Assessing Riparian Vegetation

Using UAS-mounted Lidar, Multispectral, and Color Sensors

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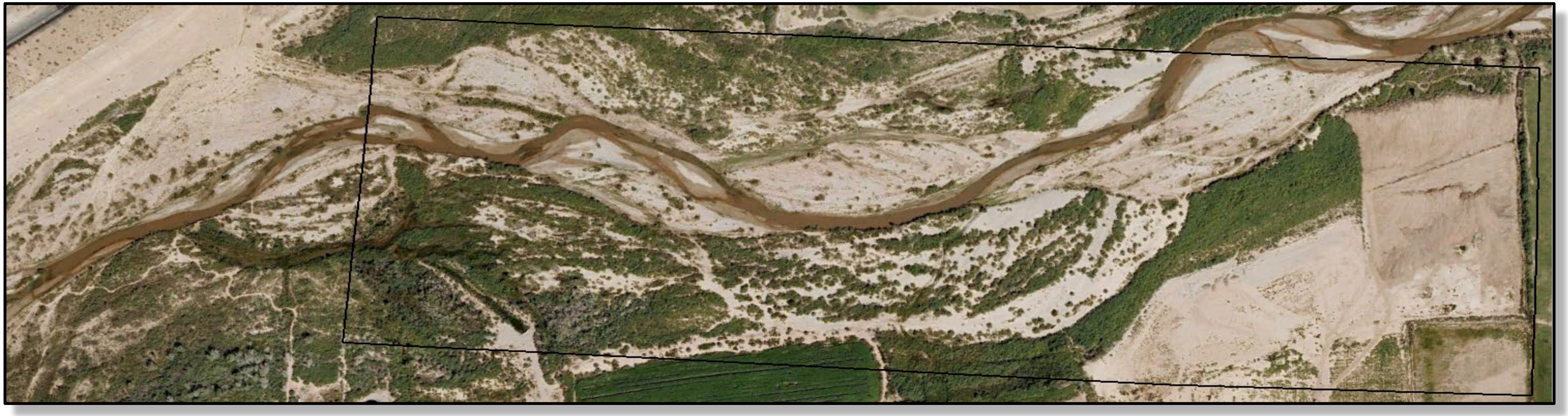
UAS-based remote sensing tools are **superior** to ground-based traditional vegetation surveys in terms of their **finer resolution** and **greater spatial extent** of **quantitative data** collection



Desert Conservation Program

desert conservation PROGRAM

- Clark County, Las Vegas, Henderson, North Las Vegas, Boulder City, Mesquite, NDOT
- Multiple Species Habitat Conservation Plan authorizing take of protected species
- Compliance with the Endangered Species Act

Avian Habitat Quality Monitoring

Species	Desired habitat characteristics
Yellow-billed cuckoo	Extensive, mature cottonwood and willow stands
Southwestern willow flycatcher	Dense, diverse riparian shrubs
Blue grosbeak Phainopepla Summer tanager Vermillion flycatcher Arizona Bell's vireo	Cottonwood-willow habitat and associated desert washes with shrubby woodlands

- Vegetation conditions are an index of habitat quality
- Metrics for vegetation condition include:
  - vegetation canopy cover
  - canopy height
  - vegetation density
  - greenness / vigor
- Traditional data collection requires field- & time- & personnel-intensive survey methods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Objectives

Identify the vegetation metrics and habitat descriptions that can be obtained using very high resolution sensors and evaluate their usefulness for monitoring riparian restoration

- Test recently emerging remote sensing technologies
- Desired characteristics include:
    - Adaptive methods
    - Cost-effectiveness
    - Straight-forward analysis
    - Comparability to other data sets
    - Nested and opportunistic monitoring
    - Measure attributes that indicate habitat quality for MSHCP-covered riparian species
- Integrate technologies into DCP’s long-term habitat quality monitoring

Metrics for Habitat Quality Monitoring

Vegetation Attribute	Specific Attribute / Analysis	Sensor Type* Lidar	MS	RGB
Cover	Vegetation & ground composition		X	X
	Total cover		X	
	Cover by groups & species	X	X	
	Understory vs. overstory	X		
Height	Overall/average height	X	x	x
	Height by canopy layer	X		
Density	LAI, Ch, LAD, TGI ***	X	X	
	NDVI, MSAVI ***	X		
Greenness	NDVI, MSAVI, TGI ***		X	
	Live vs stressed vs dead		X	x
Other	Slopes, bank height, erosion,	X		
	river channel shifts	X	X	X

*** LAI: **L**eaf **A**rea **I**ndex
Ch: **Ch**lorophyll concentration
LAD: **L**eaf **A**rea **D**ensity
TGI: **T**riangular **G**reenness **I**ndex
NDVI: **N**ormalized **D**ifference **V**egetation **I**ndex
MSAVI: **M**odified **S**oil-**A**djusted **V**egetation **I**ndex

* Lidar: **Li**ght **D**etection **A**nd **R**anging
MS: 5 band **M**ulti**S**pectral sensor
RGB: standard digital camera

Sensors & UASs

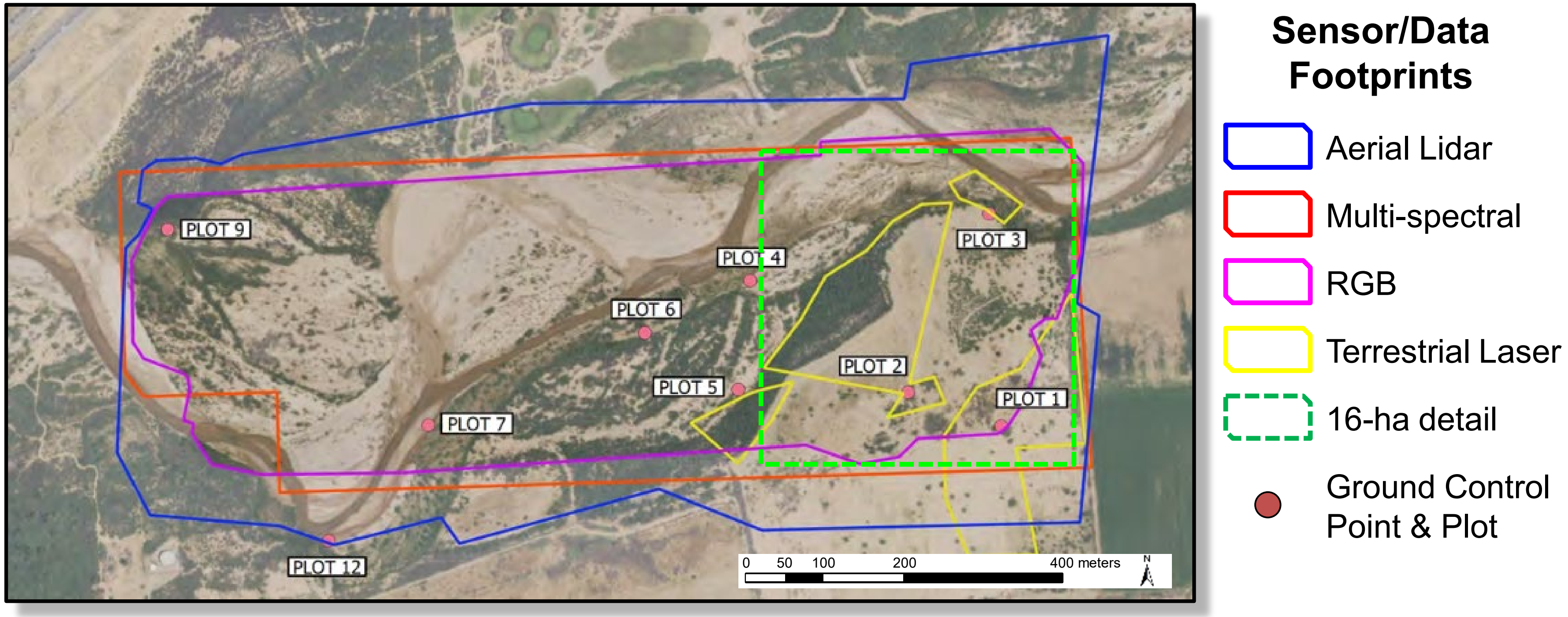
Each sensor was mounted on a different Uncrewed Aerial System and required unique flight parameters

Imagery/ Data Type[1]	Lidar	Multispectral [B, G, R, RE, NIR]	RGB
UAS	 DJI Matrice 600 Pro	 Draganflyer Commander	 DGI Phantom 4 Pro v2.0
Sensor	 Velodyne HDL-32E	 MicaSense RedEdge-MX	 20MP Camera [1" CMOS]
Altitude (m)	60	110	80
GSD[2] (cm)	86*	7.4	2.2
Area (ha)	65	52	43

1. RGB: 3 wide overlapping bands in the **R**ed, **G**reen, & **B**lue wavelengths
   Multispectral: 5 discrete narrow bands centered on 475 (blue), 560 (green), 668 (red), 717 (red edge), & 842 nm (near infrared)
2. GSD: **G**round **S**ampling **D**istance – the distance on the ground represented by each pixel in the image

* Average number of laser "ground returns per square meter"

Data Collection Areas



- 62 ha “Bunkerville East” parcel in the floodplain of the Virgin River, southwest of Mesquite, NV
- All flights and field data collection were completed on April 7-8, 2021
- Nine ground control points (GCPs) located with a Trimble R8 Base Station & R10 RTK Rover
- GCPs served to accurately georeference imagery & as centroids for training data plots

Data Analysis

Vegetation Attribute	Specific Attribute / Analysis	Analysis	Analysis Software & Packages
Cover	Vegetation & ground composition	Individually detected hull area	FUSION – CanopyModel, R – lidR
	Total cover	NDVI, MSAVI**	QGIS/GRASS – r.reclass function
	Cover by groups & species	Supervised land cover classification	R – RandomForest
	Understory vs. overstory	Canopy relief ratio (CRR)	FUSION – Gridmetrics
Height	Overall/average height	Maximum height from hulls	FUSION – CanopyModel, R-lidR
	Height by canopy layer	Structure from motion (SfM)	Global Mapper or Pix4Dmapper
Density	LAI, Ch, LAD, TGI ***	Leaf area density (LAD)	R – RStoolbox & Raster
	NDVI, MSAVI ***	Leaf area index (LAI)	R – lidR
Greenness	NDVI, MSAVI, TGI ***	NDVI, MSAVI**	R – RStoolbox & Raster
	Live vs stressed vs dead	Live vs dead	Part of land cover classification
Other	Slopes, bank height, erosion,	Terrain models (DEM, DTM)	Global Mapper, FUSION
	river channel shifts	Surface models (DSM)	Global Mapper, Pix4Dmapper

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Calculating Vegetation Canopy Cover

Normalized Difference Vegetation Index

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

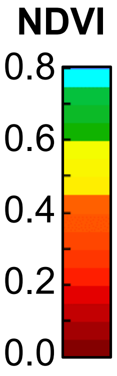
$(-1 \leq NDVI \leq 1)$

Calculating Vegetation Canopy Cover

Normalized Difference Vegetation Index

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

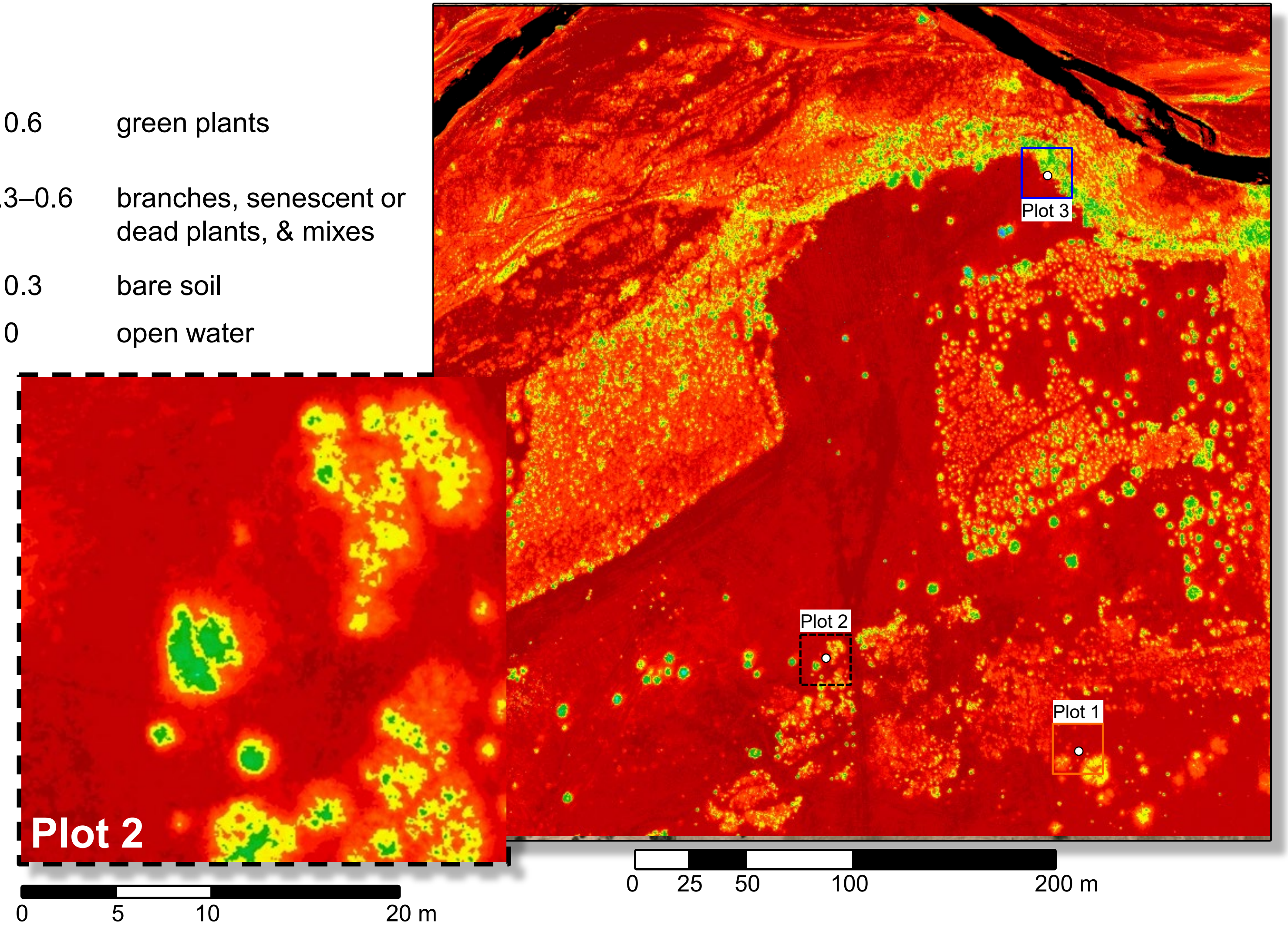
($-1 \leq NDVI \leq 1$)



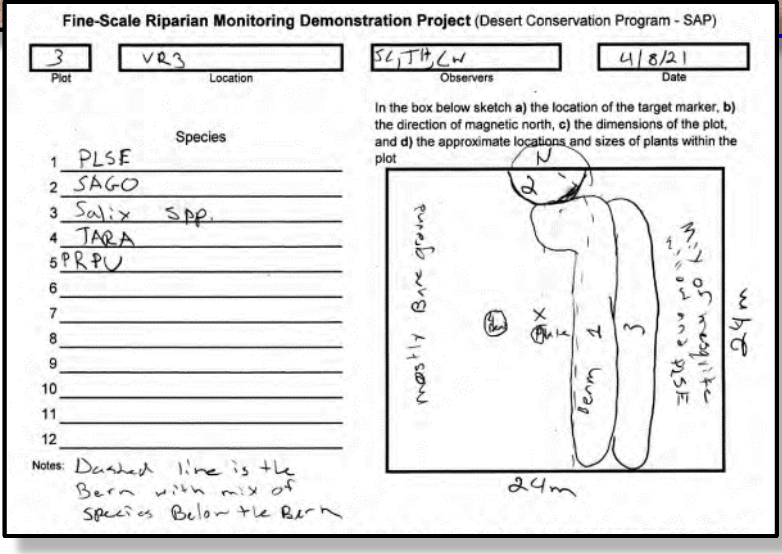
> 0.6	green plants
0.3–0.6	branches, senescent or dead plants, & mixes
< 0.3	bare soil
< 0	open water

The “Bunkerville East” parcel consists of

1.2%	green vegetation
78%	bare soil
20.8%	*other*



Supervised Land Cover Classification



Fine-Scale Riparian Monitoring Demonstration Project (Desert Conservation Program - SAP)

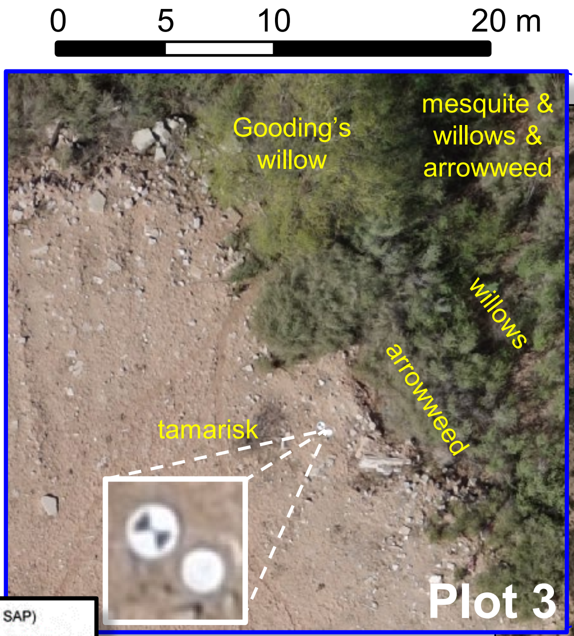
3	VR3	SC, TH, CW	4/8/21
Plot	Location	Observers	Date

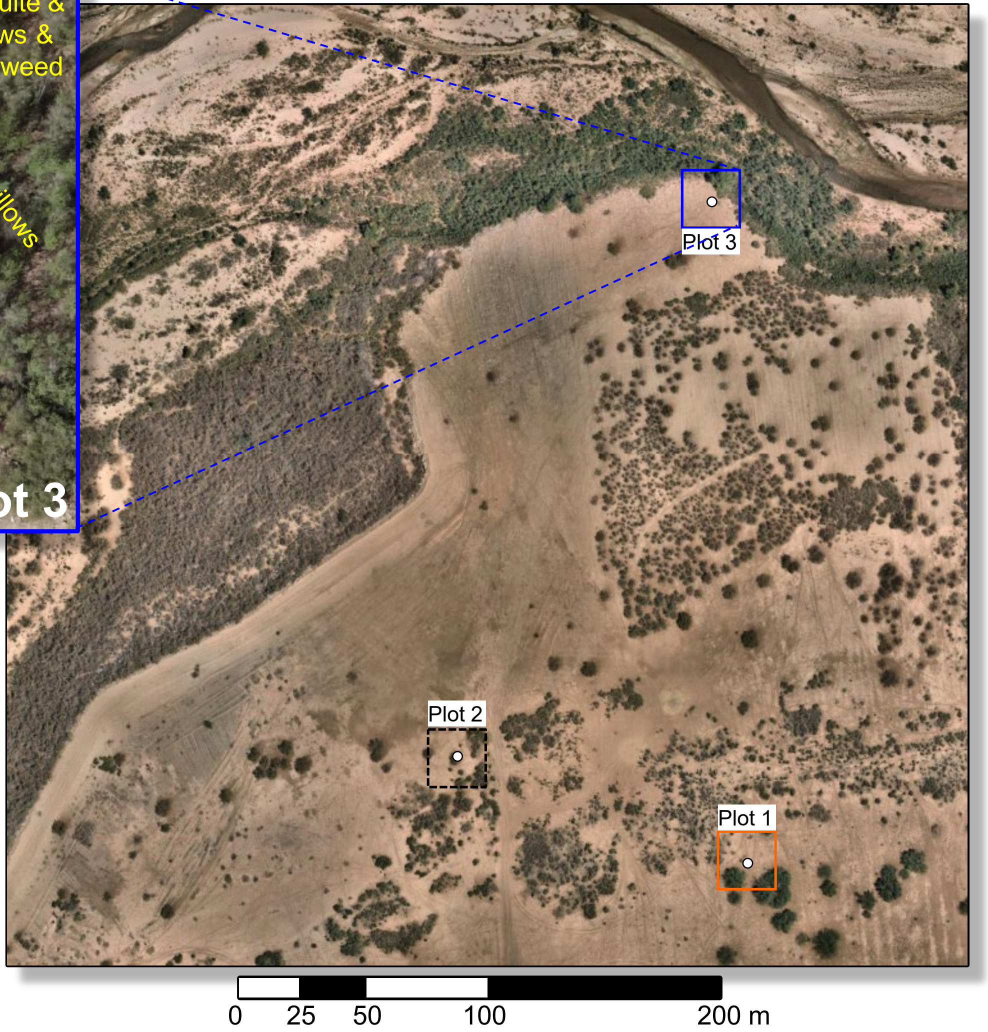
Species

1 PLSE
2 SAGO
3 Salix spp.
4 TARA
5 PRPU
6
7
8
9
10
11
12

In the box below sketch a) the location of the target marker, b) the direction of magnetic north, c) the dimensions of the plot, and d) the approximate locations and sizes of plants within the plot

Notes: Dashed line is the Berm with mix of Species Below the Berm





Land Cover Classification Models

Evaluated six models for accuracy at classifying the project area

- Original reflectance bands
  Models 1, 4 & 6
- Principle components analysis (PCA) of reflectance data
  Models 2, 3, 5 & 6
- Indices of soil salinity & surface water presence
  Models 4, 5 & 6
- Vegetation canopy heights
  Models 4, 5 & 6

RandomForest analysis in R

Models 4, 5 & 6 all were highly accurate

Model #	Model	Overall Accuracy[1]	Kappa[2]	Para-meters[3]
1	Blue + Green + Red + Red Edge + NIR[4]	0.771	0.754	5
2	PC1 + PC2 + PC3[5]	0.749	0.729	3
3	Model 2 + PC4 + PC5	0.817	0.803	5
4	Model 1 + NDSI + NDWI + CHM[6]	0.853	0.841	8*
5	Model 2 + NDSI + NDWI + CHM	0.874	0.864	6*
6	Model 5 + PC4 + PC5	0.894	0.886	8*

1. Proportion of correctly classified land cover types
2. Overall accuracy adjusted by imbalance frequency of cover type occurrence
3. Number of predictive parameters (i.e., model complexity)
4. Multispectral visible light bands and a near infrared (NIR) band
5. **P**rincipal **C**omponents (PC1–PC5)
6. **N**ormalized **D**ifference **S**alinity **I**ndex [*NDSI = (G-R)/(G+R)*]
   Normalized **D**ifference **W**ater **I**ndex [*NDWI = (G-NIR)/(G+NIR)*]
   Canopy **H**eight **M**odel (CHM) from aerial lidar data

* Extra blue band

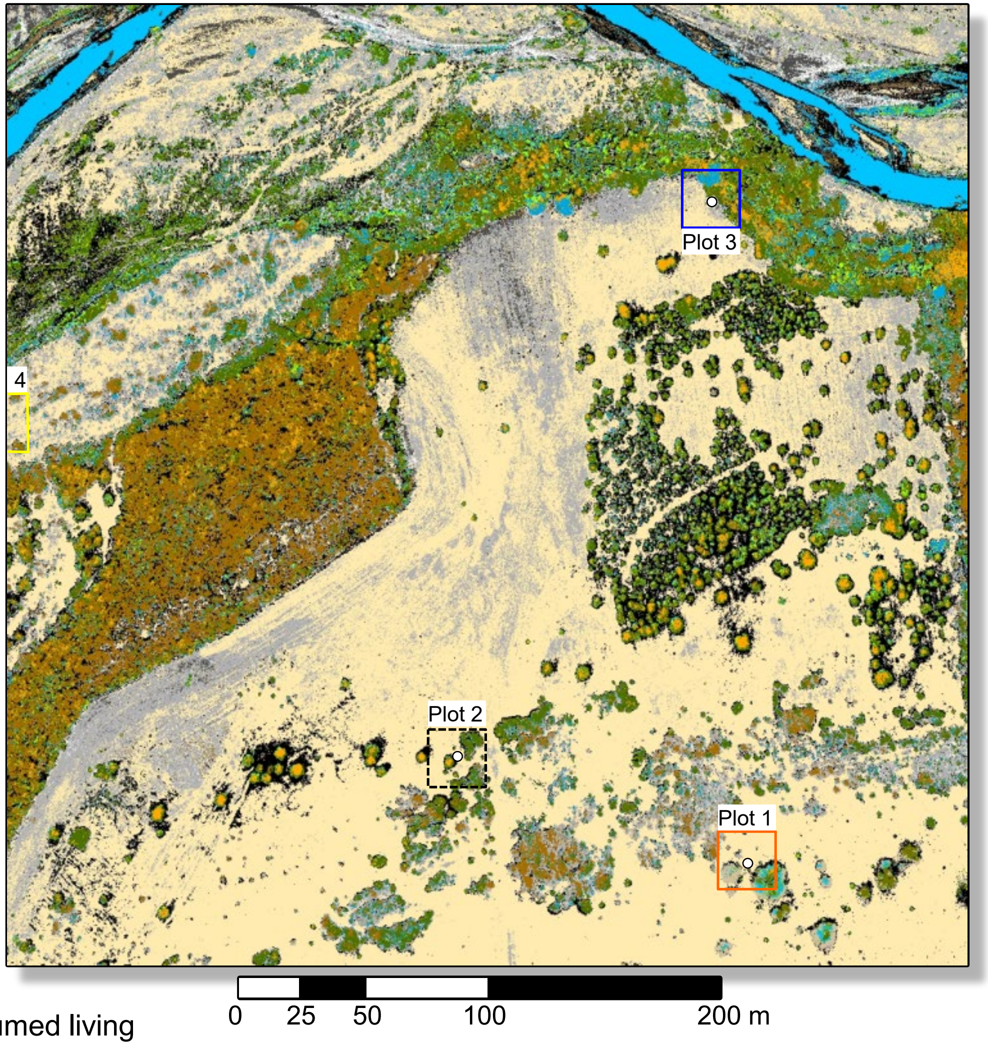
Land Cover Classification

Land Cover (LC) classes most accurately described by Model 6

LC = PC1 + PC2 + PC3 + PC4 + PC5 + NDSI + NDWI + CHM

[Overall accuracy = 0.894   Kappa = 0.886]

Common Name	Error (%)
Quailbush	**0**
Mule-fat	**2.4**
Rabbitbrush	6.7
Arrowweed	15.1
Honey mesquite - g	13.3
Goodding's willow	**4.8**
Tamarisk - g	6.8
Screwbean mesquite	**4.8**
Honey mesquite - b	**4.2**
Tamarisk - b	13.8
Dead wood	31.2
Dry soil	8.3
Mud	0
Salt crust	**3.6**
Rock	20.9
Open water	**0**
Shadow	5.4



"g" = green, or fully leafed out
"b" = brown, no leaves but presumed living
Error = % of training cells misclassified

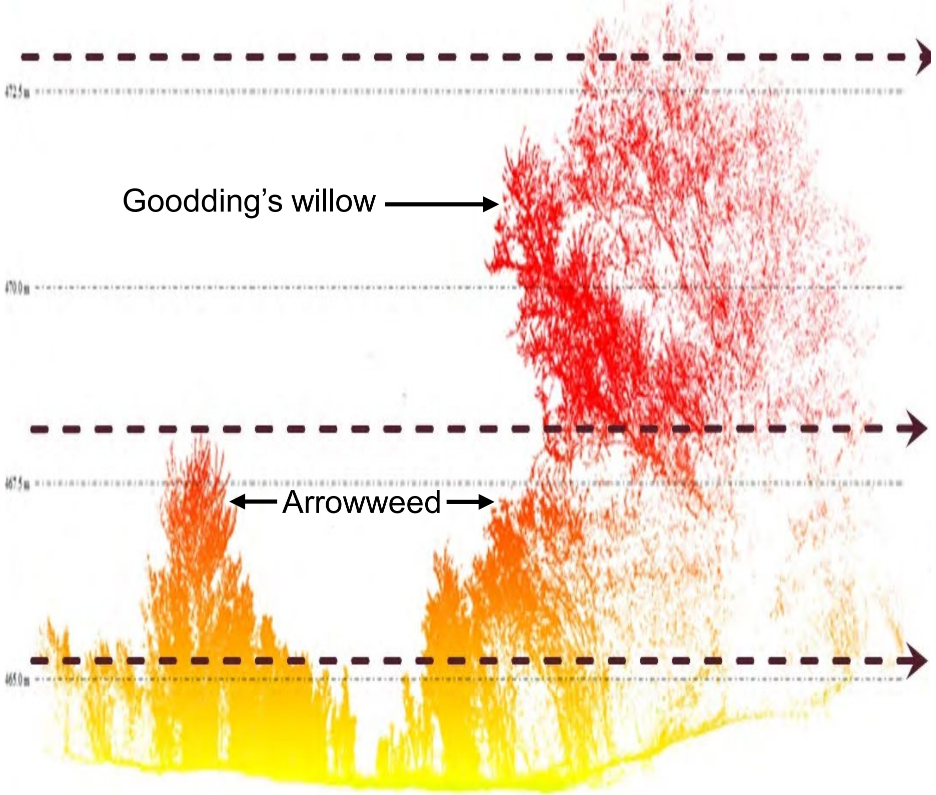
Describing Species' Habitat Characteristics

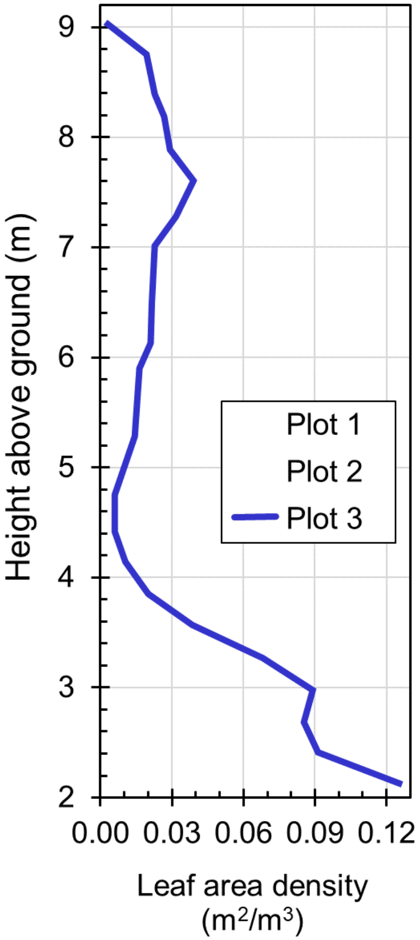
Species	Desired habitat characteristics
Yellow-billed cuckoo	Extensive, mature cottonwood and willow stands
Southwestern willow flycatcher	Dense, diverse riparian shrubs
Blue grosbeak Phainopepla Summer tanager Vermillion flycatcher Arizona Bell's vireo	Cottonwood-willow habitat and associated desert washes with shrubby woodlands

- Birds have specific habitat requirements, e.g.,
  - specific trees for foraging or nesting
  - specific structure, including overstory and understory densities
- Lidar provides detailed measurements of structure
  - terrestrial and/or aerial lidar

Lidar data → Leaf Area Density

Terrestrial laser point cloud – Plot 3





Plot 3

Leaf Area Density

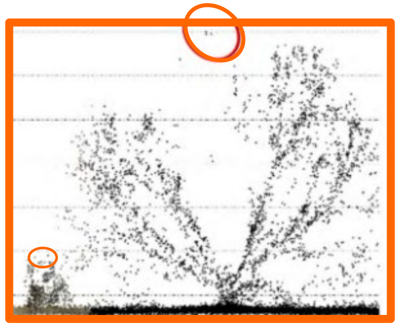
Characterizing riparian vegetation structure:

Plot 1 – sparse vegetation, ≤ 3.75 m, mostly < 2.8 m

Plot 2 – sparse vegetation, ≤ 3 m, mostly < 2.5 m

Plot 3 – denser vegetation & > 1 canopy layer,
dense arrowweed < 4 m,
upper canopy of Goodding's willow 9m tall

Plot 1

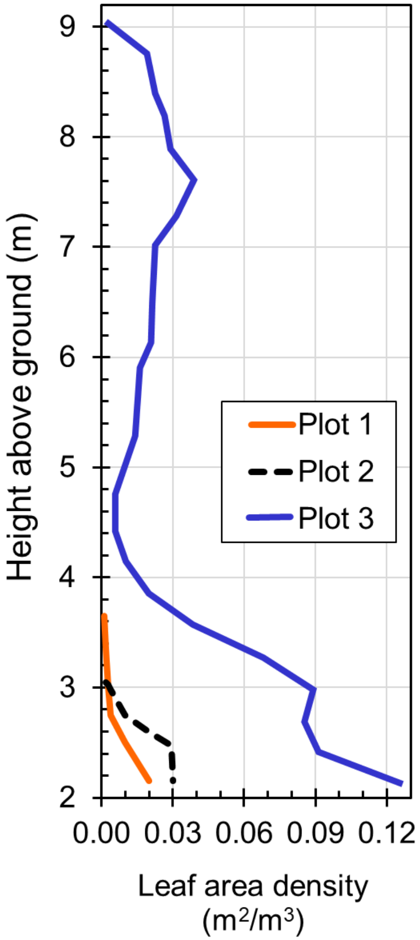


Aerial lidar point cloud

Honey mesquite & rabbitbrush

Plot 2

Arrowweed



Plot 3

Remote Sensing Provides Quantitative Metrics

Vegetation Attribute	Specific Attribute / Analysis	Data Quality by Sensor**		
		Lidar	MS	RGB
Cover	Vegetation & ground composition	QUANT	QUANT	*qual*
	Total cover	QUANT	QUANT	*qual*
	Cover by groups & species	*qual*	QUANT	*qual*
	Understory vs. overstory	QUANT	NA	NA
Height	Overall/average height	QUANT	*qual*	*qual*
	Height by canopy layer	QUANT	NA	NA
Density	LAI, Ch, LAD, TGI ***	QUANT	QUANT	NA
	NDVI, MSAVI ***	NA	QUANT	NA
Greenness	NDVI, MSAVI, TGI ***	NA	QUANT	NA
	Live vs stressed vs dead	NA	*q* / Q	*qual*
Other	Slopes, bank height, erosion, river channel shifts	QUANT	*qual*	*qual*
Ratings	Generalized cost (data collection & processing)	$$$	$$$	$
	Analysis complexity (1- low, 3= complex)	2	3	1

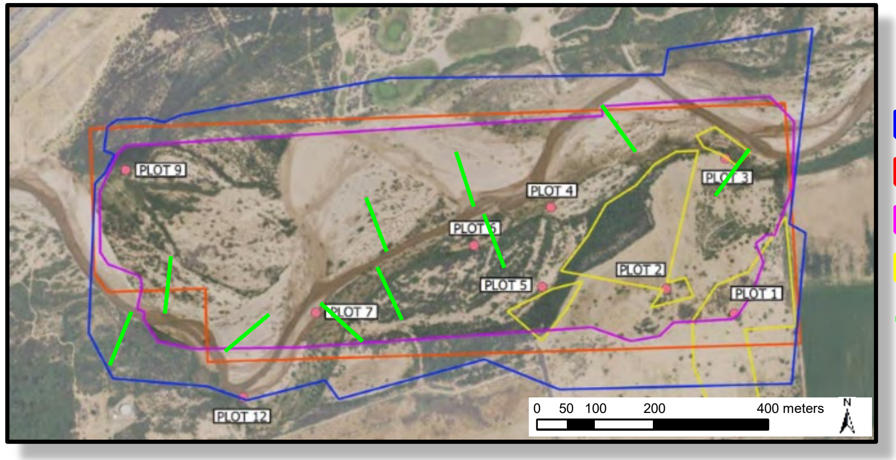
qual: qualitative data only

QUANT: high quality quantitative measurements

High Resolution Sensors Provide More Data

Imagery/ Data Type[1]	Lidar	Multispectral [B, G, R, RE, NIR]	RGB
Sensor	 Velodyne HDL-32E	 RedEdge-MX	 20MP Camera
GSD[2] (cm)	86*	7.4	2.2
Area (ha)	65	52	43
Time (hr)	~ 3	~ 3.5	~ 2.5
Samples (#)	> 50 million	~ 500 million	~ 900 million
Samples (ha^{-1})	~ 1 million	~ 9 million	~ 20 million

LPI
Pin or Laser pointer
100*
0–25*
~ 8
1,000
~ 40

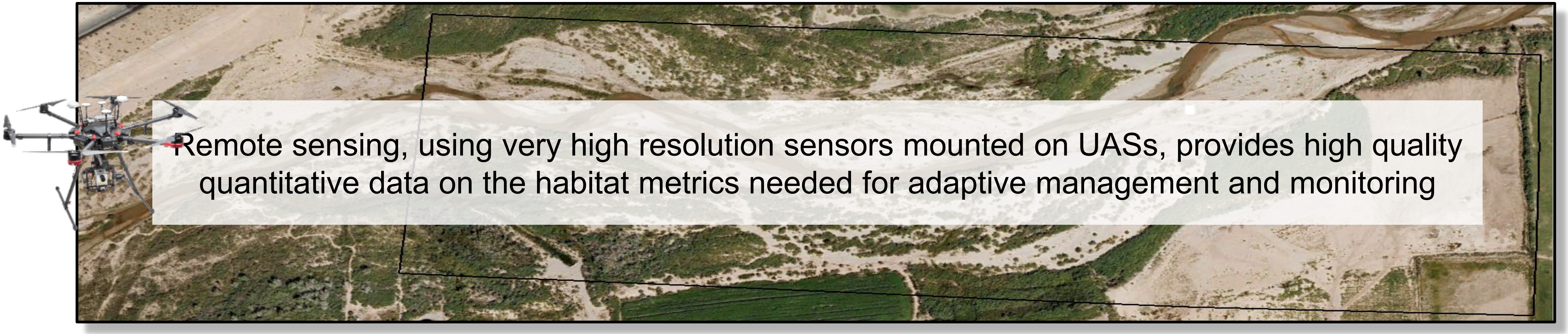


Sensor/Data Footprints

- Aerial Lidar
- Multi-spectral
- RGB
- Terrestrial Laser
- 100-m Transect
- Ground Control Point & Plot

Summary

Sensor	Positives	Negatives
Multi-spectral	• Out-performs other sensors for species & functional grp differentiation & plant vigor • Calculate indices of vegetation density	• Surface & height measurements coarse • High processing power required for large areas
Aerial Lidar	• Best for calculating surfaces and heights • Ability to calculate density/canopy layers	• High processing power required for large areas • Requires additional data to ID species
Terrestrial Lidar	• Maximum detail (point density) collected	• Short data collection range • Bulky, heavy equipment • Requires additional data to ID species
RGB	• Easiest and cheapest • Useful for identifying common species • Complements abilities of other sensors	• Least capable of producing data for rigorous quantitative analysis on its own



Remote sensing, using very high resolution sensors mounted on UASs, provides high quality quantitative data on the habitat metrics needed for adaptive management and monitoring

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