A framework to Quantify the Contribution of Plant Functional Types to Semiarid Ecosystem Productivity

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1. Introduction

Motivation:

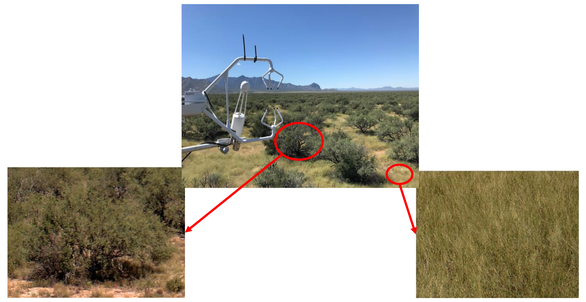
Flux tower measurements are representative of ~1 km patch-scale composite fluxes of an ecosystem, not its individual components (e.g., bare soil, grasses, trees). Understanding how this mixture of plant species' leaf phenology and functioning contribute to the flux tower footprint (area being measured by the tower at a given time) and Gross Primary Productivity (GPP) may provide better context to discover which plant types are active and when throughout the season.

Objective:

To quantify the effect that different plant leaf phenology may have on the monsoonal pattern of ecosystem GPP in a semiarid savanna and grassland.

Hypothesis:

1.



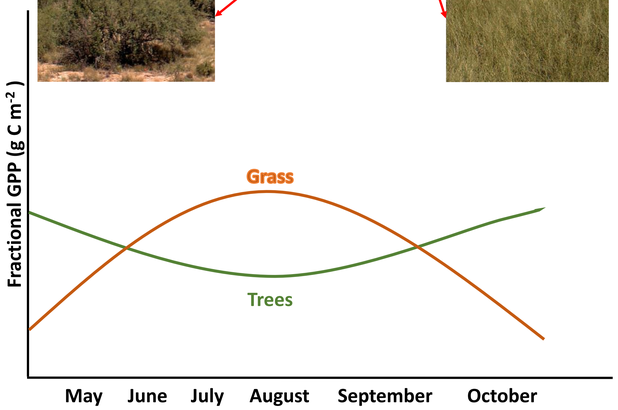


Figure 1. Predicted seasonality in the contribution of tree (*Prosopis velutina*, "velvet mesquite") and grass (*Aristida sp.*, "three awn" and *Digitaria californica,* "Arizona cottontop") GPP to total GPP.

2. Site Descriptions

	Santa Rita Mesquite Savanna (US-SRM)	Santa Rita Grassland (US-SRG)
Latitude, longitude (°)	31.8214, -110.8661	31.789379, -110.827675
Elevation (m)	1120	1291
Mean air temp. (°C)	17.92	17.00
Mean annual precip. (mm)	380	420
Mean annual GEP (g C m^{-2} $year^{-1}$)	323	433
Woody cover (%)	35	11
Perennial grass/forb cover (%)	15	44
Soil type	Deep loamy sands	Deep loamy sands
Phenology Plots	Grass (n = 30) Trees (n = 15)	Grass (n = 15) Trees (n = 15)

2. (**a**) Savanna (**b**) Grassland

Figure 2. Images depicting the vegetation type of the mesquite savanna (**a, US-SRM**) and grassland (**b, US-SRG**) sites.

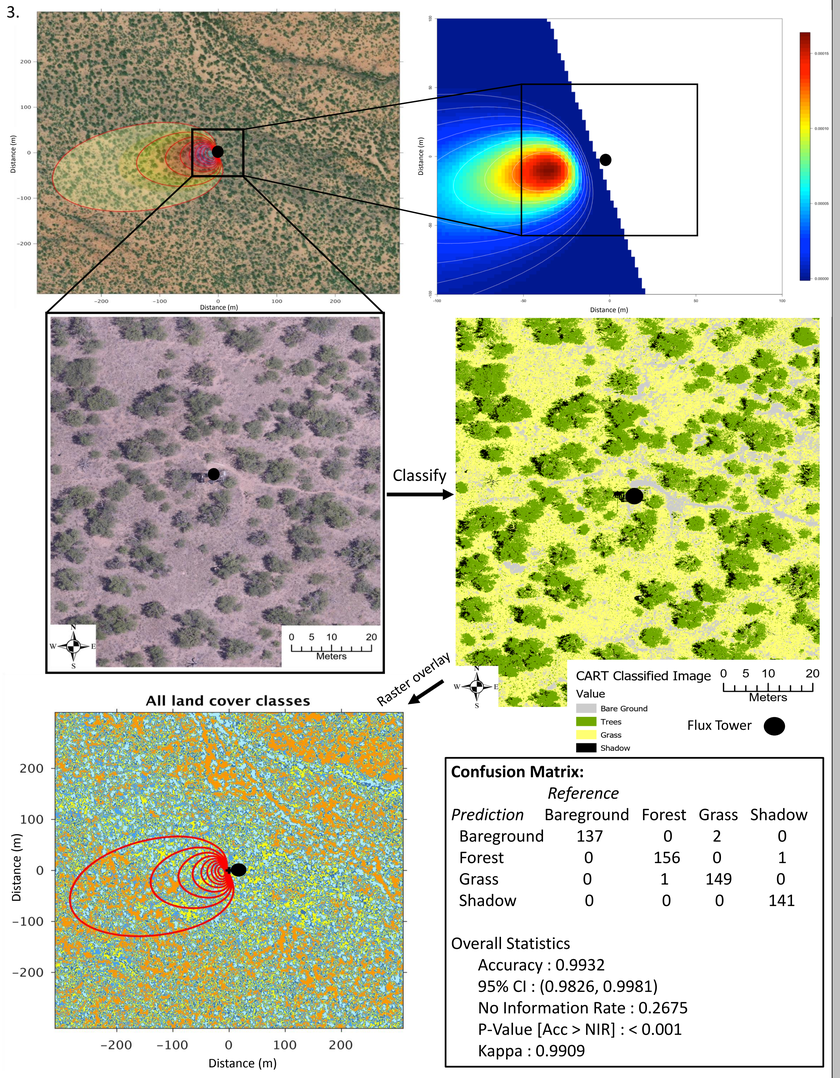
DGI Phantom 3 Quadcopter:
Flew at 40 m altitude, Nadir to get 1.76 cm resolution. A red, green, blue (RGB) Camera with 80% overlap and ~124 photos per site per trip was used to get Green Chromatic Chromatic (G_{cc}). G_{cc} is a calculated value from the RGB bands that is used to account for changes in scene illumination between flights. Drone processing was done in Agisoft Metashape Professional ver. 1.5.2.7838.

Eddy covariance:
Used to estimate gross primary productivity (*GPP*) via night-time partitioning of net ecosystem exchange and ecosystem respiration.

***In situ* phenology:**
Leaf phenology was collected using USA National Phenology Network vetted protocols. It was used to ground truth aerial phenology observations.

3. UAV Imagery and Footprint

3.



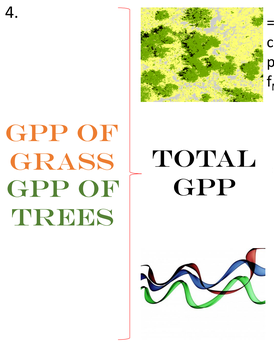
Confusion Matrix:

	Reference			
Prediction	Bareground	Forest	Grass	Shadow
Bareground	137	0	2	0
Forest	0	156	0	1
Grass	0	1	149	0
Shadow	0	0	0	141

Overall Statistics
Accuracy : 0.9932
95% CI : (0.9826, 0.9981)
No Information Rate : 0.2675
P-Value [Acc > NIR] : < 0.001
Kappa : 0.9909

Figure 3. The top two images show the flux tower footprint (FFP) from 0900 to 0930 on 6/8/2019 using Kljun *et al.,* 2015 methodology. Below, UAV Imagery (middle left) was taken June 8th, 2019 and a Classification and Regression Trees (CART) classification was completed (middle right). CART was done in R which generates the confusion matrix. The bottom picture is an idealized picture (generated from Kljun *et al.,* 2015 tool, http://footprint.kljun.net). Unfortunately, the classes were not given but will be in the final product. From the future overlay, we can get fractional cover of trees vs. grass.

4.

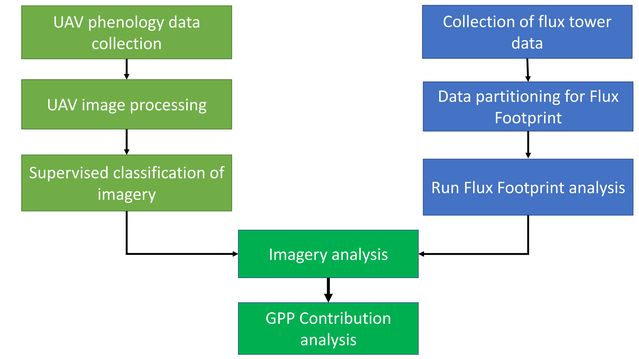


1. $G_{cc} = \frac{G}{(R+G+B)}$
2. $GPP_T = (x * GPP_M) + (y * GPP_G) + error$
3. $x \propto G_{cc,M} * f_M$
4. $y \propto G_{cc,G} * f_G$
5. $GPP_M = \frac{(GPP_T - GPP_T * f_G) * f_M}{2 * f_G * G_{cc,M}}$

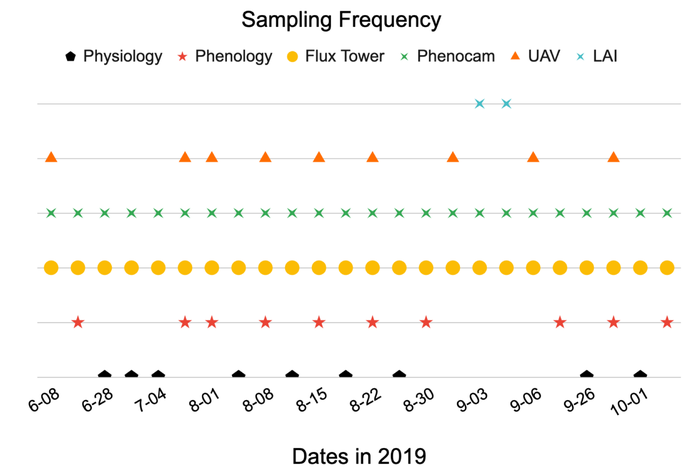
Figure 4. The equations to estimate the either mesquites' or grass' contribution to GPP. **GPP_T** is the total GPP estimated by the flux tower; **G_{cc}** is the Green Chromatic Coordinate calculated from the red (**R**), blue (**B**), and Green (**G**) digital numbers taken from the drone; **f_M** and **f_G** are the fractional cover of mesquite and grass, respectively, from the CART image classification for; **GPP_M** and **GPP_G** are the calculated GPP for mesquite and grass, respectively.

4. Workflow and Data Collection

5.



6.



Figures 5 and 6. Figure 5 shows the workflow for UAV image processing, flux footprint (FFP) processing, and bringing both layers together. Figure 6 shows a timeline of different data collection efforts. The contribution, FFP, Image, and Model analyses are being done in R 3.6.1 (R Core Team, 2019). Supervised Classification was done in ArcGIS Pro.

5. Next Steps

- Create contribution analysis for GPP.
- Introduce photosynthetic capacity of dominant species to equation 2.
- Bring in climate analyses to gain insight into the temporal context to GPP.
- Compare collected ground phenology to UAV imagery.

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