USDA United States Department of Agriculture

GTAC-10175-RPT1 January, 2019

Riparian Existing Vegetation (REV) Mapping on the Carson NF

Clark, A.; Goetz, W.; Maus, P.; Megown, K.; Triepke, J.; Matthews, B.; Muldavin, E.; 2018. Riparian Existing Vegetation (REV) Mapping on the Carson National Forest. GTAC-10175-RPT1. Salt Lake City, UT: U.S. Department of Agriculture, Forest Service, Geospatial Technology and Applications Center. 9 p.

Abstract

Existing vegetation products were developed to better understand the spatial distributions of vegetation types, height classes, and canopy cover on the Carson National Forest. The vegetation maps comprise of five vegetation types, four leaf retention types, five canopy cover classes for trees and shrubs, and five vegetation height for trees and shrubs. The existing vegetation products discussed in this document will help users to better understand the extent and distribution of vegetation, and disclose the methods and summaries of these products.

Authors

Adam Clark is a remote sensing specialist employed by RedCastle Resources at the Remote Sensing Applications Center (RSAC) in Salt Lake City, Utah.

Wendy Goetz is the vegetation mapping group leader employed by RedCastle Resources at RSAC.

Paul Maus is a contract leader and a principal of RedCastle Resources at RSAC.

Kevin Megown is the Resource Mapping, Inventory, and Monitoring program leader at RSAC.

Jack Triepke is the Regional Ecologist for the Forest Service Southwestern Region in Albuquerque, New Mexico.

Bart Matthews is the Photogrammetry Program Specialist for Forest Service Southwestern Region.

Esteban Muldavin is the Director and Ecologist for Natural Heritage New Mexico, Biology Department, University of New Mexico in Albuquerque.

Table of Contents

Introduction 1
Study Area 1
Methods 2
Results/Discussion 3
Conclusion 8
References 11

Introduction

Existing vegetation maps characterizing riparian lifeform, leaf retention, canopy cover, and canopy height for the Carson National Forest were developed using geospatial data including imagery, topographic and LiDAR data, photo-interpreted reference data, and modeling algorithms. These maps provide basic information on vegetation structure and composition patterns for analysis of current conditions and trends, per the 2012 Plan Rule, and to supplement R3 monitoring needs.

This work is a continuation of a previous project completed on the Gila National Forest (Clark et al. 2016) which assessed the efficiency of digital surface models (DSM) produced from stereo image pairs for mapping canopy cover and canopy height.

Study Area

The study area is located in the Santa Fe National Forest in east-central Arizona. The area included all riparian corridors within the Carson National Forest as defined by boundaries created by the Regional Riparian Mapping Project (RMAP), encompassing about 59,085 acres/23,910 hectares and an elevation range from 1,572 to 4,000 meters (5,157 to 13,123 feet). RMAP was produced in 2013 using topographic information and photo-interpretation methods to delineate all riparian corridors in the Forest Service Southwestern Region (Triepke et al. 2013).

Data Collection

This project used a wide variety of geospatial data including Landsat 8 imagery, topographic data, and photo-interpreted data. All data were projected to a NAD 83 UTM Zone 13 projection.

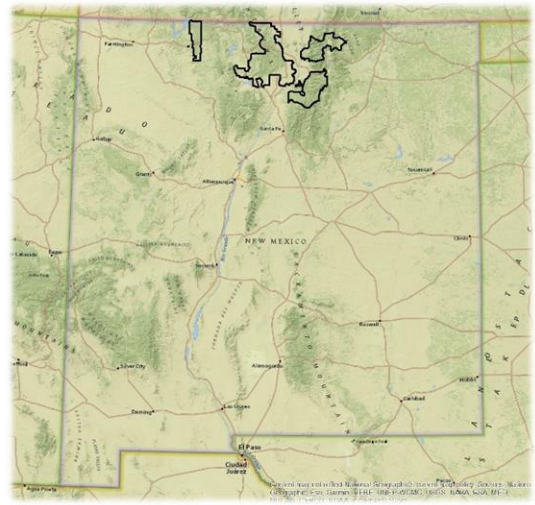

Figure 1 Carson NF boundary within New Mexico

Landsat Seasonal Coefficients

Landsat scenes from 2014-2017 were compiled into a time series using Google Earth Engine. Angle, a derivative from the Tasseled Cap Transformation, was calculated for each scene and a harmonic regression equation was then built for each pixel. These equations used the cosine and sine of time as independent variables and angle values as the dependent variable. These equations then represented the seasonal variability (speed, magnitude, and longevity of green-up and senescence). The equations each had three coefficients (slope of cosine, slope of sine, and y-intercept) which were represented as individual bands in an image.

NED

The National Elevation Dataset (NED) is a seamless elevation dataset for the entire United States provided by the USGS (Siddiqui and Garrett, 2008). Multiple sources such as LiDAR, contour maps, and data from the Shuttle Radar Topography Mission were used to create this dataset (Gesch, 2002). Although throughout the US different spatial resolutions are available, within the Carson NF the NED data resolution is 1/3-arcsecond (about 10 meters). Slope and elevation were created for use as predictor variables in the modeling phase.

LiDAR

LiDAR data intersecting 98% (55,154 acres) of the RMAP project area were provided by the Southwestern Regional Office. These data were acquired in 2017 using three Leica ALS80 HP sensors collecting at a nominal pulse spacing of 0.7 meters with 4 returns per pulse. LiDAR were used as predictor layers, to assign height and cover classes, and for model validation.

Figure 2 LiDAR data coverage (green) within Carson NF

Reference Data

Reference data for this project were comprised of approximately 2,500 photo-interpreted sites. These plot data were synthesized to represent project map themes of lifeform and leaf retention. A quality check was done to ensure all plots represented the entire mapping segment in which they were located.

Methods

The development of the final vegetation maps was accomplished in three main phases. First predictor layers to aid in modeling from a number of sources were gathered and produced. Second, modeling units were generated. Third, the lifeform and leaf retention maps were produced using Random Forest classification and photo-interpreted reference data. The canopy cover and canopy height maps were derived from the LiDAR data. The final maps clipped to the RMAP boundary and filtered to a .25 hectare minimum map feature size.

Phase I: Development of Predictor Layers

Landsat mosaics and composites were processed in Google Earth Engine. NAIP, DEM, and LiDAR were all processed and resampled using tools in ArcGIS and ERDAS Imagine.

Phase 2: Image Segmentation

Image segmentation is the process of partitioning digital imagery into spatially cohesive polygonal segments (modeling units) that represent discrete areas or objects on a landscape (Ryherd and Woodcock 1996). The goal of developing segments is to simplify complex images comprised of millions of pixels into more meaningful objects. Modeling units (segments) were produced in eCognition using NAIP imagery. A minimum size filter of approximately 40 square meters was used to screen out the segments that were too small to be useful. Quality was determined by assessing the homogeneity in lifeform, leaf retention, canopy cover, and canopy height.

Phase 3: Modeling

The modeling phase developed the statistical relationships between the reference data and the geospatial predictor data. These statistical relationships were then applied to the full extent of the census data to build a map. The first step involved producing zonal statistics (mean and standard deviation) for each modeling unit using Landsat 8 imagery and seasonal coefficients, and the topographic data. Random Forest algorithm was then used to assign lifeform and leaf retention classes (Breiman 2001). The canopy cover maps were created by taking a summary of pixels within a segment identified as tree or shrub, this identification was done by assigning any pixel with a LiDAR height more than 1 meter as tree or shrub. Canopy Height maps were created by summarizing the height above .2 meters according to the LiDAR data, and assigning the most often occurring size class within each segment. Areas without LiDAR data (approximately 2% of study area or 1,474 acres) were interpreted using all available data by an analyst and assigned a cover and height class manually. Each model output was carefully evaluated for inconsistencies or misclassification using the NAIP imagery. Areas that were misclassified were reassessed, new training data added, and new models developed. This modeling procedure was repeated until the maps were considered satisfactory. The map was finalized by clipping it to the RMAP boundary and aggregating and filtering the map features to the minimum feature size.

Results/Discussion

Mapping

Map attributes characterizing lifeform and leaf retention were developed using the Random Forest algorithm while canopy cover and canopy height were derived from LiDAR data and data interpretation. Random Forest is an advanced machine-learning algorithm based on the recursive generation of classification and regression trees. The resulting map products provide for continuous vegetation information for the RMAP area. The final map was aggregated and filtered to the .25 hectare minimum map feature size.

Lifeform Attribute

The final map contained six lifeform classes (Figure 3). Of the total 56,627 acres, 57% percent or approximately 33,000 acres were mapped as tree or shrub. The herb class was more common in lower elevation, wide riparian corridors, adjacent near private land that was used for grazing. The sparse vegetation class was typically found along the river banks as sand bars or as dry stream beds for ephemeral streams.

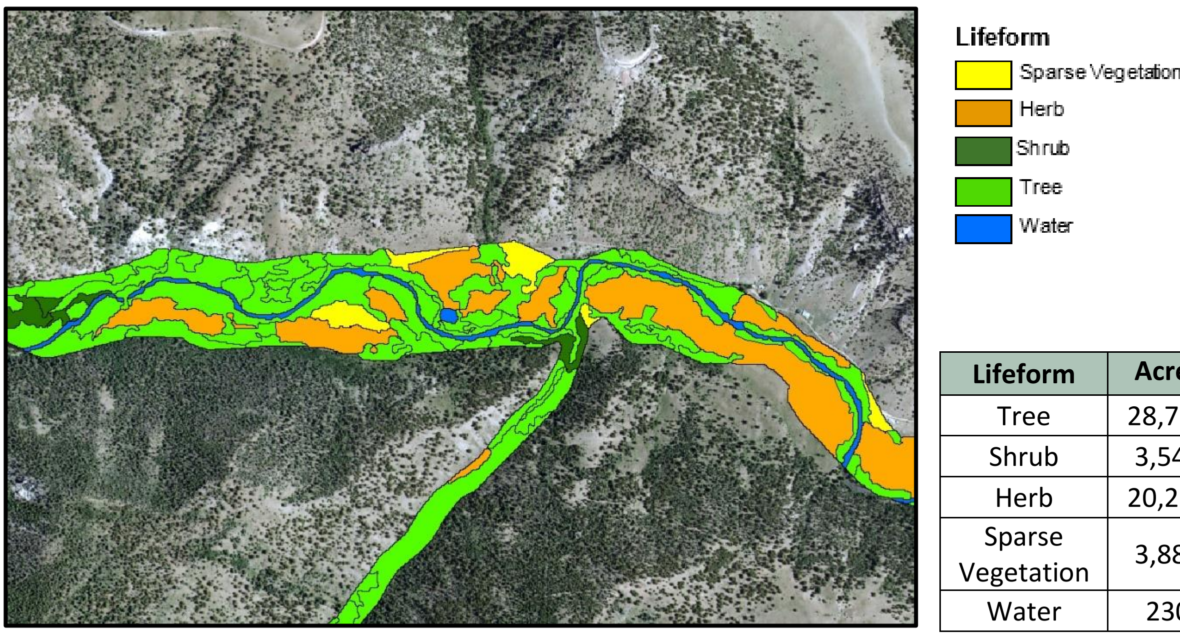

Figure 3 Lifeform map

Lifeform	Acres	%
Tree	28,751	50.8%
Shrub	3,545	6.3%
Herb	20,212	35.7%
Sparse Vegetation	3,885	6.9%
Water	230	0.4%

Table 1 Lifeform acre summaries

Leaf Retention Attribute

Classes describing leaf retention were assigned to tree and shrub polygons identified in the lifeform classification (Figure 4). Evergreen was mainly mapped in higher elevations surrounding headwater streams, while the deciduous type was more commonly found in the wide flat riparian corridors. Mixed evergreen-deciduous occurred the least. This may have been a result of limited training points, as well as segments that succesfully captured leaf retention homogeneity.

Leaf Retention	Acres	%
Non Tree-Shrub	24,329	43%
Deciduous	15,988	28.2%
Evergreen	11,408	20.1%
Mixed Evergreen-Deciduous	4,900	8.7%

Table 2 Leaf Retention acre summaries

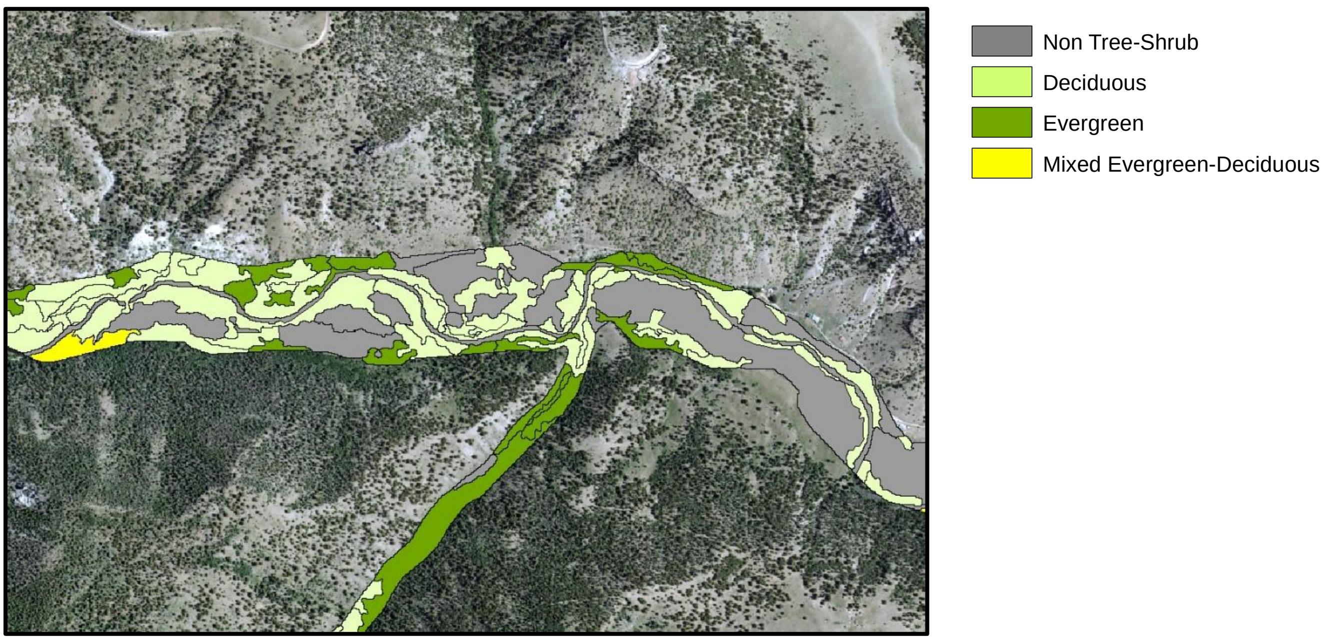

Figure 4 Leaf Retention map

Canopy Cover Attribute

Canopy cover classes were assigned to tree and shrub lifeform polygons (Figure 5). The 75-100% class was the most dominant, occupying approximately 10,200 acres or 18% of the project area.

Canopy Cover	Acres	%
0) Non Tree-Shrub	24,329	43%
1) 10 – 25%	5,405	9.5%
2) 25 – 50%	6,860	12.1%
3) 50 – 75%	9,800	17.3%
4) 75-100%	10,231	18.1%

Table 3 Canopy Cover acre summaries

Figure 5 Canopy cover map

Canopy Height Attribute

Canopy height classes were assigned to tree and shrub lifeform polygons (Figure 6). The least dominant class was the 0-.5 meter class, occupying about 3,100 acres and 5.5% of the project area. The .5-5 meters class was the most dominant, occupying approximately 14,600 acres or 25.8% of the project area.

Canopy Height	Acres	%
0) Non Tree-Shrub	24,329	43%
1) 0 - 0.5 m	3,097	5.5%
2) 0.5 – 5 m	14,598	25.8%
3) 5 – 12 m	5,188	9.2%
4) 12+ m	9,413	16.6%

Table 4 Canopy Height acre summaries

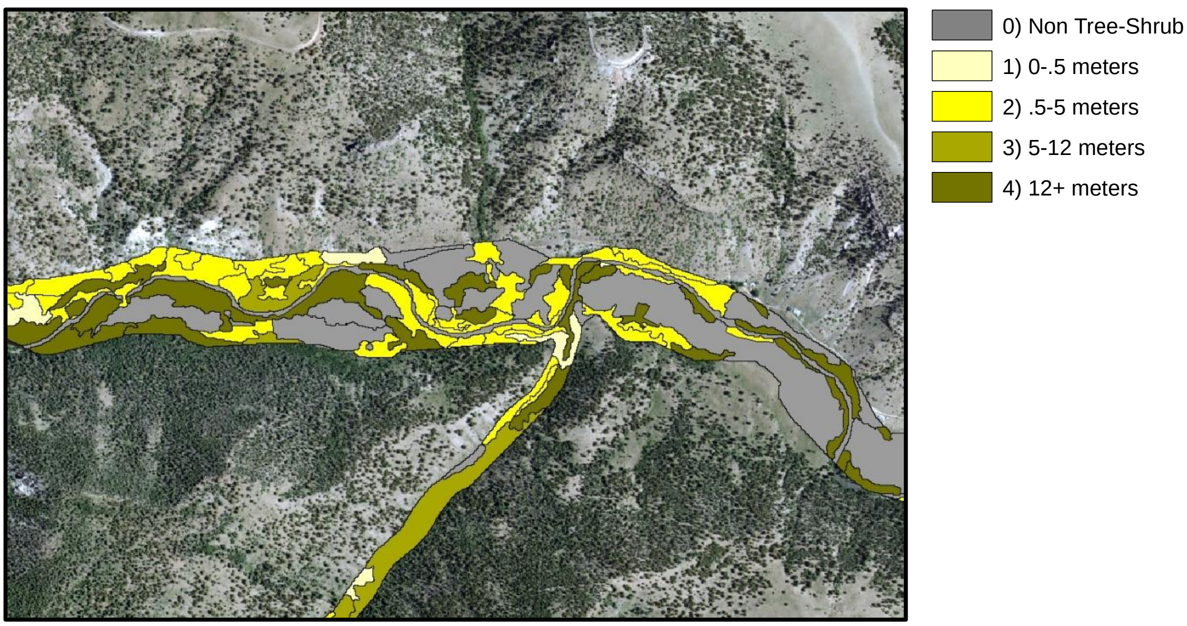

Figure 6 Canopy Height map

Conclusion

Understanding the current structure and composition of riparian areas is key to riparian resource management. Riparian corridors make up a small area but can house the largest amount of biodiversity in a forest. Using machine learning algorithms on spatial data combined with detailed information from local experts, a riparian vegetation map identifying lifeform, leaf retention, canopy cover, and height features were created.

Lifeform	
Tree	Tree canopy cover ≥ 10%
Shrub	Shrub canopy cover ≥ 10% and tree canopy cover < 10%
Herb	Herbaceous cover ≥ 10% and tree and shrub canopy cover < 10%
Barren	All vascular plant canopy cover < 10% and barren
Water	All vascular plant canopy cover < 10% and water
Shadow	Shadowed areas
Leaf Retention	
Evergreen	Relative evergreen tree and shrub canopy cover ≥ 75%
Deciduous	Relative deciduous tree and shrub canopy cover ≥ 75%
Mixed Evergreen-Deciduous	Relative evergreen and deciduous tree and shrub canopy cover each < 75%
Vegetation Height	
< 0.5 meters	The plurality of a size class or the tree and shrub height of the greatest aerial extent in a mapping segment (modeling unit).
0.5 - 4.9 meters	
5 - 11.9 meters	
≥ 12 meters	
Canopy Cover	
< 10%	The total non-overlapping shrub and tree canopy cover in a mapping segment (modeling unit).
10 - 24%	
25 - 49%	
50 - 74%	
≥ 75%	

Table 5 Classification rules

Attribute label	Definition
Lifeform	Represents the dominant cover within a given polygon either shadow, tree, shrub, herbaceous, sparsely vegetated-barren, or sparsely vegetated-water (see classification rules).
Leaf_Reten	Represents the dominant leaf retention of the woody component within a given polygon (see classification rules).
Canopy_Cov	Represents the canopy cover class corresponding to the total tree and shrub cover within a given polygon, either 0) non Tree-Shrub, 1) 10-25%, 2) 25-50%, 3) 50-75%, or 4) 75-100%. For polygons where LiDAR were available, the cover class corresponds to the value calculated for cover_mean, otherwise the value was assigned after data interpretion by an analyst.
Size_Class	Represents the class relating to the mean height value; either 0) non Tree-Shrub, 1) 0-.5 meters, 2) .5-5 meters, 3) 5-12 meters, or 4) 12+ meters for all vegetation (life forms) within a given polygon. Where LiDAR was not available values were based on analyst data interpretation.
height_mea	Represents mean LiDAR height in meters within a given polygon for all vegetation (life forms). Values are not included for polygons where height was based on analyst data interpretation (LiDAR not available).
height_std	Standard deviation of LiDAR height values in meters for all vegetation (life forms). Values are not included for polygons where height was based on analyst data interpretation (LiDAR not available).
cover_mean	Proportion of pixels within segment with a LiDAR height value $\geq$1 meter, representing the tree and shrub component within a given polygon. Values are not included for polygons where height was based on analyst data interpretation (LiDAR not available).
cover_std	Represents the standard deviation in meters calculated for the proportion of pixels with a LiDAR height value $\geq$1m for the tree and shrub component within a given polygon. Values are not included for polygons where height was based on analyst data interpretation (LiDAR not available).
ndvi_mean	Represents zonal mean for each polygon based on NDVI layer from NAIP imagery converted to 8 bit. Some null values a result of segment below minimum size unit for zonal statistics tool.
ndvi_std	Represents standard deviation of zonal mean for each polygon based on NDVI layer from NAIP imagery converted to 8 bit. Some null values a result of segment below minimum size unit for zonal statistics tool.
Data_Source	Source of data used for deriving canopy cover and canopy height. LiDAR is labeled where coverage was available. In the absence of LiDAR photo interpretation (PI) of the available data was conducted by an analyst to assign values
wdy_ht_m	Mean LiDAR height in meters of tree and shrub life forms within a given polygon (i.e., after a 0.2m threshold was applied). Values are not included for polygons where height was based on analyst data interpretation (LiDAR not available).
wdy_ht_sd	Standard deviation of LiDAR mean height values in meters for tree and shrub life forms (i.e., after a 0.2m threshold was applied). Values are not included for polygons where height was based on analyst data interpretation (LiDAR not available).
Wdy_Size (=Wdy_SizeAv)	Represents the mean height class of greatest aerial extent for all vegetation within a given polygon, either 0) non Tree-Shrub, 1) 0-.5 meters, 2) .5-5 meters, 3) 5-12 meters, or 4) 12+ meters. Where LiDAR were available size class was derived by zonal mean within a given polygon, while size class was assigned by an analyst after data interpretation where no LiDAR coverage existed.
Wdy_Sizemj	Represents the plurality (zonal majority) height class of greatest aerial extent for tree and shrub life forms (i.e., after a 0.2m threshold was applied) within a given polygon, either 0) non Tree-Shrub, 1) 0-.5 meters, 2) .5-5 meters, 3) 5-12 meters, or 4) 12+ meters. Where LiDAR were available size class was derived by zonal majority within a given polygon, while size class was assigned by an analyst after data interpretation where no LiDAR coverage existed.

Table 6 Map attribute label and definitions

References

Breiman, L. 2001. Random Forests. Machine Learning. 45: 5–32.

Clark, A.; Stam, C.; Goetz W.; Maus, P.; Megown, K.A.; Triepke, J.; Matthews, B.; Muldavin, E. 2016. Mapping riparian vegetation on the Gila National Forest using photogrammetric techniques. RSAC-10121-RPT1. Salt Lake City, UT: U.S. Department of Agriculture, Forest Service, Remote Sensing Application Center. 9 p.

Gesch, Dean, et al. "The national elevation dataset." *Photogrammetric engineering and remote sensing* 68.1 (2002): 5-32.

Gobakken, Terje, Ole Martin Bollandsås, and Erik Næsset. "Comparing biophysical forest characteristics estimated from photogrammetric matching of aerial images and airborne laser scanning data." *Scandinavian Journal of Forest Research* 30.1 (2015): 73-86.

Hirschmüller, Heiko. "Stereo processing by semiglobal matching and mutual information." *Pattern Analysis and Machine Intelligence, IEEE Transactions on* 30.2 (2008): 328-341.

Pyysalo, Ulla, and H. Hyyppa. "Reconstructing tree crowns from laser scanner data for feature extraction." *International Archives Of Photogrammetry Remote Sensing And Spatial Information Sciences* 34.3/B (2002): 218-221.

Siddiqui, Yusuf, and Mick Garrett. 2008 "DATADOORS: A SYSTEM FOR CATALOGING, ACCESSING, PROCESSING, AND DELIVERING LARGE AMOUNTS OF IMAGE DATA."

Triepke, F.J., M.M. Wahlberg, D.C. Cress, and R.L. Benton. 2013. RMAP – Regional Riparian Mapping Project. USDA Forest Service project report available online < http://www.fs.usda.gov/main/r3/landmanagement/gis>. Southwestern Region, Albuquerque, NM. 53 pp.

Westoby, M. J., J. Brasington, N. F. Glasser, M. J. Hambrey, and J. M. Reynolds. 2012. 'Structure-fromMotion' photogrammetry: a low-cost, effective tool for geoscience applications. Geomorphology 179:300-314. DOI 10.1016/j.geomorph.2012.08.021. http://www.sciencedirect.com/science/article/pii/S0169555X12004217

Ziegler, Michaela, et al. "Assessment of forest attributes and single-tree segmentation by means of laser scanning." *AeroSense 2000*. International Society for Optics and Photonics, 2000.