# Estimating Alfalfa Biomass Volume from UAV-Based Multispectral Imagery

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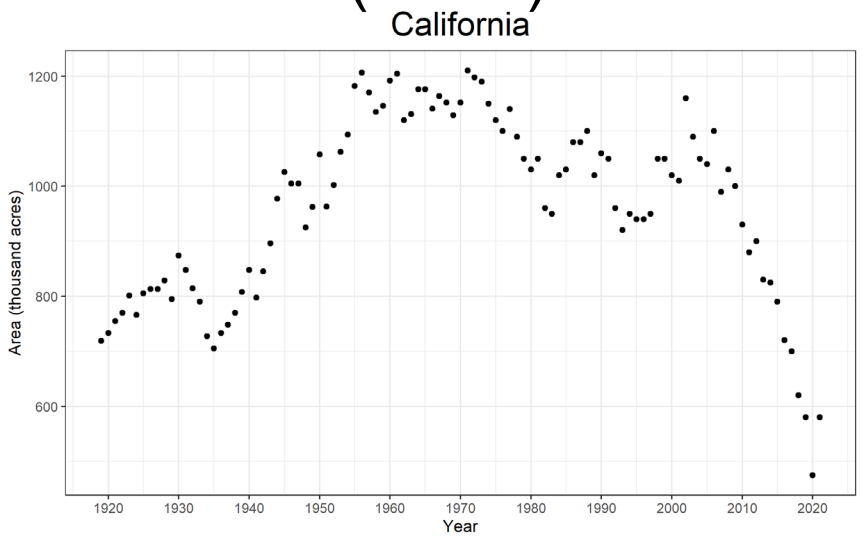
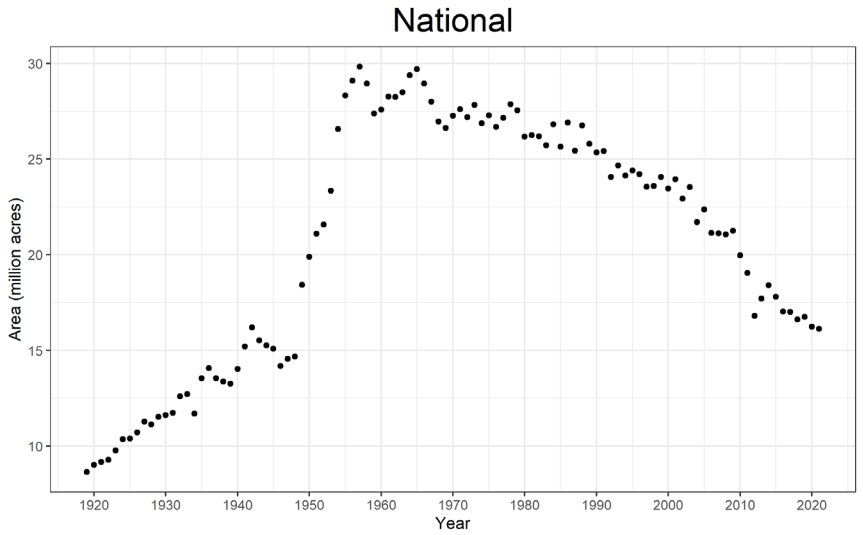
# Outline

- The importance of improvement in alfalfa
- UCD alfalfa breeding program
- Estimating biomass using a drone-based multispectral camera
- Recommendations for trial design

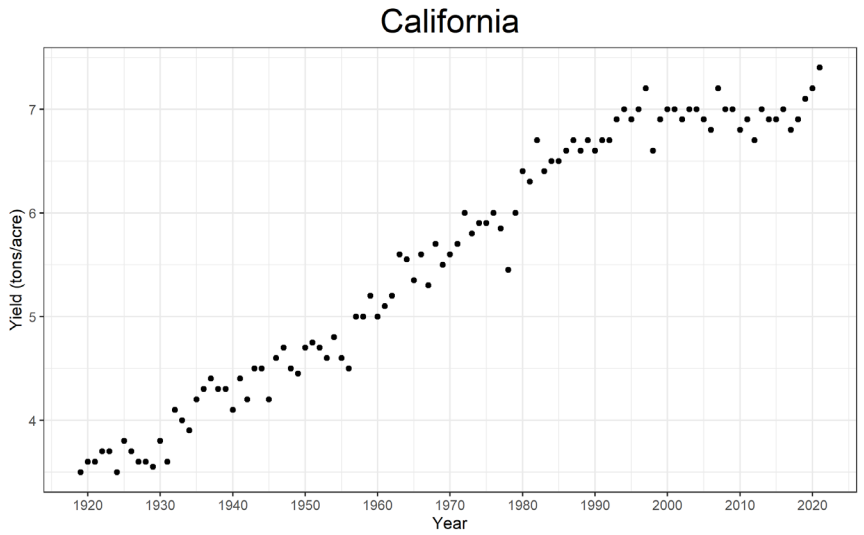
# Acreage declining & yield plateauing

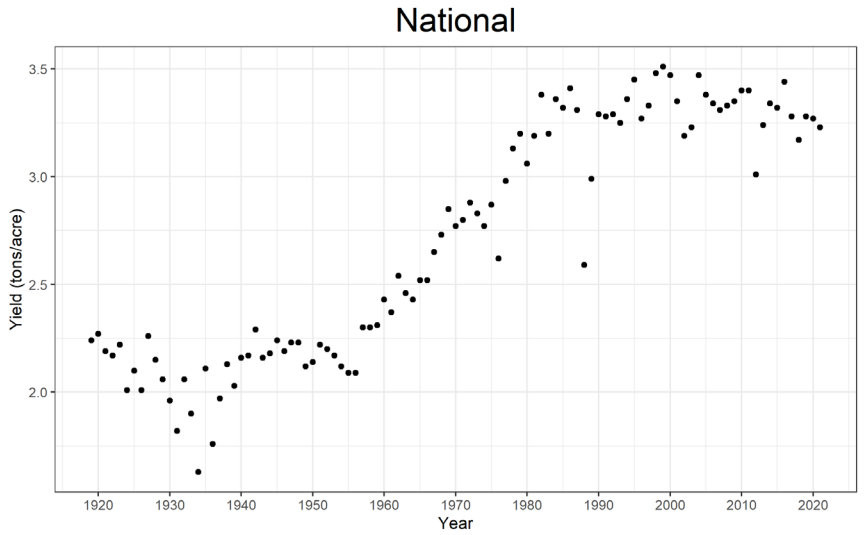
## Production area (acres)




## Hay yield (tons/acre)



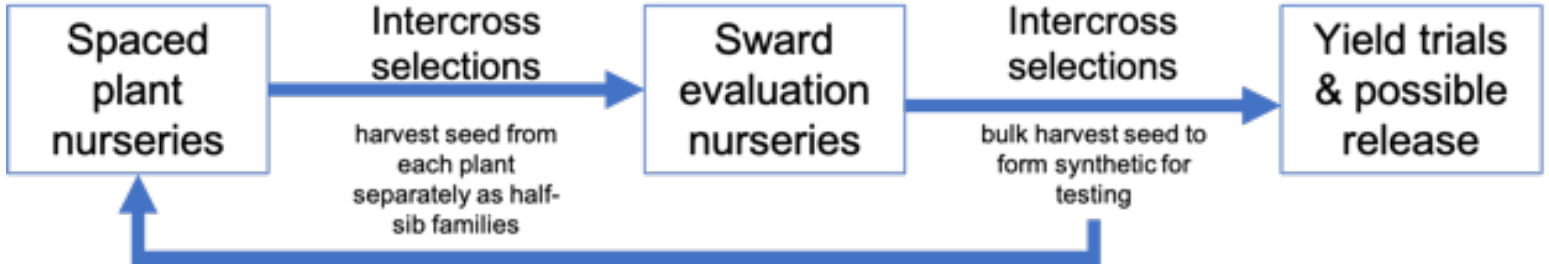




Source: USDA National Agricultural Statistics Service

# The UCD alfalfa breeding program

## Breeding goals

- High yield
- Persistence
- Forage quality
- Disease/insect resistance
- (Grazing tolerance)
- (Grass compatibility)




## Target regions in California

- Low Desert (DREC) – Fall Dormancy 9-10 (heat, salinity, deficit irrigation)
- Central Valley (Davis, WSREC) – FD 7-9 (heat, salinity, deficit irrigation)
- Intermountain (IREC) – Fall Dormancy 3-5 (winter survival)
- Selection on organically managed land (IREC, Davis, [DREC])

# Variety of plot types used in breeding programs

Transplanted row plots (top left), transplanted sward plots (bottom) and sown sward plots (top left)

# Remote sensing

- Phenotyping is laborious, expensive and time-consuming e.g., yield assessment routinely requires > 20 harvests over the life of a trial
- Flying a drone over a trial takes approx. 10 mins
- Imagery has a wide range of potential applications

Drone with RGB and multispectral cameras

# Objective

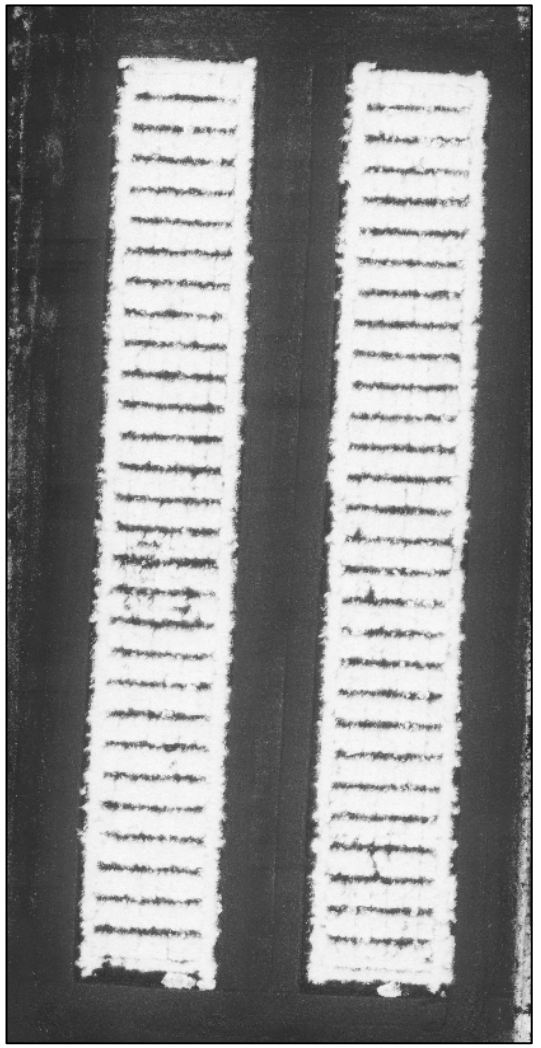
- Determine whether remote sensing can be used to supplement or replace biomass yield measurements

# Extracting biomass estimates

- Drone flown at 15m above field taking images with 80% overlap
- Images stitched together to form orthomosaic using software such as Pix4D or OpenDroneMap
- Calculate normalized difference vegetation index (NDVI):

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

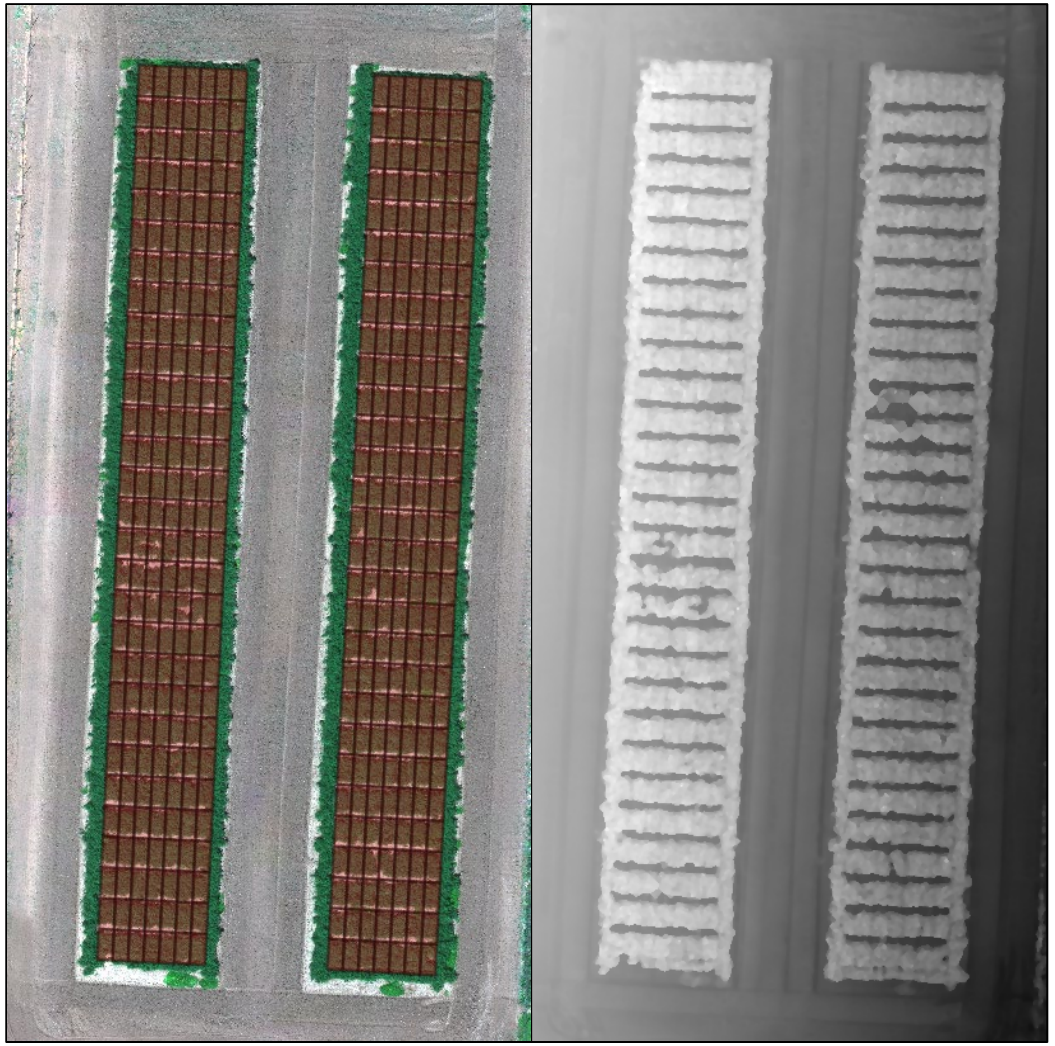
- Use NDVI to separate soil and plants into separate layers



NDVI of Solano County trial

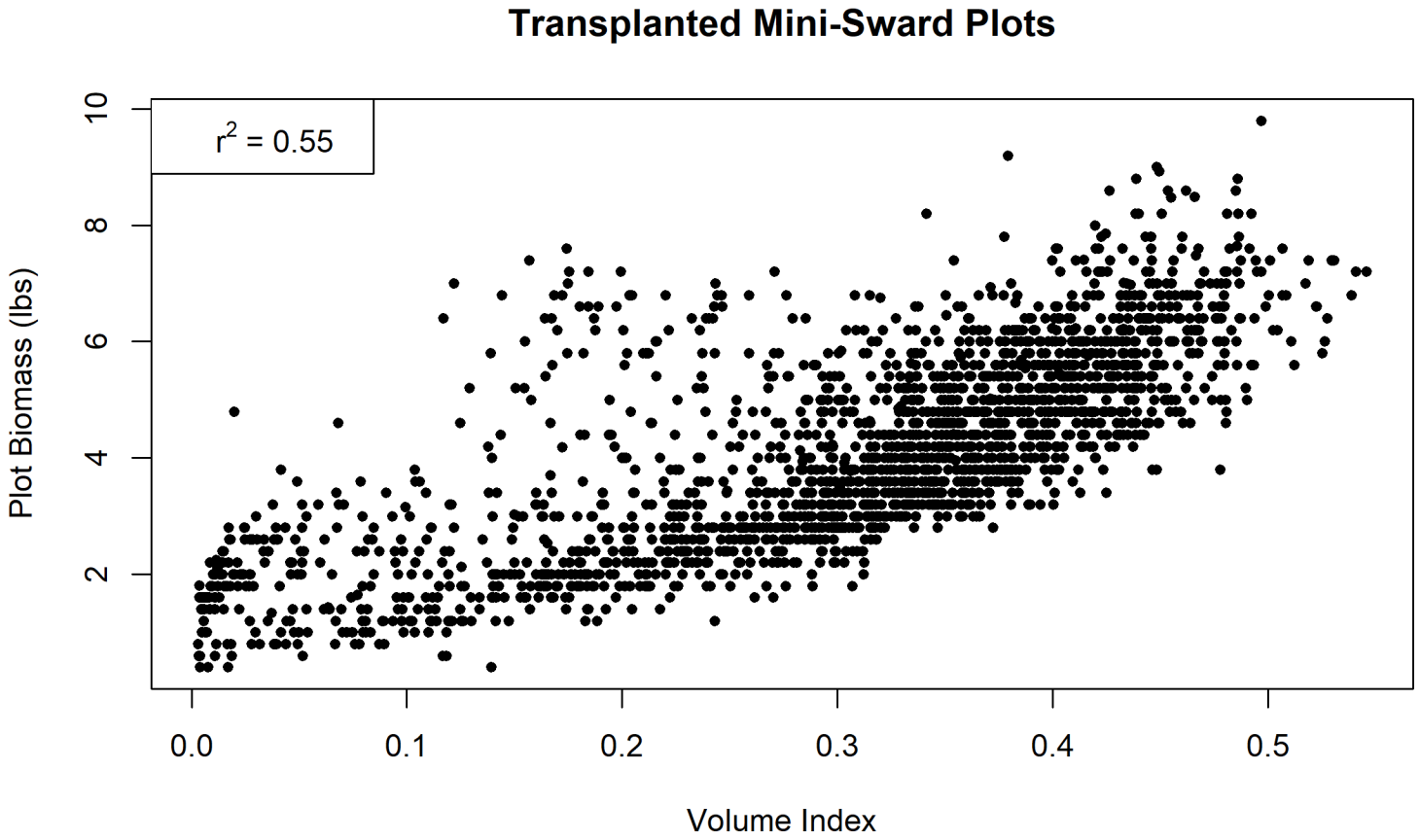
# Extracting biomass estimates

- Overlay a grid to separate individual plots
- Use digital surface model (DSM) to extract relative heights of each pixel
- Subtract soil height from plant height for each plot then multiply by the proportion of the plot that is covered by vegetation to get average biomass volume

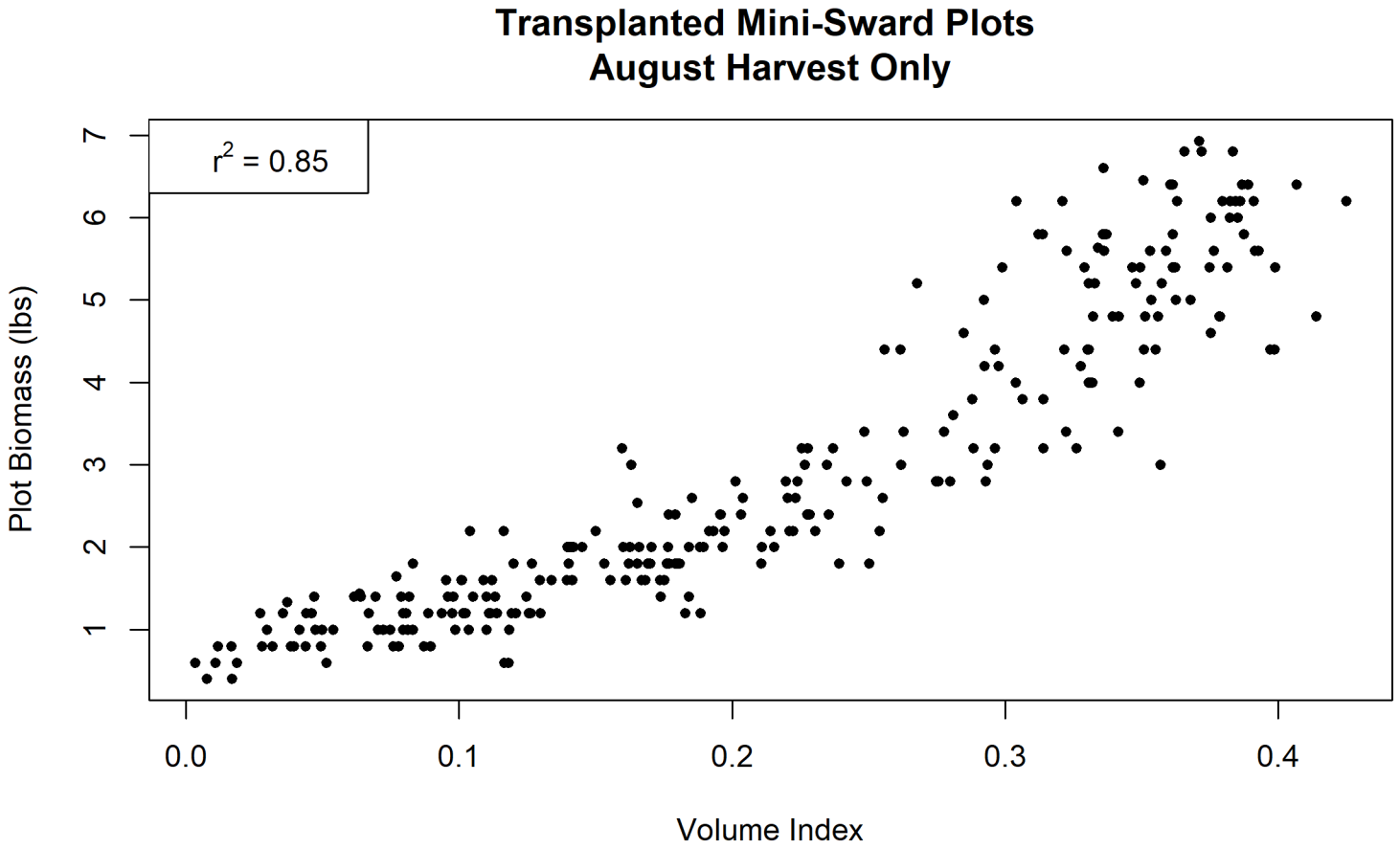


True color image and DSM of Solano County trial

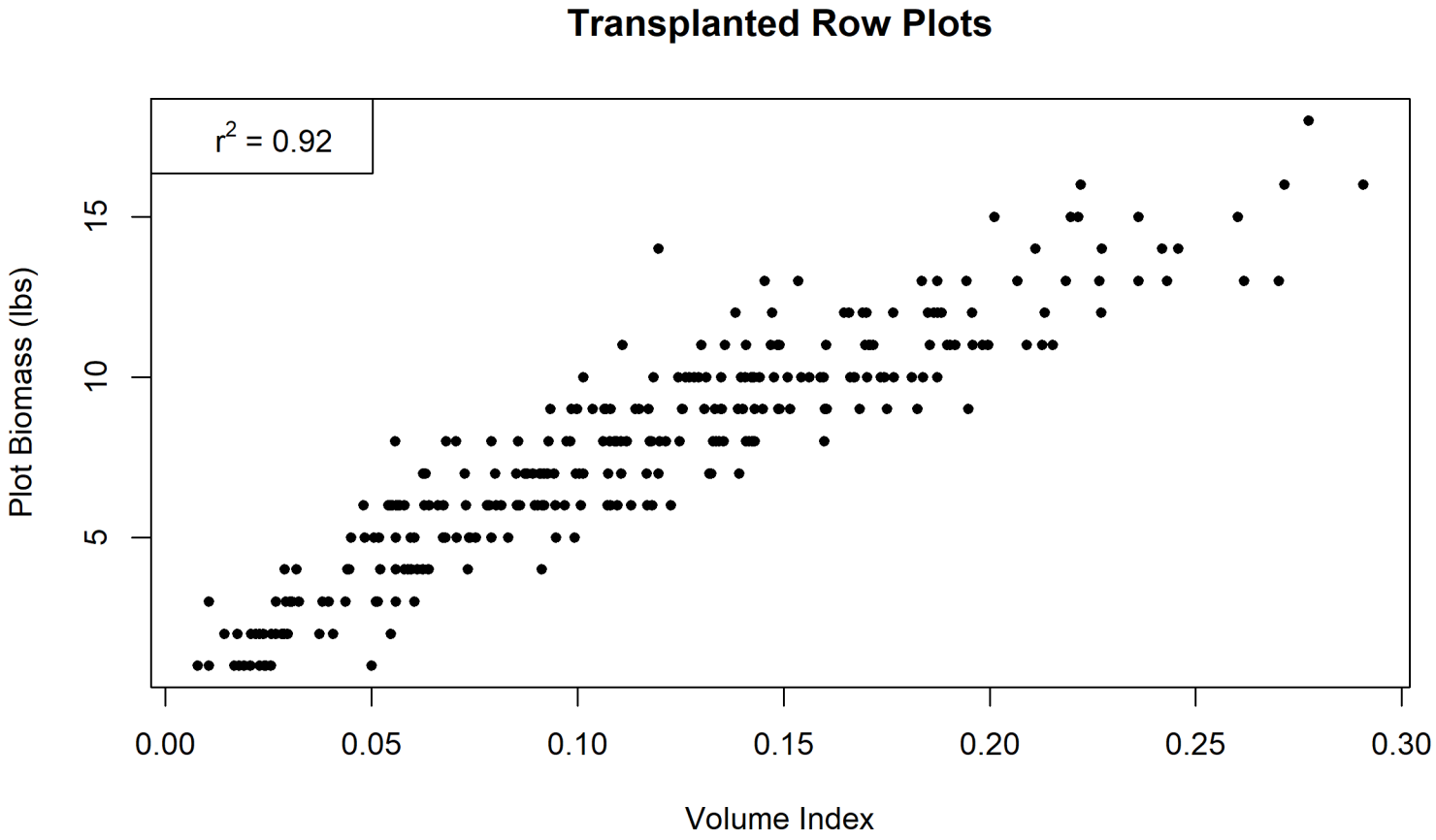
# Results


Transplanted Mini-Sward Plots
$r^2$ = 0.55
Plot Biomass (lbs)
2
4
6
8
10
0.0
0.1
0.2
0.3
0.4
0.5
Volume Index

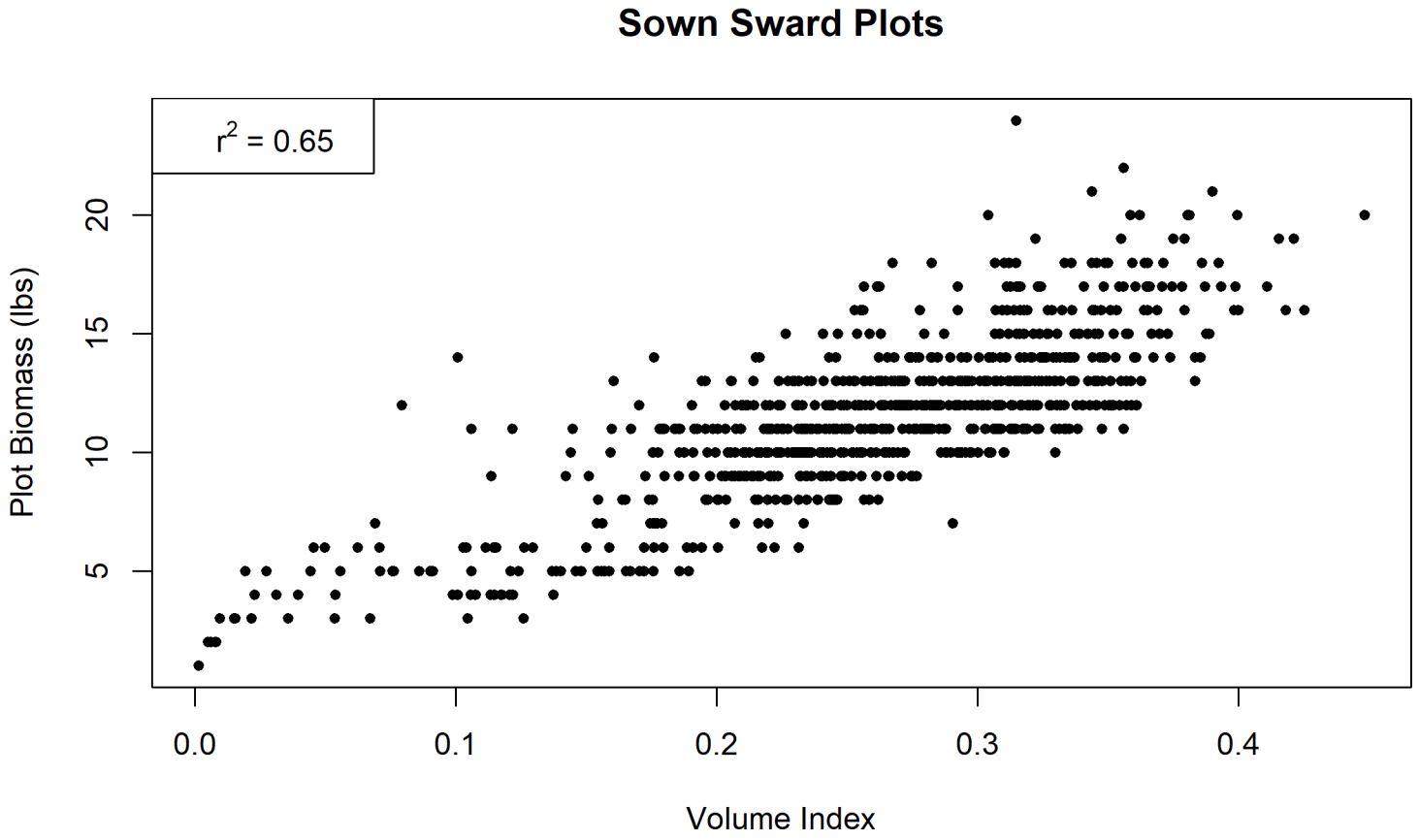
# Results


Transplanted Mini-Sward Plots
August Harvest Only
$r^2$ = 0.85
Plot Biomass (lbs)
1
2
3
4
5
6
7
0.0
0.1
0.2
0.3
0.4
Volume Index

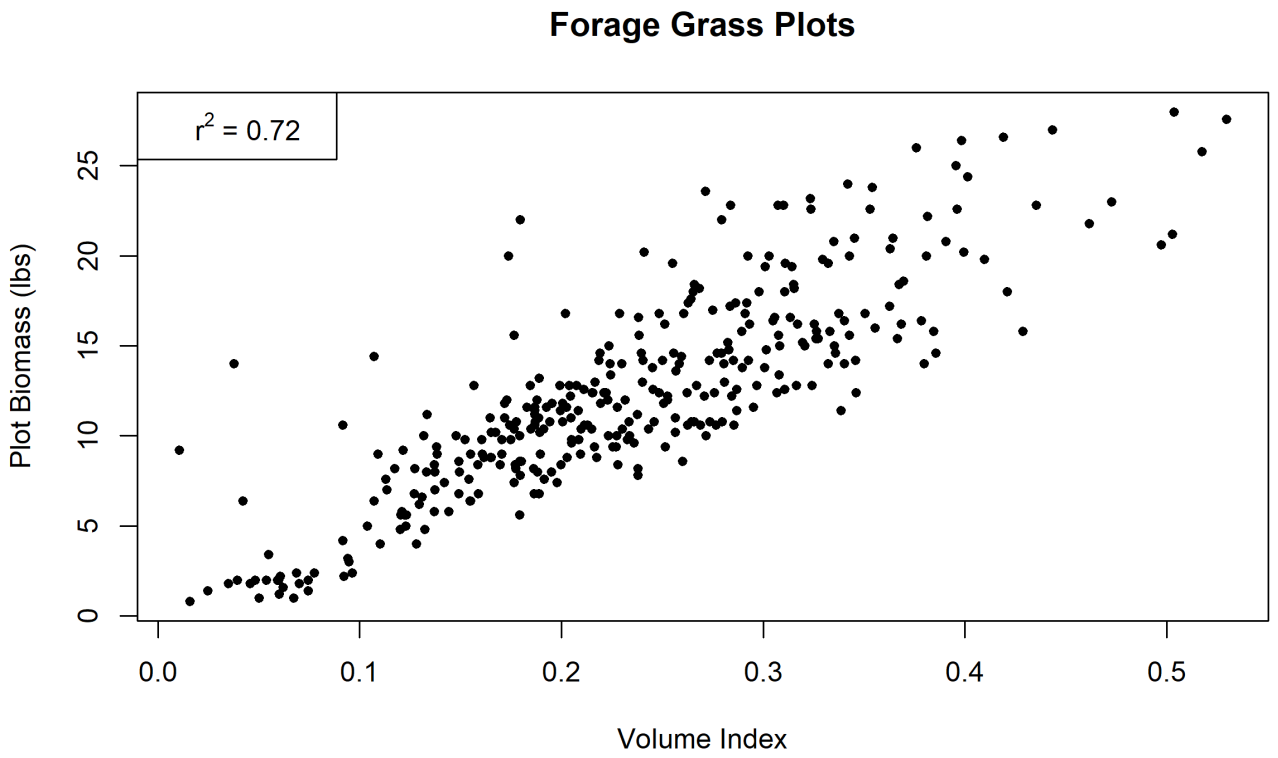
# Results


Transplanted Row Plots
$r^2$ = 0.92
Plot Biomass (lbs)
5
10
15
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Volume Index

# Results


Sown Sward Plots
$r^2$ = 0.65
Plot Biomass (lbs)
5
10
15
20
0.0
0.1
0.2
0.3
0.4
Volume Index

# Results


Forage Grass Plots
$r^2$ = 0.72
Plot Biomass (lbs)
0
5
10
15
20
25
0.0
0.1
0.2
0.3
0.4
0.5
Volume Index

# Factors influencing prediction accuracy

- Anything interfering with soil level or plant height can cause large discrepancies in the data e.g., animal damage (gophers, rabbits & ground squirrels), lodging, tire tracks etc.
- Weather can also play a large role – wind, sun position etc.

Gopher damage

Lodging

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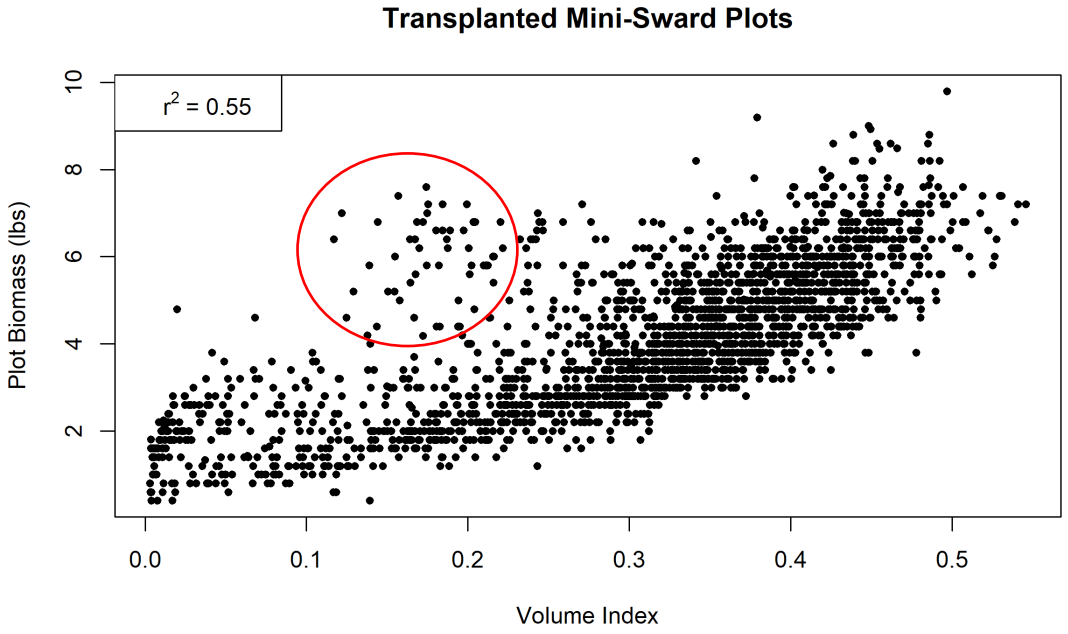
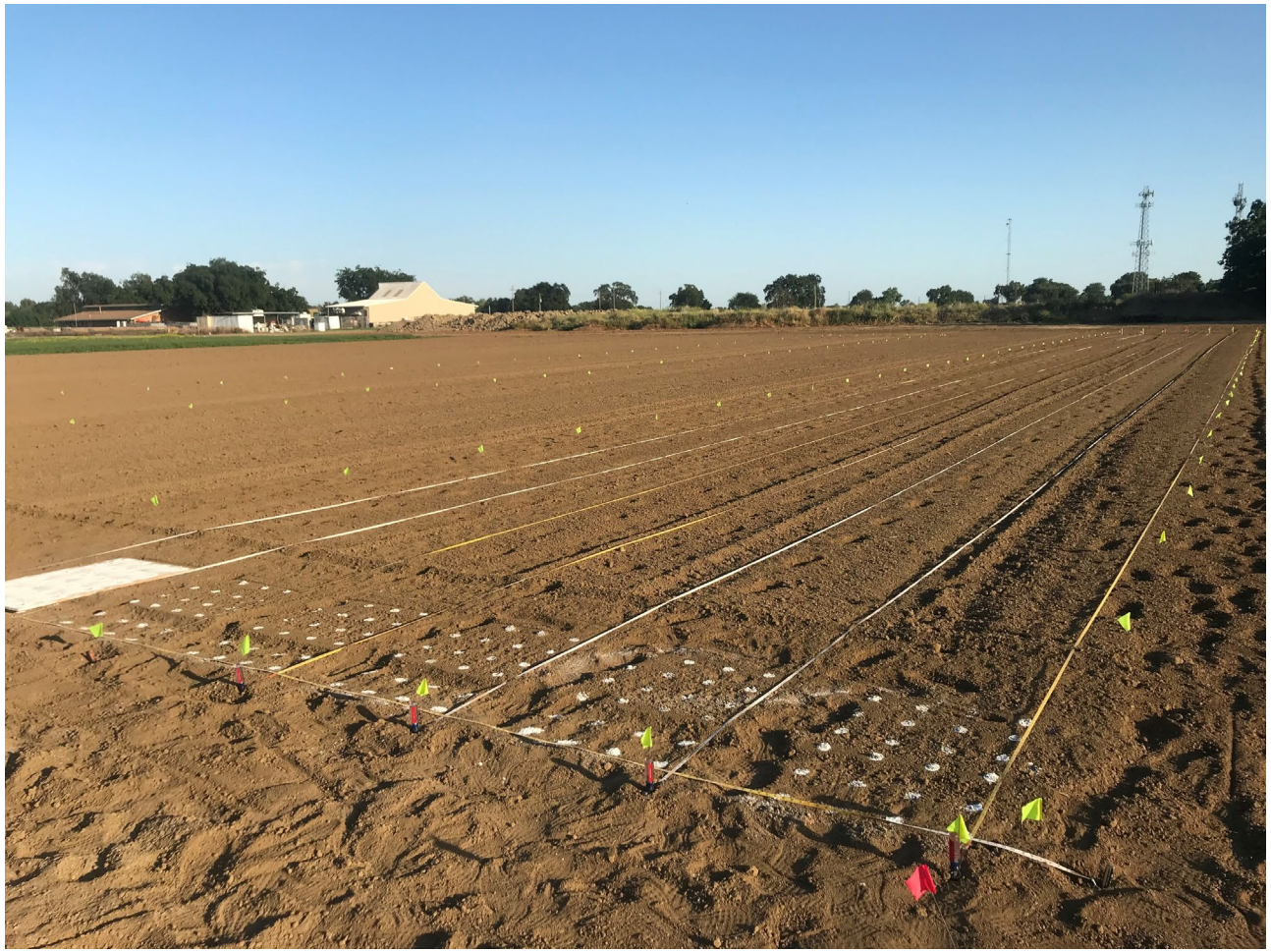



Lodging

# Trial recommendations

- Begin with a level seedbed
- Straight lines - makes the processing steps much simpler
- Must have an area of soil-level ground around each plot. Larger spacing between plots can be helpful
- Pest and weed control



# Summary

- Quick and easy to collect data
- Mixed accuracy when estimating volume, but some promise under the correct conditions.
- Many other uses to explore - fall dormancy, forage quality, plant health, stand counts, tracking growth rates, measuring plot size etc.
- Beneficial to have a visual record of each trial

# Thank you for listening!


Thanks to Grasslands Innovation and PGG Wrightson Seeds/DLF for their support of my graduate studies and special thanks to Charlie and the Brummer Lab for all their help and to Travis Parker for monthly drone flights and image processing.