Estimating Rangeland Forage Production Using Remote Sensing Data from a Small Unmanned Aerial System (sUAS)

Han (Grace) Liu¹, Yufang Jin¹, Scott Devine¹, Randy Dahlgren¹, Royce Larsen², Sarah Covello², Anthony O’Geen¹ and Leslie Roche¹

¹Department of Land, Air and Water Resources, University of California, Davis, CA, USA
²University of California Cooperative Extension, San Luis Obispo, CA, USA
Rangelands in California

- High areal coverage – 62 million acre
- High ecological and economical value
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- High ecological and economical values
  - wildlife habitat
  - fresh water
  - recreation
  - ...
  - $3 billion beef cattle industry
Challenges in mapping California forage production

• Highly sensitive to weather, soil and topographic variabilities

• Hard to monitoring due to more cloudy days in growing season
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Objectives

1) Study the feasibility of estimating forage production using a small unmanned aerial system
   ▪ Accuracy?
   ▪ Technological gap?

2) Understand the influence of abiotic drivers of forage production at very high spatial resolution
   ▪ Soil moisture?
   ▪ Topographic variables?
Study Area

- Camatta, topographically complex
- Located 56 km east of the coast in San Luis Obispo County, CA, USA
- Mediterranean climate – winter-spring growing season
- Mean annual rainfall is < 305 mm
- Mean annual forage production was 1486 lbs/acre during 2001-2014
Ground Data

• 16 sets of Soil moisture and temperature sensors were installed in November 2016
Ground Data

- 36 vegetation samples are clipped for dry biomass measurements following each sUAS flight
Remote Sensing Data

- The small unmanned aerial system
  - 3DR Solo
  - MicaSense RedEdge camera
  - Flight height 350 m
  - Spatial resolution 8 cm

- RapidEye satellite data
- CIMIS spatial
  - incoming solar radiation
A Light Use Efficiency (LUE) based approach for forage production estimate

Biomass \((x, y, t) = \sum [\text{LUE} (x, y, t) \times \text{APAR}(x, y, t)]\)

\[
\text{LUE} \sim f(\text{soil moisture}) \times f(\text{temperature})
\]

\[
\text{APAR} = f\text{PAR} \times \text{PAR} = f(\text{NDVI}) \times \text{PAR}
\]

Terminologies

- PAR = photosynthetically active radiation
- \(f\text{PAR} = \text{fraction of absorbed PAR}\)
- APAR = absorbed PAR
- LUE = light use efficiency
sUAS Data Processing

raw data

initial prepressing

radiometric correction

illumination correction

DSM

reflectance data

NDVI

RapidEye daily NDVI

interpolated daily NDVI

daily APAR

daily PAR
sUAS Data Processing

raw data → initial prepressing → radiometric correction → illumination correction → reflectance data → DSM → NDVI

RapidEye daily NDVI

interpolated daily NDVI → daily APAR

daily PAR

Before

After
Fusing sUAS and RapidEye data: from snap-shot to daily time series

NDVI

Soil Moisture (VWC)

interpolated NDVI  RapidEye NDVI

sUAS NDVI  soil moisture

2016-11-19

2016-12-15

2017-01-16
Time series of a randomly selected ground sampling pixel

- NDVI
- Soil Moisture (VWC)
- PAR (MJ/m\(^2\) day)
- APAR (MJ/M\(^2\) day)

**Legend:**
- green line: interpolated NDVI
- green dashed line: RapidEye NDVI
- blue triangle: sUAS NDVI
- blue line: soil moisture
Cumulative APAR is highly correlated with biomass

$R^2 = 0.69$

$RMSE = 630 \text{ lbs/acre}$
Forage estimation: constraints on LUE

\[ \text{Biomass}(x, y, t) = \sum_{t_0}^{t} \text{APAR}(x, y) \times f(\text{SoilM}, x, y) \times f(\text{SoilT}, x, y) \times f(\text{Elevation}, x, y) \]

Mod I – LUE (with soil mea.)

\[ R^2 = 0.73 \]
\[ \text{RMSE} = 488 \text{ lbs/acre} \]
\[ \text{MAE} = 352 \]
Forage estimation: constraints on LUE

\[ \text{Biomass}(x, y, t) = \left[ \sum_{t_0}^{t} \text{APAR}(x, y) \right] \cdot f(\text{Elevation}, x, y) \]

Mod II – LUE (without soil mea.)

\( R^2 = 0.72 \)
\( \text{RMSE} = 539 \text{ lbs/acre} \)
\( \text{MAE} = 406 \)

Date
- 2017-01-16
- 2017-02-15
- 2017-03-17
- 2017-04-06
Phenology on different aspects

2017-02-15

2016-03-17

2017-04-06

Biomass (lbs/acre)

0 25 50 100

0 3500
Conclusions

1. Is it feasible to estimate forage production using a small unmanned aerial system?
   • $R^2 = 0.73$, RMSE = 488 lbs/acre
   • High computing machine requirement

2. What is the influence of abiotic drivers of forage production at centimeter resolution?
   • For a relatively wet year, soil moisture measurements are not closely related to forage production
   • Elevation is negatively related to forage production
   • Temporally, south facing slope greens up earlier than north facing slope when water is sufficient during the growing season, but eventually the two slopes have similar annual productivity
Thank you!

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RANGELAND AND CATTLE
RESEARCH ENDOWMENT
Seasonal distribution of soil moisture

- Soil moisture has been consistently above the wilting point during after Nov. 2016 till late Apr. 2017
- Soil moisture kept increasing from Nov. 2016 to Feb. 2017