Using UAS Multispectral Imagery to Estimate Yield Contributing Physiological Parameters of Cotton

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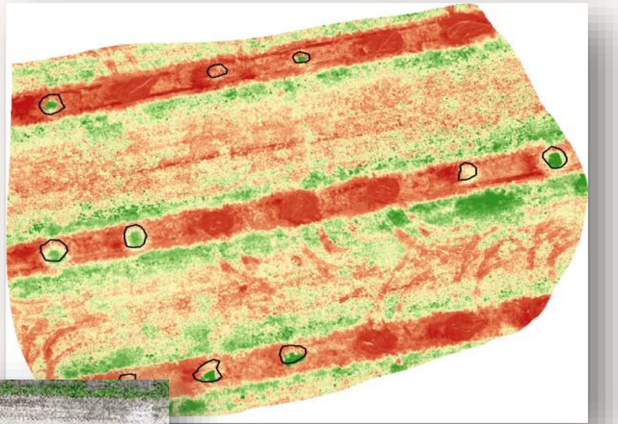
Introduction

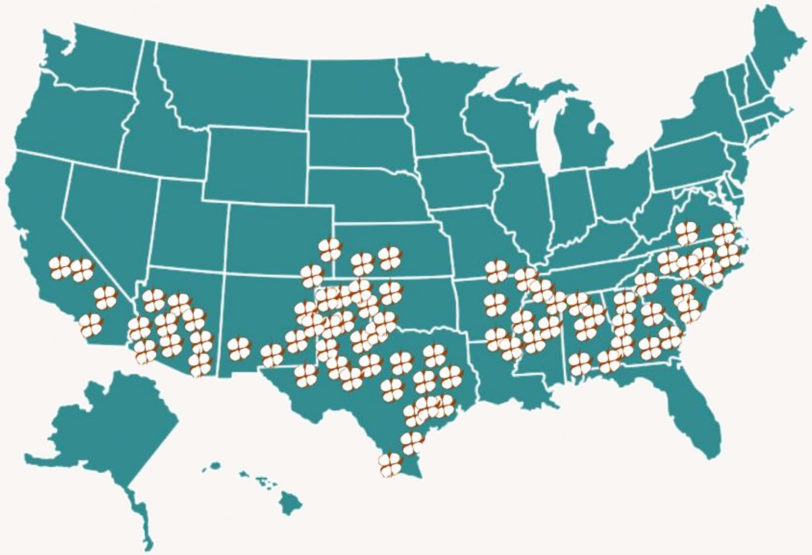
Unoccupied Aerial Systems (UAS) application in agriculture:

- Mapping field variability
- Crop species classification
- Growth monitoring
- Stress detection
- Crop phenotyping
- Yield prediction



Importance of Cotton

- Cotton has global importance as a commercial crop and substantial contribution to clothing and textile industry.



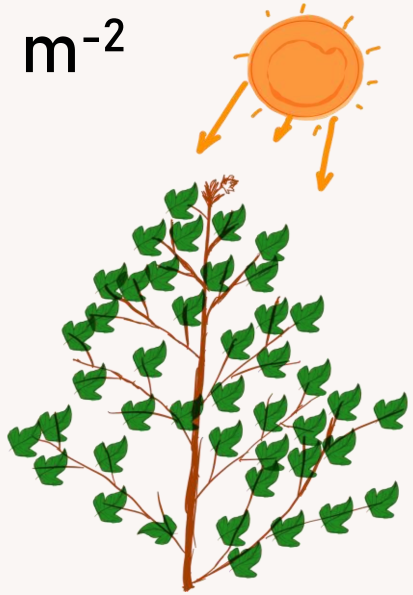
- ❑ Among top 3 cotton-producing countries
- ❑ Contribute 35% of global cotton export (USDA 2021)

Yield Function

Yield = IPAR x RUE x HI

IPAR

- Intercepted Photosynthetically Active Radiation
- MJ m^{-2}

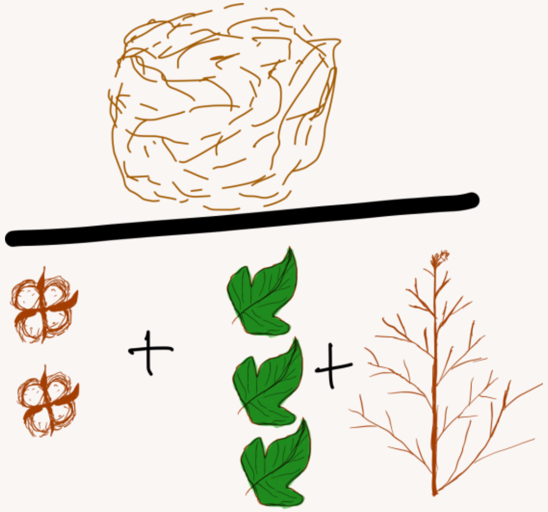


RUE

- Radiation Use Efficiency
- g MJ^{-1}

HI

- Harvest Index



Hypothesis

- Vegetation indices from UAS-based multispectral imagery can be utilized to predict in-season physiological parameters in cotton.

Objectives

- To assess the relationship between vegetation indices derived from UAS multispectral imagery and cotton physiological parameters (IPAR and RUE)
- To develop models using vegetation indices that can be used to predict IPAR and RUE in cotton

Experimental Layout

Study Year:

- 2021, 2022

Cultivar:

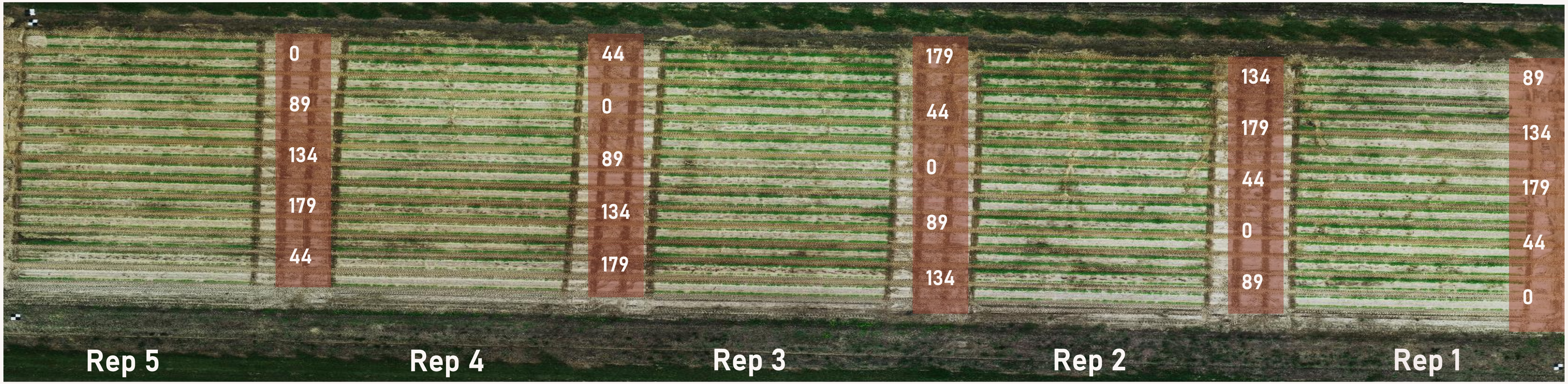
- DP 1646

Nitrogen Treatments:

- 0 kg N ha^{-1} (0)
- 44 kg N ha^{-1} (40)
- 89 kg N ha^{-1} (80)
- 134 kg N ha^{-1} (120)
- 179 kg N ha^{-1} (160)

Design:

- RCBD
- 5 replications
- 6 row plots



Measurements

Planting Date
06/01/2021
04/26/2022

42-43 DAP | 56-58 DAP | 69-74 DAP | 93-97 DAP | 114-115 DAP

Harvest Date
10/22/2021
09/21/2022

1. UAV Imagery

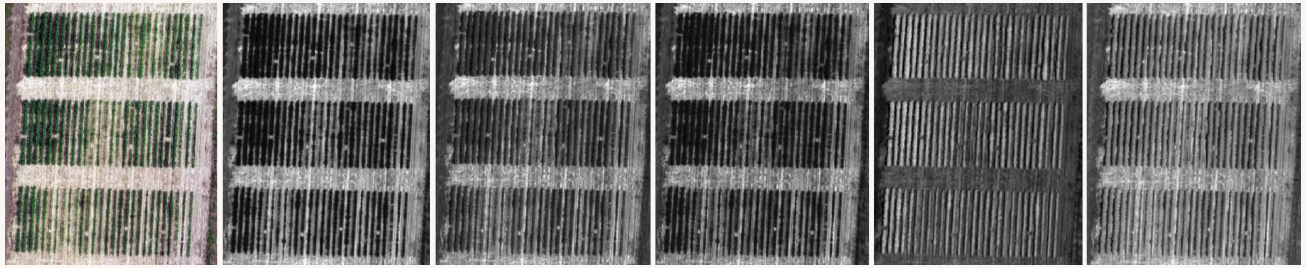
- Multispectral imagery using MicaSense RedeEdge-MX™ Camera on DJI Inspire 2
- RGB imagery using DJI Phantom 4 Pro V2.0

2. Physiological measurements

- Light Interception using ceptometer
- In season aboveground biomass collection

Image Processing and Analysis

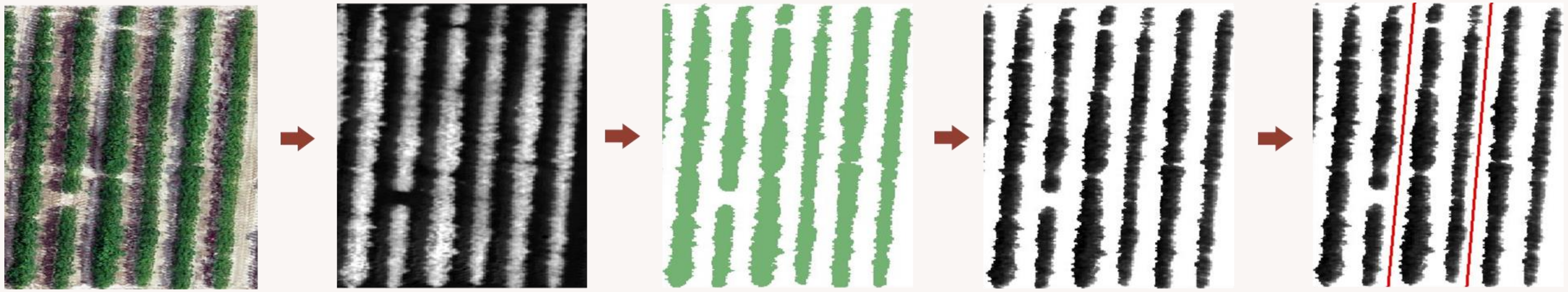
- Image Processing: Pix4D® software was used to obtain mosaic images combining imagery for each sample date.



RGB Red Green Blue NIR Rededge

Sample aerial images at 56 DAP (2021) from 45 m height.

- Imagery Analysis: Arc Map 10.7.1® was used to extract reflectance index for vegetation indices (VI's) computation.



RGB Aerial Image → Classified Aerial Image → Binary Mask Layer → Red Band without soil → Region of Interest

Vegetation Indices (20 total)

Abbreviated VI's	Nomenclature	Formula
ExG	Excessive Greenness	$2 \times \mathrm{G} - \mathrm{R} - \mathrm{B}$
NDVI	Normalized Difference Vegetation Index	$\frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}}$
ExG*NDVI	ExG multiplied by NDVI (Classification Index)	$(2 \times \mathrm{G} - \mathrm{R} - \mathrm{B})\left(\frac{\mathrm{NIR} - \mathrm{R}}{\mathrm{NIR} + \mathrm{R}}\right)$
GNDVI	Green Normalized Difference Vegetation Index	$\frac{\mathrm{NIR} - \mathrm{G}}{\mathrm{NIR} + \mathrm{G}}$
NDRE	Normalized Difference Red Edge Index	$\frac{\mathrm{NIR} - \mathrm{RE}}{\mathrm{NIR} + \mathrm{RE}}$
RVI	Ratio Vegetation Index	$\frac{\mathrm{NIR}}{\mathrm{R}}$
SCCCI	Simplified Canopy Chlorophyll Content Index	$\frac{\mathrm{NDRE}}{\mathrm{NDVI}}$
RE/R	Red edge and Red Ratio	$\frac{\mathrm{RE}}{\mathrm{R}}$
GRVI	Green Ratio Vegetation Index	$\frac{\mathrm{NIR}}{\mathrm{G}}$

Statistical Analysis

Software:

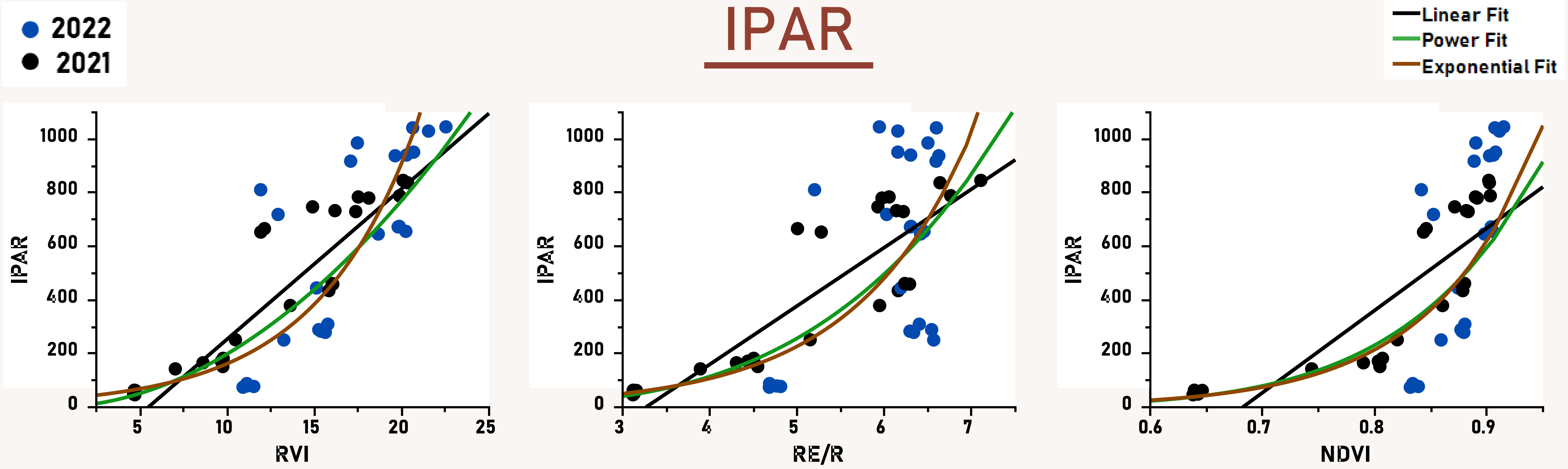
- Pix4D® for image processing
- ArcGIS 10.7.1® for geospatial analysis and computing vegetative indices
- JMP® Pro 16.0.0 for modelling and graphs

Data Analysis:

- Scatter plots and outlier analysis
- Regression Models:
  - Linear relationship ($y = a + bx$)
  - Power relationship ($y = ax^b$)
  - Exponential relationship ($y = ae^{bx}$)
- Test model significance (alpha = 0.05)
- R^2 and RMSE values for comparing models

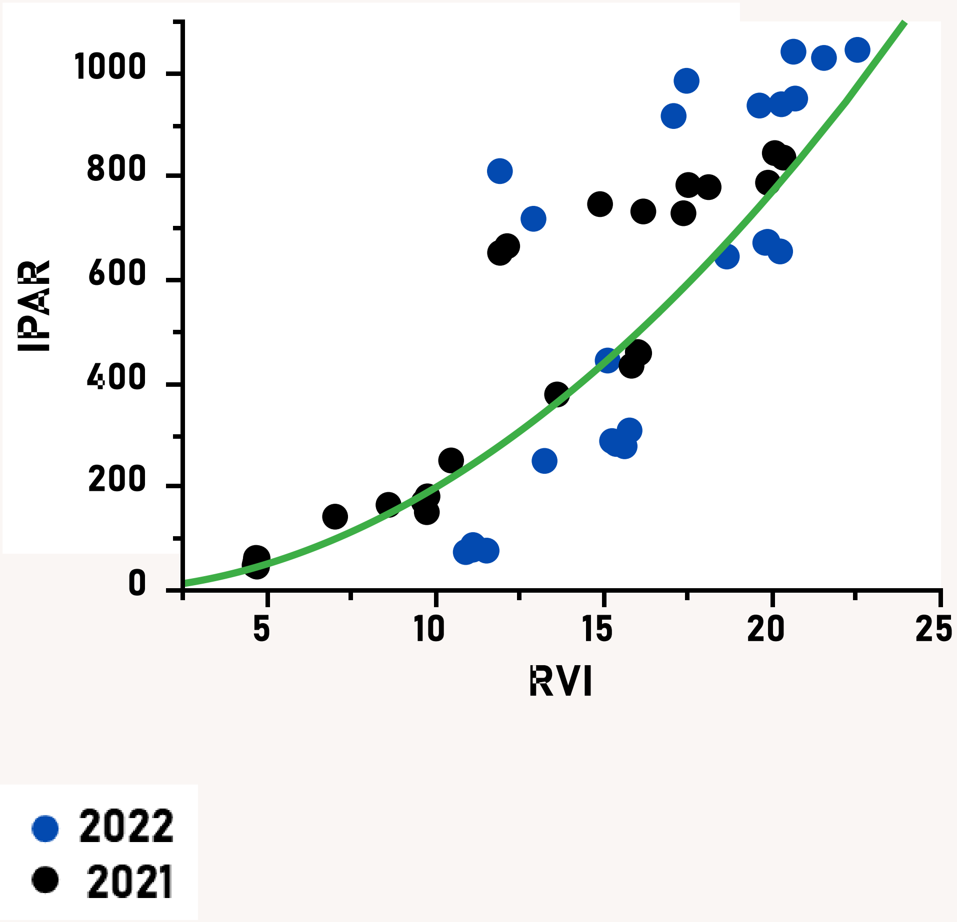
Results

IPAR



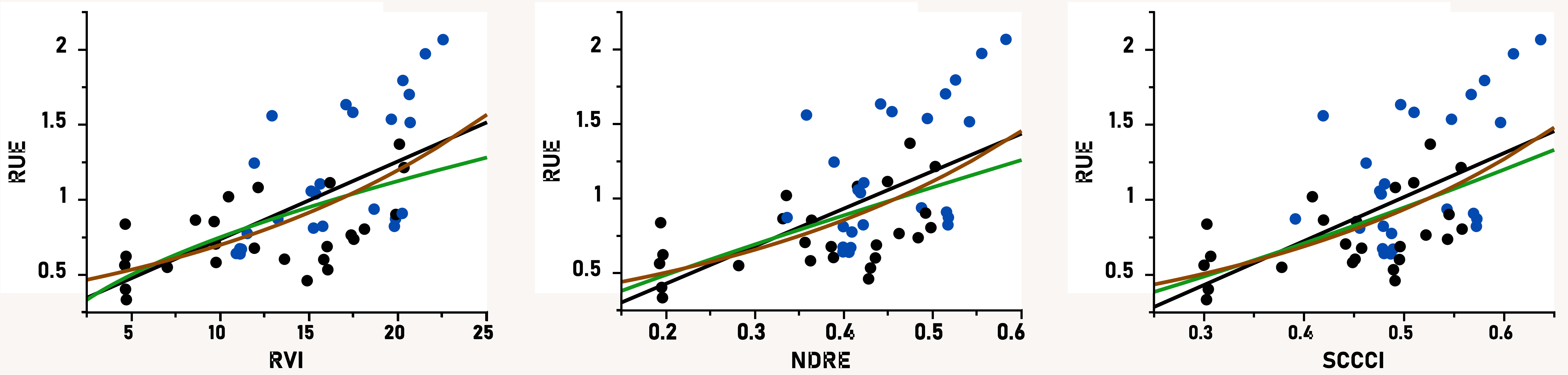
VI's	Linear		Power		Exponential	
	R^2	RMSE	R^2	RMSE	R^2	RMSE
RVI	0.703	185.77	0.747	188.12	0.755	205.64
RE/R	0.526	234.66	0.713	245.10	0.715	252.43
NDVI	0.498	241.57	0.652	231.25	0.675	220.62

IPAR



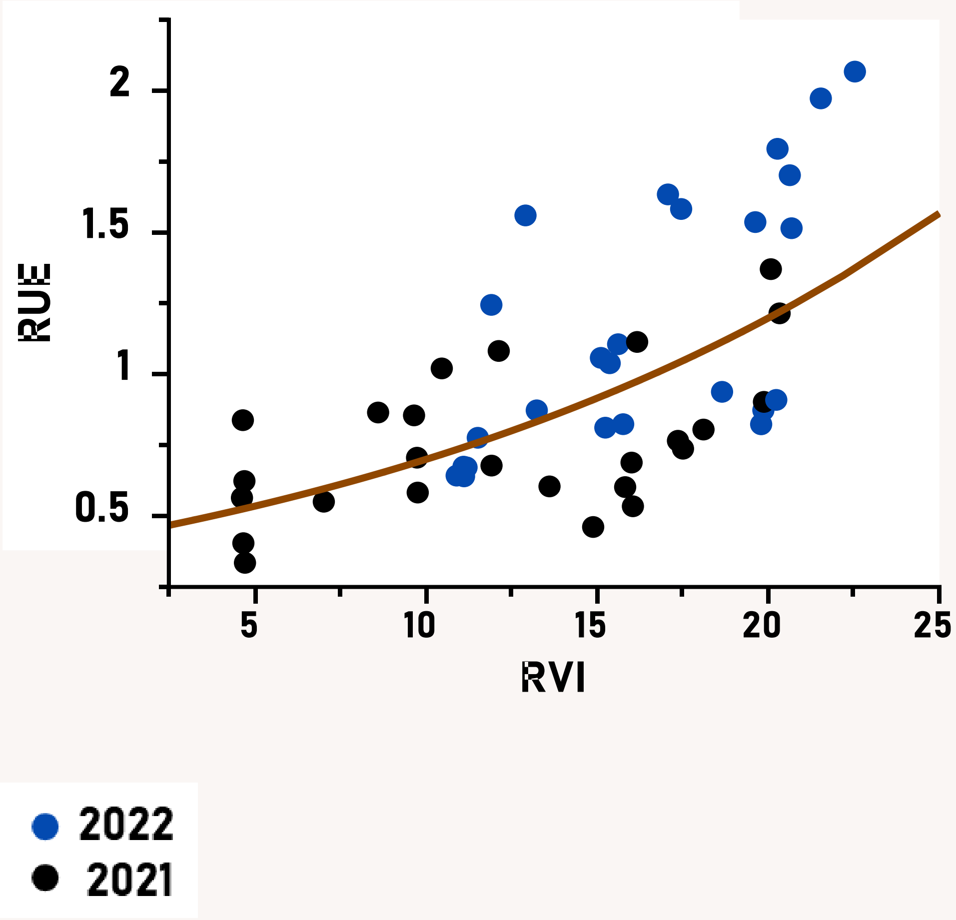
- Power relationship
- Ratio Vegetation Index (RVI):
  NIR / Red
- $IPAR = 2.199 + (RVI)^{1.956}$
- $\ln(IPAR) = 0.788 + 1.956 \times \ln(RVI)$

RUE



VI's	Linear		Power		Exponential	
	R^2	RMSE	R^2	RMSE	R^2	RMSE
RVI	0.394	0.328	0.387	0.343	0.426	0.325
NDRE	0.339	0.343	0.344	0.353	0.380	0.337
SCCCI	0.327	0.346	0.339	0.351	0.360	0.341

RUE

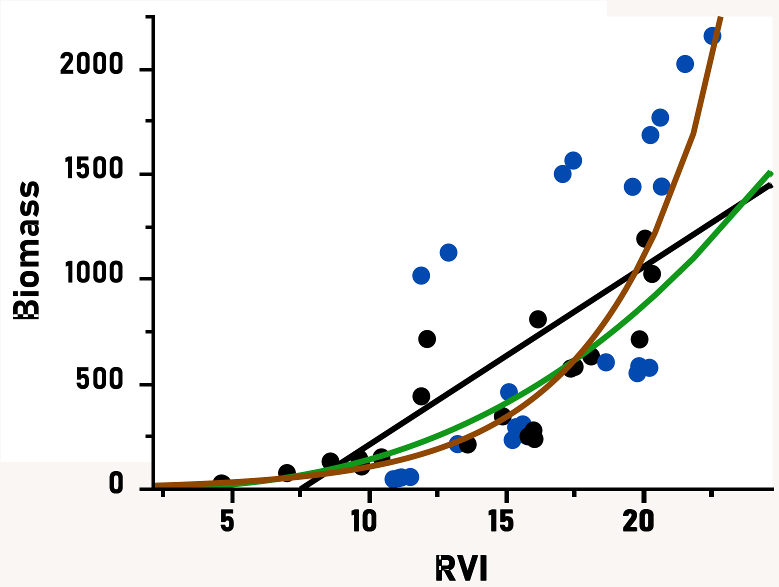


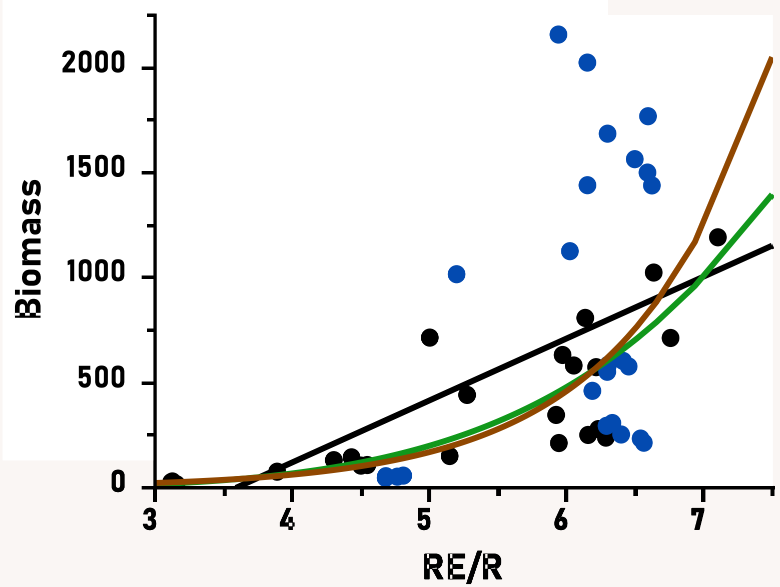
- Exponential relationship
- Ratio Vegetation Index (RVI):

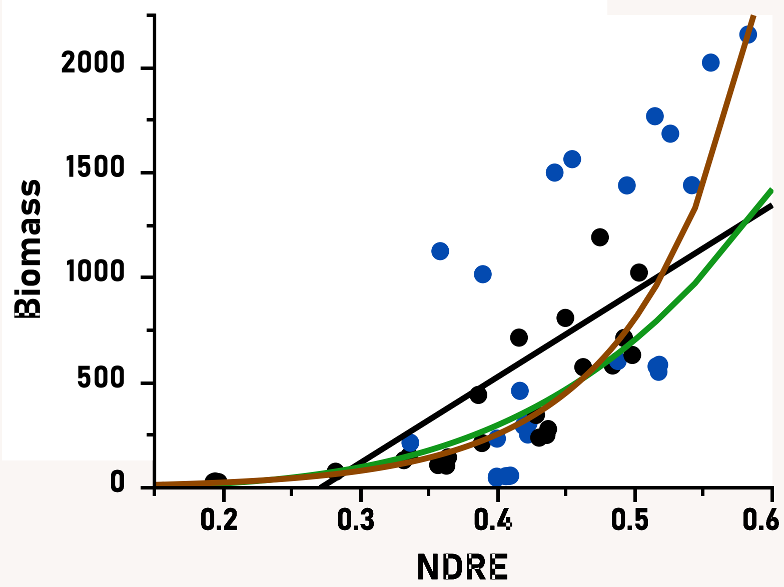
  NIR / Red
- $RUE = 0.409 \times e^{0.054(RVI)}$
- $\ln(RUE) = -0.895 + 0.054 \times (RVI)$

Biomass

Biomass = IPAR x RUE

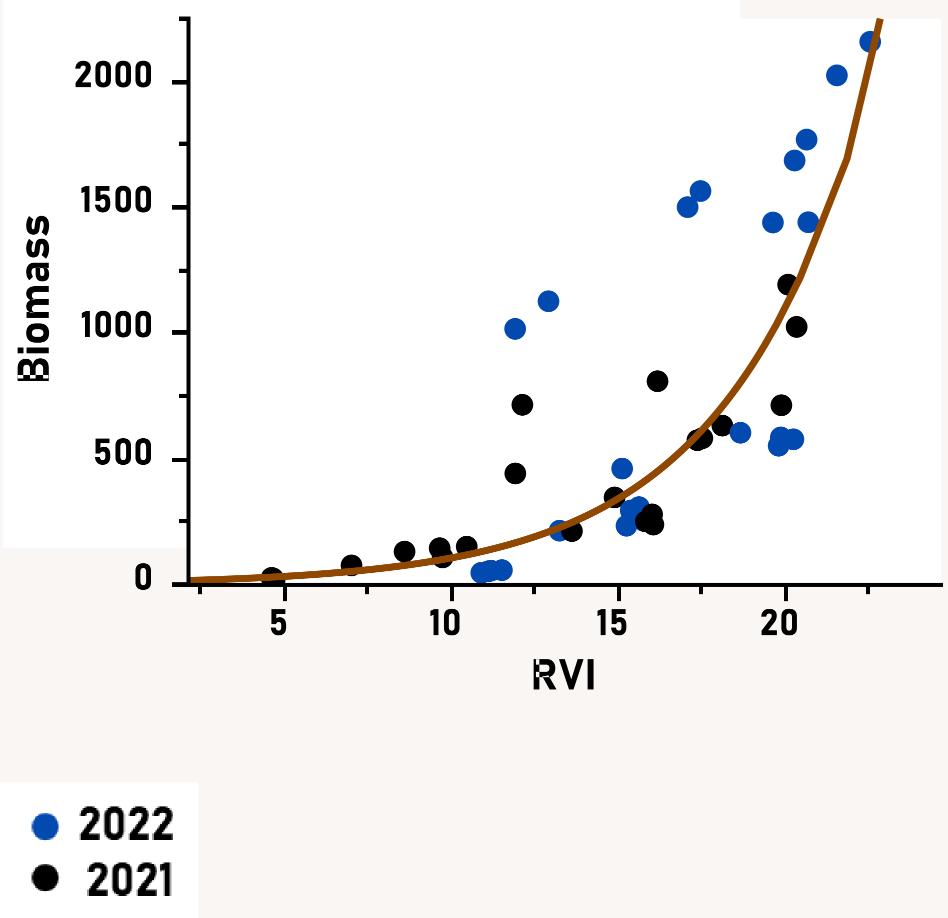


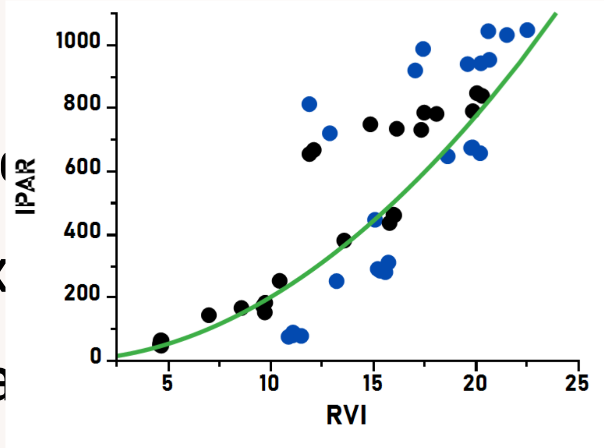




VI's	Linear		Power		Exponential	
	R^2	RMSE	R^2	RMSE	R^2	RMSE
RVI	0.538	407.6	0.751	409.8	0.770	354.6
RE/R	0.318	490.2	0.693	513.9	0.696	513.4
NDRE	0.453	438.9	0.655	440.6	0.684	390.3

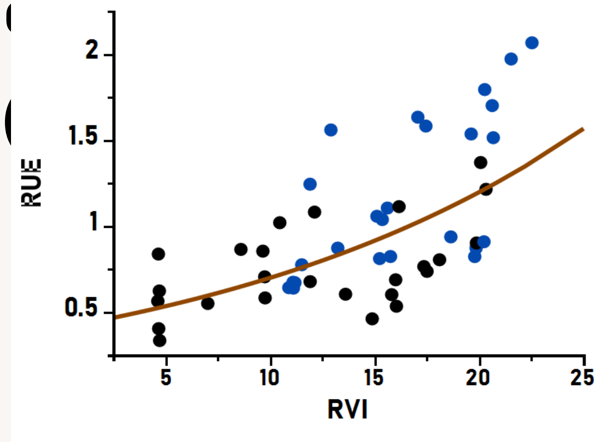
Biomass





- Bi
- Ex p
- Ra (RVI):

  NIR / Red



- Bi 0.234(RVI)
- ln(.234 ×(RVI)

Conclusions

- IPAR -
  - RVI, RE/R, and NDVI were strongly related (R^2: 50 -75%) with IPAR.
  - A power regression model for RVI explained the highest variation (75%) in IPAR.
- RUE -
  - RVI, NDRE, and SCCCI were moderately (R^2: 32-43%) related with RUE.
  - An exponential model for RVI explained the highest variation (43%) in RUE.

Future Work:

- Validation of the prediction models using next year data and development of a model to predict harvest index (HI)

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Thanks!

Acknowledgements

- Dr. Simerjeet Virk
- Dr. John L Snider
- Dr. George Vellidis
- Ved Parkash
- Coleman Byers

GEORGIA Precision Ag

GEORGIA COTTON COMMISSION

Cotton Incorporated