

REMOTE SENSING 101 & LIDAR

MODERNIZING 4FRI IMPLEMENTATION - PROGRESS







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REMOTE SENSING 101

- Lidar is an active sensor
- Pulse emitted with known direction, contacts something and reflected back to device
- Device recognizes these timestamped, reflected photons
- Calculates the time between emission and return
- Produces a "cloud" of points









Campbell and Wynne 2011

TYPES OF LIDAR

li∙dar

/ˈlīdär/

noun

a detection system which works on the principle of radar, but uses light from a laser.



 lines show track of scan across ground circles show actual ground return footprints



NOT ALL LIDAR IS CREATED EQUAL



0.2 ha near A1 Mtn, Flagstaff, AZ





28.26 returns/m² 0.19 m pt spacing **Quantum Spatial** 2019

QL0*: Accuracy: RSME, 5 cm Pt density: ≥8 pulses/m²



7.84 returns/m² 0.36 m pt spacing Sanborn Mapping 2013



QL1:

1m²

Accuracy: RSME_z 10 cm pt density: 8 pulses/m²

2.49 returns/m² 0.63 m pt spacing Who knows? 2009

QL2:

Accuracy: RSME, 10 cm Pt density: 2 pulses/m²

HOW IS IT USED?

- Classify and utilize the returns
- Create a digital surface model (DSM) from the first returns
- Or flip the point cloud and create a digital terrain model (DTM) from the ground returns
- Subtracting the DTM from (nonground) returns to get height above ground level (i.e. a canopy height model or CHM)
- 1st-Order Products or Derivatives

REMOTE SENSING, LIDAR, UAS





MORE ON USING LIDAR





TWO MAIN APPROACHES IN FORESTRY

Area-based Individual-based

AREA-BASED APPROACH

- Extract lidar data associated with sample locations
- Quantify lidar metrics
- Process plot data and develop relationships between lidar metrics and plot metrics
- Computer lidar metrics on a grid (i.e., raster)
- 2nd-Order Products or Derivatives



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INDIVIDUAL-BASED APPROACH

- Normalize the point cloud
- Use algorithm to classify points into unique tree id's
- Process points to quantify individual tree attributes
- Computer tree metrics for all trees (i.e., vector)
- ??-Order Products or Derivatives





LIDAR AVAILABILITY, STRATEGY, AND TRAINING

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LIDAR COVERAGE FOR 4FRI



GTAC Image Server

Four standard lidar derivatives hosted on the Image Server

https://image-services-gtac.fs.usda.gov/arcgis

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GTAC Image Server





Regional Lidar Strategy

SW Regional Restoration Committee requested a more comprehensive strategy for future investments in lidar

Three phase process

- Phase 1 Develop maps and tables to document current and planned coverage by acres and type
- Phase 2 Gather and document how lidar information is being used in the Region
- Phase 3 Restoration Steering Committee to review info from Phase 1 & 2 and develop comprehensive strategy for budget discussions



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Regional Lidar Strategy Components

Establishment of Regional Lidar Technical Group (RLTG)

Tom Mellin (Geospatial), Jack Triepke (EAP), Ryan Heaslip (Forestry), Will Reed (Heritage), Mark Christiano (GIS-Kaibab)

Vetting of Lidar proposals

Business case/Prioritization of acquisition areas.

Awareness and Training





Geospatial Training

- https://usdagcc.sharepoint.com/sites/fs-gtac-tus/SitePages/Home%20Page.aspx
- Overview of Lidar Technology and FUSION Software
- Lidar Point Cloud Visualization
- Lidar Derivatives: Processing and Analysis





MODERNIZING 4FRI IMPLEMENTATION - PROGRESS







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10m Resolution Digital Elevation Model







10m Resolution Digital Elevation Model







10m Resolution Digital Elevation Model







10m Resolution Digital Elevation Model





Existing Roads (Levels 2 & 1)



Additional Linear Features Identified from Lidar Digital Elevation Model



Operability – Santa Fe National Forest: Temp Road Example



Operability – Santa Fe National Forest: Operability Example





Operability – Bill Williams Mtn. Example





NAIP Imagery



1m Resolution Canopy Height Model





1m Mean Canopy Height for 30m x 30m Neighborhood



1m Resolution Canopy Height Model





CREATE TILE PACKAGES FROM IMAGE SERVICES

Scripts

| 2 | Create Tile Package |
|-------------------------------|--|
| Input Geodatabase | ^ |
| Input Image Service | |
| Cutput Felder Cutput Name | |
| | Create Tile Package From Lidar Mosaic Dataset |
| | |
| | Output Folder |
| | Output Name Create higher resolution tiles visible at scales larger than 1:2,500 (Note: This setting increases file size and time to create tiles) |
| | OK Cancel Environments Show Help >> |

Forest Service Image Server:

https://image-services-gtac.fs.usda.gov/arcgis/services



CREATE TILE PACKAGES FROM LIDAR MOSAIC DATASETS

Scripts

| 3 | Create Tile Package |
|---------------------------------------|--|
| Input Geodetabase | |
| Input Image Service | |
| Input Area of Interest | |
| Output Folder | |
| Output Name | |
| | Create Tile Package From Lidar Mosaic Dataset |
| | Input Working Geodatabase |
| | Input Mosaic Dataset |
| | Output Folder Output Name |
| | Create higher resolution tiles visible at scales larger than 1:2,500 (Note: This setting increases file size and time to create tiles) |
| | OK Cancel Environments Show Help >> |

Forest Service Image Server:

https://image-services-gtac.fs.usda.gov/arcgis/services



CREATE TILE PACKAGES – FOR YOUR AREA OF INTEREST

Scripts

| 3 | Create Tile Package |
|------------------------|--|
| Input Geodatabase | |
| Input Image Service | |
| Input Area of Interest | |
| Cutput Name | |
| | Create Tile Package From Lidar Mosaic Dataset |
| | Input Working Geodatabase Input Mosaic Dataset |
| | Input Area of Interest |
| | Output Name |
| | Create higher resolution tiles visible at scales larger than 1:2,500 (Note: This setting increases file size and time to create tiles) |
| | OK Cancel Environments Show Help >> |

Area of Interest





PRELIMINARY LESSONS INTEGRATING LIDAR WITH TWO-PHASED SAMPLING

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WHAT DOES THIS WORK RESPOND TO?

As managers are asked to determine stand characteristics and obtain volume estimates to appraise and prepare timber sales for <u>larger and larger landscapes</u>, remote sensing and especially lidar, have to become integral components of the Forest Service's work pipeline.



WHAT WAS DONE?

Utilizing existing timber sales that occurred within lidar acquisition footprints, associated cruise plots were located using sub-meter gps and analyses is currently underway to assess the potential of lidar to increase the efficiency of existing cruising methods using a two-phase sample approach.

<u>Two-phase sampling design</u> is a sampling design where the sample selection is performed in two phases

- first phase the auxiliary variable x (<u>lidar-derived</u> <u>estimates</u> of volume to be removed)
- second phase the study variable y (<u>cruise-</u> <u>derived estimates</u> of volume to be removed)

Identified potential timber sales

Collect existing/new fixed area plot data to be used in conjunction with lidar data

Determine a way to estimate volume removed (cruised) using lidar in the first phase.

Examine the reduction in plots required to achieve desires sample error in second phase.

REMOTE SENSING, LIDAR, UAS







Well, it's ongoing....

but I can offer some preliminary lessons learned/observations that will be key for implementation.

I'll come back to this at the end!



High accuracy (sub-meter) GPS locations are imperative.





Sampling based on frequency will likely need to shift to <u>list</u> or gradient sampling when using remote sensing.





With more and more prescriptions moving towards <u>DxP</u>, remote sensing's ability to estimate "volume removed" becomes increasingly difficult.

Remote sensing is best suited for estimating gross volume/biomass.

Solutions "simulating" silvicultural prescriptions and harvest activities may be necessary to obtain estimates.

Development, training, and support will be essential.



- Increase awareness/availability of high-accuracy GPS.
- Alterations in sample selection (list sampling) and sample design (geographically balanced sample) needed.
- Novel ways to model attributes of interest (e.g., stand characteristics or yield estimates following DxP) are needed.



- Programming a DxP is... hard.
- 2PRS stemmed from a 3P approach (3PRS) utilizing aerial photo interpretation and maybe the need suggests an approach with new (old?) tools.
- First Phase calls of Relative Volume (removed) Index (RVI) in the office.
- List sampled plots visited for second phase estimates.





USING LIDAR PRODUCTS TO ESTIMATE VOLUME

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WHAT DOES THIS WORK RESPOND TO?

Using remotely sensed data products to estimate field based derivatives

Efficiencies

Industry Support



WHAT WAS DONE?

Approach...

Estimate Gross Volume with LiDAR

Compare to Volume Removed estimates from cruising

Develop Ratio of:

Predicted Total Existing Volume | Estimated Volume Removed



WHERE DID WE DO IT?

<u>Coconino</u>

Johnneys

Chimney Springs

<u>Kaibab</u>

Moonset

Junction

Clover

Dude

Zorro



WHERE DID WE DO IT?

<u>Coconino</u>

Johnneys

Chimney Springs

<u>Kaibab</u>

Moonset

Junction

Clover

Dude

Zorro

PARKS WEST



Donager and Sanchez Meador 2019

WHAT WAS DONE?

Gross Volume Estimation - LiDAR 2nd Order products

1 Area based volume predictions

2 Individual tree list volume predictions

Estimate existing gross volume

I Area-Based Approach

Plot data

and....

1st order products

Random Forest models

Raster of predicted volume



Donager and Sanchez Meador 2019

Estimate existing gross volume

2 Individual Tree Segmentation Approach

LiDAR point cloud segment individual trees

Predict diameter and volume for each tree

Summarize tree list by unit and strata



Estimate existing gross volume

2 Individual Tree Segmentation Approach

LiDAR point cloud segment individual trees

Predict diameter and volume for each tree

Summarize tree list by unit and strata



WHAT WORKED? ...and what didn't?

LIDAR CRUISING



- 27% error in estimates of validation plot data
- Very little bias in estimates





- 82% error in estimates of validation plot data
- Underprediction in estimates where higher volume exists



predicted



WHAT WORKED?

Ratio



Estimated Volume Removed

Predicted Total Existing Volume

| | Area-based Total | ITS |
|-----------------|------------------|--------------------|
| Project Area | Volume Ratio | Total Volume Ratio |
| | | |
| <u>Coconino</u> | | |
| Johnneys | 0.32 | 0.48 |
| Chim. Springs | 0.39 | 0.58 |
| | | |
| <u>Kaibab</u> | | |
| Clover | 0.48 | 0.56 |
| Zorro | 0.62 | 0.67 |
| Dude | 0.56 | 0.64 |
| Junction | 0.42 | 0.58 |
| Moonset | 0.48 | 0.57 |
| | | |
| Average | 0.51 | 0.58 |
| Stand. Dev. | 0.10 | 0.06 |



WHAT WORKED?





WHAT WORKED?







WORK IN PROGRESS!!!!

Improved training dataset

Stratified plot network to improve model

Measurements of both total existing volume and volume removed base don Rx

Developing products requires spatial and modeling analysis skills



WORK IN PROGRESS!!!!



WORK IN PROGRESS!!!!

ECHO WHAT ANDREW SAID!!!!!



WORK IN PROGRESS!!!!

In addition to a potential cruising toolset...

Project implementation process

Economic/Operational feasibility

Landscape scale understanding/planning



THANK YOU

| Presenter | E-mail |
|-----------------------|------------------------------|
| Andrew Sanchez Meador | andrew.sanchezmeador@nau.edu |
| Tom Mellin | thomas.mellin@usda.gov |
| Mark Nigrelli | mark.nigrelli@usda.gov |
| Travis Woolley | twoolley@tnc.org |

