody plant species, *Prosopis velutina*)?

(2) How much *P. velutina* biomass is missed using 1930s aerial photography?

(3) How well do estimates of shrub canopy area determined by manual digitizing 1930s aerial photos correspond to field measurements of canopy area?

Approach:

- Two - 1.8 ha (440-m X 40-m) plots were established on a desert grassland site at the Santa Rita Experimental Range in southeastern Arizona by W. McGinnies in 1932. The location and canopy dimensions for all *P. velutina* plants in each plot were recorded (Glendening 1952).

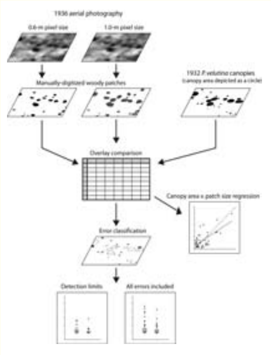

Fig. 1. Flow chart for image analysis and derivation of detection limits for 1936 B/W aerial photography resampled to 0.6-m and 1.0-m spatial resolutions using 1932 field measurements for *Prosopis velutina* on the Santa Rita Experimental Range.

- Plant locations from McGinnies' 1932 maps were digitized and incorporated into a GIS.
- Shrub canopies on February 1936 aerial photography (1:31,640) were digitized and matched with field measurements (Figs. 1 and 2). The effect of spatial resolution on detection limits was determined by re-scaling digital photos to 0.6-m and 1.0-m pixel sizes.
- *P. velutina* plants mapped in 1932 but not evident in 1936 aerial photos were tabulated and categorized as (1) missed (not discernable on photography), (2) not digitized (did not appear as a distinct shrub canopy based on pre-defined detection protocols), or (3) co-registration error (unable to confidently match the plant with associated digitized patch) (Fig. 3).
- An allometric relationship between mesquite canopy area and aboveground biomass (R^2 = 0.97, n= 32 trees) (Archer et al., *in prep*) was used to estimate woody biomass for each plant.
- Linear regression was used to quantify relationship between patch area delineated on 1936 photography with 1932 field measurements of canopy area (projected as a circle) at two spatial resolutions (0.6-m and 1.0-m) (Figs. 4 and 5) for patches that corresponded to a single *P. velutina* plant.

Results:

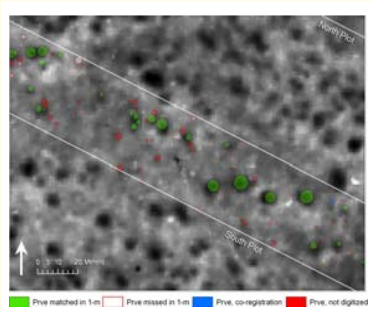

Fig. 2 Panchromatic 1936 aerial photograph of McGinnies plot. 1932 field measurements of velvet mesquite (*P. velutina*) canopy area are depicted as circles. Color designations represent correspondence with patches hand-digitized on the digital photography (with 1.0-m pixel size).

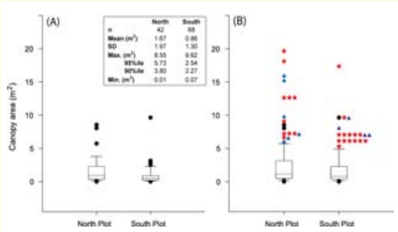

Fig.3. Detection limitations (A) and common errors (B) associated with manually digitized *Prosopis velutina* shrubs on 1936 aerial photography. Field-validation data consisted of an exhaustive survey of all *P. velutina* trees within two 1.8-ha plots in 1932. Criteria for defining a "shrub" included color, shape, and spatial context. Imagery was evaluated at two spatial resolutions (0.6 and 1.0-m pixel sizes). The same plants were missed at both spatial resolutions. Black dots depict plants not detected on the 1936 digital aerial photograph (A). Plants not apparent on aerial photographs are depicted with (★) ; plants not conforming to digitized shrub patches due to co-registration errors depicted with (▲) (B).

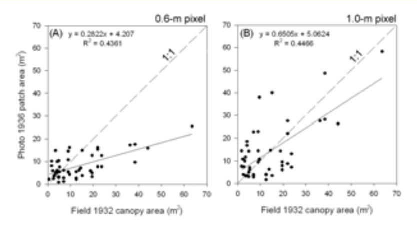

Fig. 4. Linear regression relating 1936 patch area from aerial photography at two spatial resolutions to 1932 field measurements of canopy diameter. Only patches corresponding to a single *P. velutina* plant were included. Cases where individual plant canopies could not be reliably distinguished due to their close proximity to other plants were excluded from this comparison.

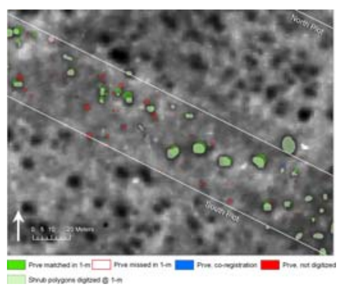

Fig. 5 Panchromatic aerial photograph of McGinnies plot on the SRER. 1932 field measurements of *P. velutina* canopy area depicted as circles. Color designations represent correspondence with patches digitized on the 1.0-m resolution image (overlaid green polygons).

1) Plants smaller than 4-m² not reliably detected with 1936 aerial photography.
2) Spatial resolution of processed imagery did not affect detection limits, but shrubs were perceived as being larger at the 1.0-m pixel size than at the 0.6-m pixel size. This is consistent with the findings of Fensham and Fairfax (2007) that canopies appear larger with larger photo scale.
3) 5.6% of aboveground woody biomass was missed using manually-delineated shrub cover estimates on 1936 photography (at both spatial resolutions) using 3.8-m² size threshold (Fig. 6).

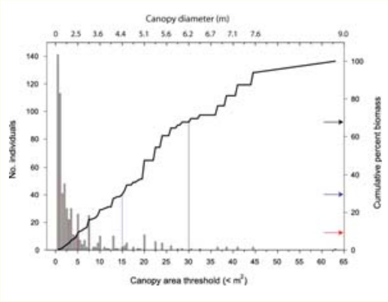

Fig.6 Cumulative percent *Prosopis velutina* biomass in relation to canopy area (m²) and counts of individual trees comprising biomass in 0.5-m² size classes. Biomass was derived using an allometric equation relating canopy area (1932 field measurements) to aboveground *P. velutina* mass. Dashed lines denote different canopy area thresholds and the corresponding fraction of woody biomass that would be missed (arrows).

Implications:

- 1936 aerial photography generated reliable, accurate estimates of woody plant cover in relation to 1932 field assessments.
- Detection limits far exceeded pixel size (i.e., 1-m²). Base-line conditions derived using 1930s aerial photography in this desert grassland system are limited by ~3.8-m² detection limitation.
- Although plants below detection limits comprised only a small fraction of the total biomass on the 1936 imagery, these are ostensibly the most dynamic constituents of the plant population and are important to projecting future stand dynamics and hence the biogeochemical consequences of woody plant encroachment (e.g., Wheeler et al. 2007). The quality and scale of aerial photography assessed in this study, which is fairly typical, cannot be used to inventory and monitor dynamics of these elements of a shrub population.
- It is not known how long it takes *P. velutina* plants to reach sizes that can be detected on aerial photographs. Estimates from a complimentary study suggest it may take 16 years for *P. veluntina* canopies to reach 4.0-m² in size (Browning et al. *In review*).

Acknowledgments:

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