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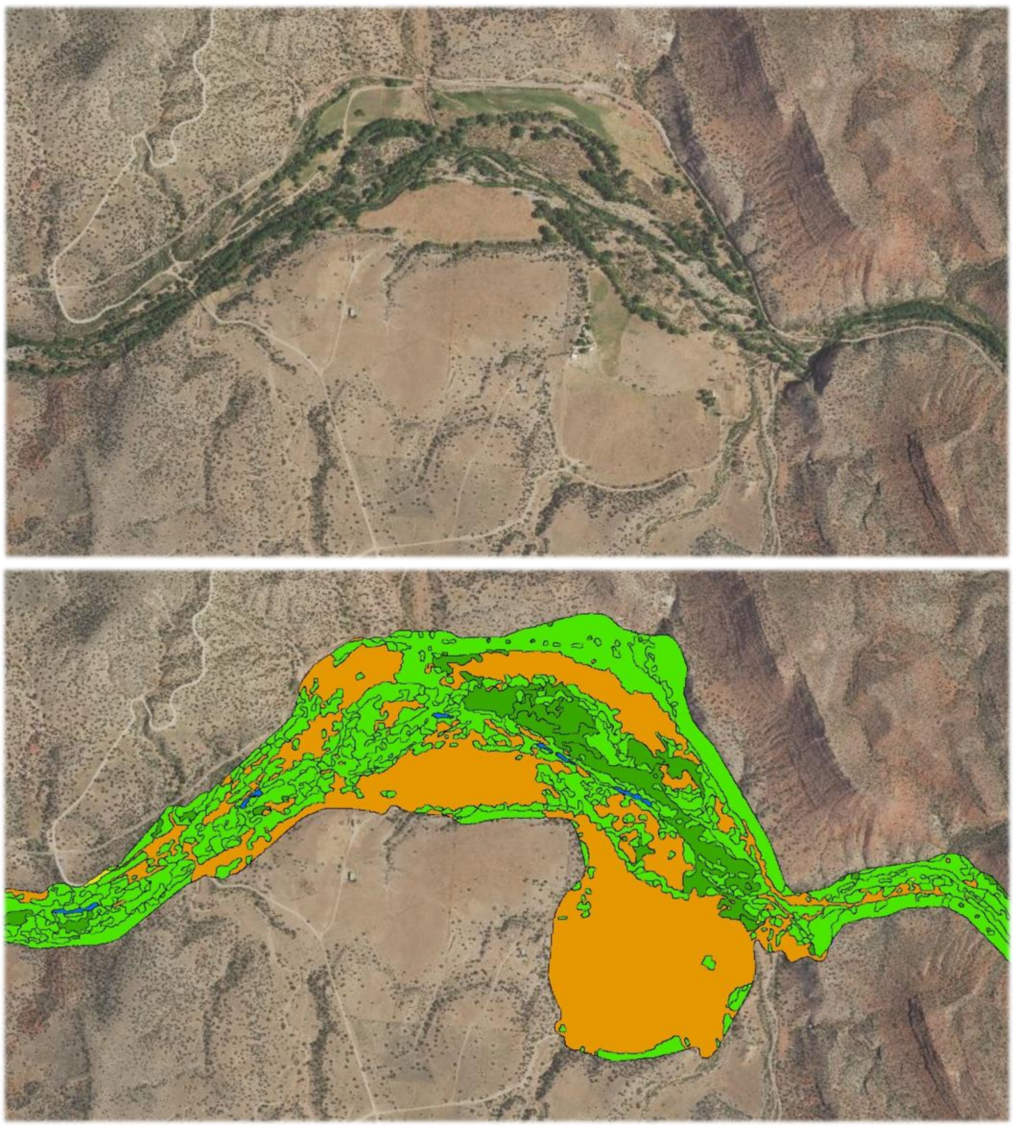
Riparian Existing Vegetation (REV) Mapping on the Tonto NF



Forest Service

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Abstract

Existing vegetation products were developed to better understand the spatial distributions of vegetation types, height classes, and canopy cover on the Tonto 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 classes 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.

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Introduction

Existing vegetation maps characterizing riparian lifeform, leaf retention, canopy cover, and canopy height for the Tonto 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.

Figure 1 Tonto NF boundary within Arizona

Study Area

The study area is located in the Tonto National Forest in Central Arizona. The area included all riparian corridors within the Tonto National Forest as defined by boundaries created by the Regional Riparian Mapping Project (RMAP), encompassing about 92,210 acres/37,316 hectares and an elevation range from about 1,100 to 2,300 meters (3,608 to 7,545 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 12 projection.

Landsat Seasonal Coefficients

Landsat scenes from 2014-2018 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 Tonto 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 54% of the RMAP project area were provided by the Southwestern Regional Office. These data were acquired in 2019 and were used as training data, predictor layers, to assign height and cover classes, and for model validation.

NAIP Point Cloud

Photogrammetric point clouds created from NAIP imagery flown in 2019 were used to create a canopy height model. The process involved using geoprocessing tools on an inverted digital surface model to create a canopy height model (Clark et al. 2016). This layer was used as a predictor layer variable in the modeling process.

Reference Data

Reference data for this project were comprised of approximately 7,000 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 where available, where LiDAR coverage did not occur these maps were produced using Random Forest classification and photo-interpreted reference 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 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. 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, leaf retention, canopy cover, and canopy height were developed using the Random Forest algorithm. In areas with LiDAR coverage 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 five lifeform classes (Figure 2). Of the total 92,210 acres, 86% percent or approximately 80,000 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 riverbanks as sand bars or as dry stream beds for ephemeral streams.

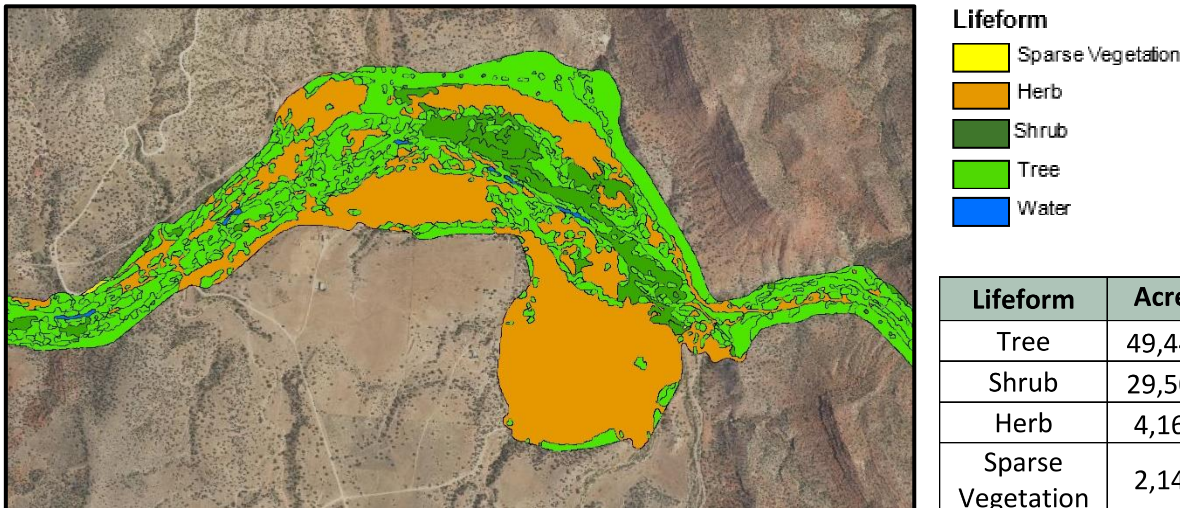

Figure 2 Lifeform map

Lifeform	Acres	%
Tree	49,440	54%
Shrub	29,503	32%
Herb	4,167	5%
Sparse Vegetation	2,143	2%
Water	6,958	8%

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 3). Evergreen was the most common leaf retention type and 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	13,268	14%
Deciduous	33,970	37%
Evergreen	40,727	44%
Mixed Evergreen-Deciduous	4,246	5%

Table 2 Leaf Retention acre summaries

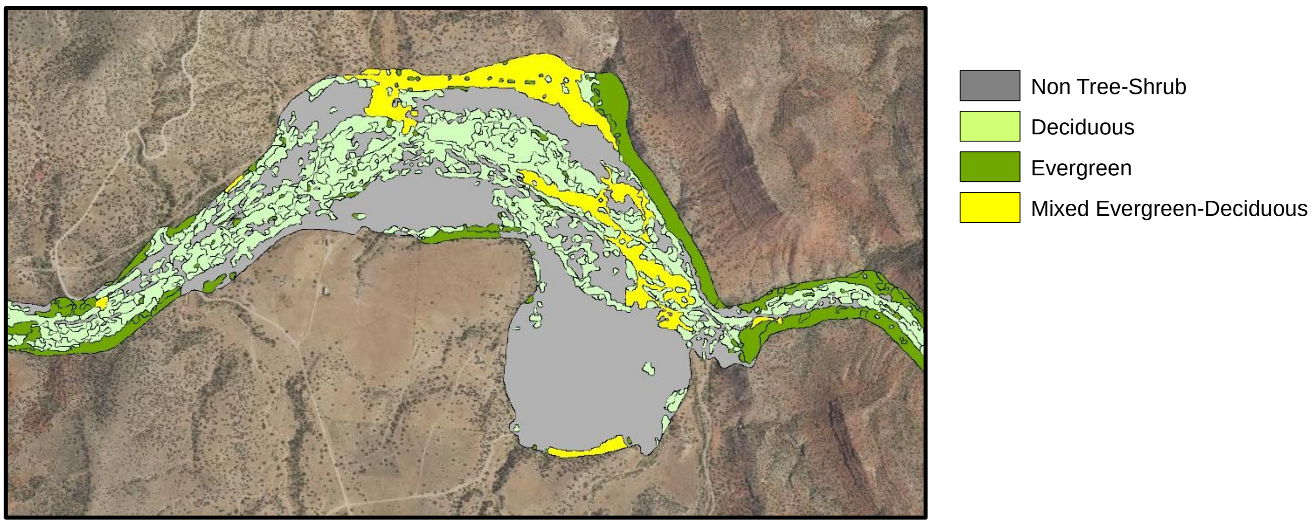

Figure 3 Leaf Retention map

Canopy Cover Attribute

Canopy cover classes were assigned to tree and shrub lifeform polygons (Figure 4). The 10-25% class was the most dominant, occupying approximately 31,321 acres or 34% of the project area.

Canopy Cover	Acres	%
0) Non Tree-Shrub	13,268	14%
1) 10 – 25%	31,321	34%
2) 25 – 50%	19,089	21%
3) 50 – 75%	15,689	17%
4) 75-100%	12,845	14%

Table 3 Canopy Cover acreage summaries

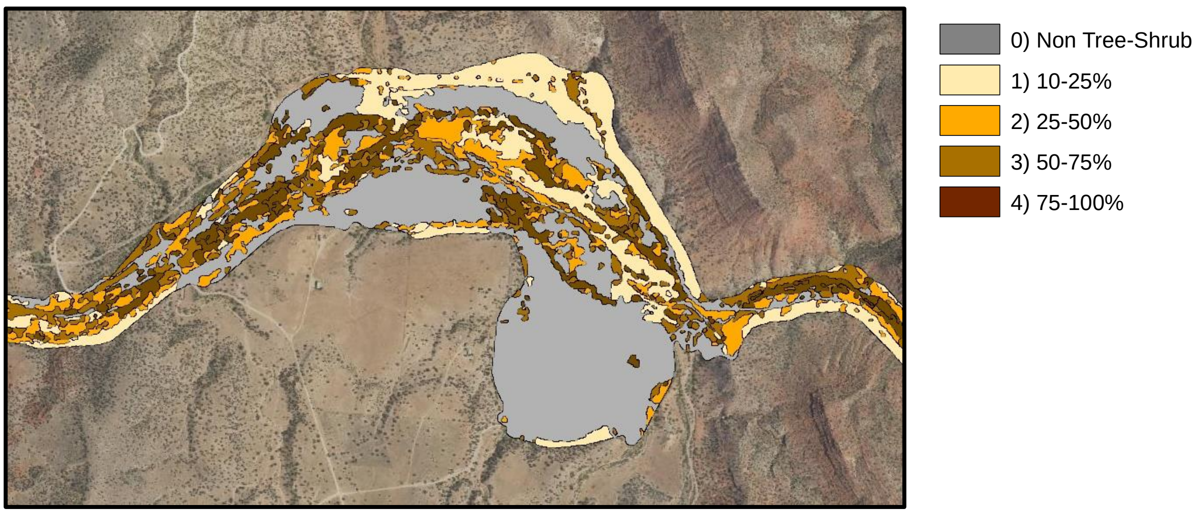

Figure 4 Canopy cover map

Canopy Height Attribute

Canopy height classes were assigned to tree and shrub lifeform polygons (Figure 5). The least dominant class was the 0-.5 meter class, occupying about 1,783 acres and 2% of the project area. The .5-5 meters class was the most dominant, occupying approximately 58,870 acres or 64% of the project area.

Canopy Height	Acres	%
0) Non Tree-Shrub	13,268	14%
1) 0 - 0.5 m	1,783	2%
2) 0.5 – 5 m	58,870	64%
3) 5 – 12 m	10,917	12%
4) 12+ m	7,374	8%

Table 4 Canopy height acreage summaries

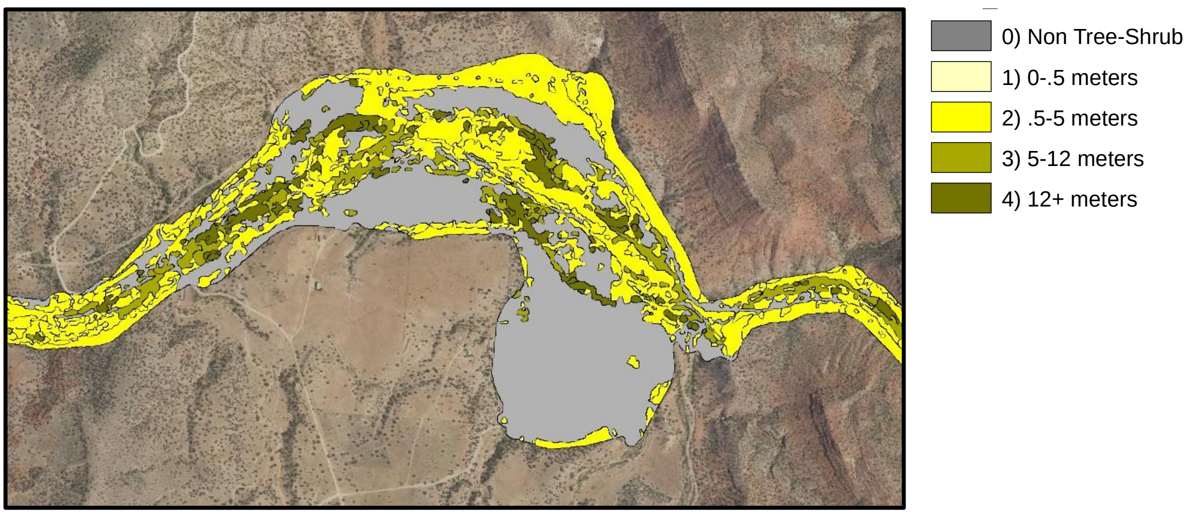

Figure 5 Canopy Height map

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 LiDAR data as well as 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 was 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

REV Table Attribute	Description
USFS_RegNm	US Forest Service Region name, "USDA Forest Service, Southwestern Region" for each polygon. USDA Forest Service data dictionary standard field.
USFS_RegNb	US Forest Service Region name, "3" for each polygon. USDA Forest Service data dictionary standard field.
Lifeform	Represents the dominant cover within a given polygon either shadow, tree, shrub, herbaceous, barren, or water (see classification rules).
Phys_Unit	Physiognomic unit assigned to polygon, either US Forest Service Region name, "3" for each polygon, either 'Forest & Woodland' (tree life form), 'Shrubland' (shrub life form), 'Herbland' (herb life form), 'Sparse Vegetation' (sparsely vegetated-barren), or 'Non-Vegetated (Water)' (sparsely vegetated-water). USDA Forest Service data dictionary standard field.
Leaf_Reten	Represents the dominant leaf retention of the woody component within a given polygon (see classification rules).
Wdy_Cov	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 interpretation or image classification (LiDAR not available).
Wdy_CovCls	Represents the canopy cover class corresponding to the total tree and shrub cover within a given polygon (Wdy_CovCls), 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 Wdy_CanopyCover, otherwise the value was assigned through analyst data interpretation or image classification.
Wdy_Cov_Sd	Represents the standard deviation in meters calculated for the proportion of pixels with a LiDAR height value >1m for the tree and shrub component within a given polygon. Values are not included for polygons where height was based analyst interpretation or image classification (LiDAR not available).
Wdy_Ht_Mn	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 LiDAR was 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 interpretation or image classification (LiDAR not available).
Wdy_SzCls	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-.5m, 2) .5-5m, 3) 5-12m, or 4) 12+m. Where LiDAR were available size class was derived by zonal majority within a given polygon, while size class was assigned through analyst interpretation or image classification (LiDAR not available).
Veg_SzCls	Size class corresponding to the mean height value (Veg_Ht_Mean), either 0) non tree-shrub, 1) 0-.5m, 2) .5-5m, 3) 5-12m, or 4) 12+m for all vegetation (life forms) within a given polygon. Values are not included for polygons where LiDAR was not available.
Veg_Ht_Mn	Represents mean LiDAR height in meters within a given polygon for all vegetation (life forms). Values are not included for polygons where LiDAR was not available.
Veg_Ht_Sd	Standard deviation of LiDAR height values in meters for all vegetation (life forms). Values are not included for polygons where LiDAR was not available.
NDVI_Mn	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_Sd	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.
NVC_Cls	USDA Forest Service data dictionary standard field based on life form, leaf retention, canopy cover, and majority ERU for each polygon. R3 target level of NVC hierarchy.
NVC_Subcls	USDA Forest Service data dictionary standard field based on NVC Subclass.
NVC_Form	USDA Forest Service data dictionary standard field based on NVC Formation.
NVC_Div	USDA Forest Service data dictionary standard field based on NVC Division.
NVC_Mg	USDA Forest Service data dictionary standard field based on NVC Macrogroup.
NVC_Group	USDA Forest Service data dictionary standard field based on NVC Group.
Map_date	Month and year of (re)mapping (e.g., May 2019). USDA Forest Service data dictionary standard field.
Map_reason	Reason for (re)mapping, "periodic base level riparian mapping" for each polygon. USDA Forest Service data dictionary standard field.
Data_Src	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 or image classification was conducted by an analyst to assign values. USDA Forest Service data dictionary standard field.
Data_SrcYr	Year of primary data (NAIP). USDA Forest Service data dictionary standard field.

Table 6 Map attribute labels and definitions

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