

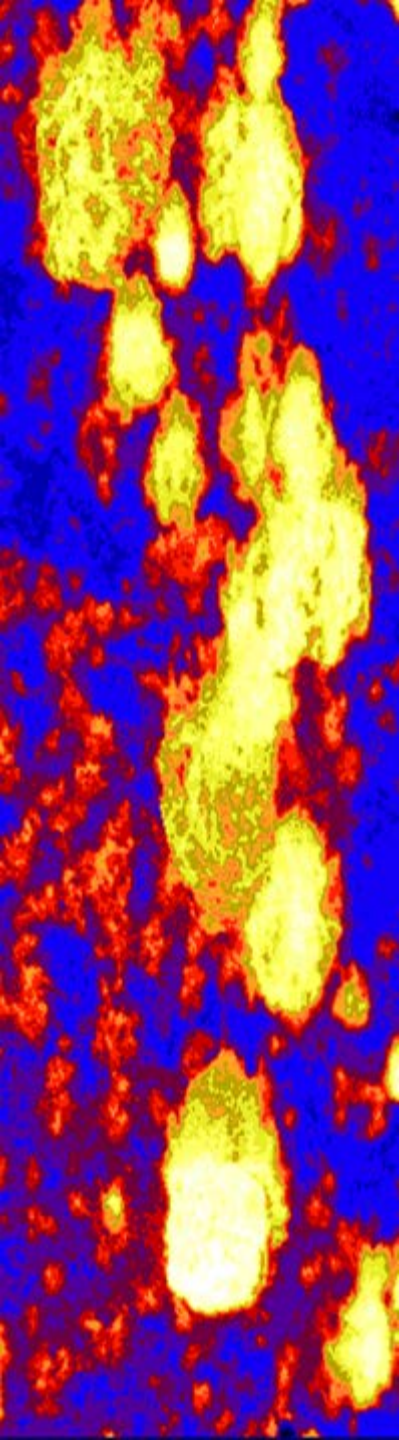
Ecological Applications of Drone-collected Multispectral Image Analyses

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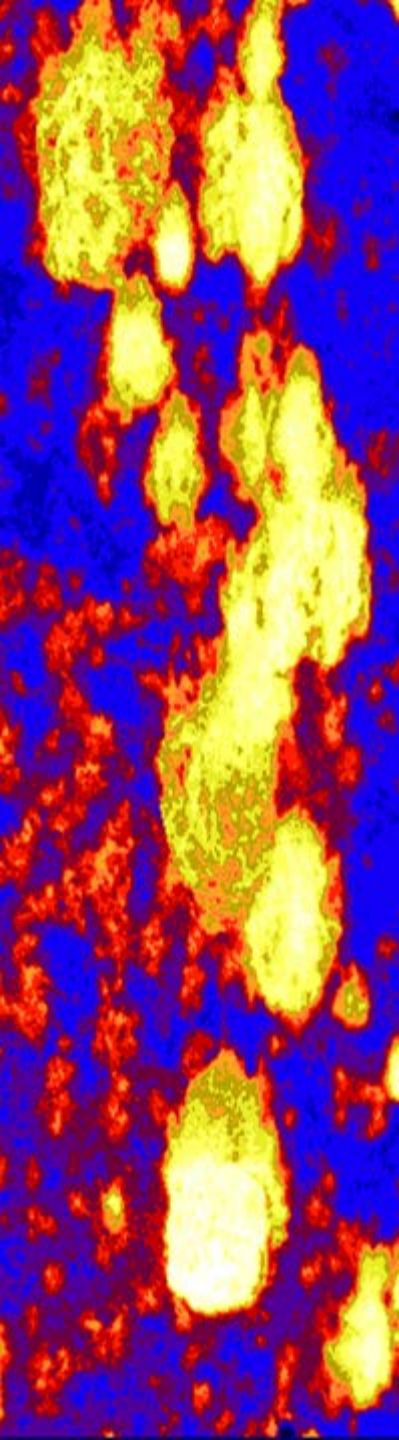
Richard Alward, Tamera Minnick, Colorado Mesa University
Unconventional Energy Center
Bureau of Land Management, White River Field Office





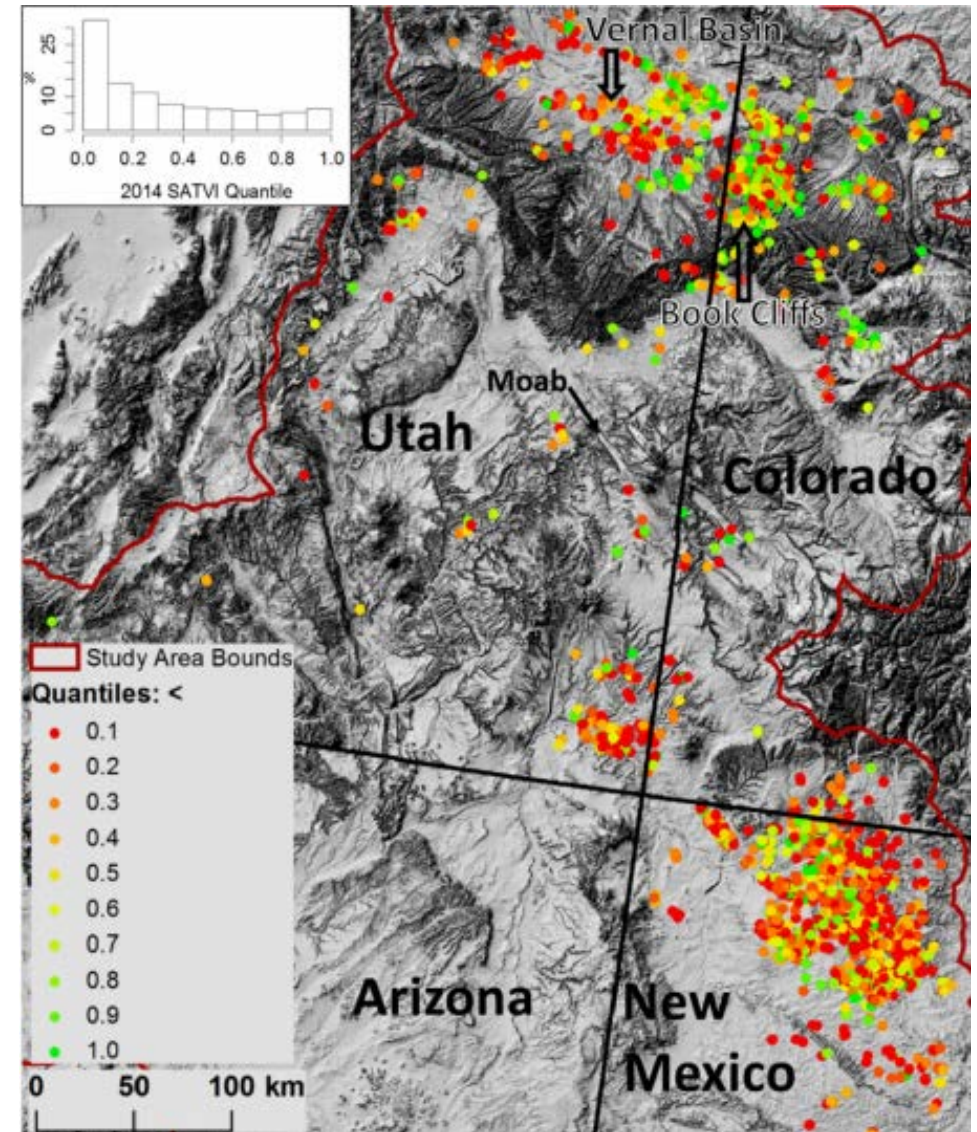
Outline

- Oil & Gas Restoration Monitoring Project
 - Challenges
 - Objectives
 - Methods
 - Results & Discussion
 - Conclusions/Evaluation
- Vegetation/Invasive Species Analysis Project
 - Site/Project background
 - Methods
 - Results & Discussion
 - Conclusions



Challenges

- Oil & Gas development
- Well pad restoration
 - Pre-disturbed state
 - Native vegetation
 - Heterogeneity
 - Monitoring
 - Tens of thousands of sites
 - Traditional/on-the-ground methods
 - Expertise
 - Time
 - Limited season
 - Travel to site
 - Representative of entire well pad?
 - Satellite imagery
 - Availability
 - Frequency
 - Resolution
 - Landsat-8



Nauman, T. W., Duniway, M. C., Villarreal M. L., and T. B. Poitras. 2007. Disturbance automated reference toolset (DART): Assessing patterns in ecological recovery from energy development on the Colorado Plateau. *Science of the Total Environment* 585: 476 – 88.

Objectives

- Primary Objective: Evaluate benefits/trade-offs
- Vegetative cover analysis
 - Functional Groups
 - Species I.D.



150 Meters

Methods: On-the-Ground

- Well pads
 - Rio Blanco County, CO
 - 1962 – 2008; abandoned or reclaimed
 - 7 well pads
 - 2 reference sites
- LPI Plots
 - 15 x 20m transects
 - 300 points
 - Area of “best” recovery chosen

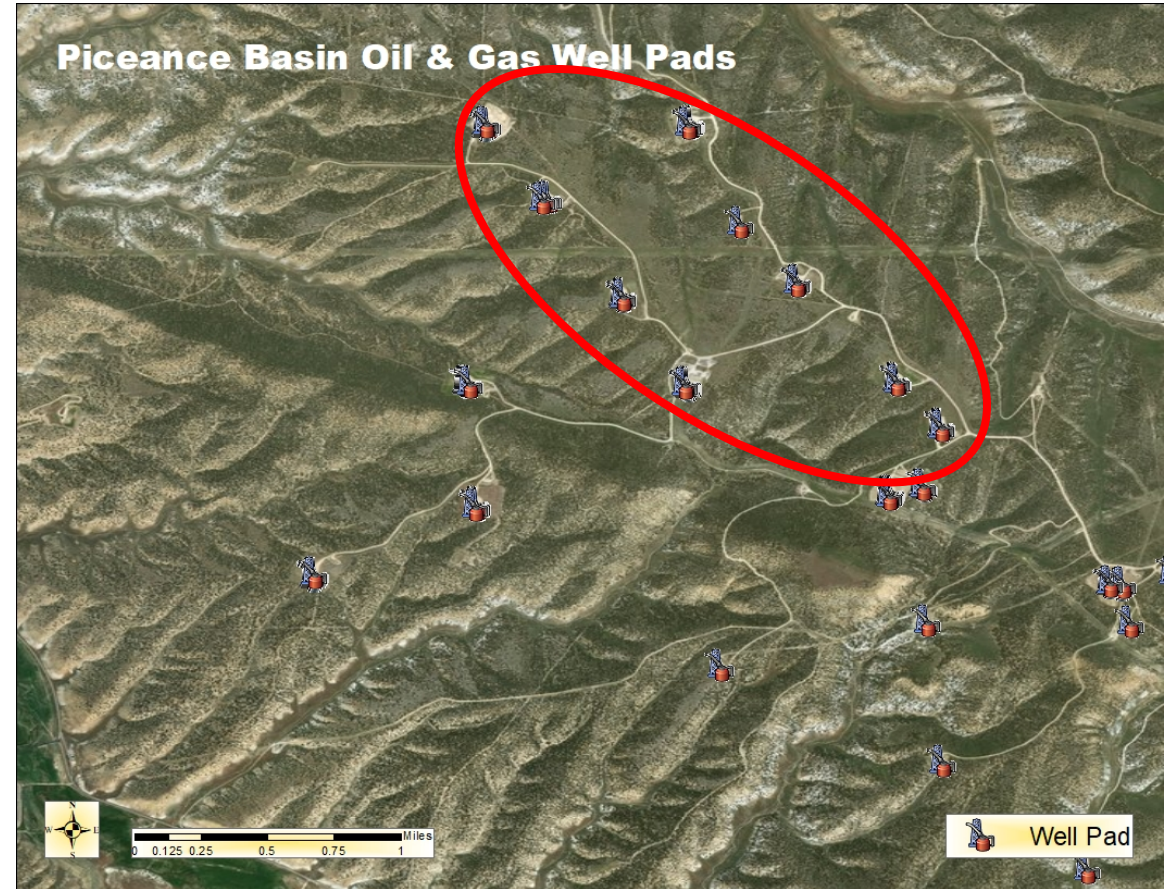
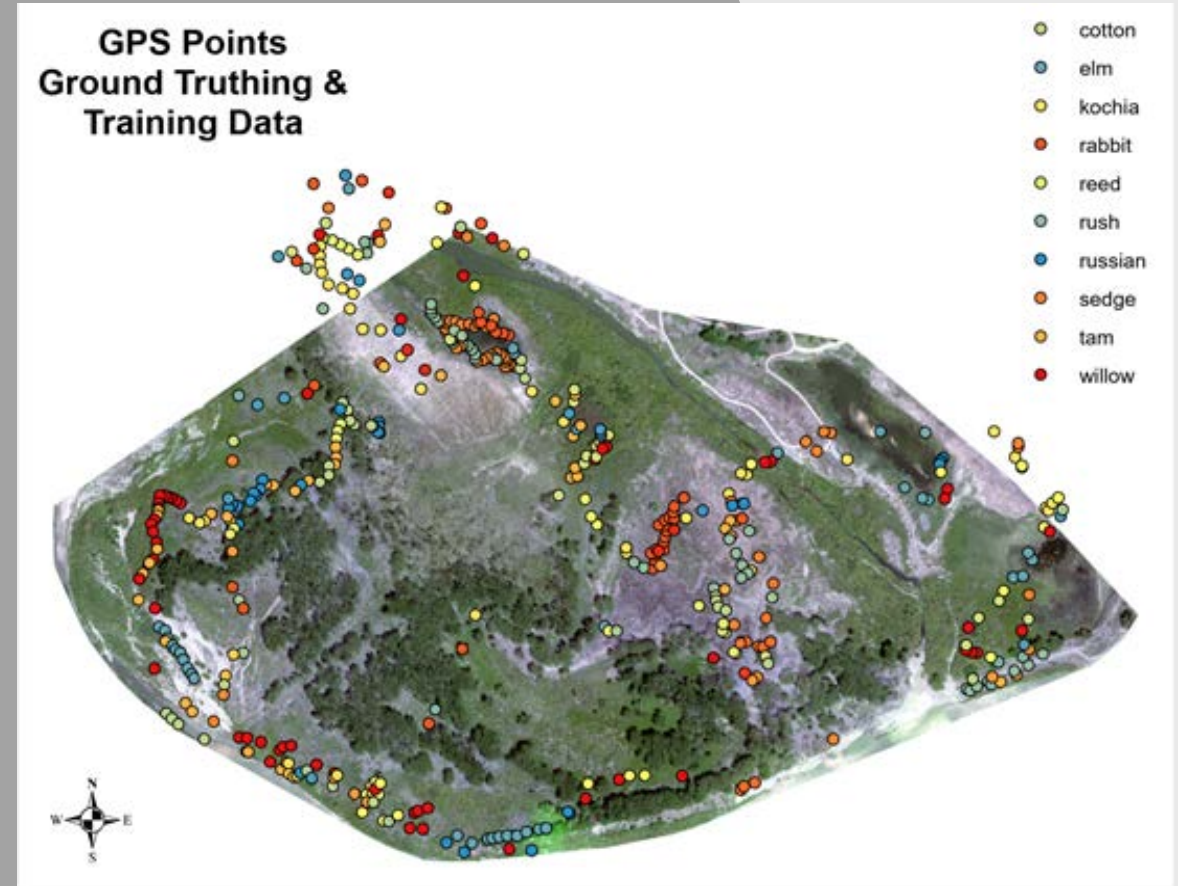


Image Analysis

- ENVI Image Analysis Software
- Pixel-based or “pixel-by-pixel”
- Image Classification
 - Unsupervised
 - Supervised
 - Training Data “ROI”s
 - GPS
 - General understanding of vegetation on site
 - Use only spectral data
 - Object-based
 - Algorithm – Multiresolution segmentation/Feature extraction
 - Meaningful “Image Objects”
 - Texture, Shape, Area, Brightness, etc.



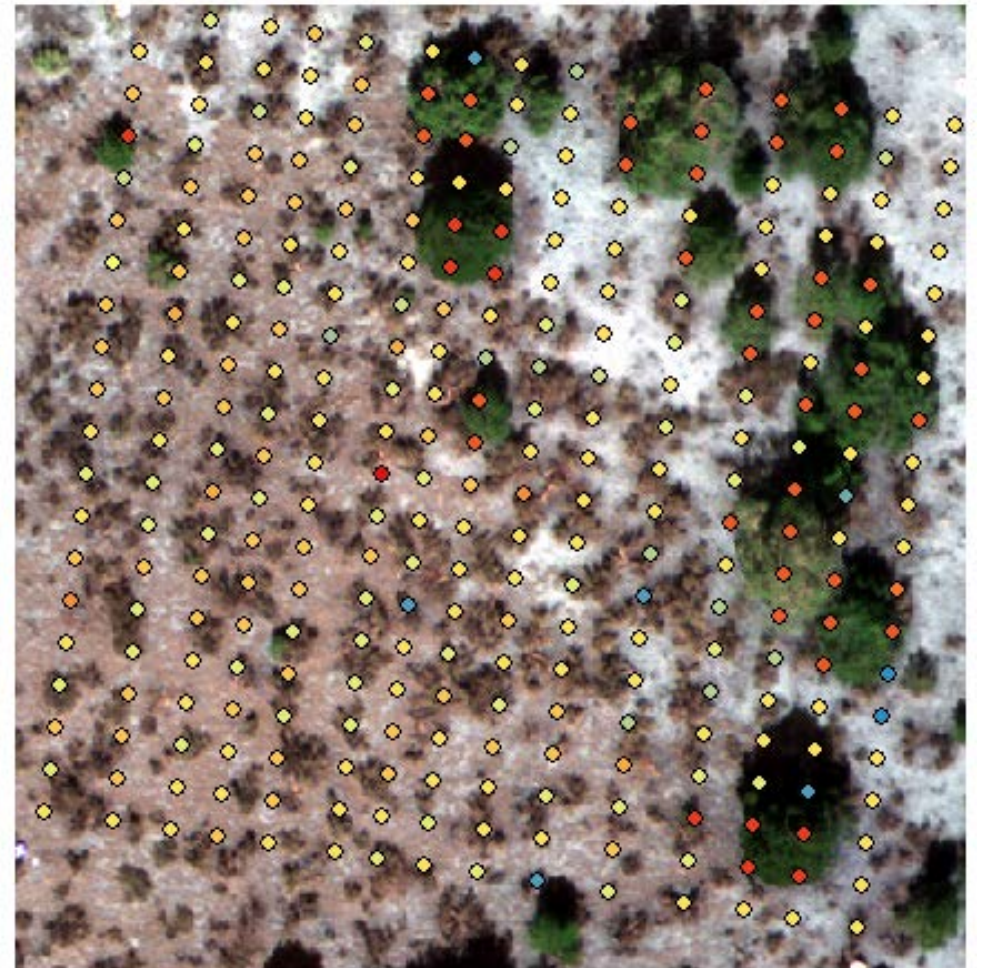
Methods: Remote Sensing

- Drone mounted camera – MicaSense Red Edge Sensor
 - 5 Bands (R,G,B,RE,NIR)
 - Average 5cm resolution (~160,000 Pixels / LPI Plot)
 - Landsat: Average 30m resolution (~1 Pixel / LPI Plot)
- Supervised Classification - ENVI
 - Created training data
 - LPI Grid
 - 5 Bands
 - Indices
 - OSAVI
 - NDVI
 - CIR (False Color)
- Extrapolation to well pad

Plot 5 LPI Grid

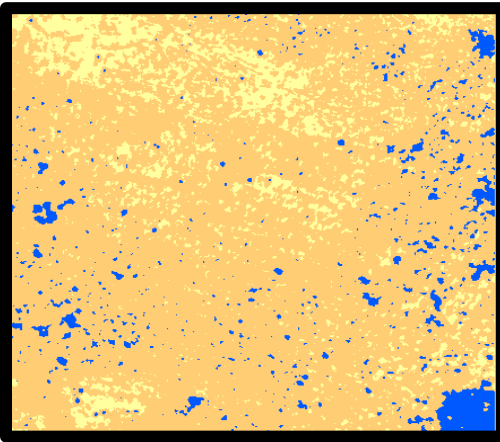
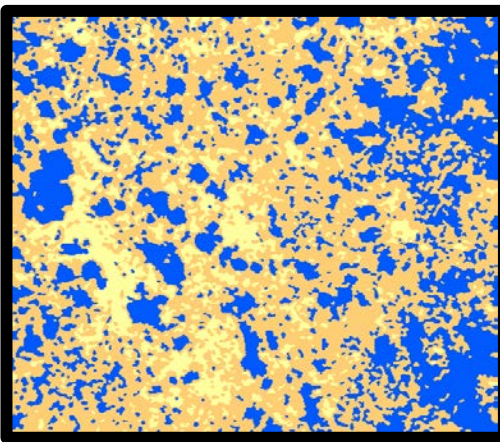
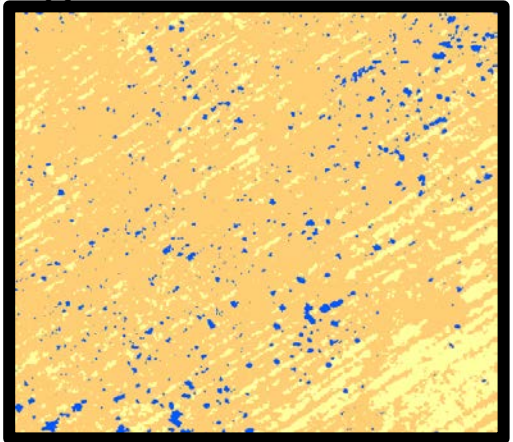
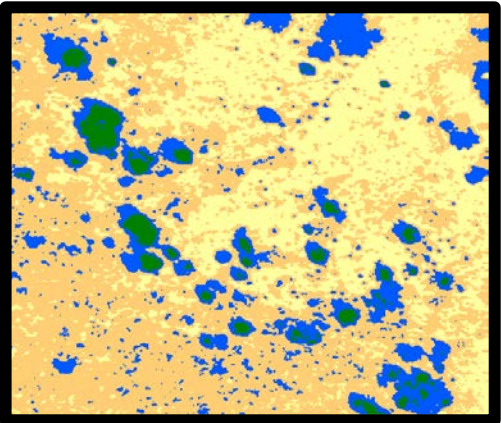
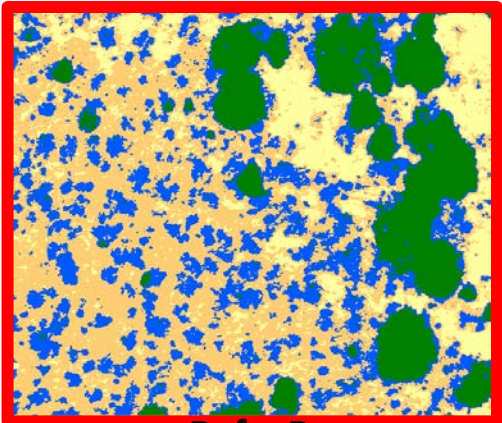
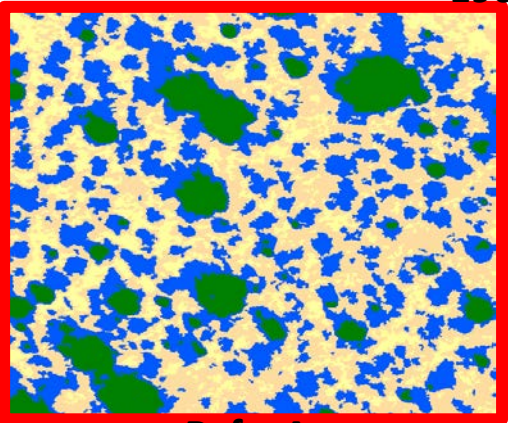
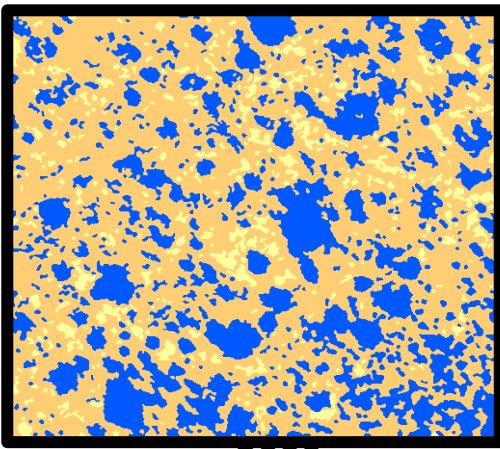
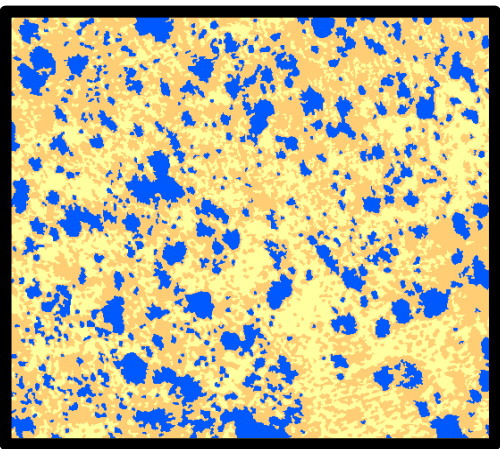
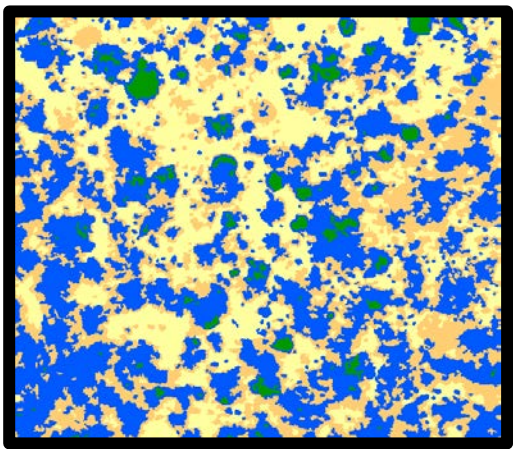
Canopy

- ACHY
- ANPA
- ARTR
- ASCO
- ASSP
- BOGR
- BRTE
- ELLA
- ERNA
- GUSA
- HECO
- JUOS
- NONE
- PAMU
- PASM
- PIED

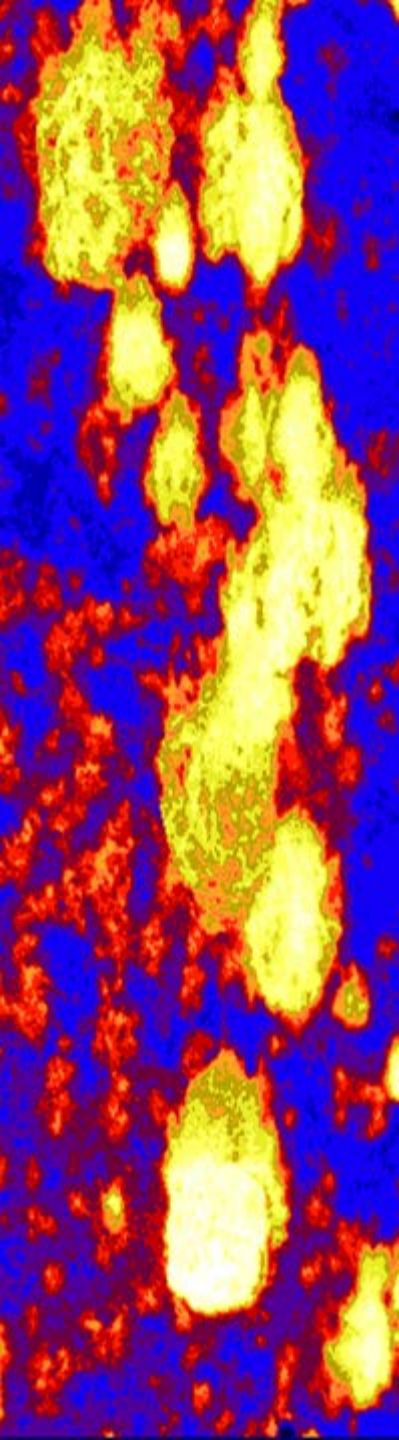


20 10 0 20 Meters

Results – Functional Groups

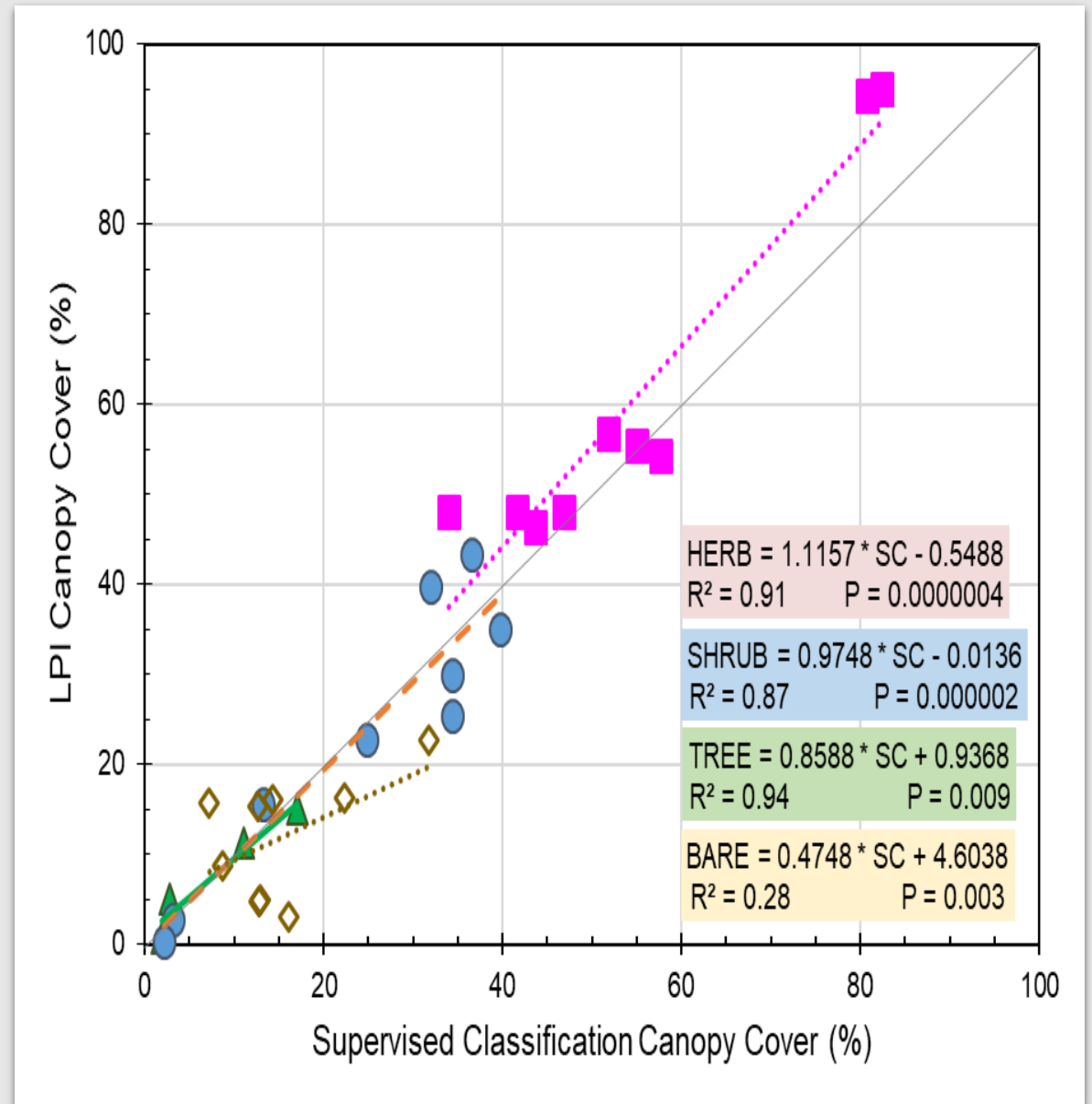


- 0: Unclassified
- 1: Herb
- 2: Bare
- 3: Tree
- 4: Shrub

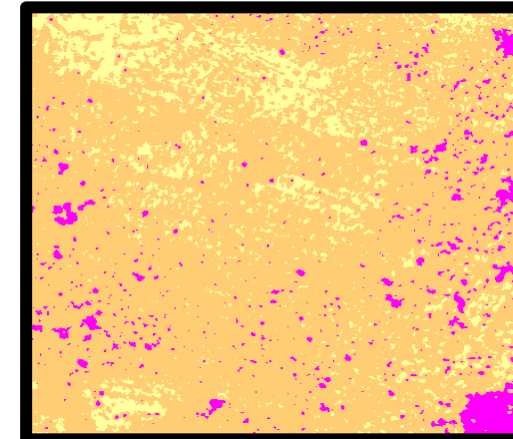
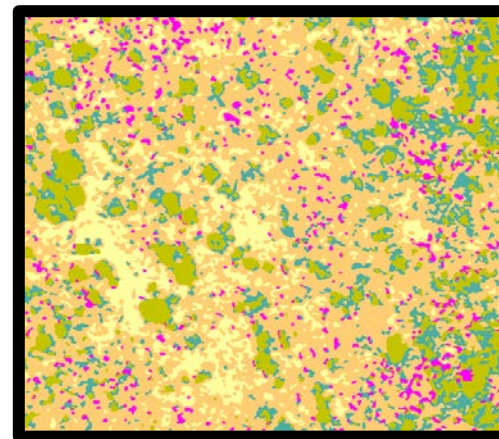
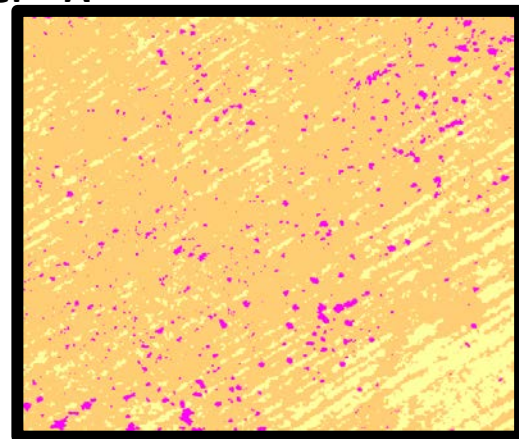
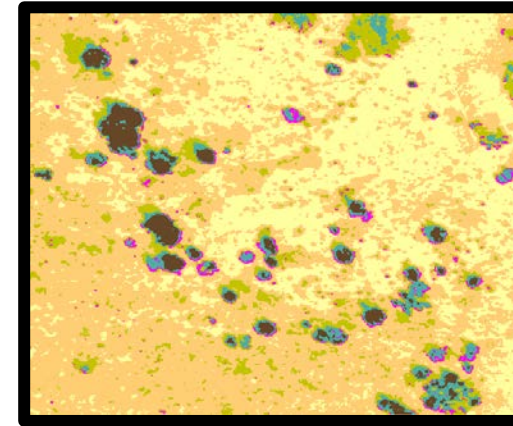
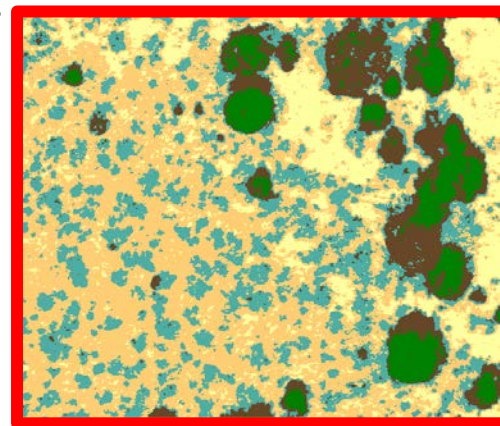
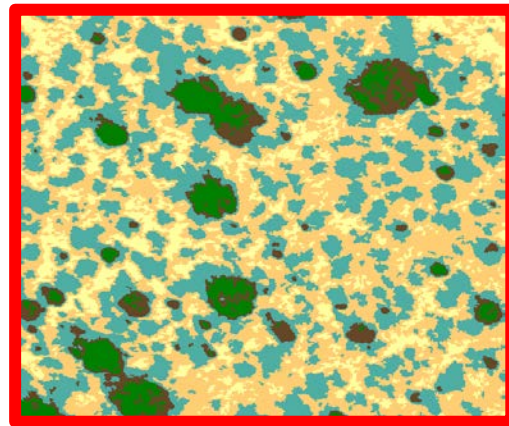
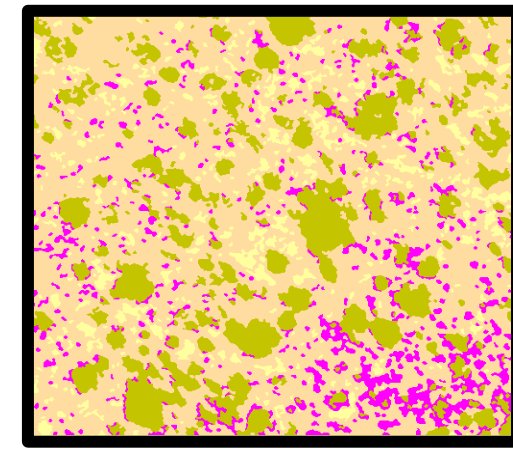
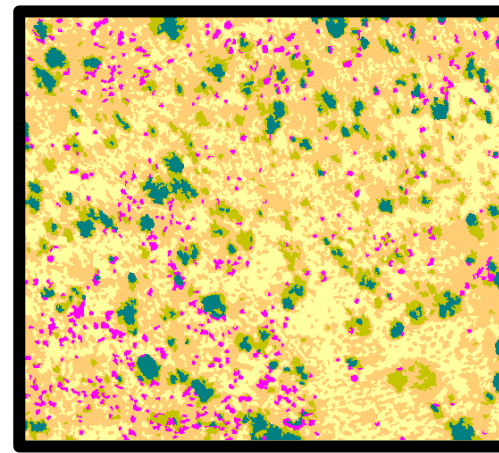
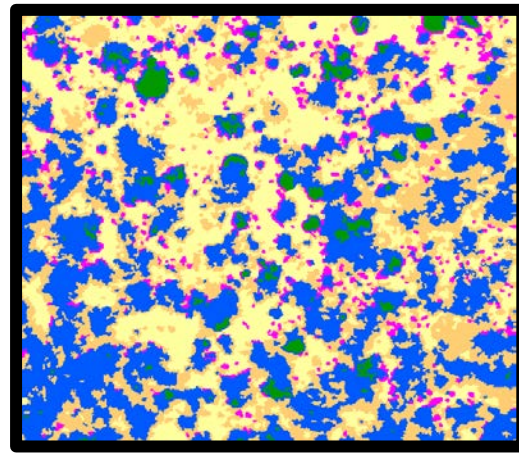


Functional Groups: Supervised Classification Cover Predicts LPI Cover

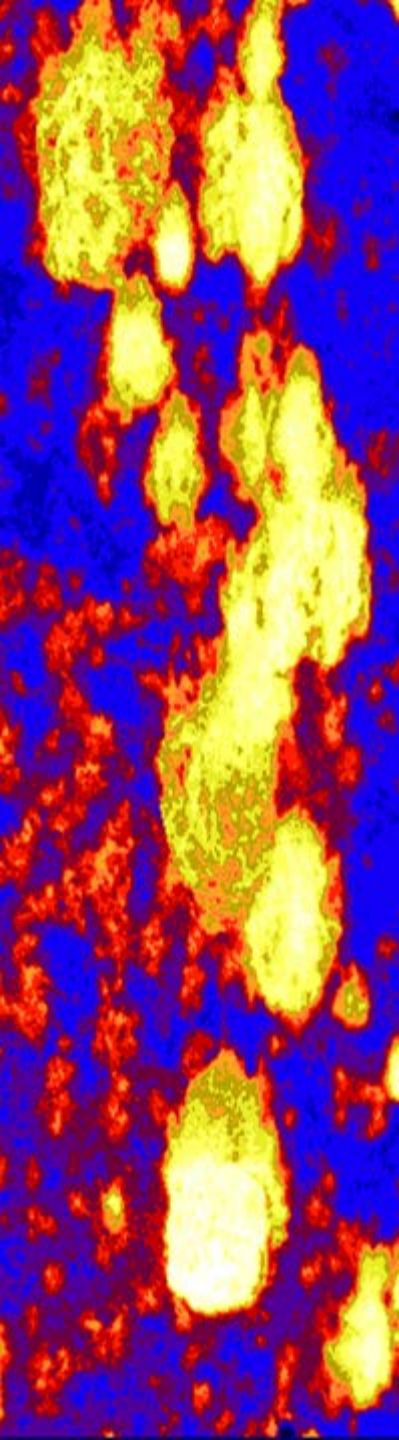
- Accurately I.D. functional groups
 - Trees ($r^2 = 0.94$)
 - Shrubs ($r^2 = 0.87$)
 - Herbaceous ($r^2 = 0.91$)
 - Differentiating litter and Herbaceous cover (August Images)
 - Bare ground



Results – Species

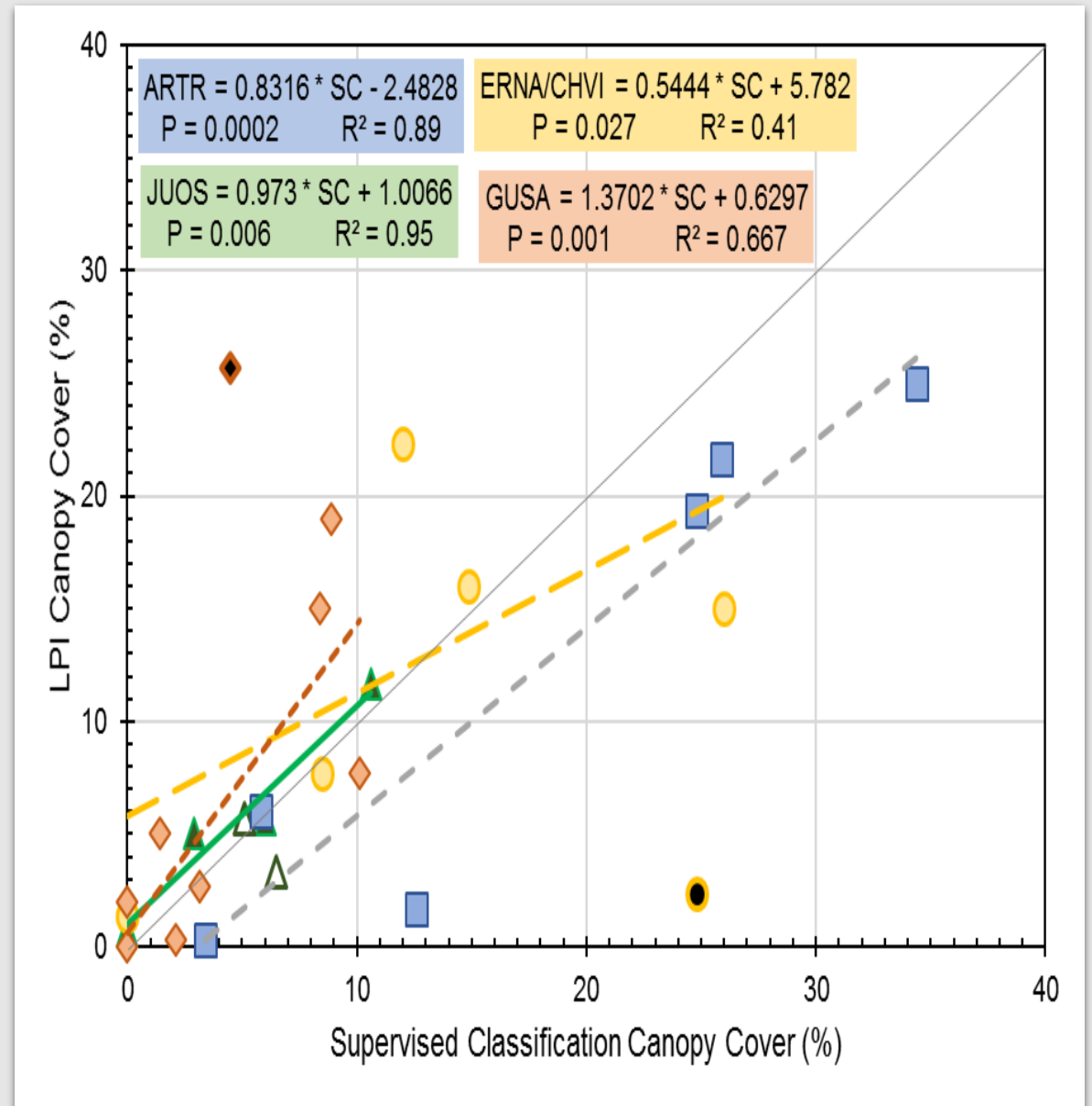


- Pinon Pine
- Juniper
- Sagebrush
- Rabbitbrush
- Snakeweed
- Herbaceous/Litter
- Bare



Species: Supervised Classification Cover Predicts LPI Cover

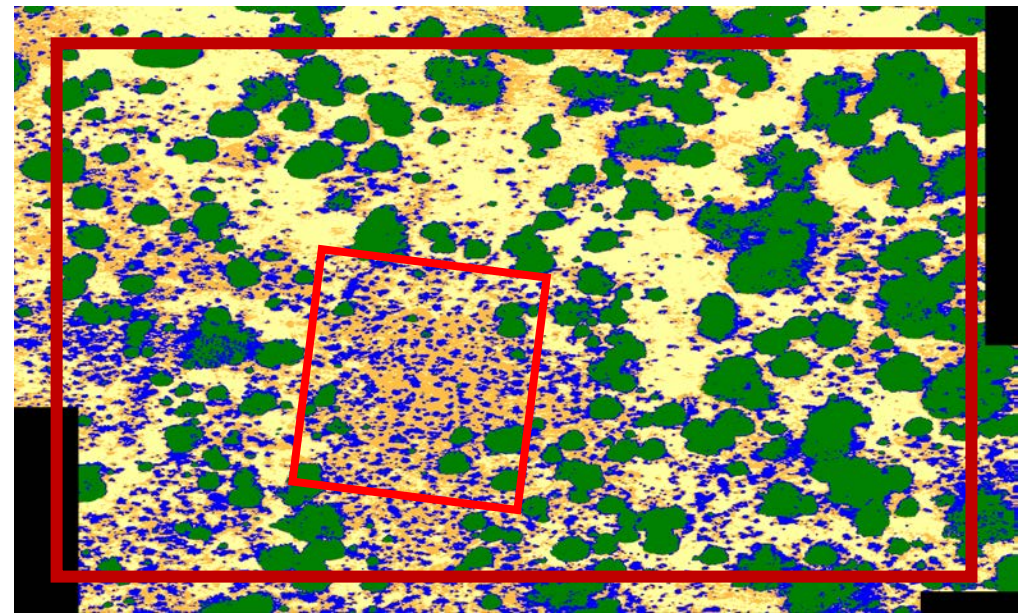
- Species I.D. w/ less accuracy
 - Juniper
 - Pinon Pine
 - Big Sagebrush
 - Snakeweed
 - Yellow Rabbitbrush & Rubber Rabbitbrush



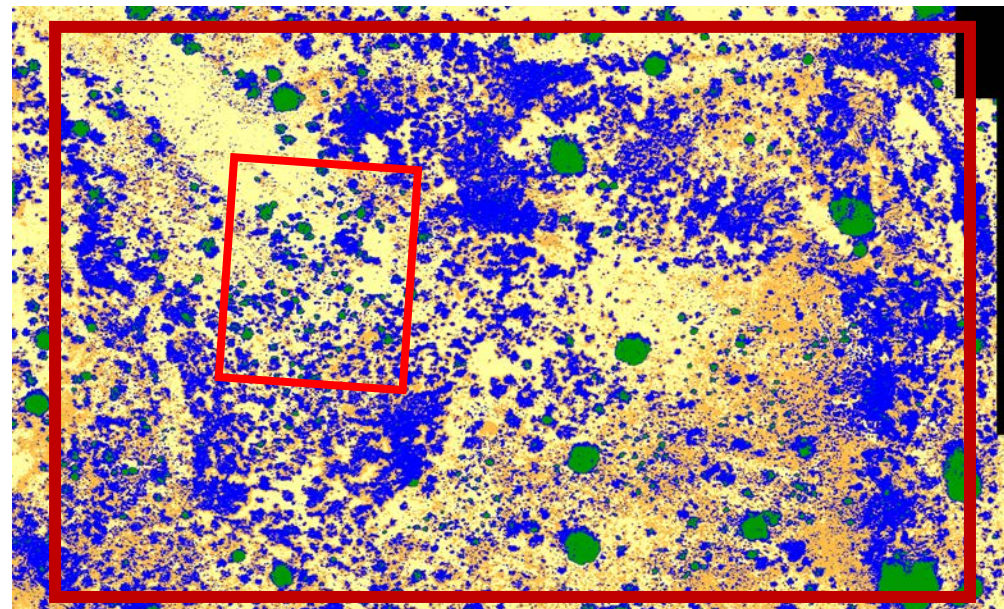
Extrapolate

Sup Class of Plot - Extrapolation

	1961 Plot	1961 Pad	Ref - B Plot	Ref "Pad"
Tree	1.9	3.9	17.1	29.3
Shrub	39.7	33.8	24.8	18.8
Herb	34	31.5	43.7	24.4
Bare	22.3	30.5	14.3	27.4



Ref - B



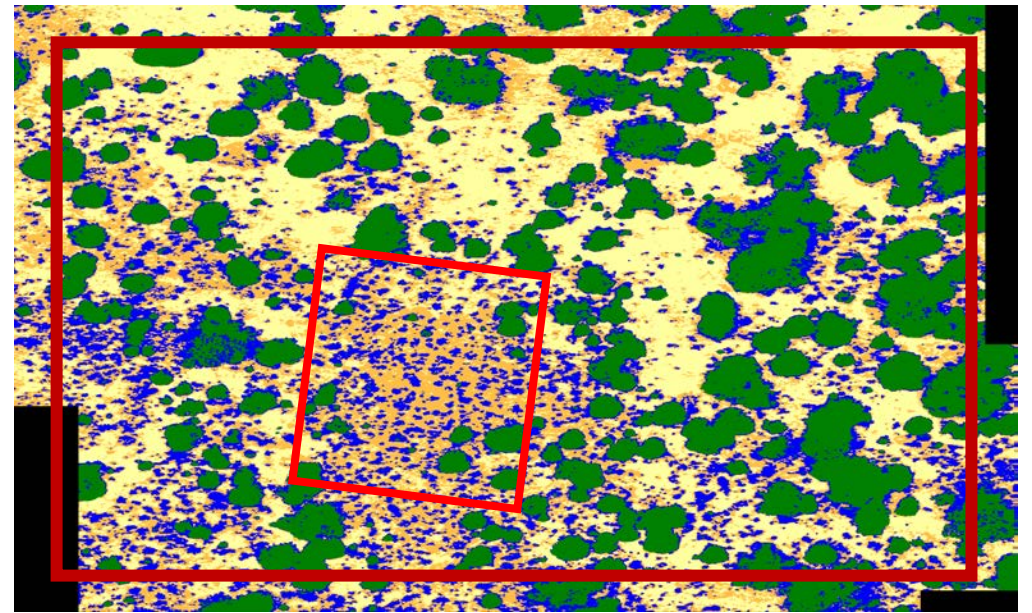
1961

- 0: Unclassified
- 1: Herb
- 2: Bare
- 3: Tree
- 4: Shrub

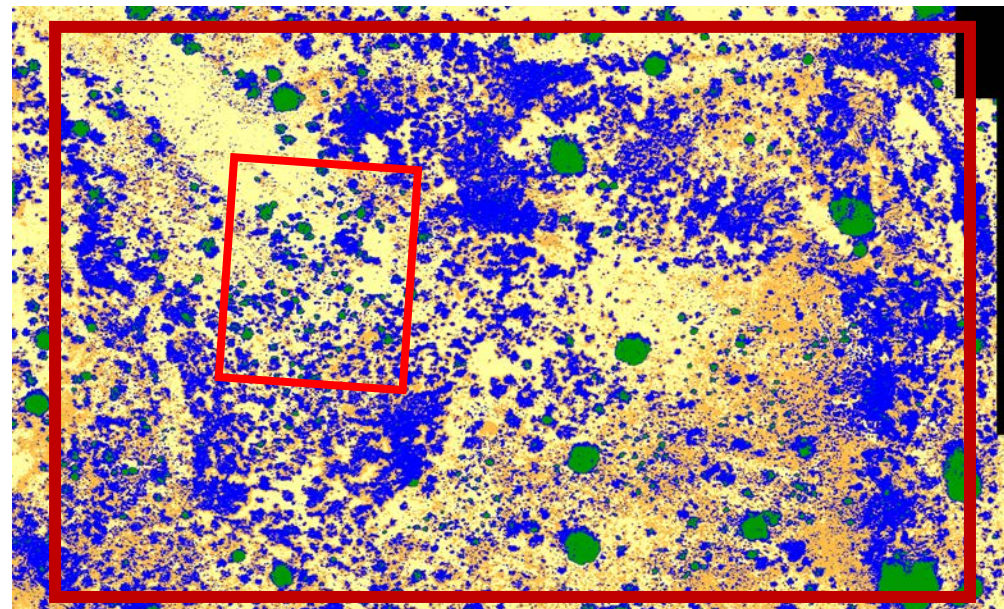
Extrapolate

According to LPI...

	1961 LPI	1961 Pad	Ref - B LPI	Ref "Pad"
Tree	0.7	3.9	15.0	29.3
Shrub	35.0	33.8	22.7	18.8
Herb	48.0	31.5	46.3	24.4
Bare	16.3	30.5	16.0	27.4

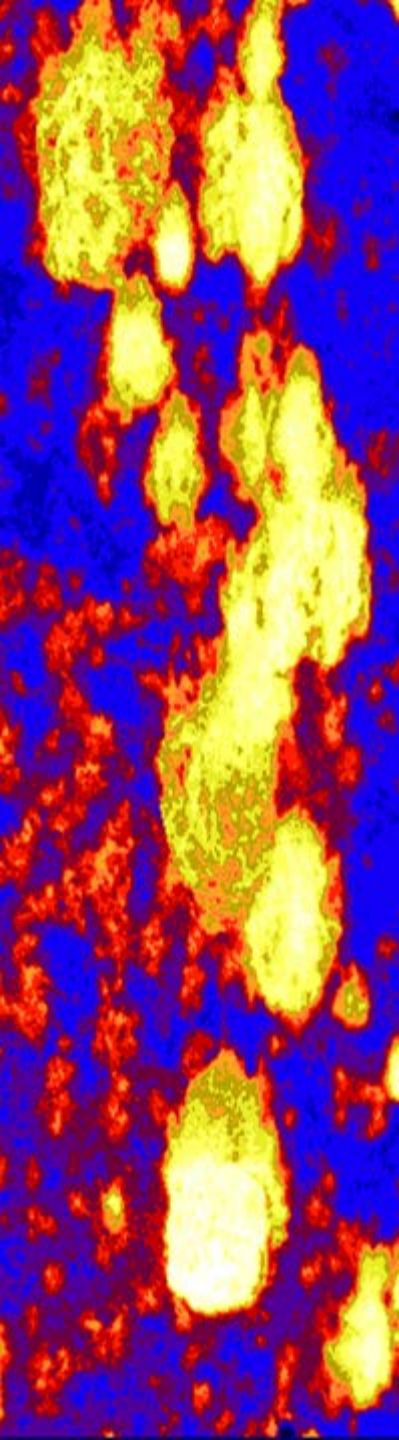


Ref - B



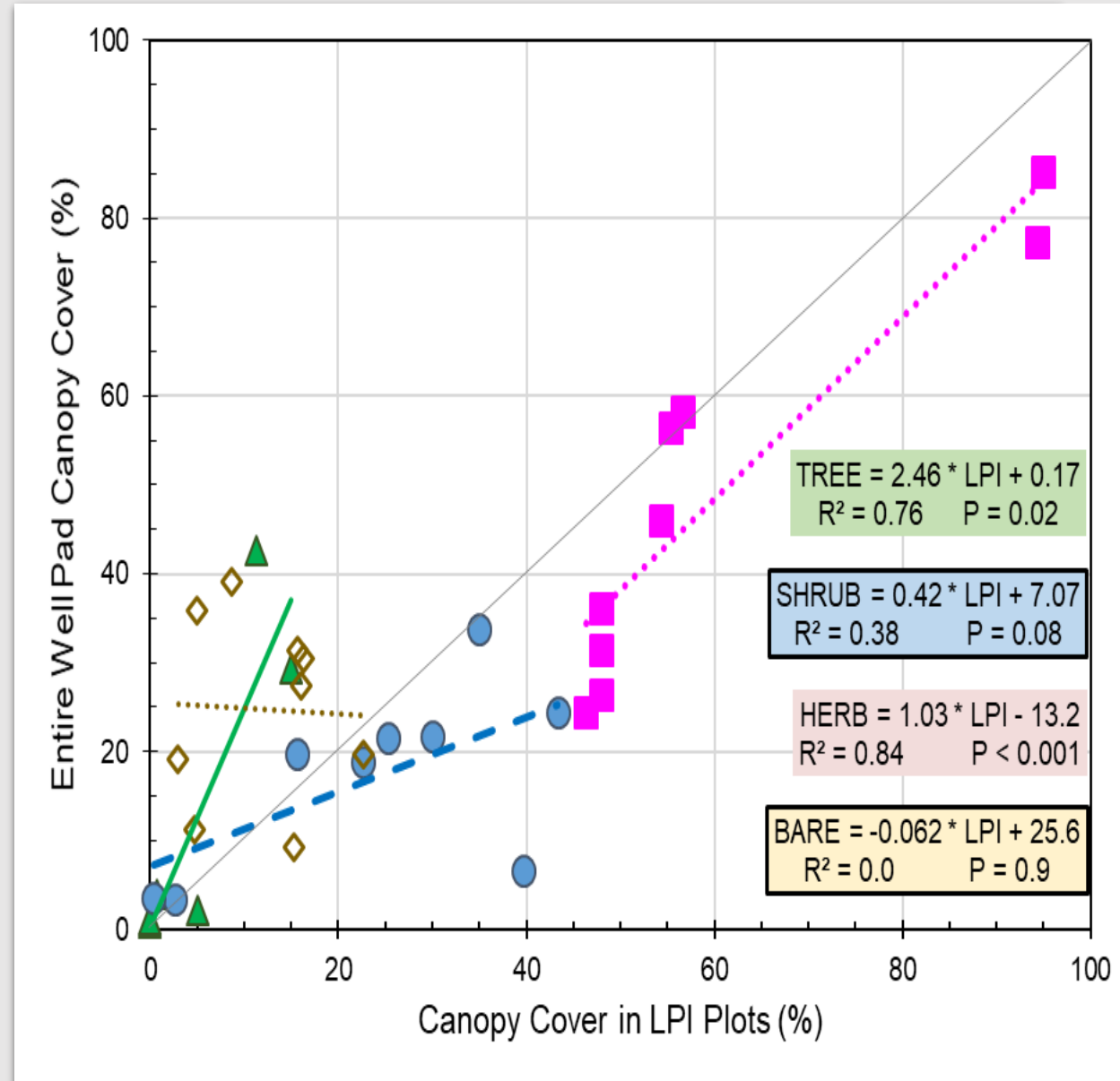
1961

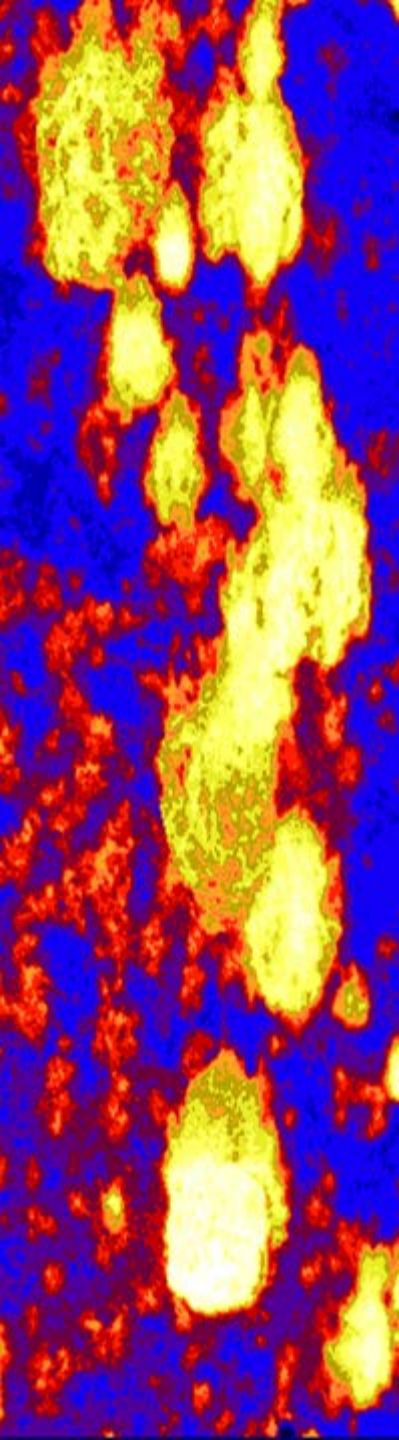
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Extrapolating from Vegetation Cover in the LPI Plots to the Entire Well Pad

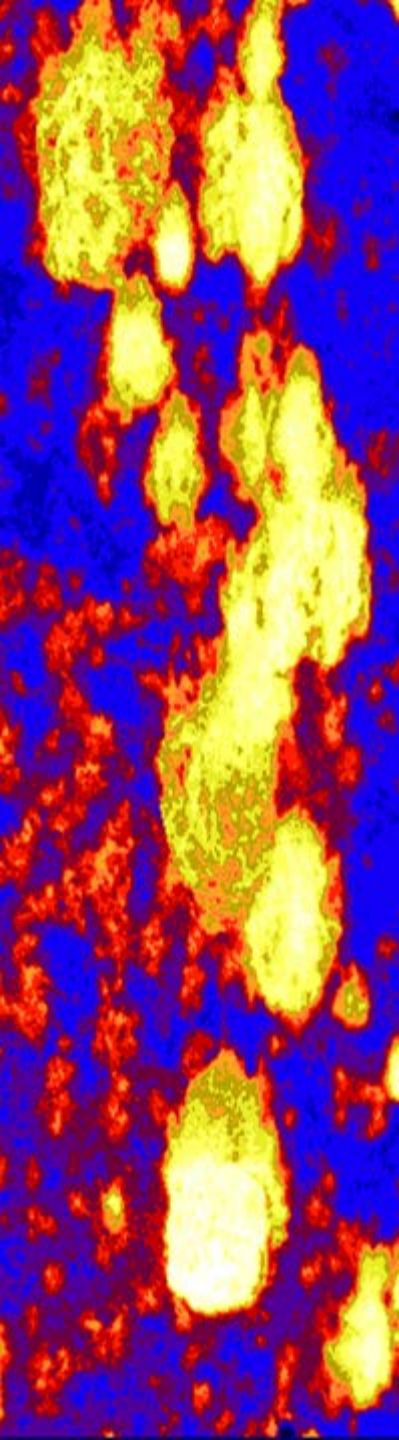
- LPI cover does not accurately predict shrubs or bare ground
- Tree cover
 - Underestimated in reference sites
 - Accurate on sites with low tree cover (<5%)
- Overestimates herbaceous cover
 - Distinguishing litter





Discussion

- Can we quantitatively monitor these sites using drone – collected data? **Yes**
- Extrapolation
 - Measure vs. inference
- Improvements to restoration



Advantages

- On-the-ground
 - Accepted method
 - Low Tech
 - Species I.D.
- Remote sensing:
 - Can accurately measure entire restoration area
 - Historical record of data
 - More frequent monitoring
 - Time (2 Person Days for All)
 - 2 People x 1 Day
 - Mostly travel to & from site

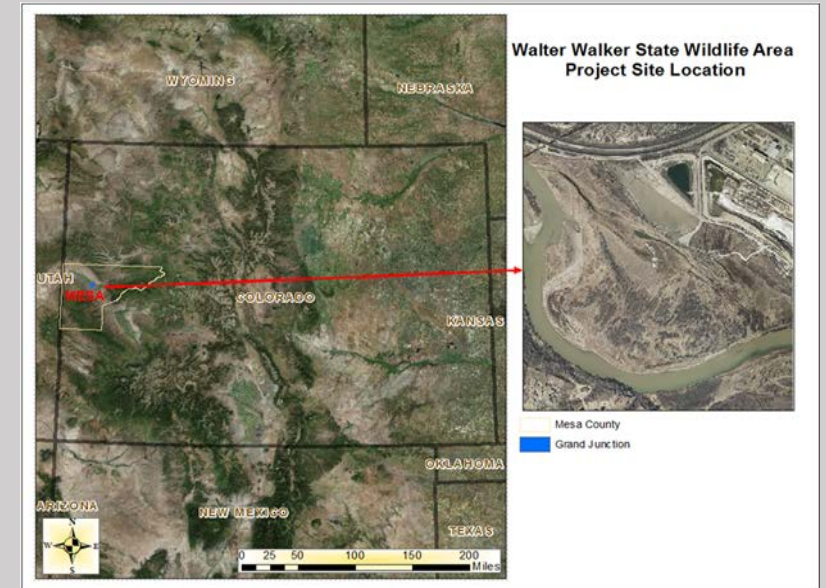
Trade-offs

- On-the-ground
 - Small area
 - Time (1 Person Day / Plot) & expertise
 - Preparation & planning
- Remote sensing:
 - Less accurate species I.D.
 - Equipment
 - Preparation & planning



Project Background

- Drone equipped with MicaSense multispectral sensor
 - 50 hectares within the Walter Walker State Wildlife Area
 - 110 meters
 - ~7 cm pixel resolution
 - 5 individual lenses
 - 5 bands of data; red, green, blue, red edge, near IR



Objective

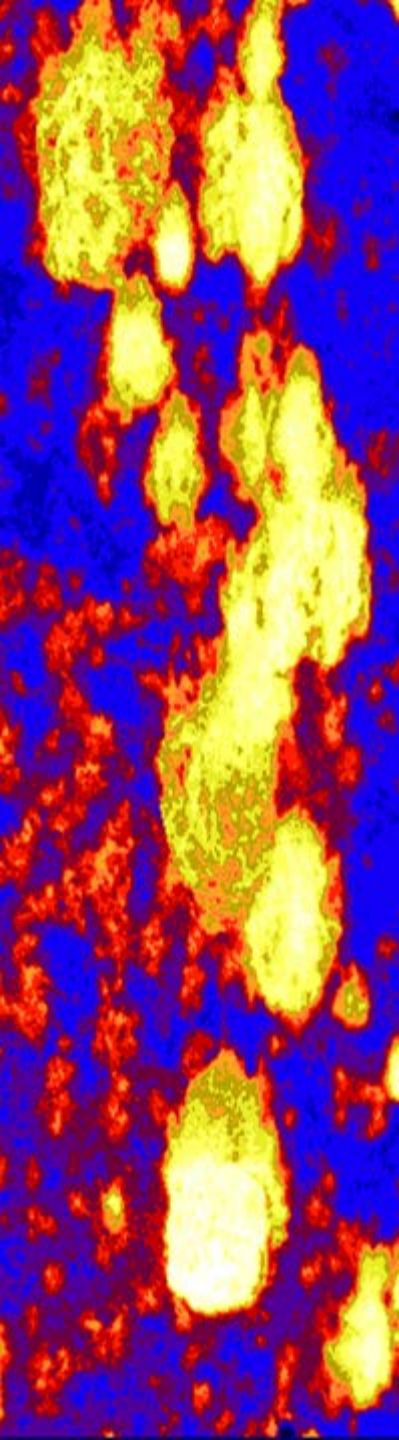
- **Primary Objective:** Can we accurately identify key species using image classifications of drone-collected imagery?
- If not, can we at least ID Functional Groups?
 - Key Native Vegetation:
 - Coyote Willow
 - Cottonwood
 - Shrub
 - Herbaceous
 - Wetland Vegetation
 - Non-native Vegetation:
 - Tamarisk
 - Elm
 - Russian olive
 - Kochia



<http://southwestdesertflora.com/WebsiteFolders/Images/Salicaceae/Salix%20exigua,%20Narrowleaf%20Willow/4059Salix-exigua,-Narrowleaf-Willow700x464.jpg>

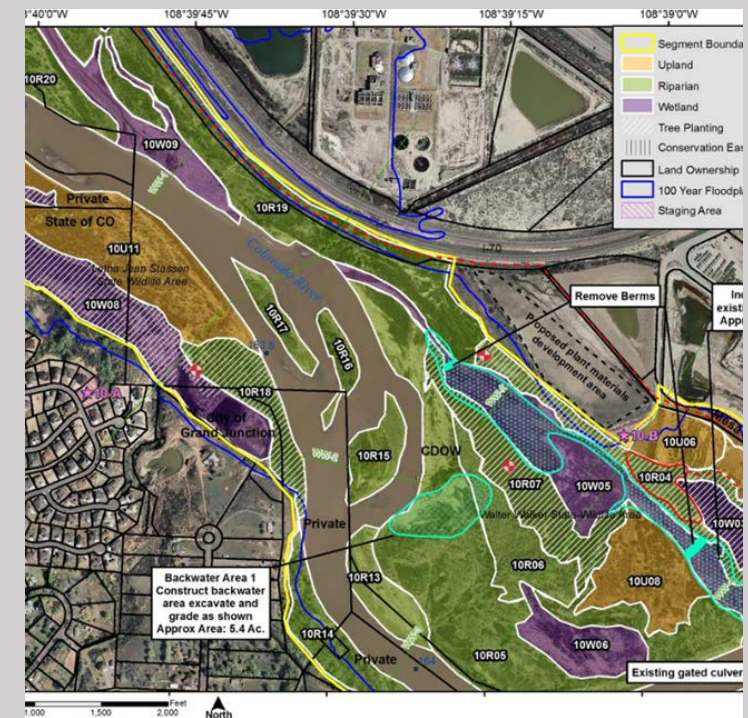


https://bcinvasives.ca/images/photos/_full/Salt_cedar003_SDewey_bugwood.org.jp



Methods

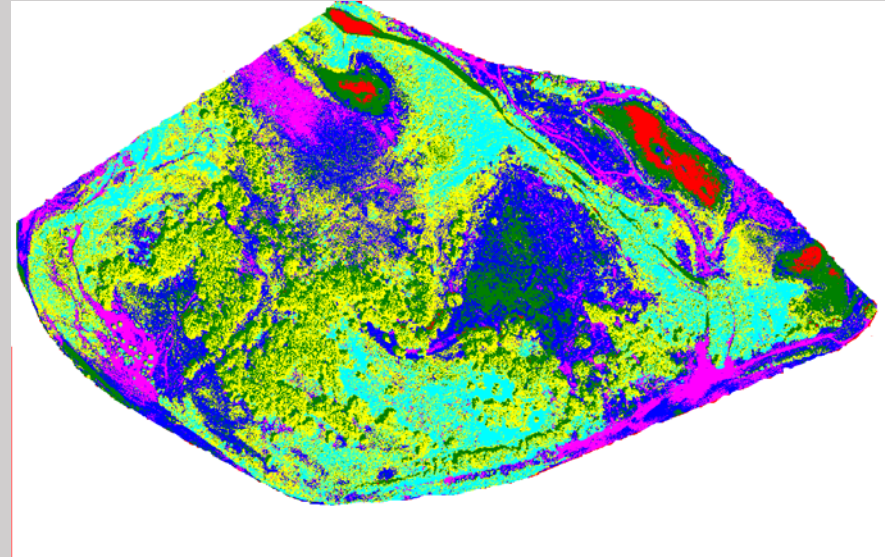
- Image pre-processing
 - Clipped into sub-sets based on functional type
 - Riparian, Upland, Wetland
 - 16 different clips
 - Allowed for faster, smoother image processing



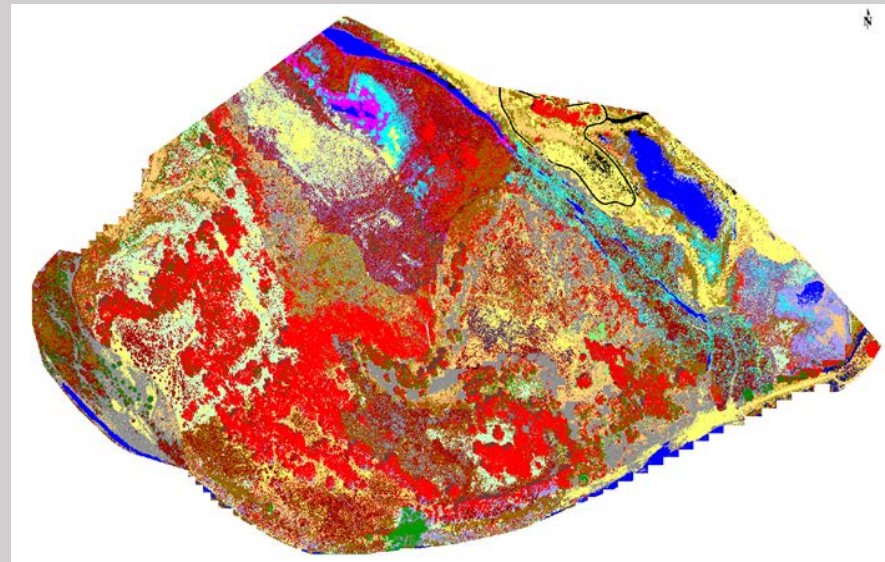
Methods

- Unsupervised Classification
 - Entire July Image
 - No training data
 - Class limit - 6
- Supervised classification
 - GPS Training Data
 - 16 Individual Classifications
 - Varying classes, depending on species present

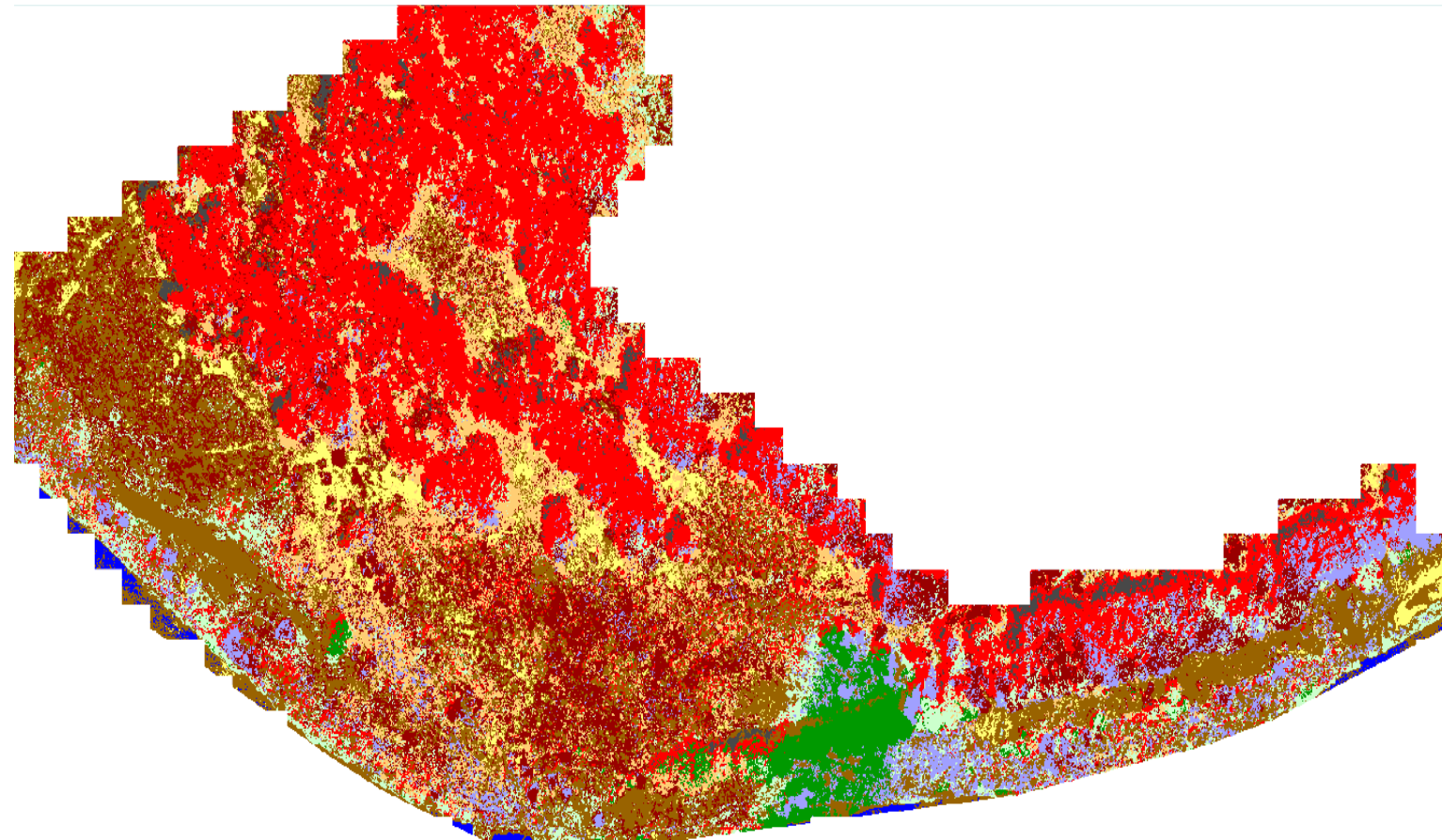
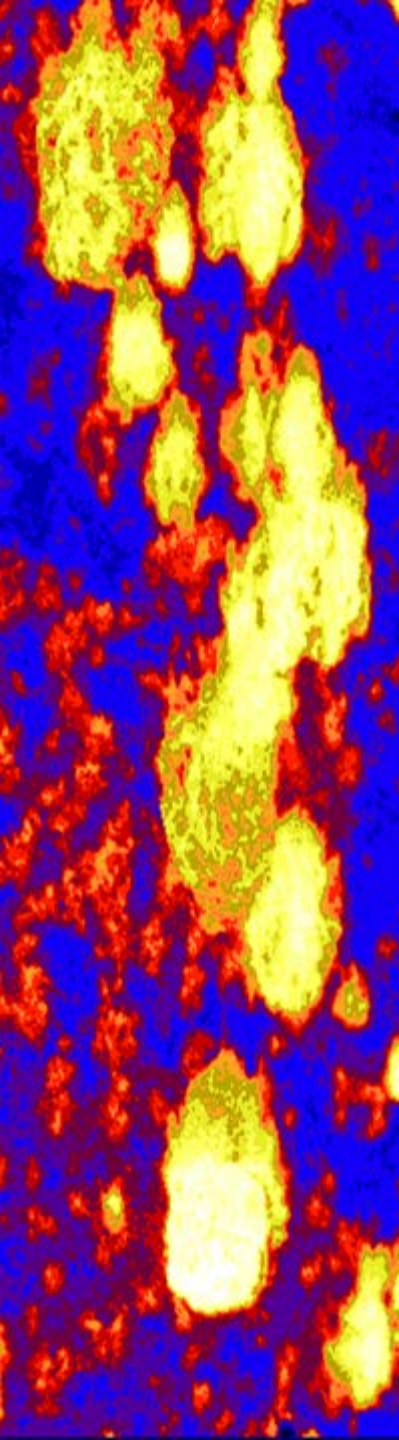
Unsupervised Classification



Supervised Classification

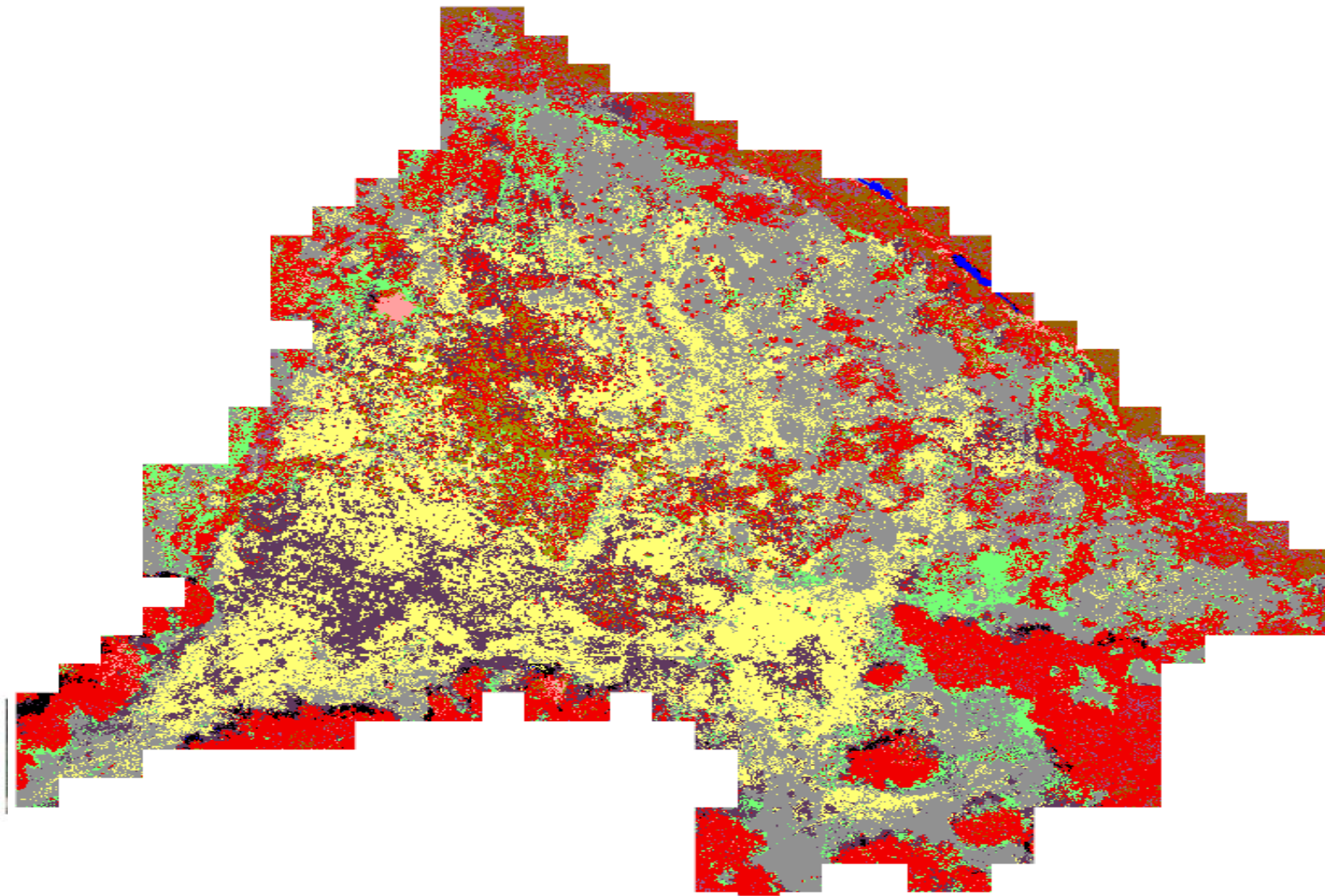
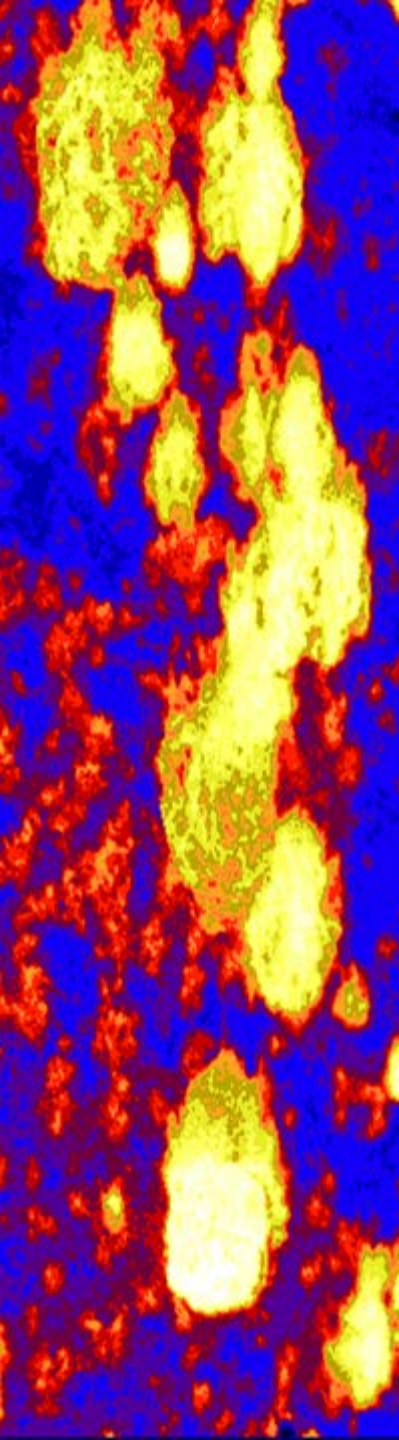


Supervised pixel-based image classification - Riparian



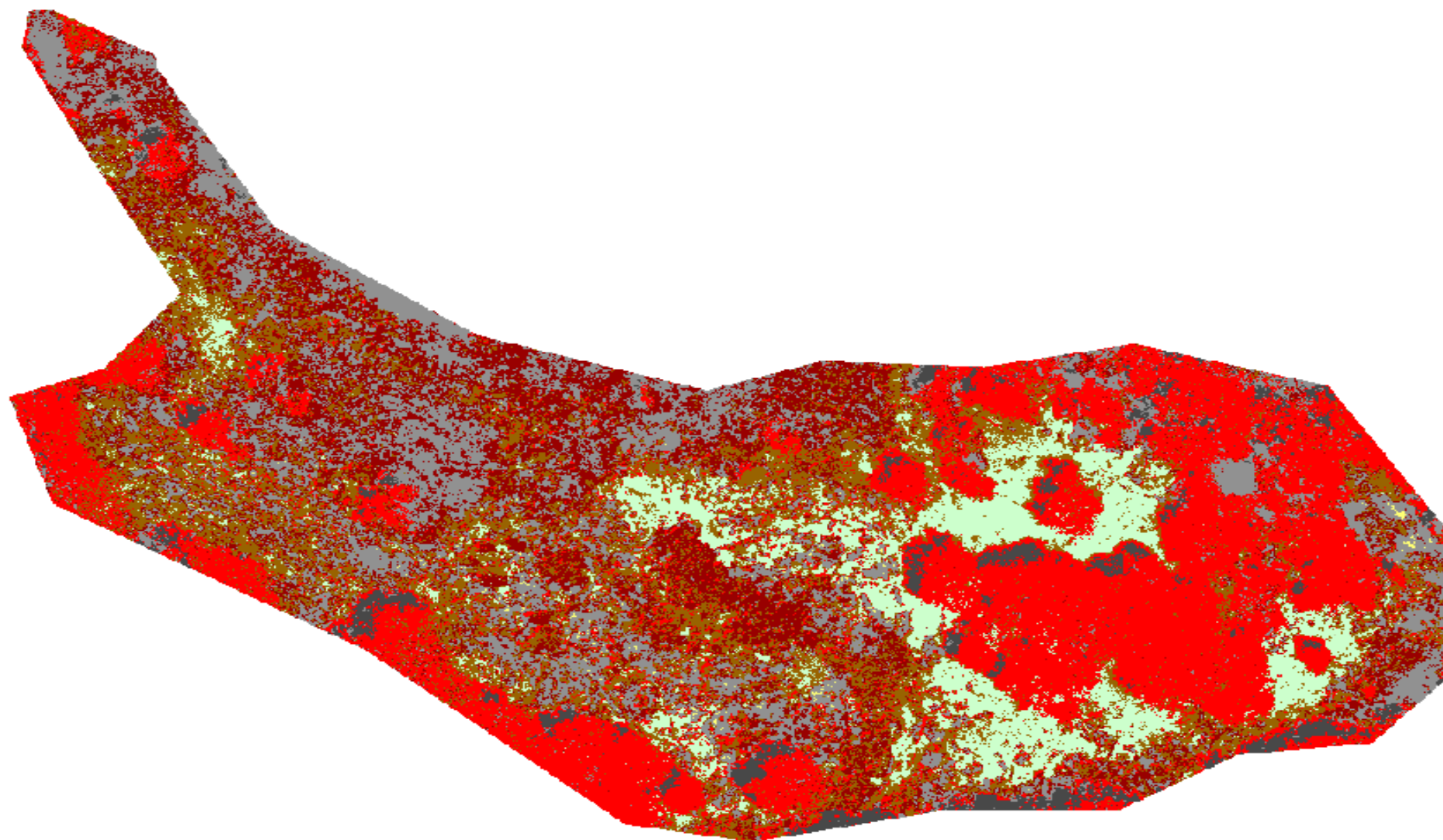
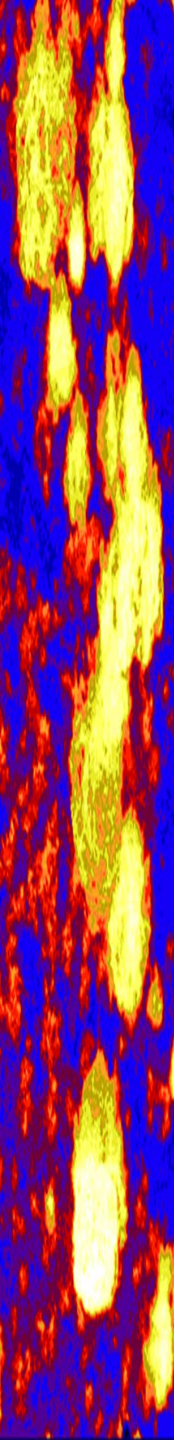
Tamarisk	Dark Red
Russian Olive	Light Blue
Kochia	Purple
Cottonwood	Red
Elm	Green
Coyote Willow	Brown
Reed Canary	Light Green
Common Rush	Cyan
Rabbitbrush	Olive Green
Sedge	Magenta
Water	Blue
Shadow	Dark Gray
Litter	Light Gray
Concrete	Black
Herbaceous	Orange
Bare Ground	Yellow

Supervised pixel-based image classification - Upland

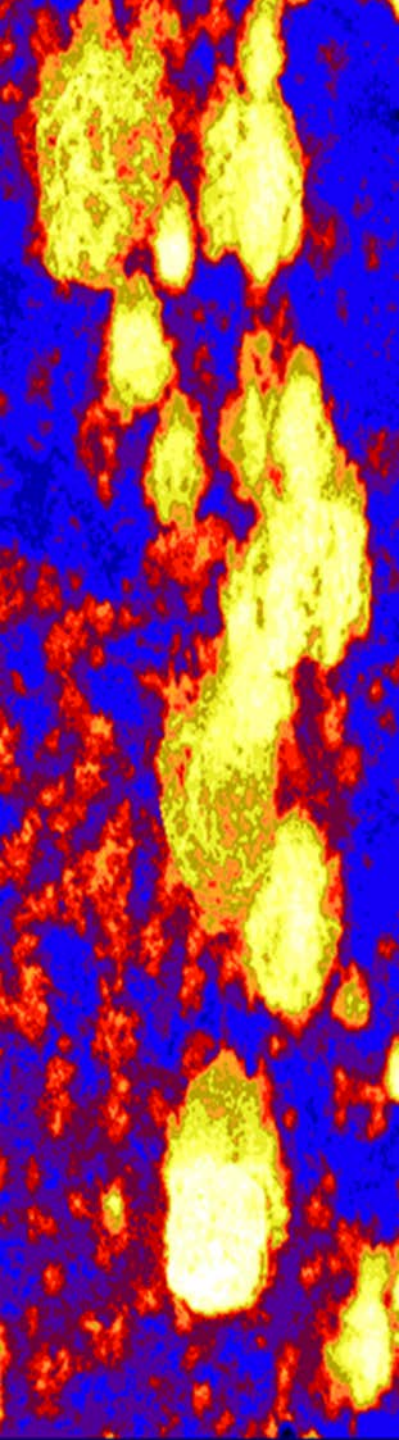


Tamarisk	Dark Red
Russian Olive	Light Blue
Kochia	Purple
Cottonwood	Red
Elm	Green
Coyote Willow	Brown
Reed Canary	Light Green
Common Rush	Cyan
Rabbitbrush	Olive Green
Sedge	Magenta
Water	Blue
Shadow	Dark Gray
Litter	Light Gray
Concrete	Black
Herbaceous	Orange
Bare Ground	Yellow

Supervised pixel-based image classification - Wetland



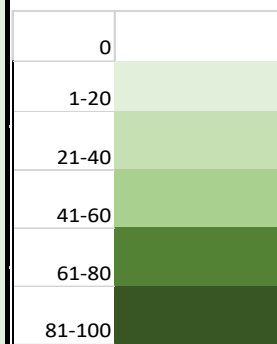
Tamarisk	Dark Brown
Russian Olive	Light Blue
Kochia	Purple
Cottonwood	Red
Elm	Green
Coyote Willow	Brown
Reed Canary	Light Green
Common Rush	Cyan
Rabbitbrush	Gold
Sedge	Magenta
Water	Blue
Shadow	Grey
Litter	Black
Concrete	Black
Herbaceous	Orange
Bare Ground	Yellow



Results – Functional Groups

Accuracy of Image Classification

Functional Group	T	S	H	W
Tree	94	4	2	9
Shrub	5	73	5	8
Herbaceous	0	5	88	7
Weedy	1	18	5	76

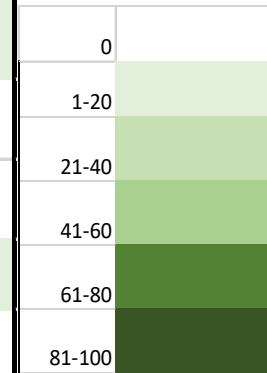


- 94% correctly classified as tree
- 5% incorrectly classified as shrub
- 1% incorrectly classified as weedy species
- Overall accuracy = 82.0%

Results – Individual Species

Accuracy of Image Classification

Individual Species	CW	EL	WL	TM	RO	RB	SD	RD	RS	KC
Cottonwood	85	3	0	5	10	10	0	7	4	8
Elm	8	94	0	0	7	0	0	0	0	0
Willow	4	3	68	5	3	0	0	13	4	4
Tamarisk	4	0	30	83	3	3	0	7	0	0
Russian olive	0	0	0	3	73	0	0	0	4	0
Rabbitbrush	0	0	0	3	0	87	0	0	0	8
Sedge	0	0	0	0	0	0	97	0	8	0
Reed	0	0	0	0	3	0	0	63	0	12
Rush	0	0	2	0	0	0	3	3	81	0
Kochia	0	0	0	3	0	0	0	7	0	68



- 94% correctly classified as elm
- 3% incorrectly classified as cottonwood
- 3% incorrectly classified as willow
- Overall accuracy = 79.6%

Discussion

- 6/10 species: > 80% Accuracy
- What was species confused for?
 - Functional Groups
 - Native vs. Non-native
- Tamarisk vs. Willow
 - 30% willow incorrectly classified
 - 5% tamarisk incorrectly classified
- Cottonwood vs. Elm vs. Russian Olives
 - Herbaceous understory



<http://www.robinsonlibrary.com/science/botany/angiosperms/salicaceae/cottonwood.htm>



<https://pfaf.org/user/Plant.aspx?LatinName=Ulmus+pumila>



<https://santafebotanicalgarden.org/february-2017/>

Discussion

- Constraints
 - Size and time
 - Expertise
 - Knowledge/familiarity of site
 - Experience with software
 - ENVI
 - eCognition – learning curve
 - GPS accuracy
 - Post-differential correction: up to 5m error

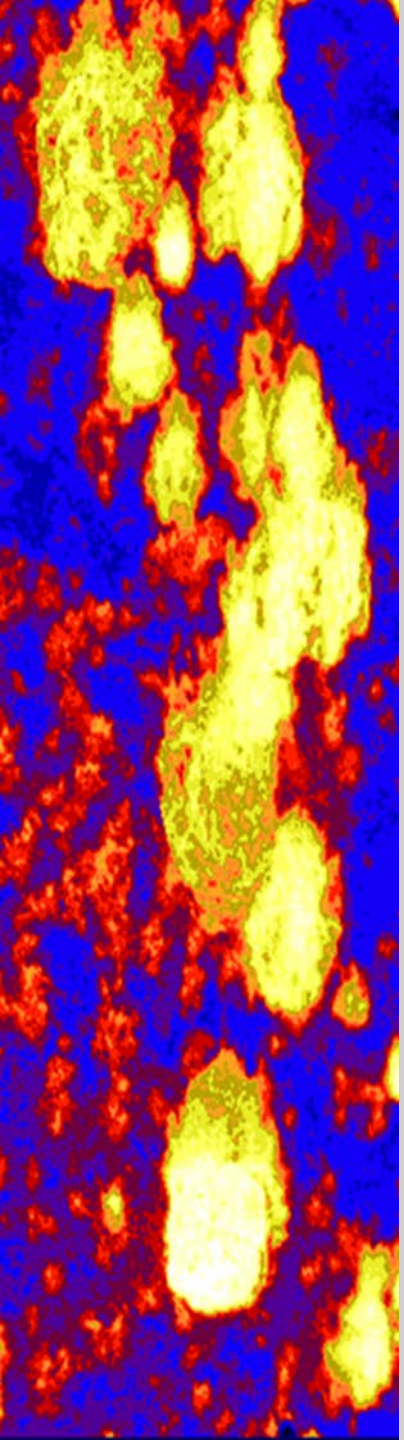


<http://www.ucy.ac.cy/artlands/en/equipment>



Conclusion

- Benefits of Image Classification
 - Can significantly reduce field time
 - Permanent record of data
 - Greatly augments field data
 - Potential for large scale analyses
- Object – based
 - Utilizes texture, brightness, area, shape, etc.
 - Other literature
- Potential for...
 - Oil & Gas restoration & monitoring
 - Mining Reclamation
 - Vegetation success
 - Monitoring
 - Water quality analyses



Acknowledgements

- Co-authors: Alicia Langton, EcoloGIS; Richard Alward & Tamera Minnick, Colorado Mesa University
- Colleagues: Quinton Barnett & Emily Tighe

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