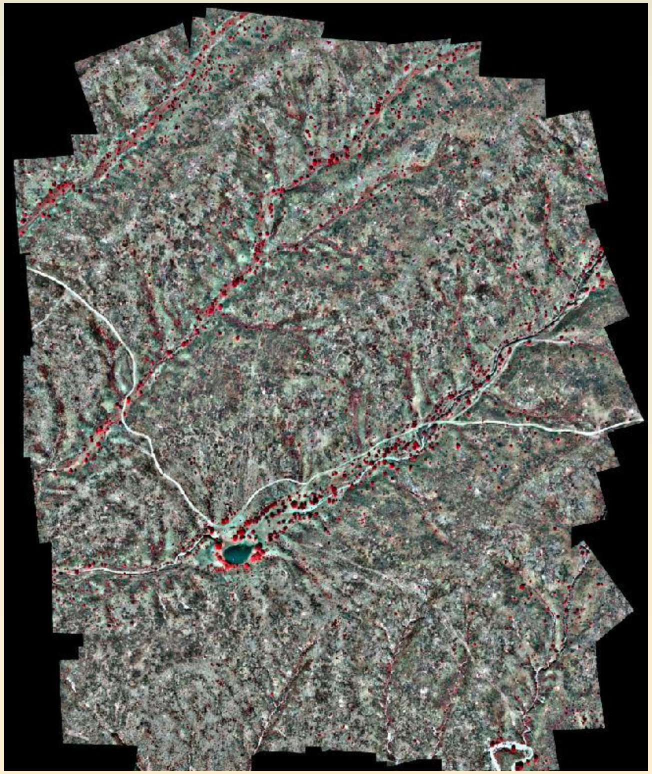
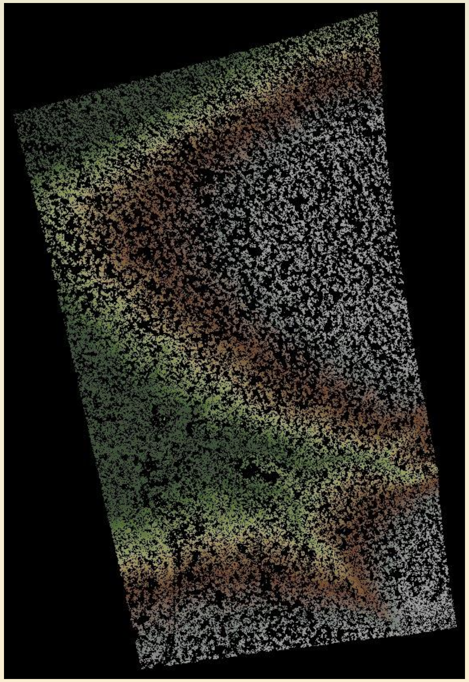
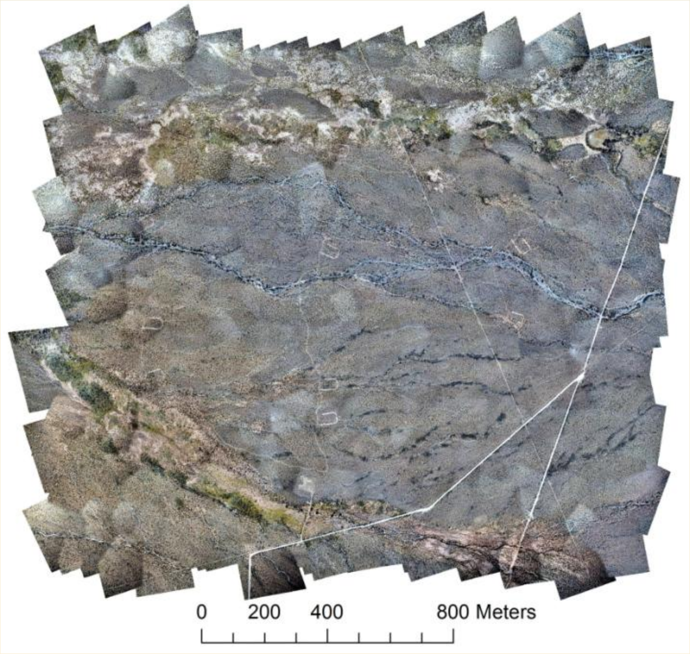
Remote Sensing from Unmanned Aircraft:
Image processing workflows, classification, and terrain extraction

Andrea S. Laliberte







earthmetrics, Brownsville, OR
formerly with USDA ARS Jornada Experimental Range, Las Cruces, NM

earthmetrics

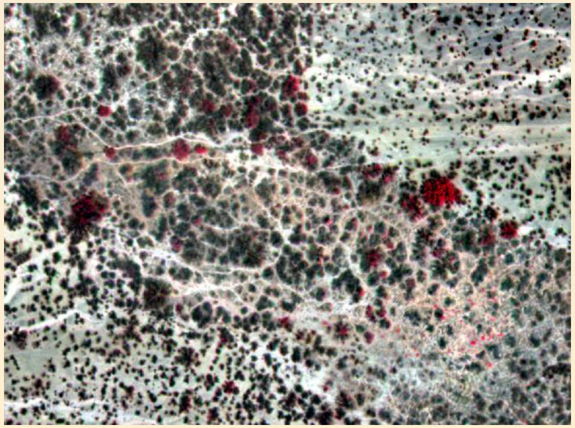
Tactical Fire RSAC meeting, Mar. 20, 2012, Sacramento, CA

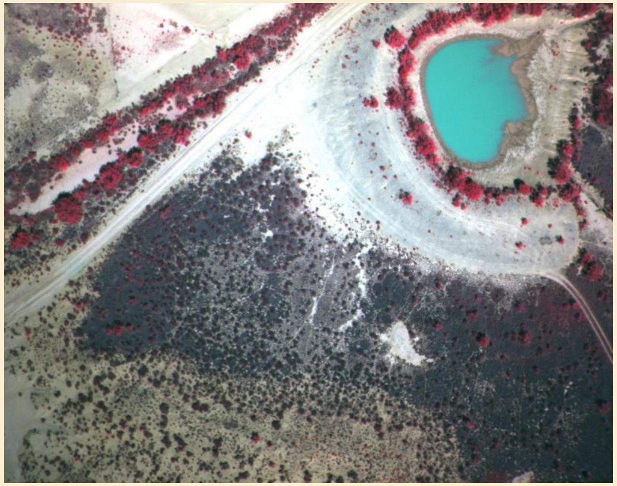
USDA ARS NM STATE

UAS for vegetation mapping

- Increased interest in using UAS for natural resource remote sensing tasks
- Smaller, light weight sensors for small UAS

- Low operating costs, imagery with very high resolution, repeated deployment for change detection, vegetation health
- FAA: Integration of UAS in National Airspace by 2015



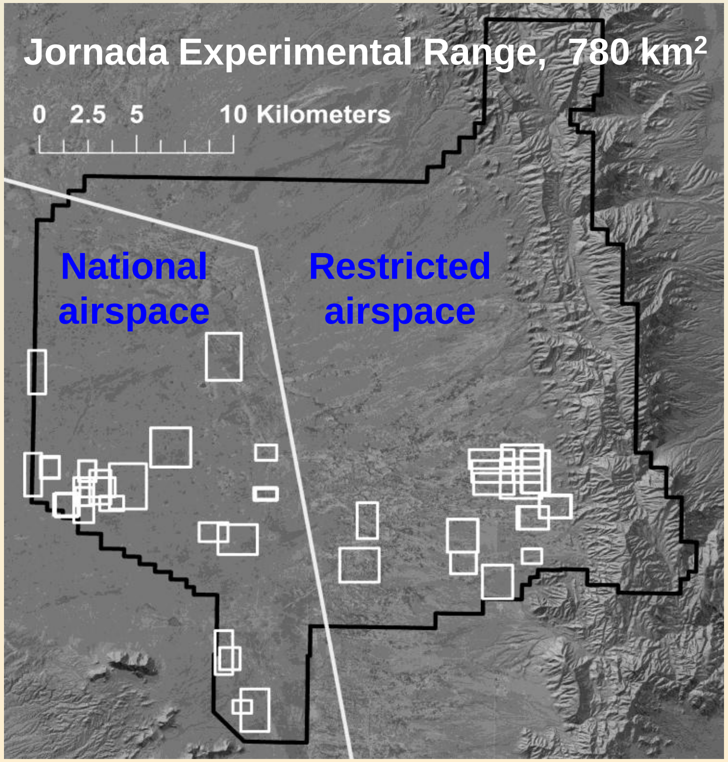


UAS Operations at the Jornada Experimental Range

- Objectives: development of operational UAS-based remote sensing program for ecological applications
- Operated 2 UAS since 2006
- Areas of interests:
  - Access to airspace
  - Image acquisition
  - Terrain extraction
  - Orthorectification
  - Mosaicking
  - Vegetation classifications
  - Geometric and classification accuracies
  - Operational workflows

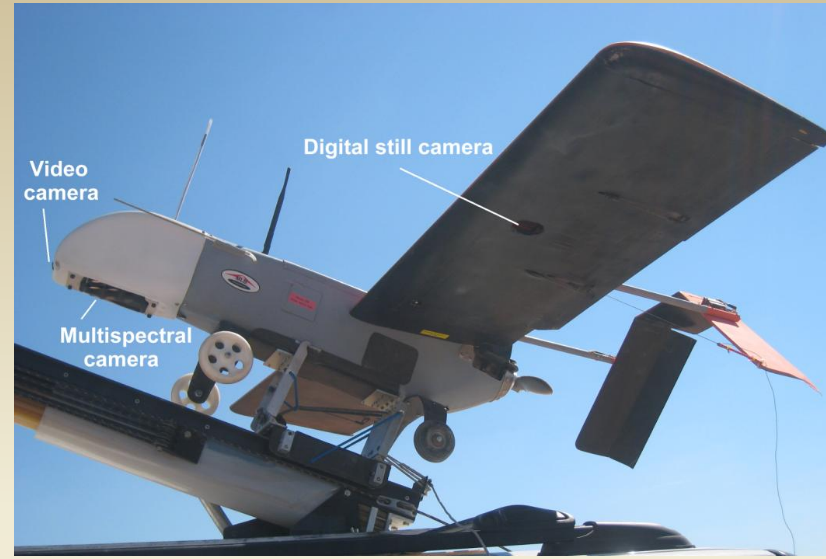
UAS Missions

- New Mexico
  - In National Airspace under a COA
  - In restricted (military) airspace
- Idaho 2008: COA issued to USDA
- Arizona 2011: COA issued to USDA
- Team of 6
  - 2 private pilot license
  - Private pilot ground school
  - FAA Class II med. cert.



BAT 3 UAS

- 1.8 m wingspan, 10 kg weight
- Flight duration: 2-5 hours



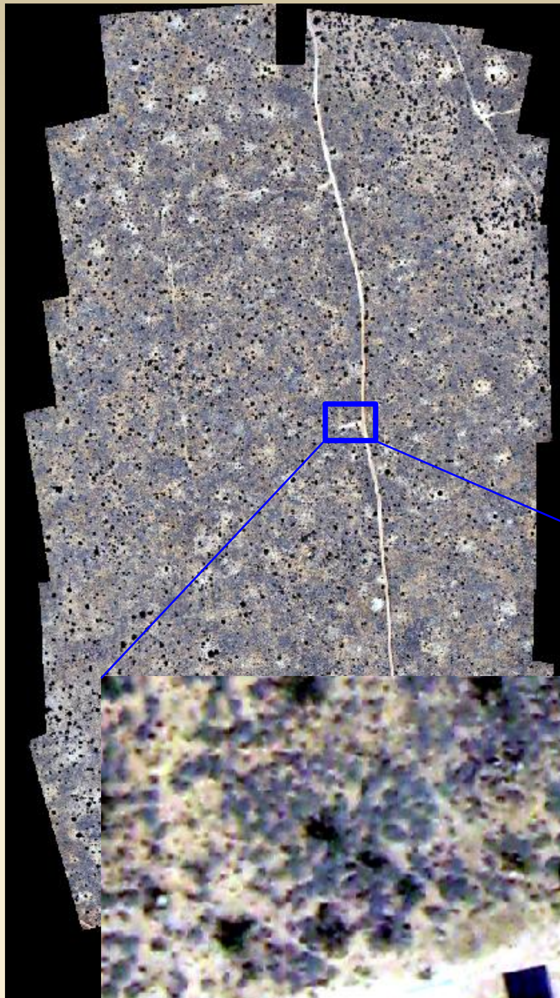
Sensors

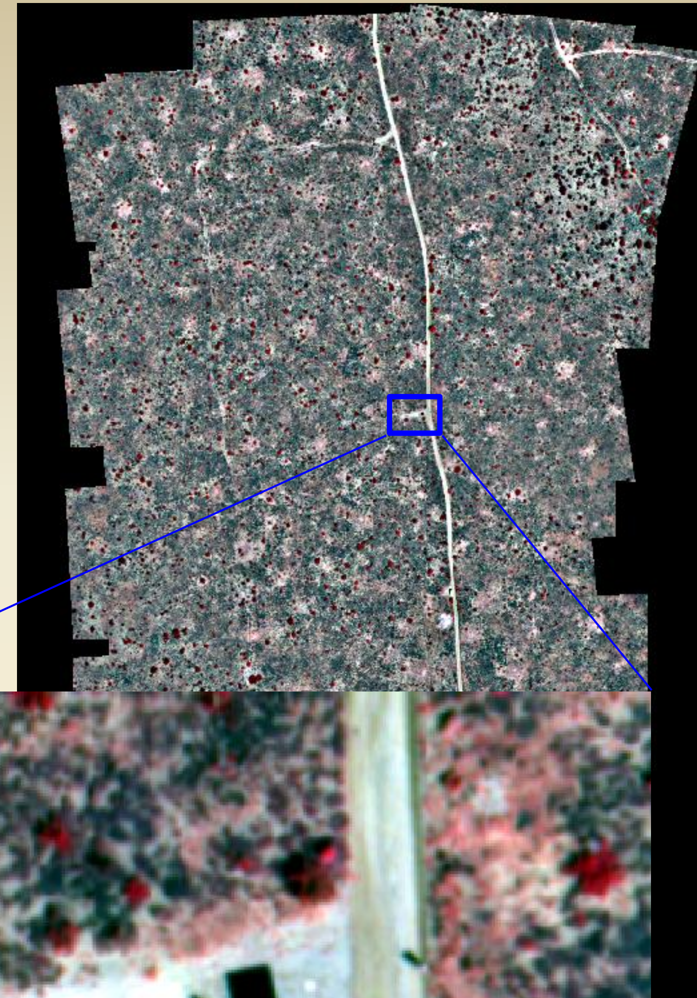
- Video camera
- Canon SD900 10 mp
- Tetracam MiniMCA, 6 narrow bands, blue to near infrared

Image acquisition

- 700 ft AGL
- 75% forward, 40% sidelap
- Data file: X,Y,Z, roll, pitch, heading

	Canon	Multispectral
Footprint:	160m x 213m	145m x 182m
Spatial:	6 cm	13 cm
Spectral:	3 bands	6 bands
Radiometric:	8-bit	10-bit

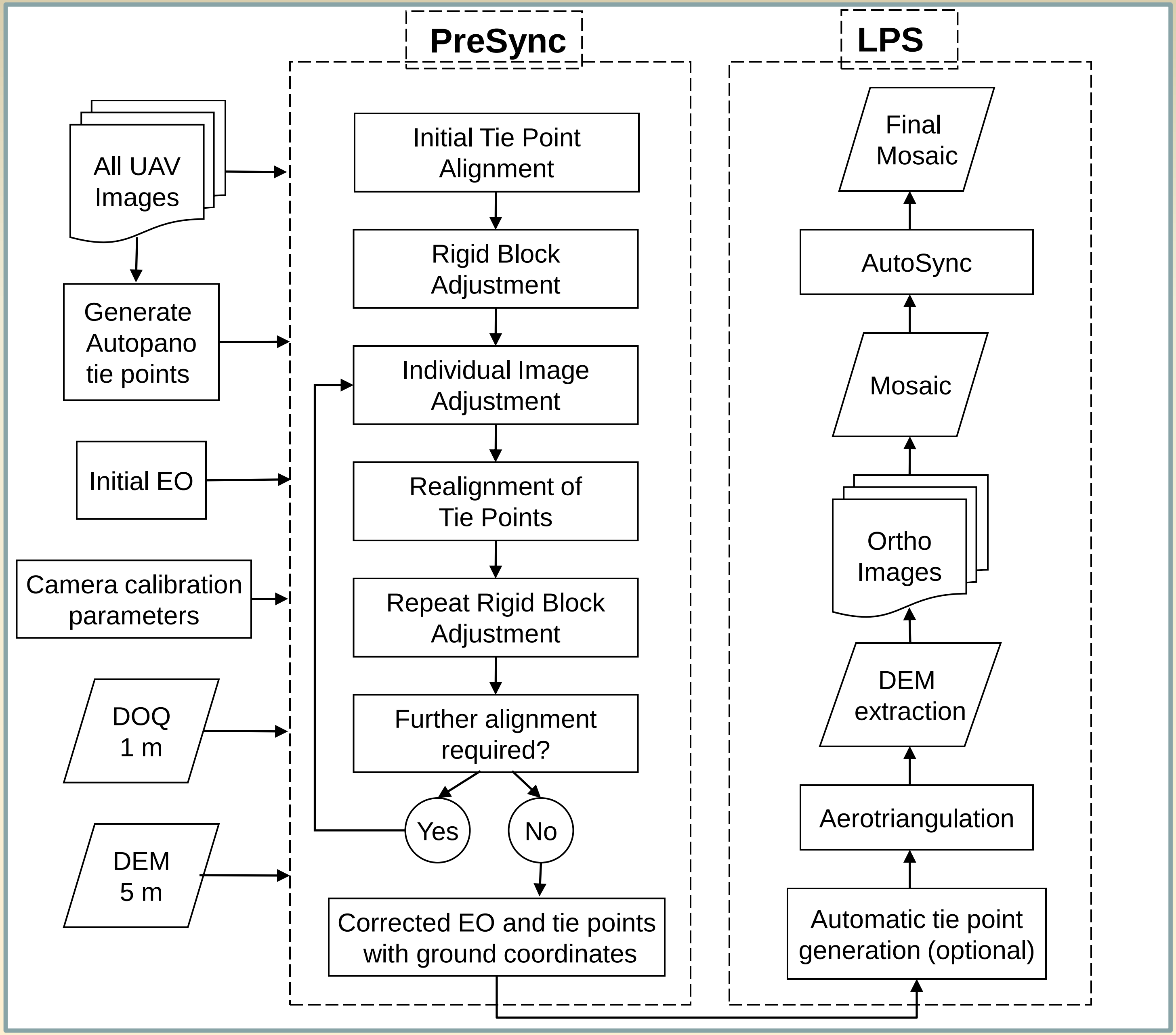




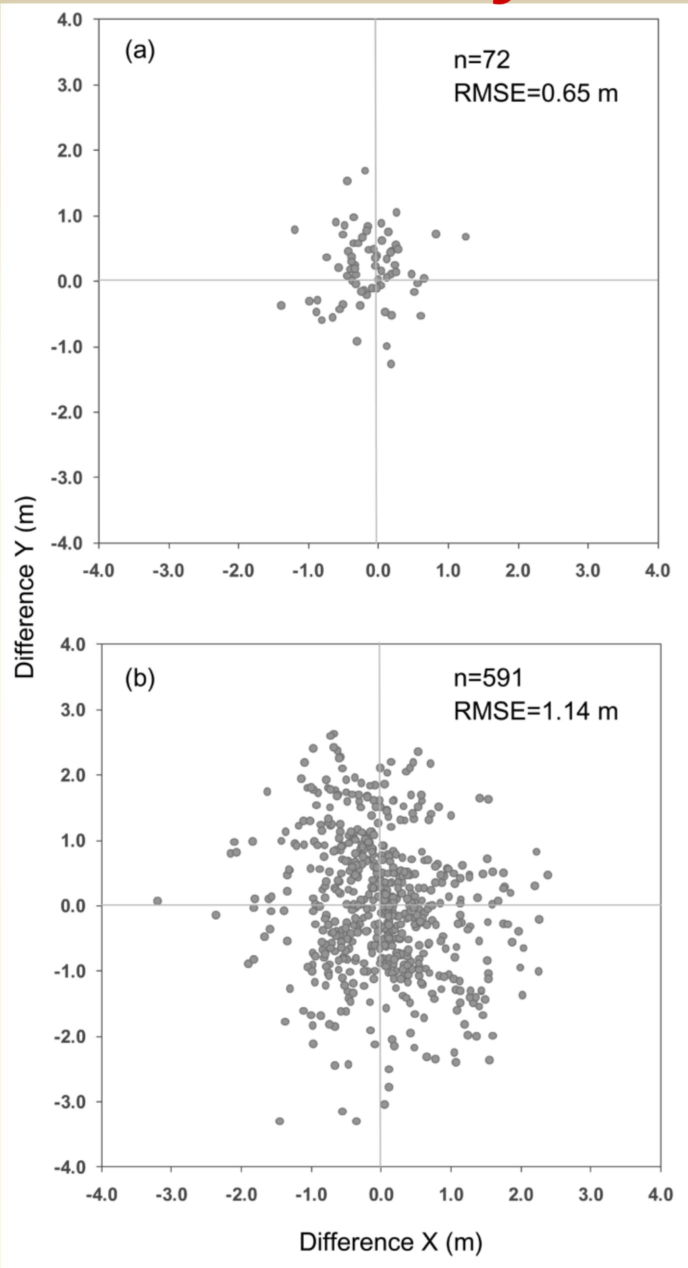
Same flight multispectral and RGB orthomosaics

Jornada
Sept. 2, 2011

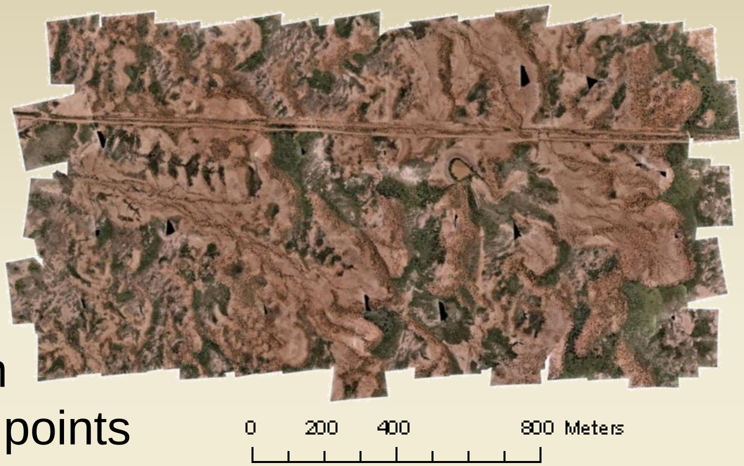
Orthorectification and Mosaicking



Accuracy of Orthorectified Mosaics



New Mexico
173 ha
257 images
Elevation diff: 14 m
Reference: dGPS points



Idaho
116 ha
156 images
Elevation diff: 113 m
Reference: UltraCam X image

Multispectral image processing workflow

1. Data download from camera
2. Raw to multipage tif conversion
3. Multipage tif splitting
4. 8-bit to 10-bit conversion
5. Band-to-band registration
6. Band stacking
7. Radiometric calibration
8. Orthorectification and mosaicking
9. Image classification

Field data collection

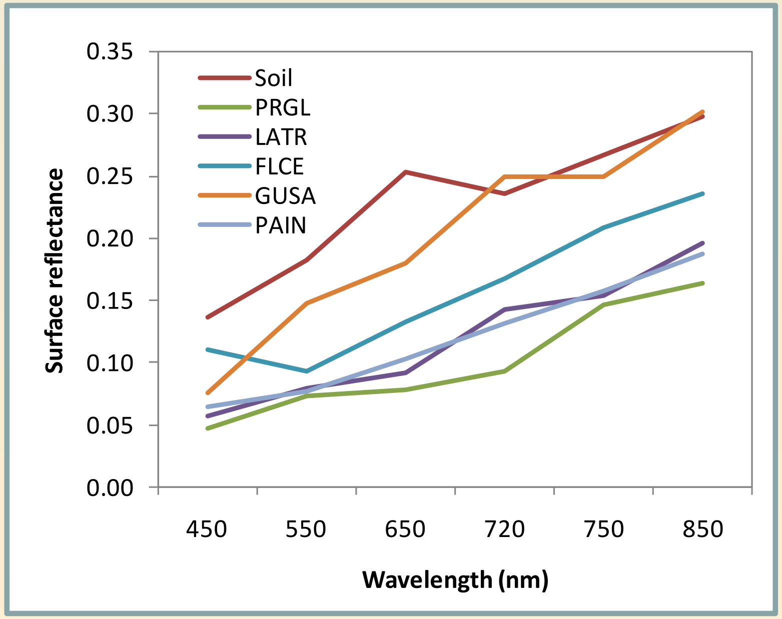
- Field spectrometer data
- Training/test samples

Issues encountered:

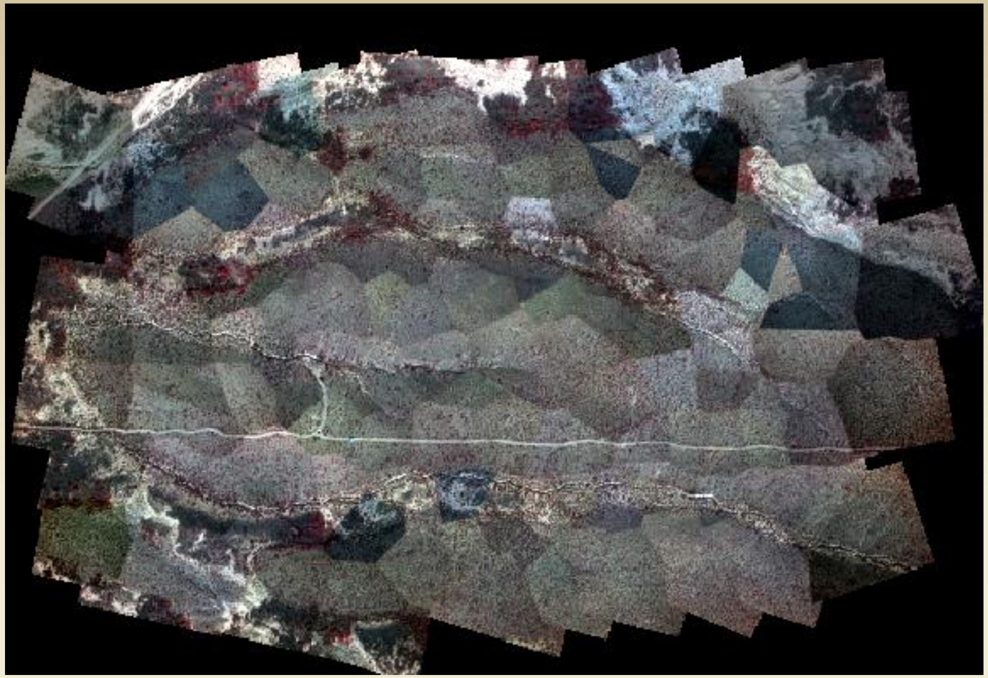
- Proprietary file format incompatible with GIS/RS software
- Software cannot handle 10-bit data in tif format
- Poor band co-registration
- Strong vignetting

Radiometric calibration

- Obtain ASD reflectance for calibration targets and dominant vegetation/soil
- Empirical line method to derive coefficients to fit digital numbers to field measured reflectance spectra



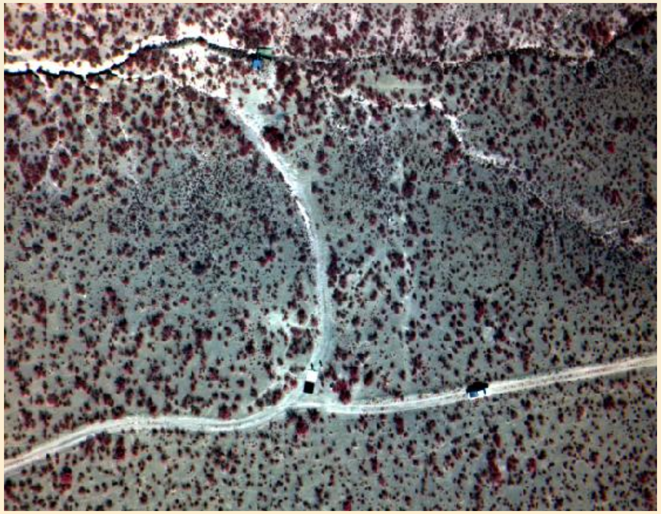
Color balancing

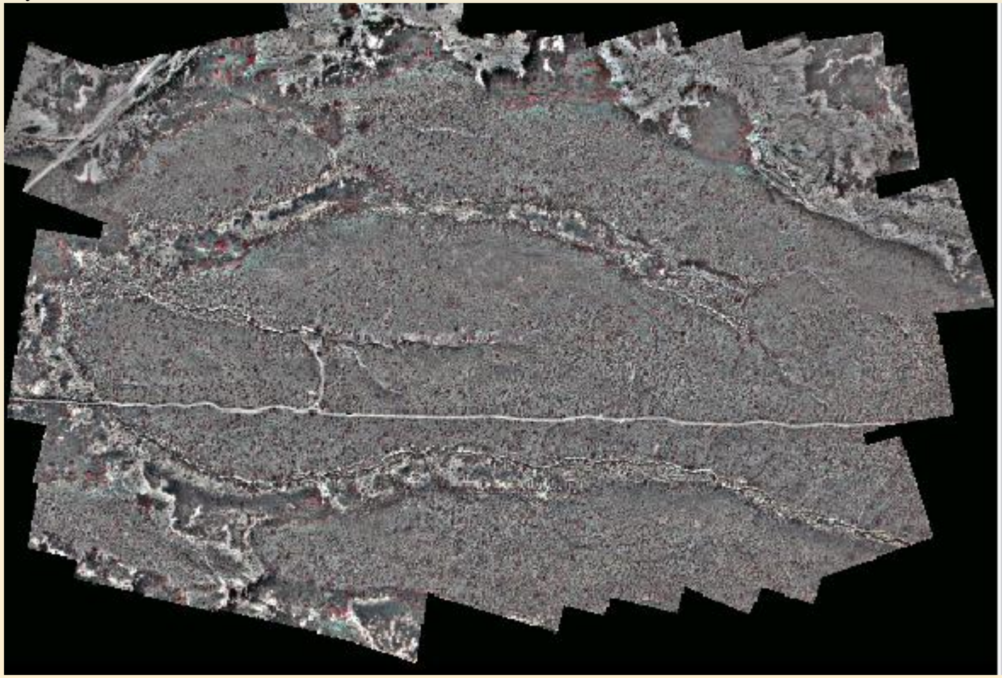


1000 m

Image dodging approach during mosacking process in Erdas

Strong vignetting



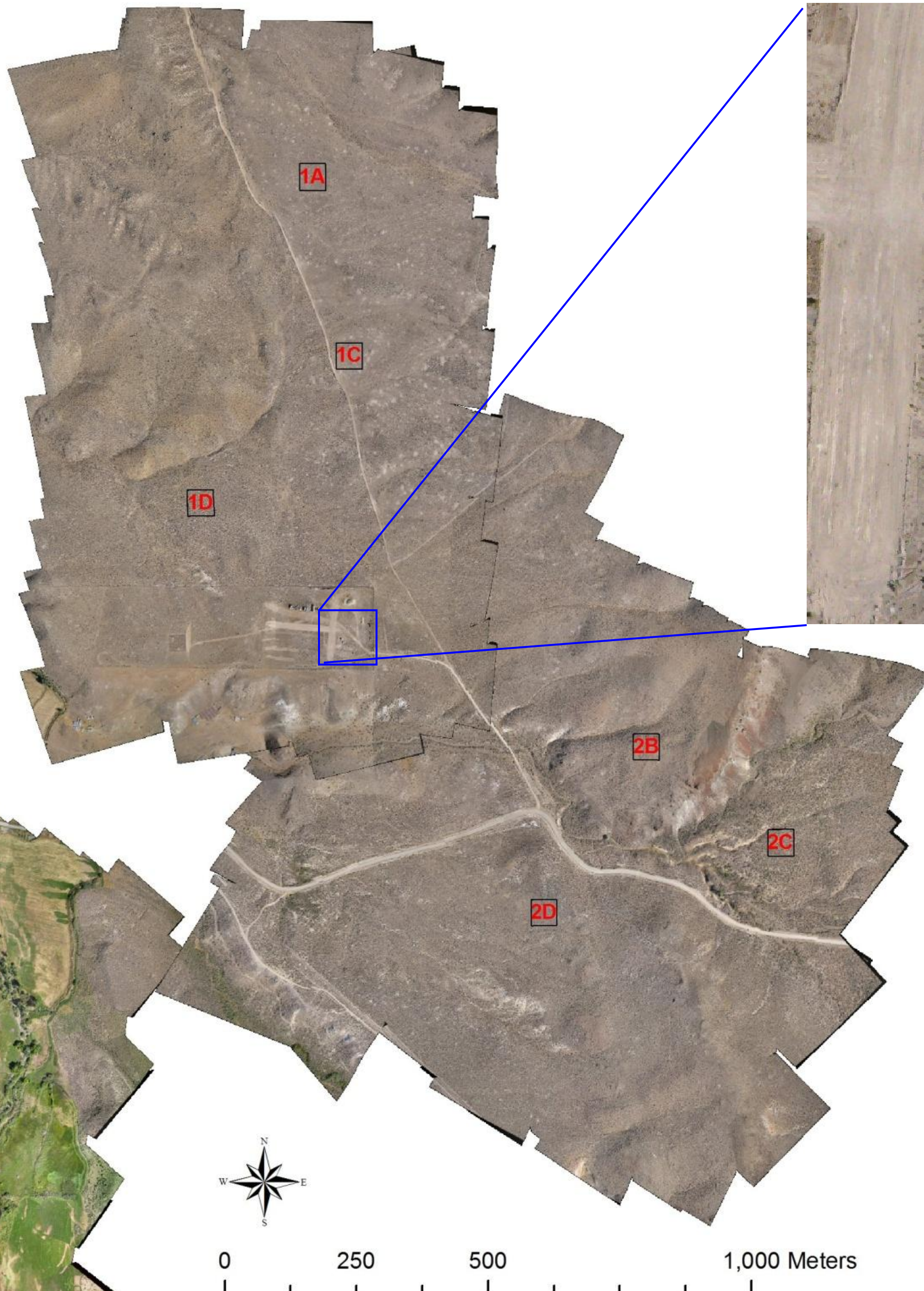


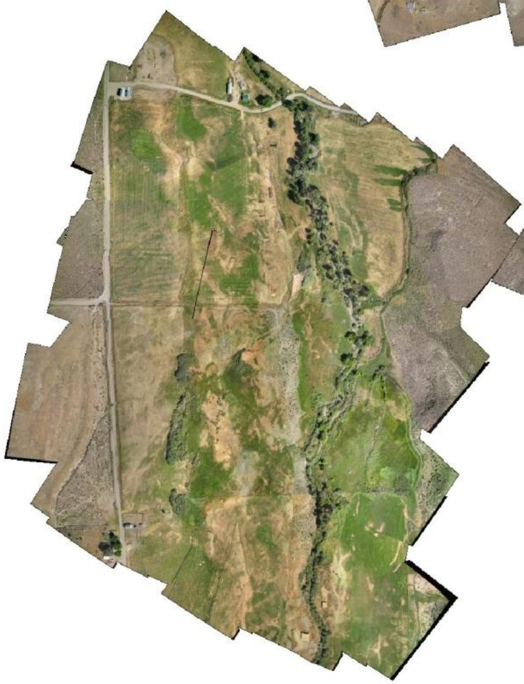
Vegetation Classifications

- Object-based image analysis workflow: eCognition
  - Feature extraction through image segmentation and classification
  - Develop approaches for large image files: transferable rule-base
  - Determine features suitable for imagery from low-cost digital cameras (I-H-S, shape, texture)
  - Use of decision trees to determine optimal features
  - Develop field sampling approaches suitable for very high resolution imagery

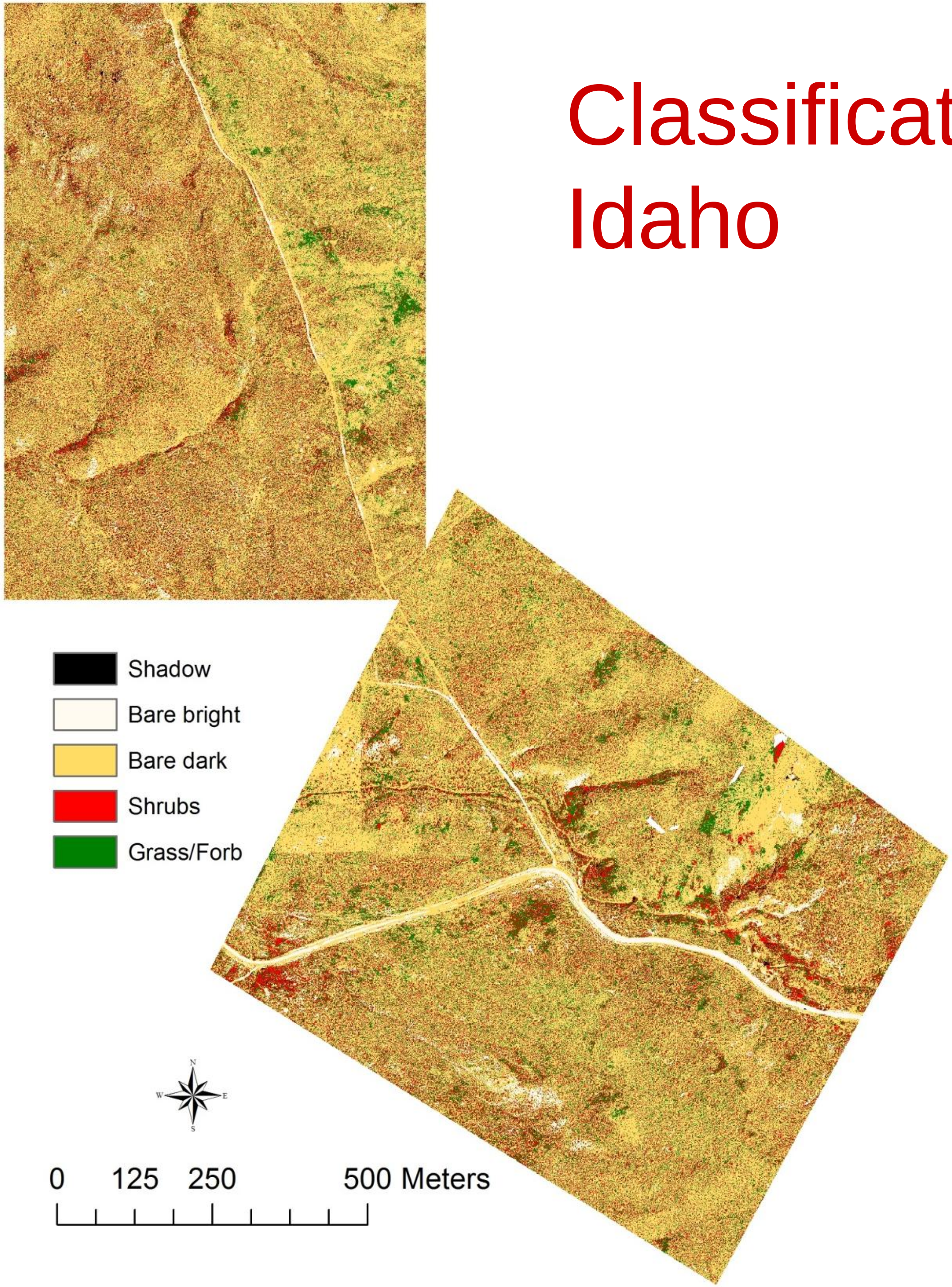
Owyhee uplands, Idaho

330 ha
403 images
7-9 cm GSD

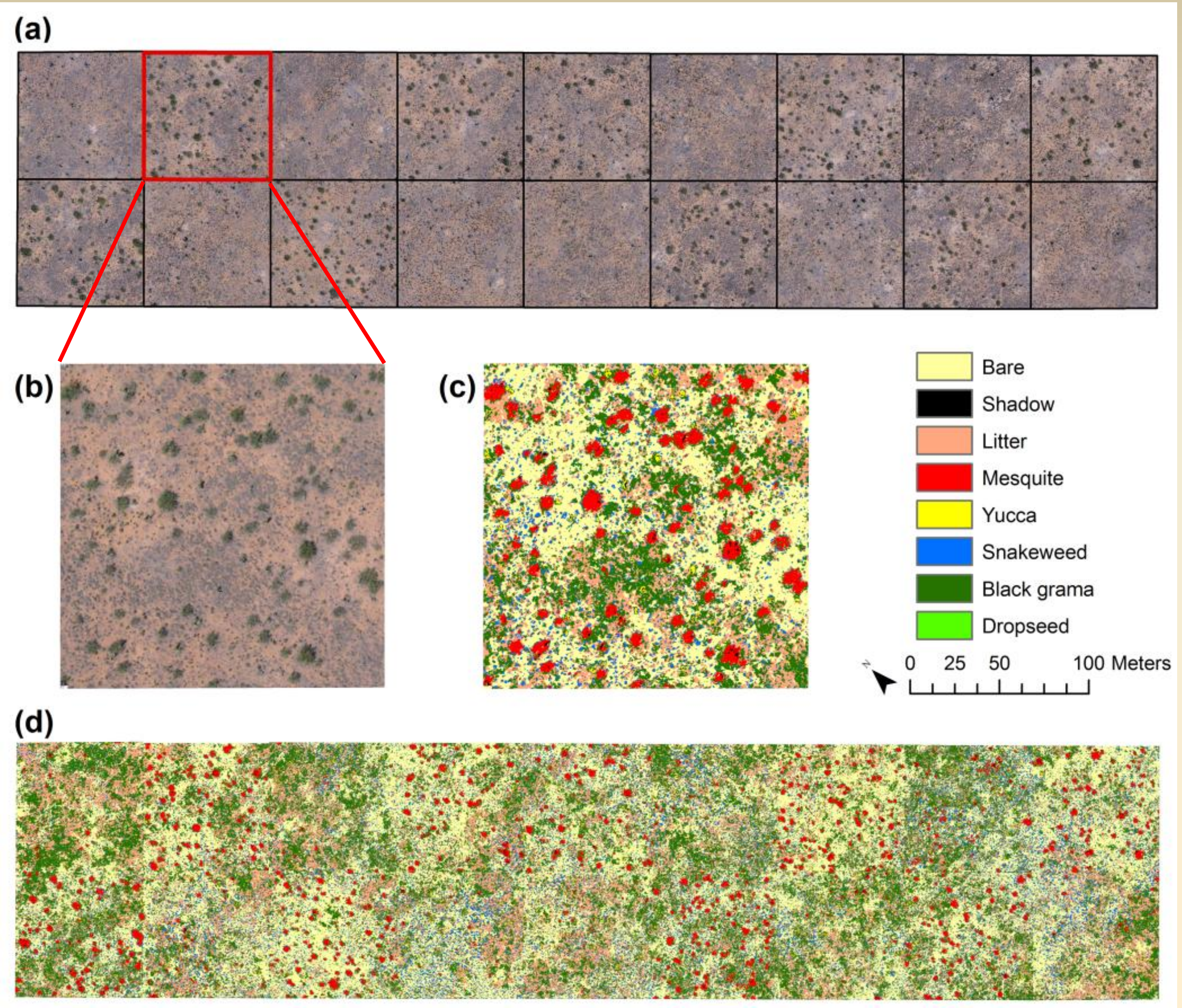




Classification of mosaics Idaho



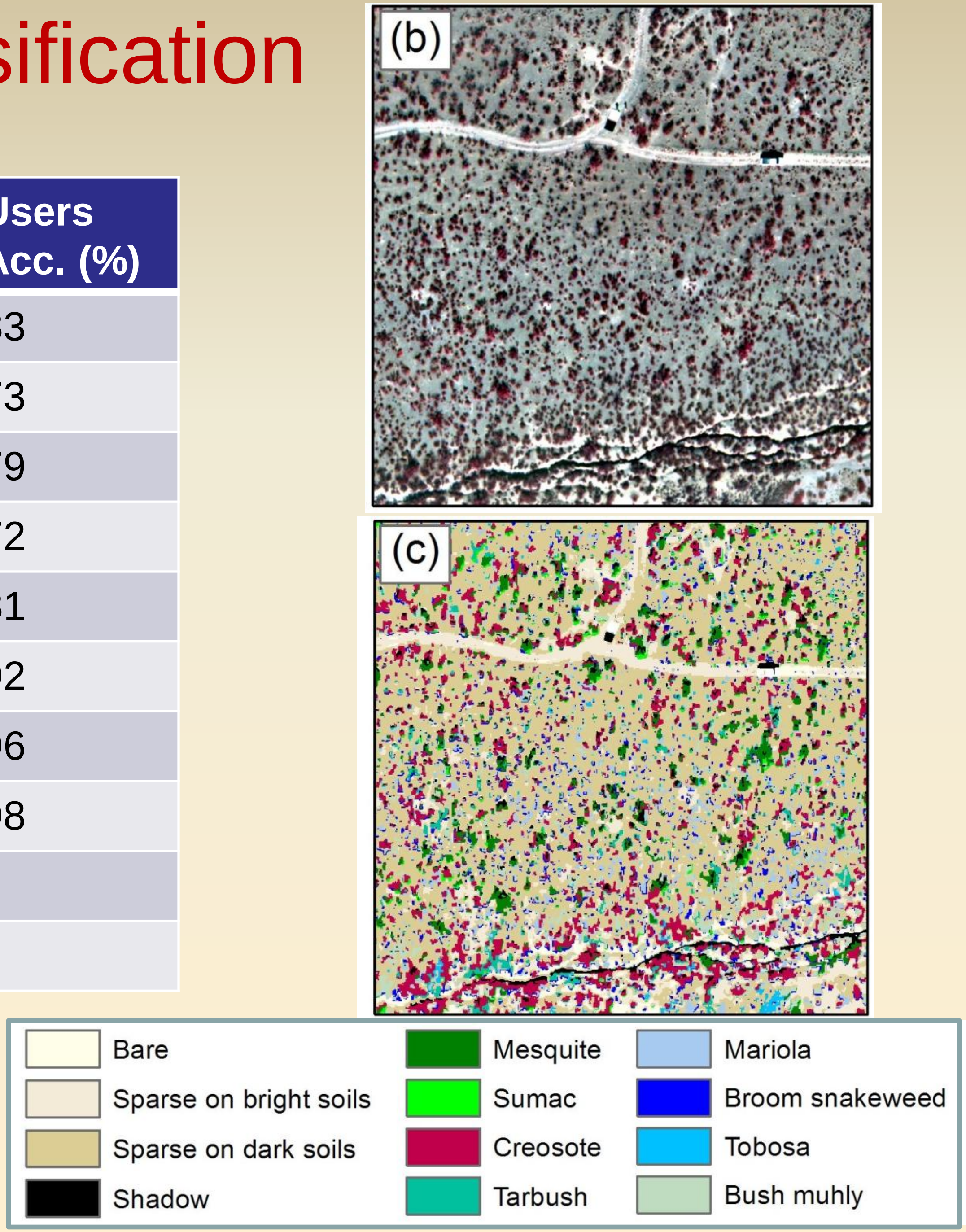
- Based on applying process tree for plots
- Required tiling and ran 10-12 hrs
- Overall classification accuracy: 83% and 88%


(a)
(b)
(c)
Bare
Shadow
Litter
Mesquite
Yucca
Snakeweed
Black grama
Dropseed
N
0 25 50 100 Meters
(d)

Multispectral classification

Class	Producers Acc. (%)	Users Acc. (%)
Tarbush	52	83
Broom snakeweed	72	73
Creosote	94	79
Bush muhly	79	72
Marioly	86	81
Mesquite	89	92
Sumac	49	96
Tobosa	93	98
Overall Acc. (%)	87	
Kappa	0.83	

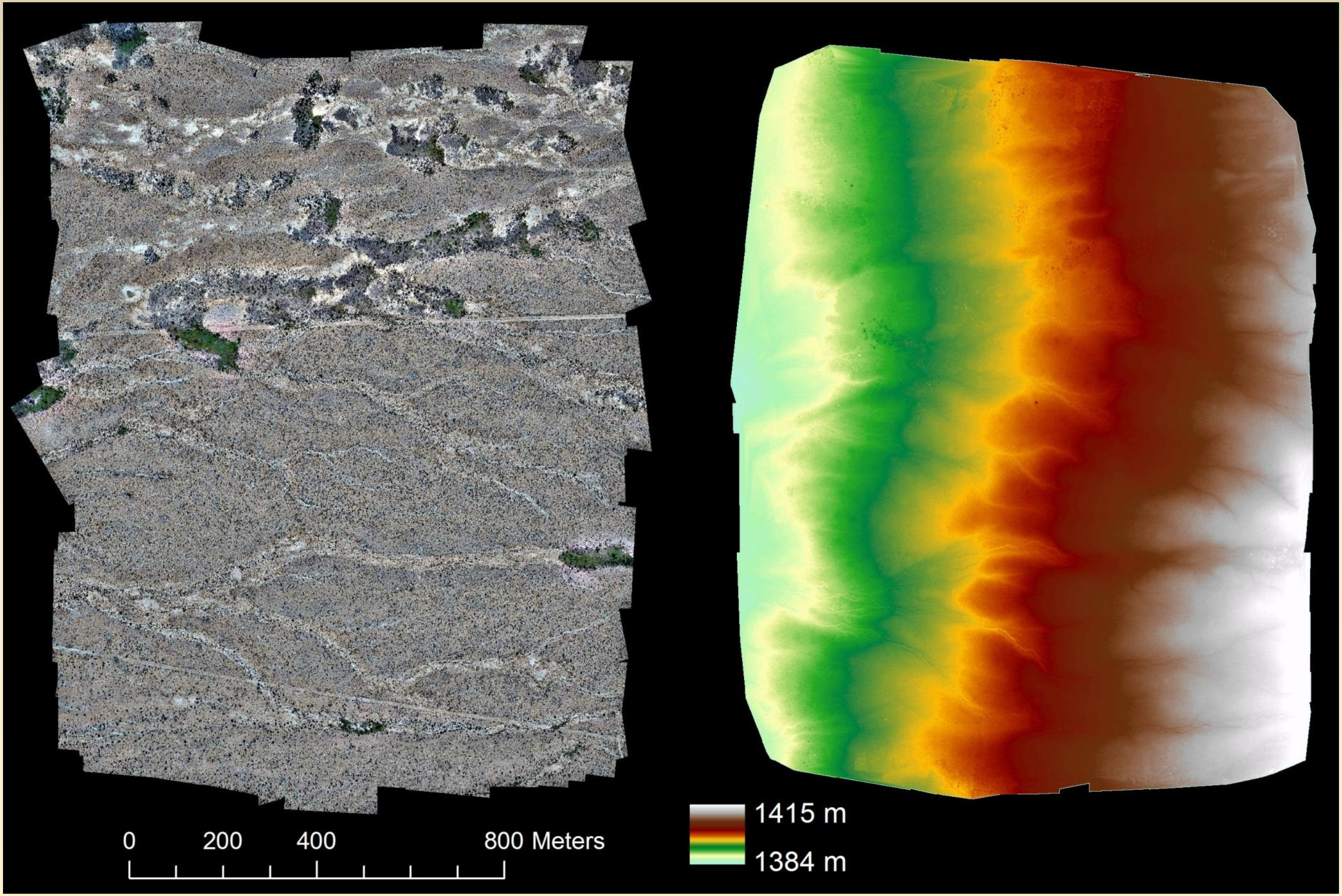
130m x 130m



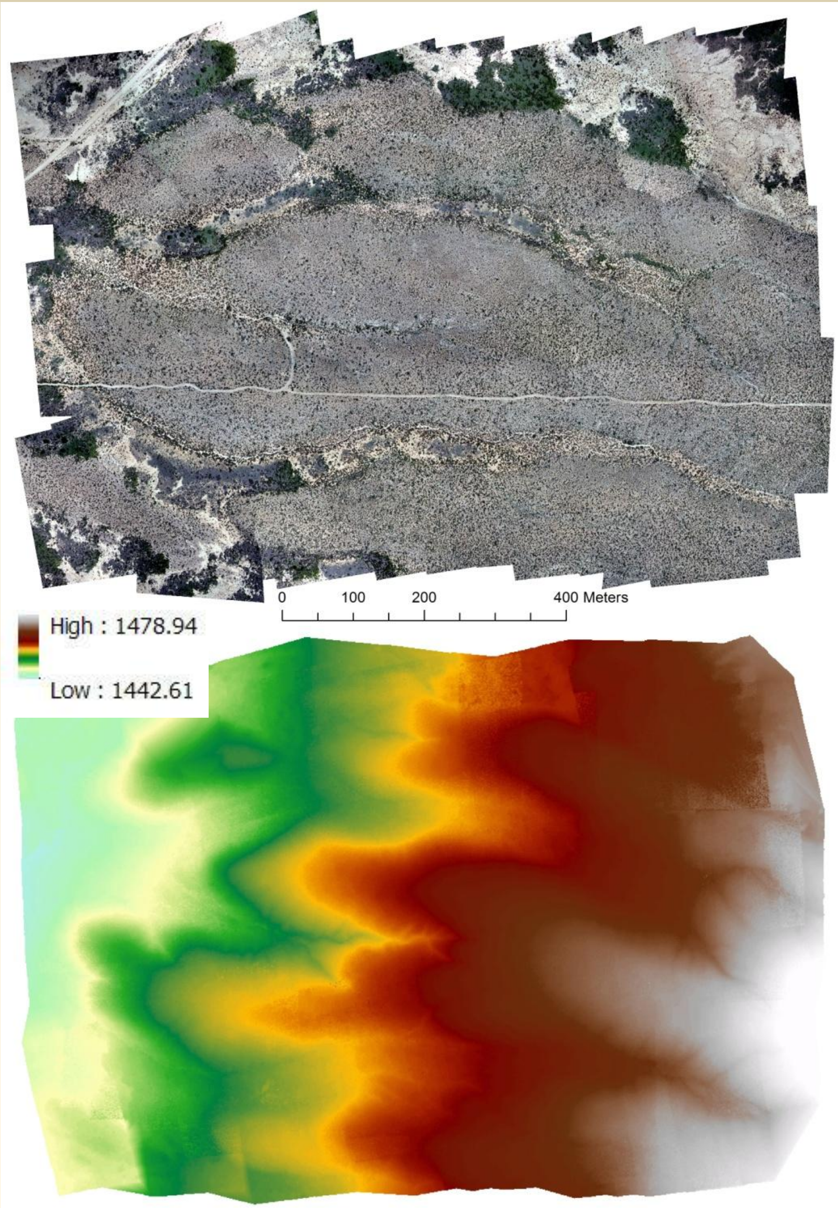
Terrain Extraction from RGB

- Extraction of digital surface model (DSM)
- Sparse DSM at 0.5-1 m resolution
  - Erdas ATE
  - Represents general terrain
- Dense DSM based on 3-D point cloud at pixel level
  - Erdas eATE
  - Fusion of RGB values with elevation data
  - Deriving vegetation heights
- Data used to estimate parameters for hydrologic and erosion models

Orthomosaic (387 images) and 50-cm resolution DSM

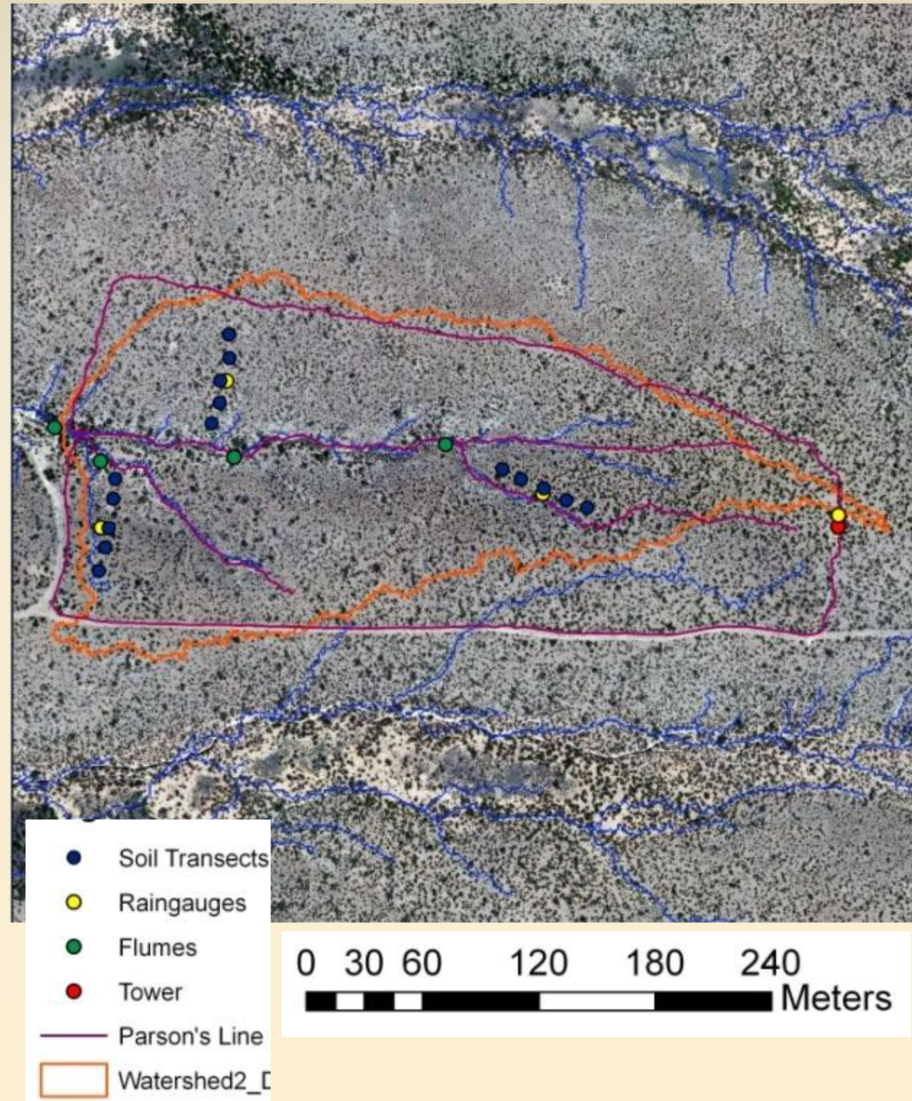


Terrain extraction from UAS imagery

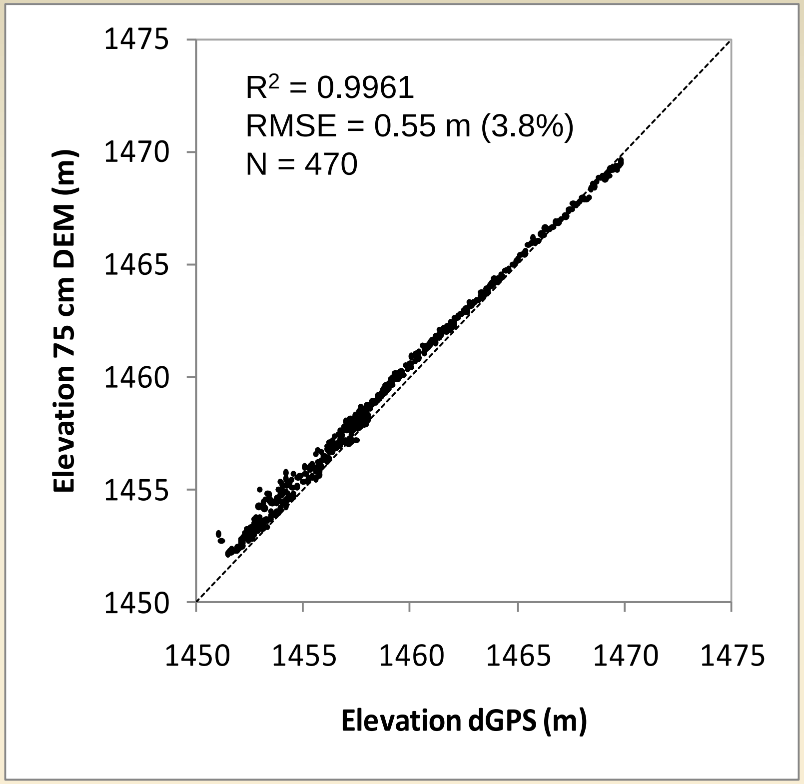


1 m resolution DSM

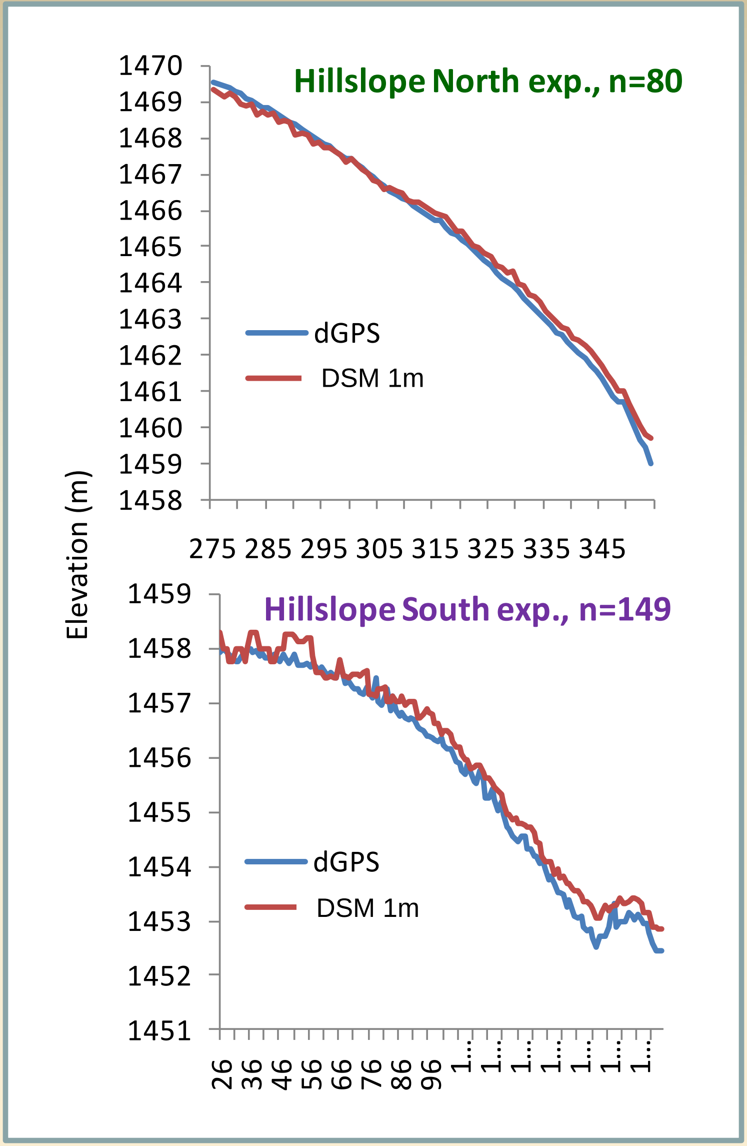
Watershed delineation



DSM validation

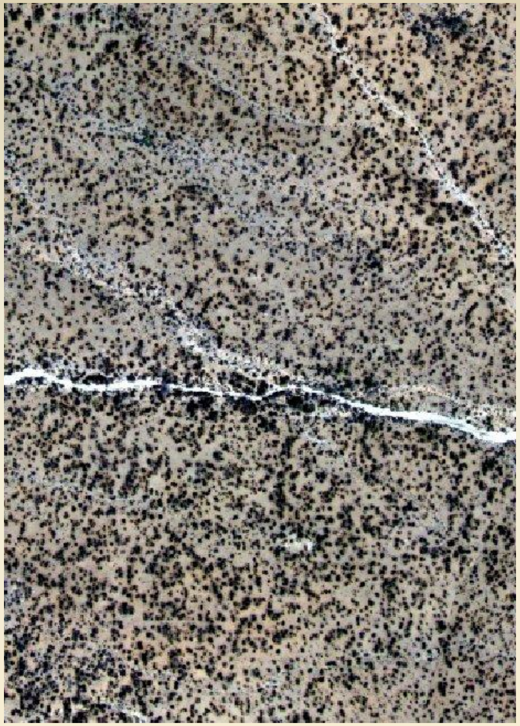


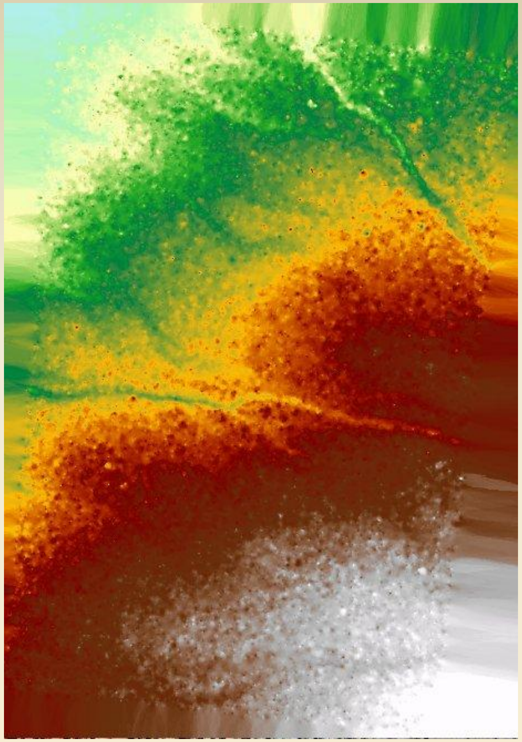
Elevation values derived from the DSM and from field measurements with survey grade dGPS



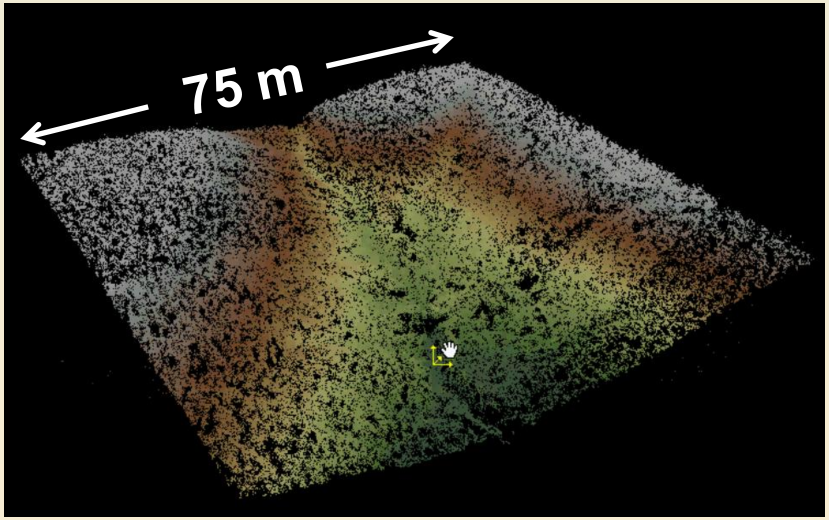
Hillslope profiles derived from the DSM and from field measurements with survey grade dGPS

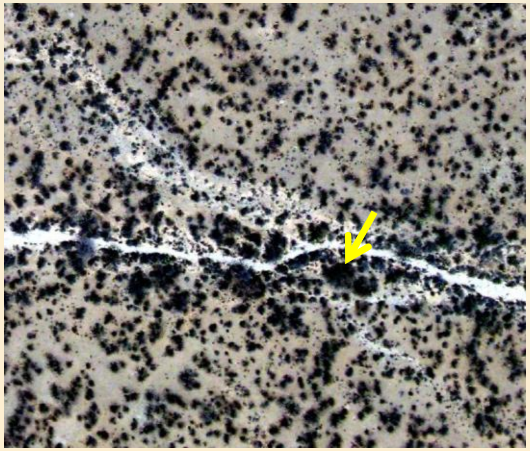
Dense DSM based on 3D point cloud

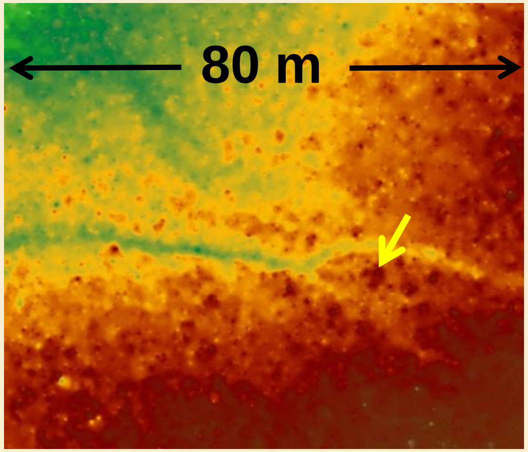




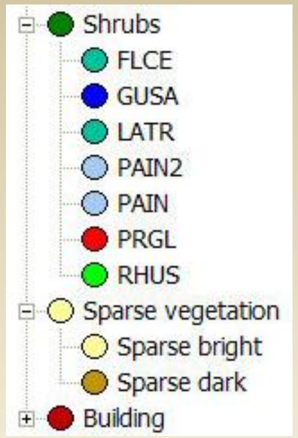
Using Erdas eATE module

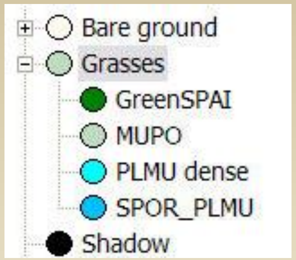


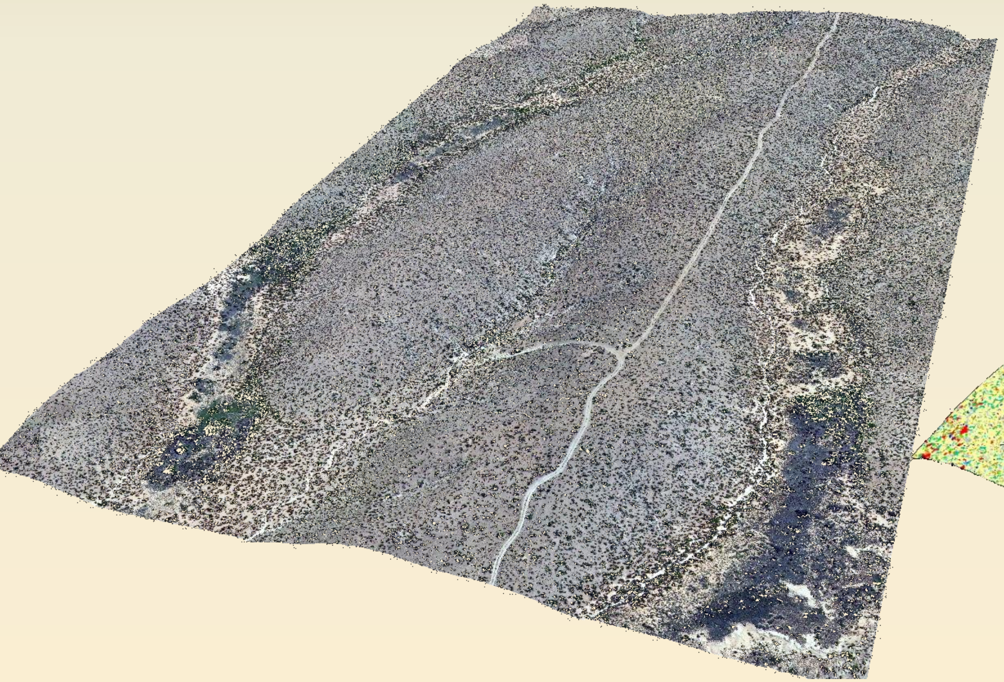


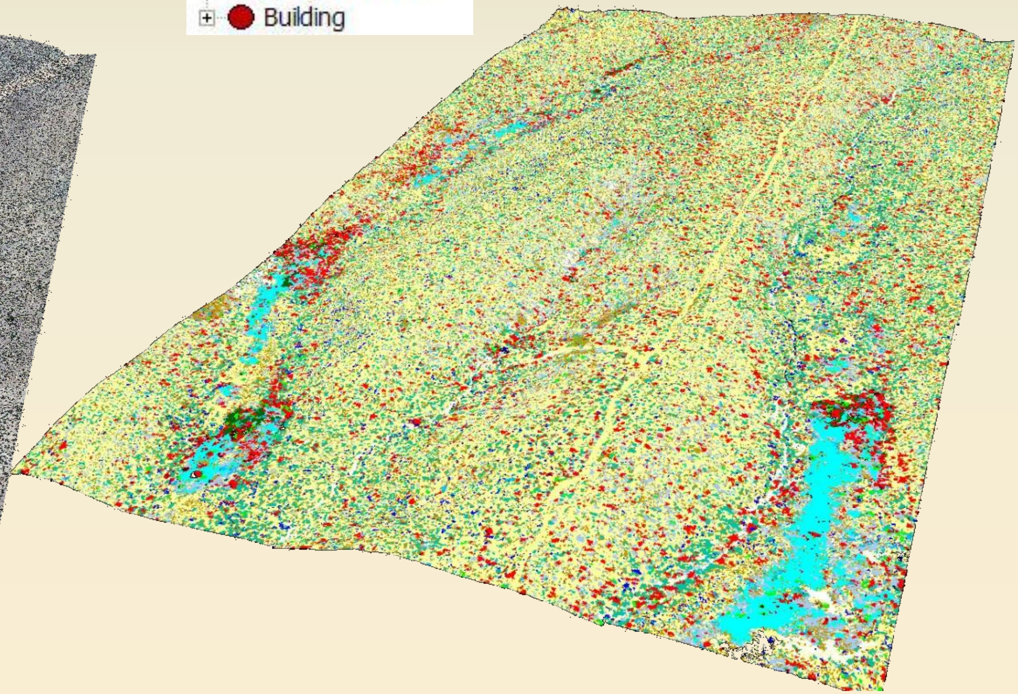


Fusion of terrain model, imagery, and vegetation classification









Summary

- Workflows for UAS image acquisition, orthorectification, mosaicking, classification
- Multispectral imagery allows for better species discrimination and change detection studies
- Terrain extraction and vegetation height estimations show promise
- UAS are viable platforms for obtaining quality remote sensing data at very high resolution
- Data use for land cover mapping, hydrologic assessment, phenology, archaeology

Ongoing and Future Research

- Multispectral imagery
  - Ongoing spectral ground and airborne measurements, change detection, vegetation indices
- Terrain extraction
  - Streamline processing of point clouds
  - Compare elevations and vegetation heights with field data
- Scale these approaches to larger areas
- Compare/upscale using WorldView-2 data
- Test other UAS sensors (thermal, lidar, hyperspectral)

BAT 4

13 ft wingspan
35 lb payload
150 W generator

Thank you!