White-tailed Ptarmigan and alpine willow distribution in the Sangre de Cristo Mountains, New Mexico
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Donald H. Wolfe and Lena C. Larsson
George M. Sutton Avian Research Center
P. O. Box 2007, Bartlesville, OK 74005

Introduction:

White-tailed Ptarmigan (*Lagopus leucura*) is one of three species of ptarmigan found in North America, and is the only ptarmigan endemic to North America (Braun et al. 1993). All three species are primarily restricted to Arctic or sub-Arctic habitats, but the White-tailed Ptarmigan has adapted to living in alpine habitats throughout the Cascade Mountains and Rocky Mountains, as far south as northern New Mexico for the latter. The closely related Rock Ptarmigan (*Lagopus muta*) exhibits a similar ecological niche and distribution throughout much of Eurasia, although in North America, this lower latitude alpine niche is occupied only by White-tailed Ptarmigan. Both species have experienced range retractions and population reduction at the southern edge of their distribution. This has been attributed primarily to warming temperatures in the alpine, leading to intolerable climate for these species, reduction in snow cover in winter, and changes in vegetation, some of which provide valuable food resources (Hoffman 2006).

White-tailed Ptarmigan were first recorded in New Mexico in 1865 (Coues 1875), although an earlier date has been suggested (Braun and Williams 2015), and likely have never been abundant in the state. In 1981, White-tailed Ptarmigan were transplanted to the Santa Barbara Divide, Pecos Wilderness Area, as a hedge against possible or looming extinction (Wolfe et al. 2011; Braun and Williams 2015). In 1993, a recently hatched ptarmigan nest was located on Barbara Peak (Wolfe 2006), and several observations of ptarmigan broods occurred from 2007 through 2016 (Wolfe et al. 2011; 2014). In 2016, two ptarmigan hens were captured and radio-tagged near Jicarita Peak (Pecos Wilderness Area), each having broods present (pers. obs. Donald Wolfe). Bulger (2017) summarizes the current status of White-tailed Ptarmigan in New Mexico, and points out the importance of alpine willows to the occurrence of ptarmigan.

As White-tailed Ptarmigan occupancy is closely tied to alpine willow (*Salix* spp.) presence, efforts to map alpine willows within the Sangre de Cristo Mountains of New Mexico began in 2011. Locations of willow thickets were recorded as they were encountered while conducting surveys for White-tailed Ptarmigan or deploying and retrieving temperature/humidity data loggers (Wolfe et al. 2014). In 2017, a concerted effort was made to visit most alpine regions in New Mexico to record many more vegetation ground-truth data and to develop detailed maps of willow distribution. The 2017 vegetation ground-truth efforts targeted several non-willow vegetation types that could be used as exclusionary points in the mapping efforts. Considerable effort was made to locate and map the very cryptic mat form of willow, which rarely can be seen and identified from more than a few meters away.

Primary objectives for 2017, as per Professional Services Contract #17-516-0000-00026, were:

1. Collect data at a total of approximately 313 new ground-truth points across the following six study site locations: Gold Hill, Latir Peak Wilderness Area, Little Costilla Peak, Pecos Wilderness Area, Vermejo Park Ranch, and Wheeler Peak Wilderness Area. Ensure that data from a total of approximately 100 points per site (200 for the Pecos Wilderness Area and no minimum for Little Costilla Peak; total points include previously collected ground-truth data) are available for development of a map of alpine willow distribution. Select ground-truth points within woody plant thickets in the alpine areas of these six study sites. Data to be collected at each point include GPS coordinates and woody plant and herbaceous species composition. Take representative photographs of the vegetation at ground-truth points and, as practicable, place some ground-truth points at locations where the low-growing, "mat form" of alpine willow is found. Ground-truth surveys will be performed from June to September 2017.

2. Develop a map of the alpine willow distribution at the six sites listed in I above using appropriate software (e.g., ENVI) and high resolution satellite imagery (e.g., WorldView). Satellite imagery will represent all study sites at multiple time points to account for the effects of variables such as snow fields and clouds. Map development will include analysis of spectral signatures at ground-truth points and identification of one or more signatures unique to alpine willows, ideally including "mat form" or low-growing alpine willows. Preliminary identification of an alpine willow spectral signature will be refined with ground-truth data collected in June-September 2017, as described in 1 above. It will also serve to guide the spatial distribution of the ground-truth points visited in 2017.

3. Concurrent with the ground-truthing described in 1 above, survey for White-tailed Ptarmigan and their sign (i.e., feces or feathers) by visual observation and by play back. Collect White-tailed Ptarmigan molted feathers and fecal piles for future genetic analysis (which is outside the scope of this project). Feather collection and play-back surveys must be done in accordance with the terms of the Contractor's Agency-issued scientific collection permit.

Accomplishments in 2017:

Four ground-truth/survey trips were made in 2017. Trip 1 (June) included visits to three portions of the Pecos Wilderness Area, and Gold Hill; 142 ground-truth points were recorded. Trip 2 (July) included visits to Wheeler Peak Wilderness Area and Latir Peak Wilderness Area; 159 ground-truth points were recorded. Trip 3 (August) was to the Vermejo Park Ranch; 353 ground-truth points recorded. Trip 4 (August) was to the northern portion of the Pecos Wilderness Area; 58 ground-truth points recorded. For the entire 2017 field season, 712 vegetation ground-truth points were recorded, in addition to 287 ground-truth points recorded from 2011-2013 (999 total ground-truth points).

Number of ground-truth points by region (2011-2017)

Pecos Wilderness Area	298
Wheeler Peak Wilderness Area	93
Vermejo Park Ranch	382
Gold Hill	116
Latir Peak Wilderness Area	110
Little Costilla Peak	0
TOTAL GT Points	999

Nine multi-spectral LandSat images (WorldView-2 (50cm), 8-Band Bundle) were purchased, including Big Costilla Peak (Vermejo Park Ranch), Little Costilla Peak, Latir Peak Wilderness Area, Gold Hill, Wheeler Peak Wilderness Area, and four images of the Pecos Wilderness Area (entire Santa Barbara Divide and Santa Fe Baldy Peak; Table 1, Figure 1).

In addition to collecting ground-truth data, records were kept of all observations of predators and other species of interest, especially of American Pika (*Ochotona princeps*), another alpine obligate species that is apparently declining over much of its range. Table 2 summarizes all observations of predators and species of interest.

Methods and Analysis:

WorldView-2 8-band multispectral satellite images (DigitalGlobe 2016) were acquired for the six focal alpine habitat regions in New Mexico. Image dates range from September 2011 through June of 2016; all images were captured in summer and early fall during snow- and ice-free periods. Prior to classification, each image was pre-processed according to the following workflow: 1) digital numbers were transformed to normalized surface reflectance values, 2) multispectral bands were pan-sharpened to a spatial resolution of ~0.5 m, and 3) pan-sharpened images were orthorectified using 10 m resolution digital elevation models (USGS 2017) and ground control points obtained from Google Earth. Pixel-based maximum likelihood classification was used to categorize vegetation in each processed image. For seven of the nine acquired images, field-collected GPS 'ground-truth points' within the image footprint, and corresponding information on dominant plant cover, were used to delineate training polygons and compute spectral signatures for both willow and non-willow herbaceous vegetation. Data from between 12 and 500 pixels from each image were used for creation of willow signatures. Per guidance from the Principal Investigator, additional training polygons were added for other land cover types (subalpine forest, rock/bare ground, water, etc.) as well as visible cloud cover and shadow. For two images (Little Costilla Peak and Pecos Wilderness Area/south) lacking sufficient field data, signature files generated from the one of the seven aforementioned images nearest in spatial distance and time were used for classification. All analysis and geoprocessing steps were performed using ERDAS Imagine 2016 software (Hexagon Geospatial). Figures 2 and 3 illustrate the initial and revised willow designations that were further refined to produce the final willow distribution maps.

Results:

The Sangre de Cristo Mountains of New Mexico encompass approximately 85 square kilometers of alpine habitat (>3658 meters ASL). This estimate is considerably smaller than that reported by Braun and Williams (2015), who gave an estimate of up to 285 square kilometers above 3505 meters ASL. This discrepancy may be due to the different definition of alpine habitat, as we used 12,000 feet (3658 meters) as a delineation zone compared to 11,500 feet (3505 meters), but the greater amount likely was also an overestimate. We mapped approximately 81.7 square kilometers, as the remaining +/-3 square kilometers are isolated peaks, and barely exceed 12,000 feet ASL. There are currently three regions in New Mexico occupied by White-tailed Ptarmigan, possibly considered subpopulations, and it is unlikely that ptarmigans move between these areas. All three regions contain alpine habitat in excess of 15 square kilometers and have an average of 11.7% willow coverage. Conversely, unoccupied regions range in size from <1 square kilometer to 11 square kilometers of alpine habitat, and have an average willow coverage of 2.6%. Indeed, the two unoccupied regions that apparently have adequate willow coverage (5.9% to 12.1%) contained only 1.8 and 2.4 square kilometers of alpine habitat. Thus, it seems apparent that both the total amount of alpine habitat and the extent of willows are likely limiting factors, although both proximity to higher elevations and structures that provide protection from predators and thermal refugia are likely also important (Wolfe et al. 2011, 2014). The use of alpine habitat, based upon sightings and observed sign, relative to its availability increases considerably as elevation increases, especially above 12,300 feet ASL (Wolfe 2014). It is important to note that in the following area descriptions and the accompanying maps the extent of willows does not imply that the amount of area or percentages are only willow. Other woody and herbaceous vegetation often grows in, and is thus comingled with, willow stands. This is especially true for mat form willows. Even in rather contiguous willow stands, there are typically gaps ranging from less than a meter to several meters that are rocky outcrops or vegetated by other species. Essentially, very few willow stands can be considered monocultures, although some shrub thickets along east slopes are nearly monocultures across several hectares. Other common woody vegetation in the sampled areas are Englemann spruce (*Picea engelmanni*), bristlecone pine (*Pinus aristata*), currants (*Ribes* spp.), and shrubby cinquefoil (*Potentilla fruticosa*). Common herbaceous vegetation included various grasses, sedges (*Carex* spp.), blueberries (*Vaccinium* ssp.), clovers (*Trifolium* spp.), and alpine avens (*Geum rossi*). Bulger (2017) provides a more comprehensive list of alpine vegetation.

One occupied region is the northern portions of the Pecos Wilderness Area, from Jicarita Peak south to Trouble Peak, although in the past several years, ptarmigan seem to be primarily restricted to the immediate vicinity of Jicarita Peak. There is evidence that peaks and ridges west from Trouble Peak to Chimayosos Peak have been occupied recently. We have found feathers and/or feces on Barbara Peak, Little Jicarita Peak, Chimayosos Peak, and unnamed peak east of Chimayosos Peak. The last known observation of ptarmigan on Chimayosos Peak was in 1992 (P. Hendricks, *pers. comm.*), and a recently hatched ptarmigan nest was found on Barbara Peak in 1993 (Wolfe 2006). Both shrub (primarily on east slopes) and mat willows (on ridges and plateaus) are abundant, at about 25% area coverage (Table 1, Figures 7 and 8).

A second occupied region includes Wheeler Peak, Mount Walter, and Kachina Peak, in the Wheeler Peak Wilderness Area. Ptarmigan have been located on either Mount Walter or

Wheeler Peak on several occasions between 2007 and 2017. In 2010, we observed ptarmigan on Kachina Peak. However, as a new ski lift was subsequently erected to the summit of Kachina Peak, it is doubtful that this peak is still occupied. Additionally, with the amount of foot traffic to the Wheeler Peak summit, often including unleashed dogs, the outlook for persistence of ptarmigan in this area is bleak. Willows, mostly shrubs, are abundant on east slopes and basins, with overall coverage of 8.5% (Table 1, Figure 12).

The third occupied region includes Big Costilla Peak, Vintrero Peak, and two other unnamed peaks in the Vermejo Park Ranch. As with the subpopulation in the Pecos Wilderness Area, recent surveys seem to indicate that ptarmigan are becoming restricted primarily to only one peak, namely Vintrero Peak. Mat willows are relatively abundant on Vintrero Peak and north slopes of other peaks and ridges, but shrub willows are sparse, mostly on east slopes near timberline. Overall willow extent was estimated at 5.7% (Table 1, Figure 11).

Of the areas surveyed that appear unoccupied by White-tailed Ptarmigan, the Gold Hill complex is the most likely to become reoccupied should populations increase. This is based on its proximity to Wheeler Peak Wilderness Area, as well as its having a substantial amount of mat willow. However, shrub willows are sparse, and mostly limited to small stands on the east slope near timberline. Overall willow coverage was 12.1%, mostly mat willows (Table 1, Figure 4).

The Latir Peak Wilderness Area encompasses nearly 8 square kilometers of alpine, and portions include large boulder fields and rift complexes, but willows were nearly absent. Small patches of mat willows were found on some north slopes, but overall coverage was only 0.7% (Table 1, Figure 5).

Little Costilla Peak was the smallest alpine area surveyed at just under 1 square kilometer. White-tailed Ptarmigan feces have been found on the summit, indicating that ptarmigan may venture to this peak occasionally, likely coming east from Big Costilla Peak, but permanent occupancy is doubtful. There was also an unverified report of ptarmigan just north of the Little Costilla Peak summit in 2010, but we feel that this sighting may have been a misidentification of Dusky Grouse (*Dendragapus obscurus*), as feces from this species was abundant on two survey visits in 2010 and 2013. As no ground-truth data was collected on Little Costilla Peak, reflectivity from other areas was used to estimate willow coverage. Based upon two survey visits to this peak (2010 and 2013), we feel the estimate of 1.1% willow coverage to be fairly accurate (Table 1, Figure 6).

The southern portions of the Santa Barbara Divide within the Pecos Wilderness Area, from the Truchas Peaks south to the Pecos Baldy Peaks, were nearly devoid of willows. This region consists of very steep peaks to the north (Truchas Peaks) and the south (Pecos Baldy Peaks), connected by a long lower alpine plateau (Trail Rider's Wall) that is vegetated mostly by herbaceous vegetation with scattered Engelmann's spruce and bristlecone pine. Overall willow coverage was estimated at 1.4%, consisting mostly of scattered shrub willows on east slopes (Table 1, Figure 9).

Santa Fe Baldy Peak has rock structure suitable for ptarmigan (boulder fields and rift complexes) and a fair amount of mat willow on the summit. However, with only 1.8 square kilometers of

alpine, and being isolated from larger or occupied alpine areas, Santa Fe Baldy likely is not permanently occupied by ptarmigan. Overall willow coverage is estimated at 5.9%, being mostly mat willow, but it is possible that some shrub willows exist on the lower east slope near timberline (Table 1, Figure 10).

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Table 1 – Extent and percentage of willow by region; White-tailed Ptarmigan occupied regions are italicized.

	Alpine habitat* (ha)	Willow canopy (ha)	Percent willow	
Gold Hill	242.43	29.28	12.1%	Figure 4
Latir Peak Wilderness Area	769.34	5.60	0.7%	Figure 5
Little Costilla Peak	98.36	1.08	1.1%	Figure 6
Santa Barbara Divide north (Jicarita Peak, Trouble Peak)	*1,195.79*	*304.38*	*25.5%*	*Figure 7*
Santa Barbara Divide middle† (Barbara Peak, Little Jicarita, Trouble Peak)	*367.95*	*88.24*	*24.0%*	*Figure 8*
Santa Barbara Divide south‡ (Chimayosos Peak, Truchas Peaks, Trail Rider's Wall, Pecos Baldy Peaks)	1,132.23	16.16	1.4%	Figure 9
Santa Fe Baldy Peak	182.16	10.80	5.9%	Figure 10
Vermejo Park Ranch	*2,610.95*	*148.14*	*5.7%*	*Figure 11*
Wheeler Peak Wilderness Area	*1,567.67*	*132.86*	*8.5%*	*Figure 12*
Total	**8,166.87**	**736.53**	**9.0%**	

* imaged areas exceeding 3,657.6 meters (12,000 feet) in elevation
† excludes overlap with 'Santa Barbara Divide north' scene
‡ excludes overlap with 'Santa Barbara Divide middle' scene

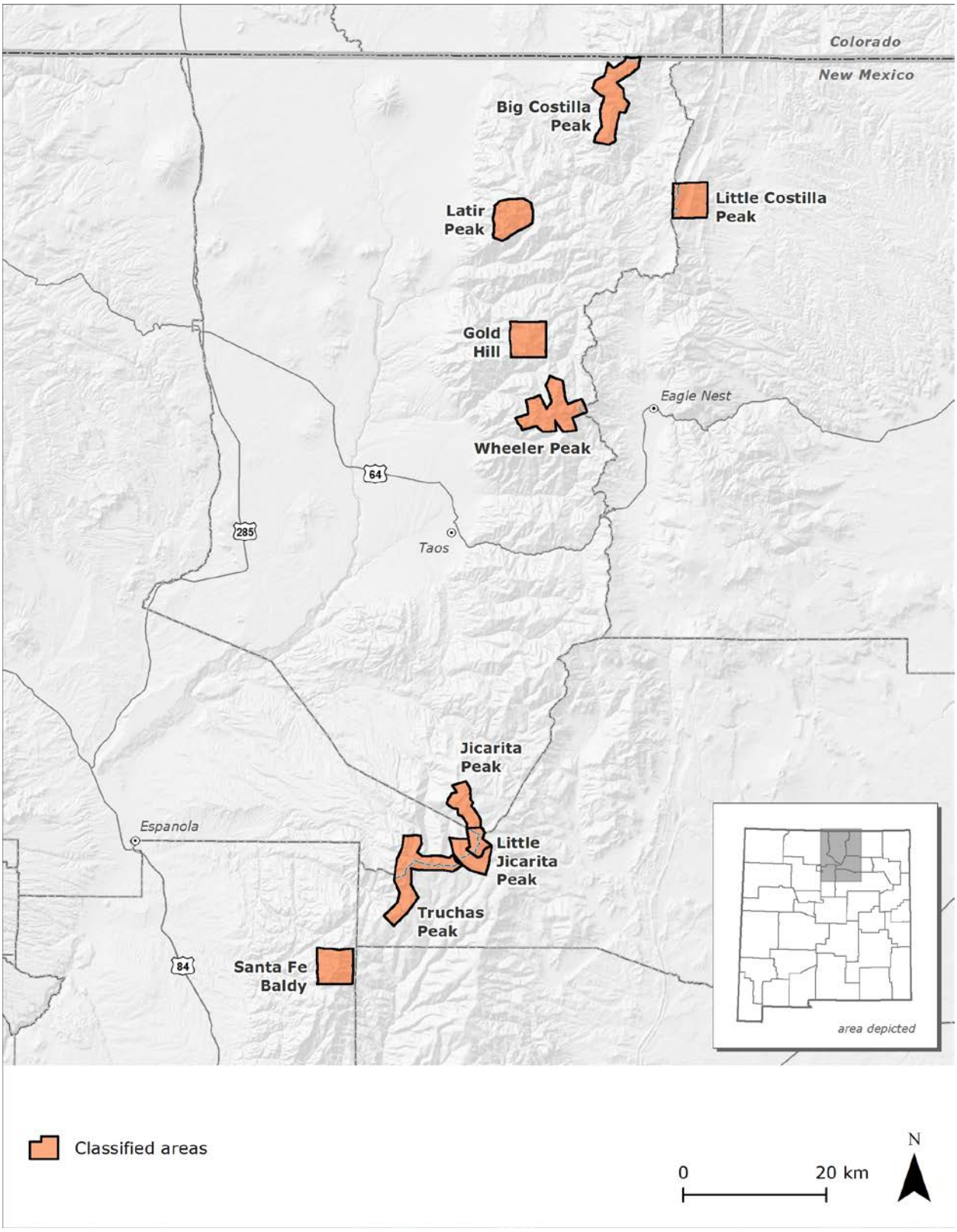

Figure 1 – Overview of all classified alpine habitat areas of the Sangre de Cristo Mountains, New Mexico.

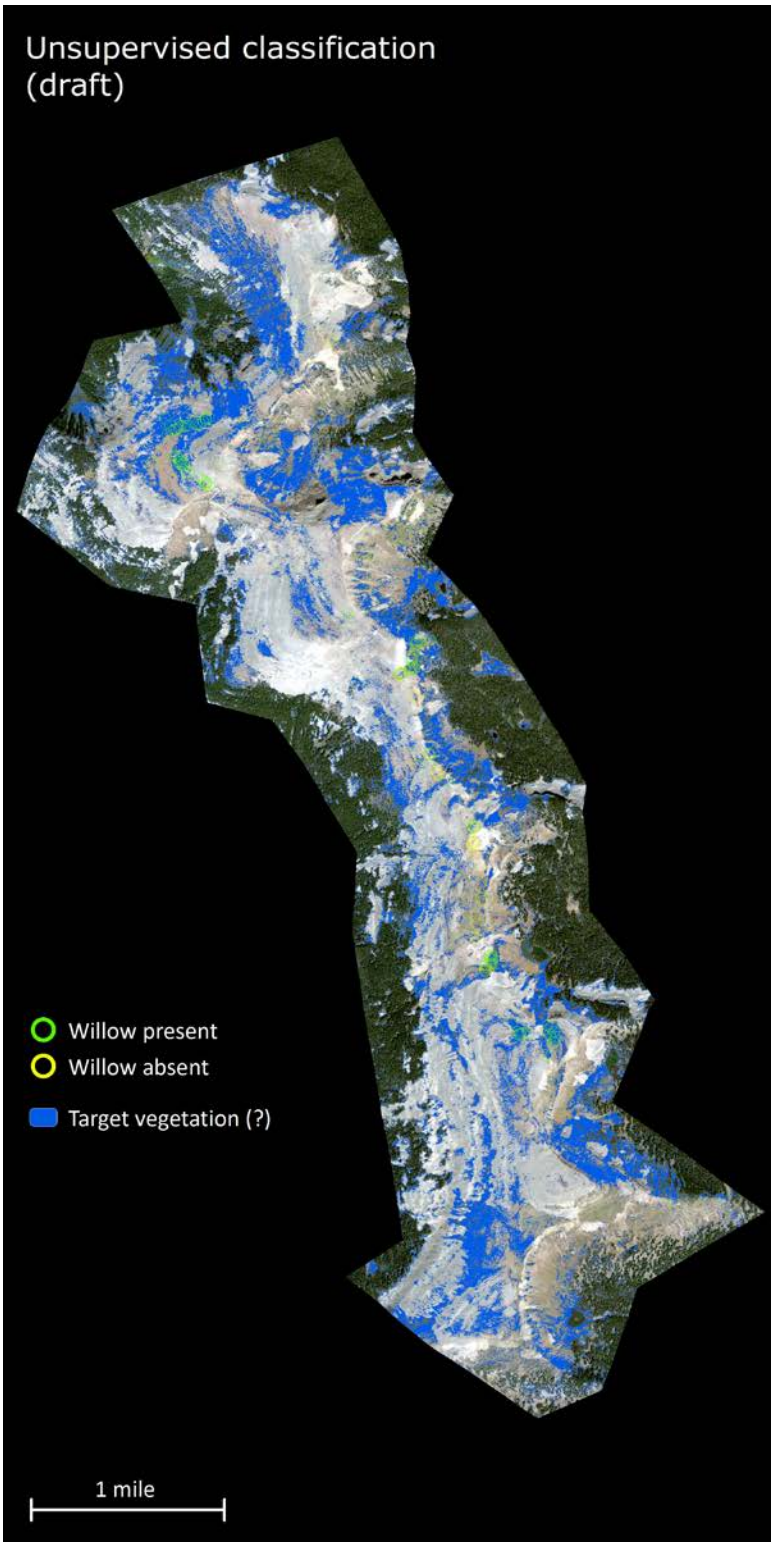

Figure 2 - Early analysis of willow distribution along Santa Barbara Divide north, Pecos Wilderness Area. WorldView-2 image.

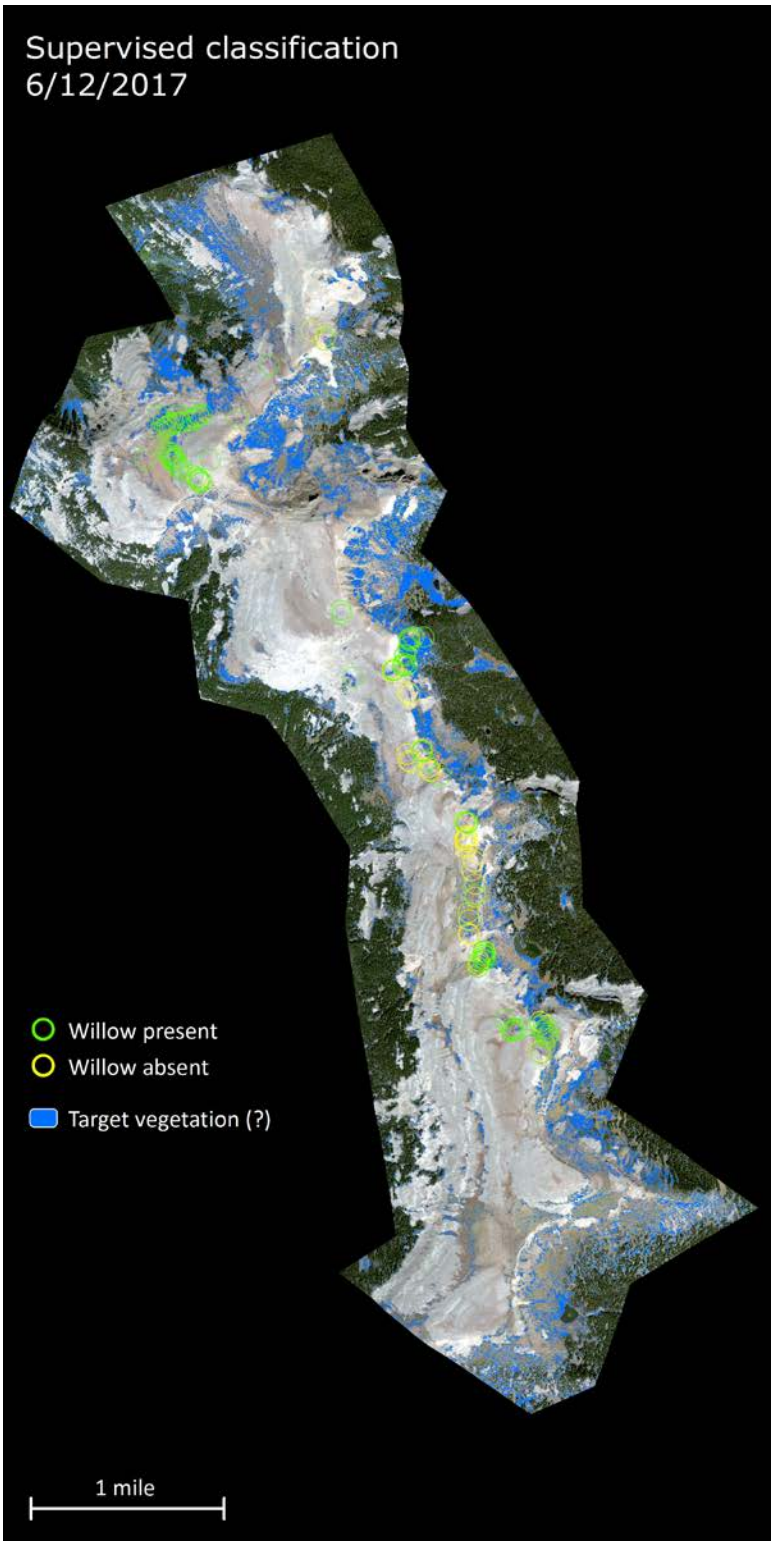

Figure 3 - Further refinement of willow distribution along Santa Barbara Divide north, Pecos Wilderness Area. WorldView-2 image.

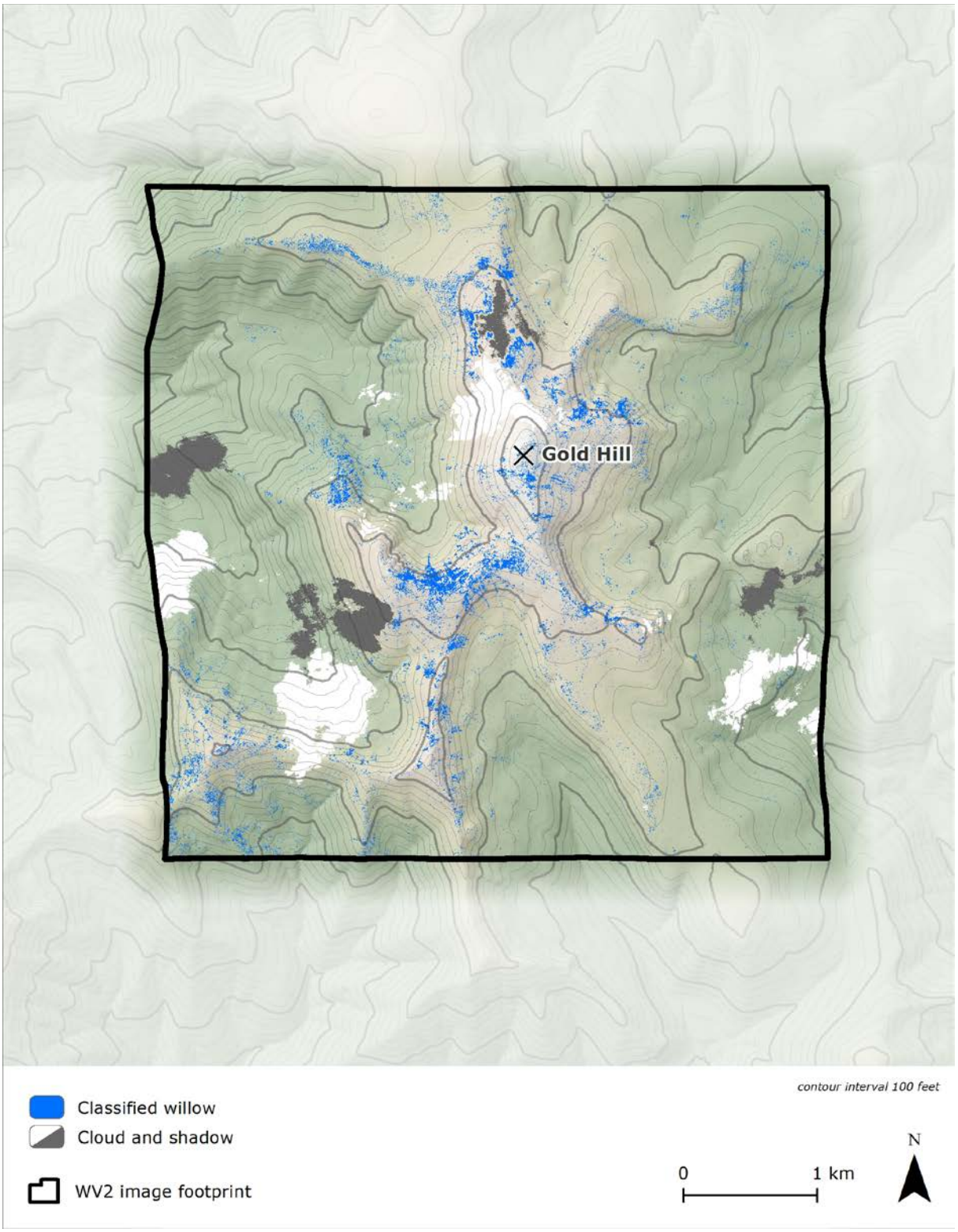

Figure 4 – Gold Hill, Taos County. 12.1% willow extent. Derived from WorldView-2 (WV2) image.

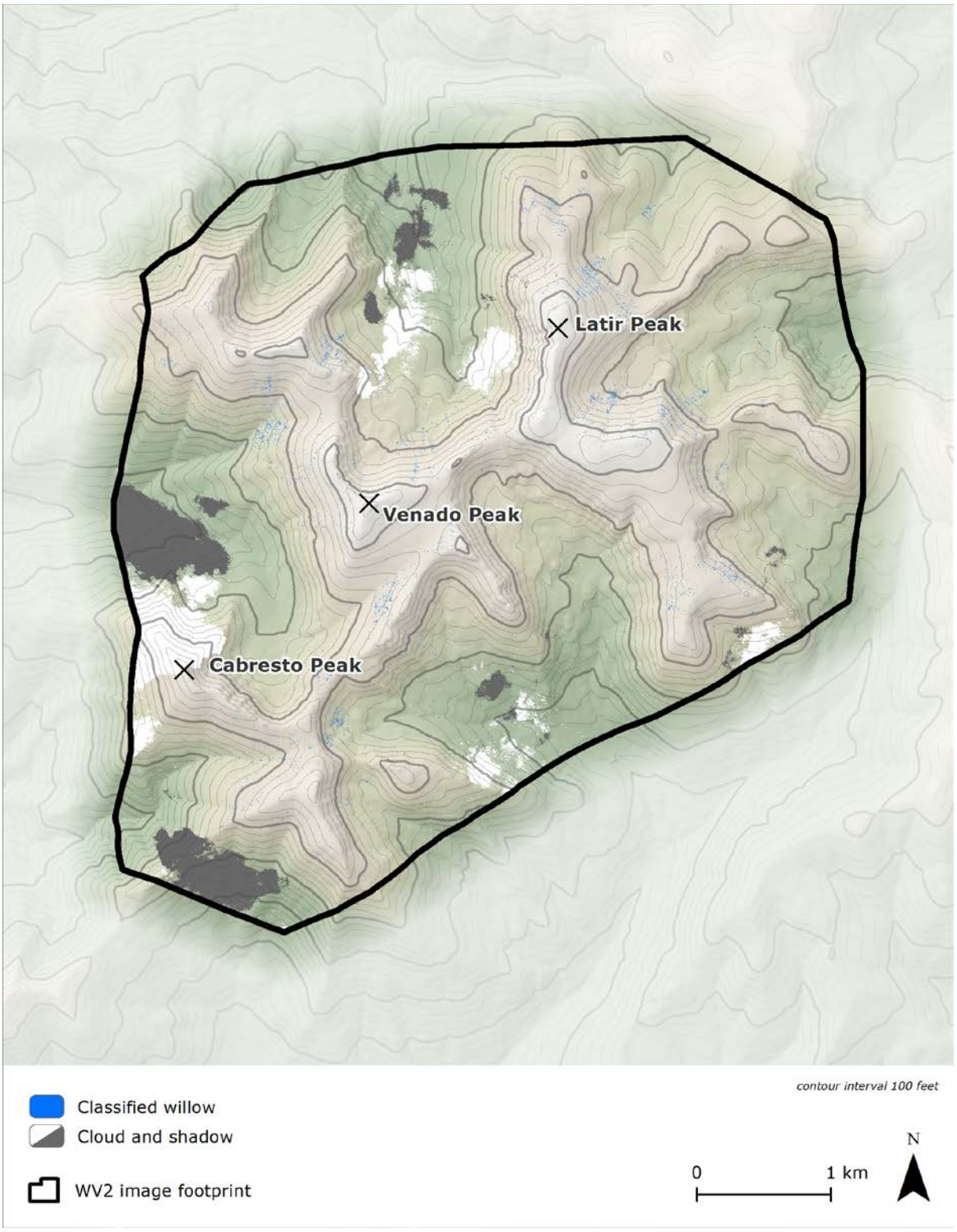

Figure 5 – Latir Peak Wilderness Area, Taos County. 0.7% willow extent. Derived from WorldView-2 (WV2) image.

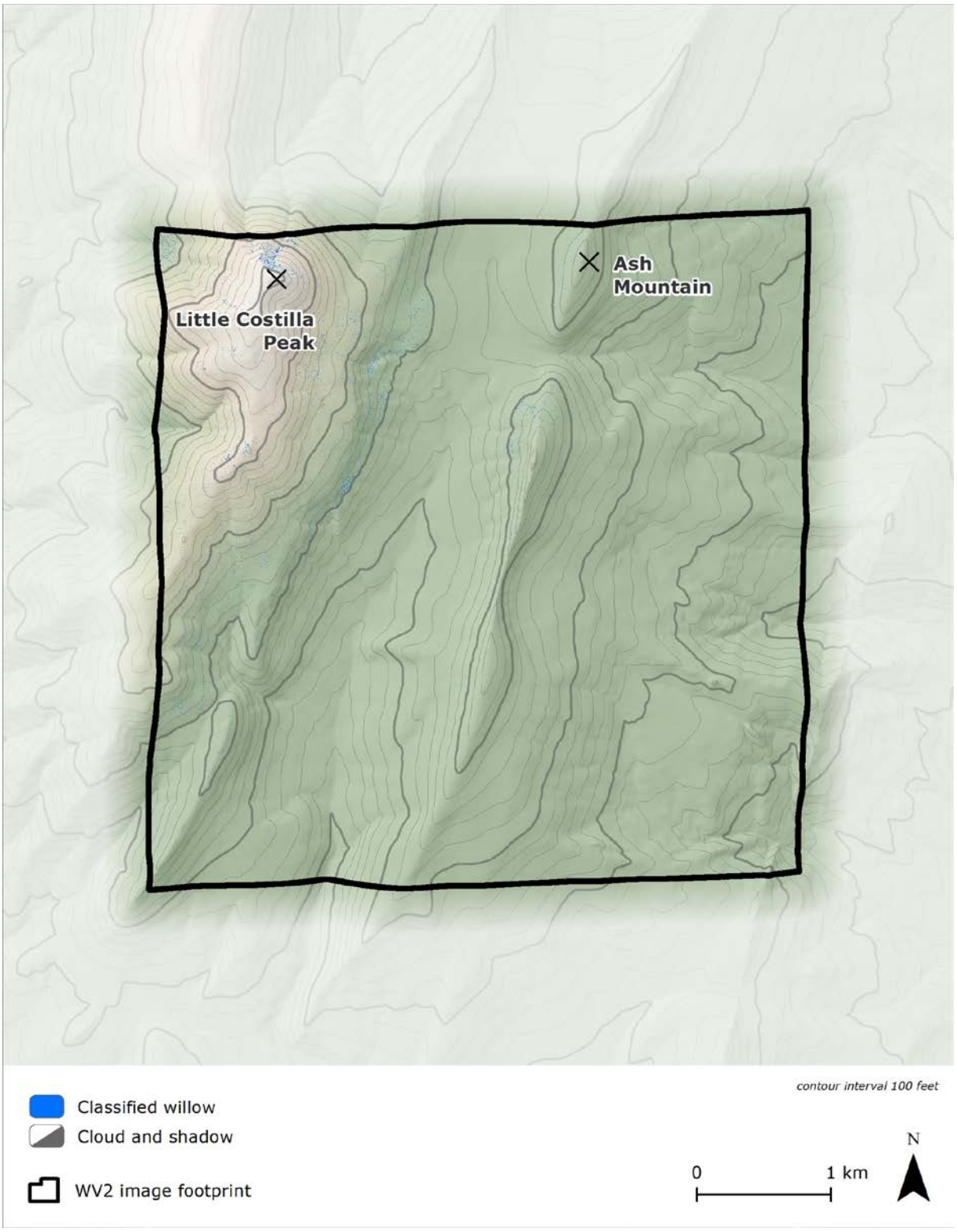

Figure 6 – Little Costilla Peak, Colfax and Taos Counties. 1.1% willow extent. Derived from WorldView-2 (WV2) image.

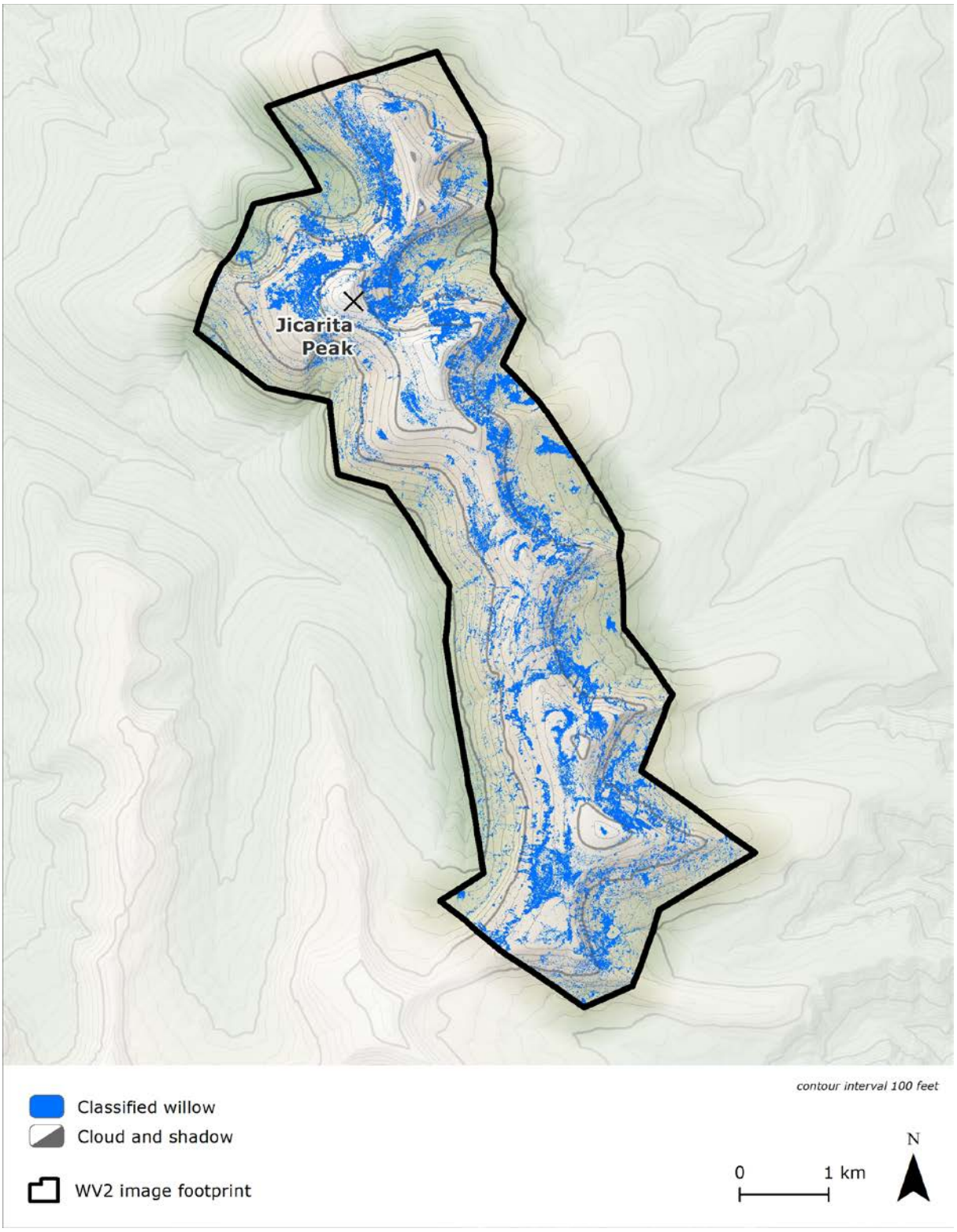

Figure 7 – Santa Barbara Divide north, Jicarita and Trouble Peaks, Pecos Wilderness Area; Mora, Rio Arriba, and Taos Counties. 25.5% willow extent. Derived from WorldView-2 (WV2) image.

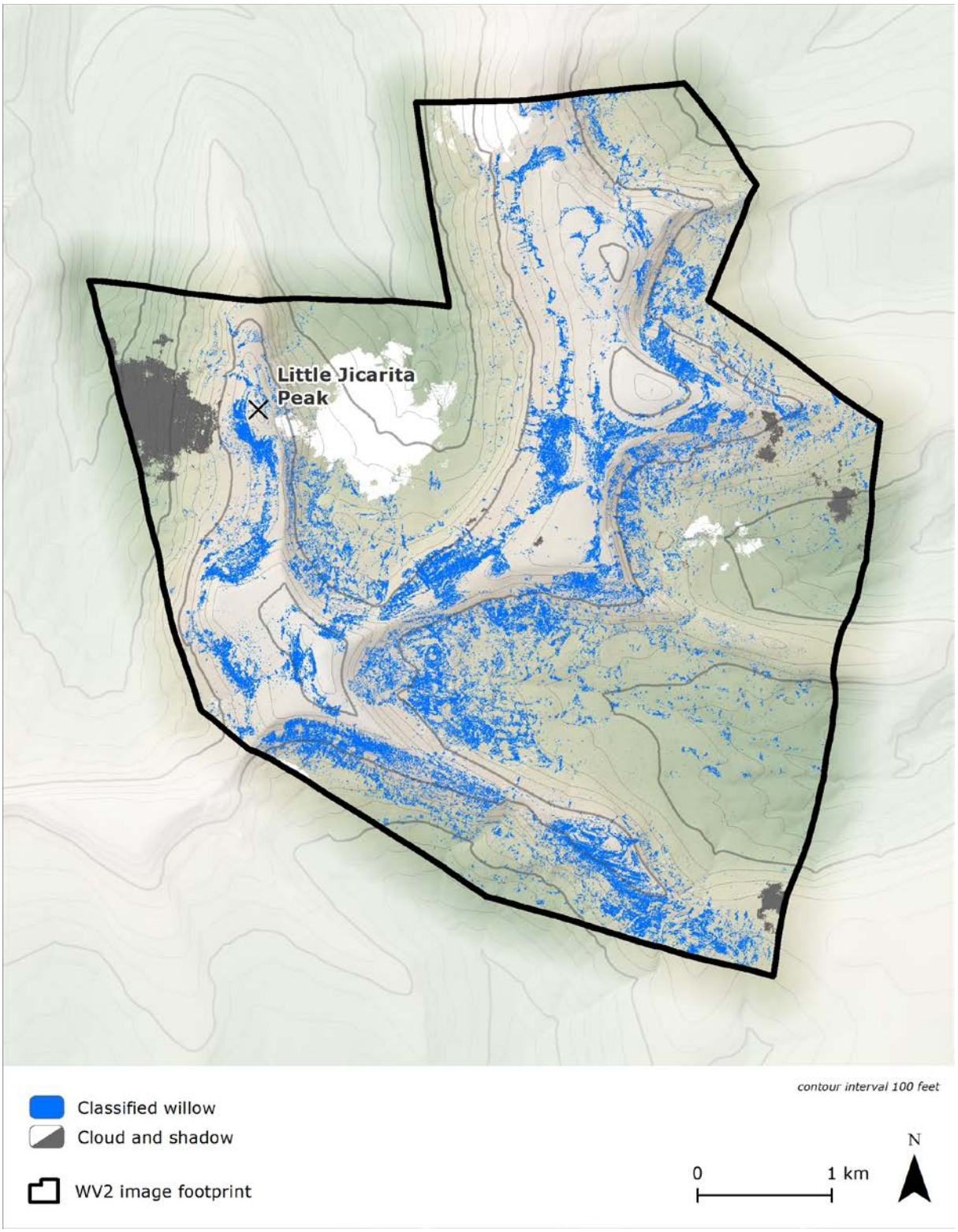

Figure 8 – Santa Barbara Divide middle, Barbara Peak, Little Jicarita Peak, and Trouble Peak, Pecos Wilderness Area; Mora, Rio Arriba, and Taos Counties. 24.0% willow extent. Derived from WorldView-2 (WV2) image.

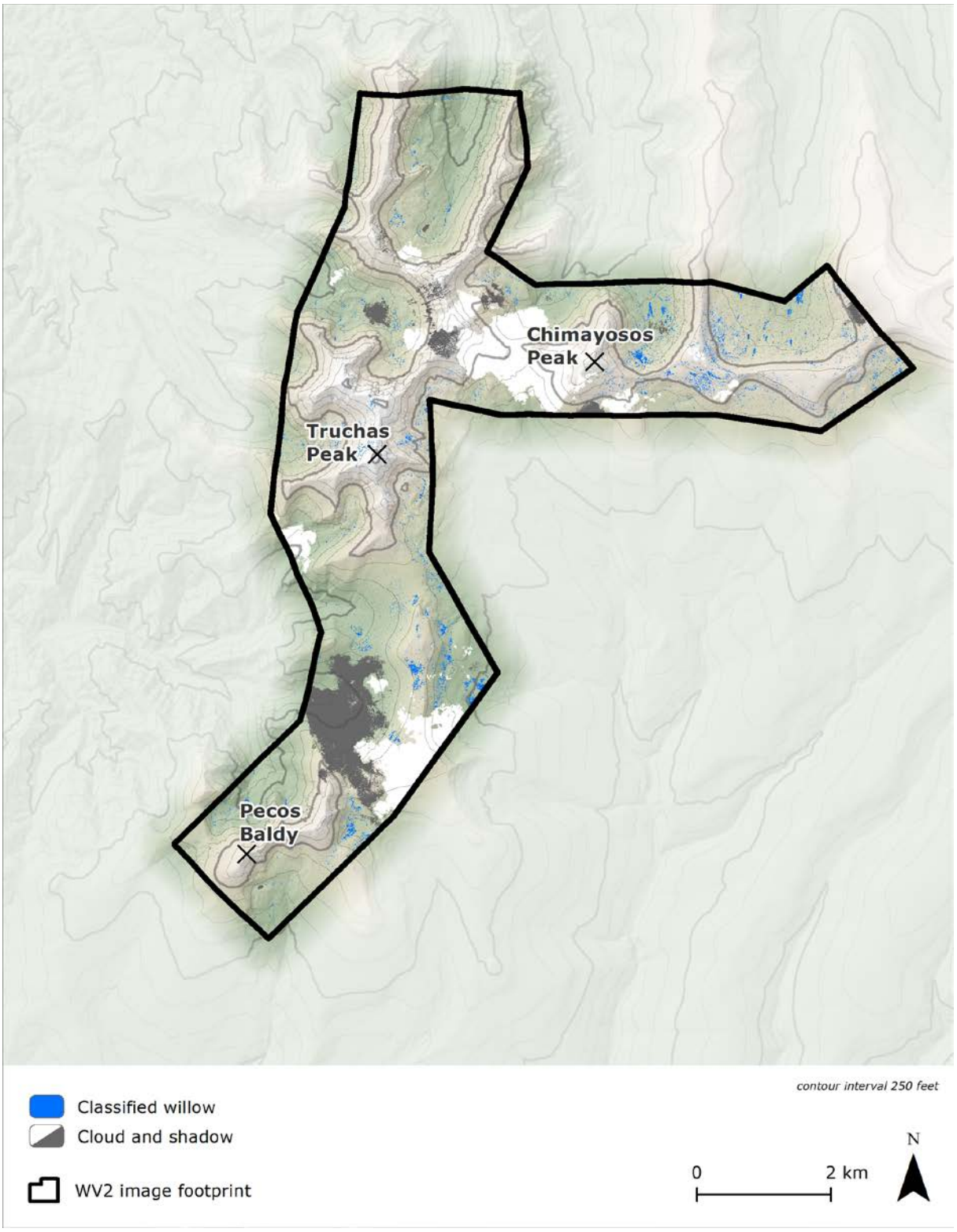

Figure 9 – Santa Barbara Divide south, Chimayosos Peak, Pecos Baldy Peaks, Trail Rider's Wall, and Truchas Peaks, Pecos Wilderness Area; Mora and Rio Arriba Counties. 1.4% willow extent. Derived from WorldView-2 (WV2) image.

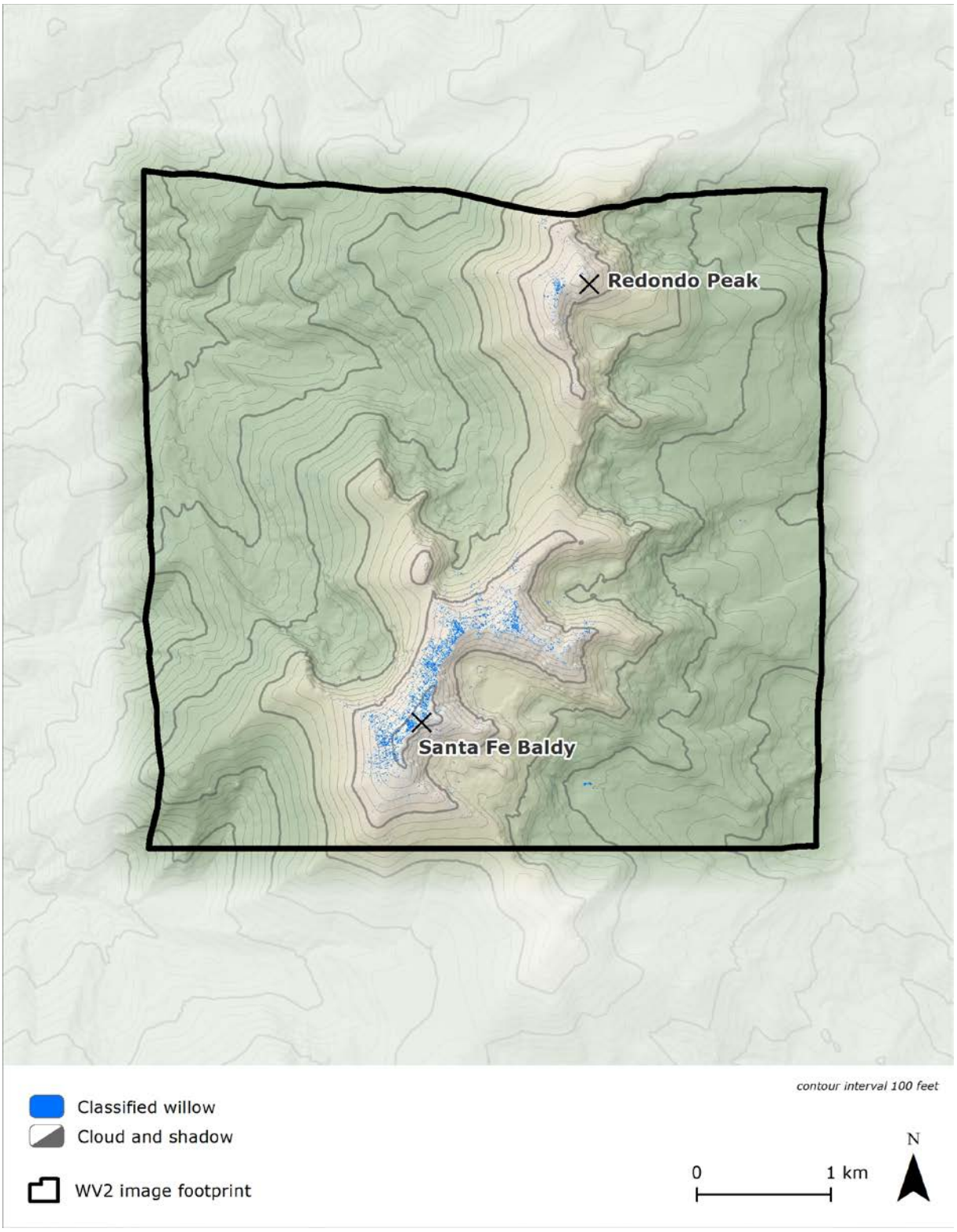

Figure 10 – Santa Fe Baldy Peak, Pecos Wilderness Area; Santa Fe County. 5.9% willow extent. Derived from WorldView-2 (WV2) image.

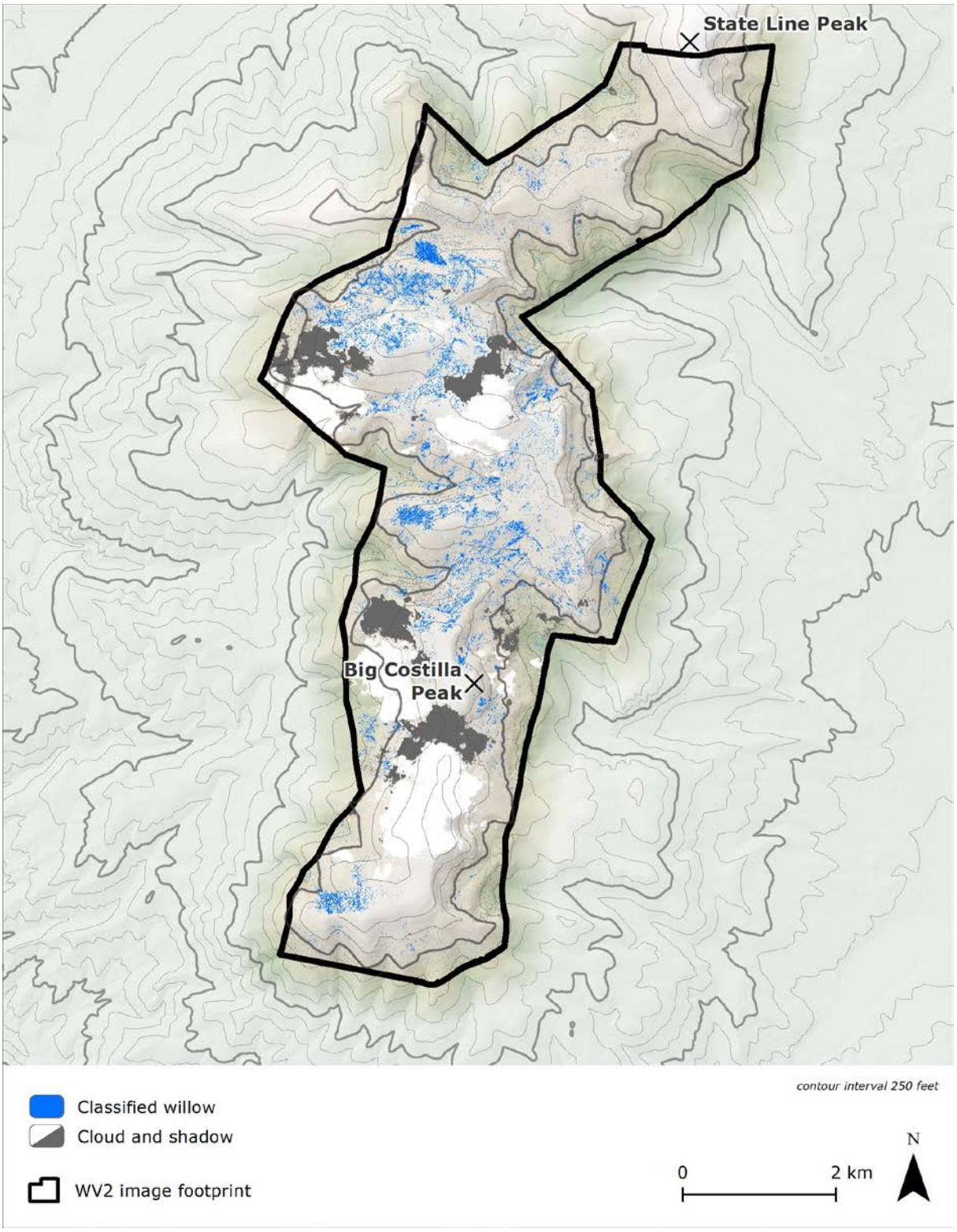

Figure 11 – Big Costilla Peak, Vintrero Peak, and Stateline Peak, Vermejo Park Ranch; Taos County. 5.7% willow extent. Derived from WorldView-2 (WV2) image.

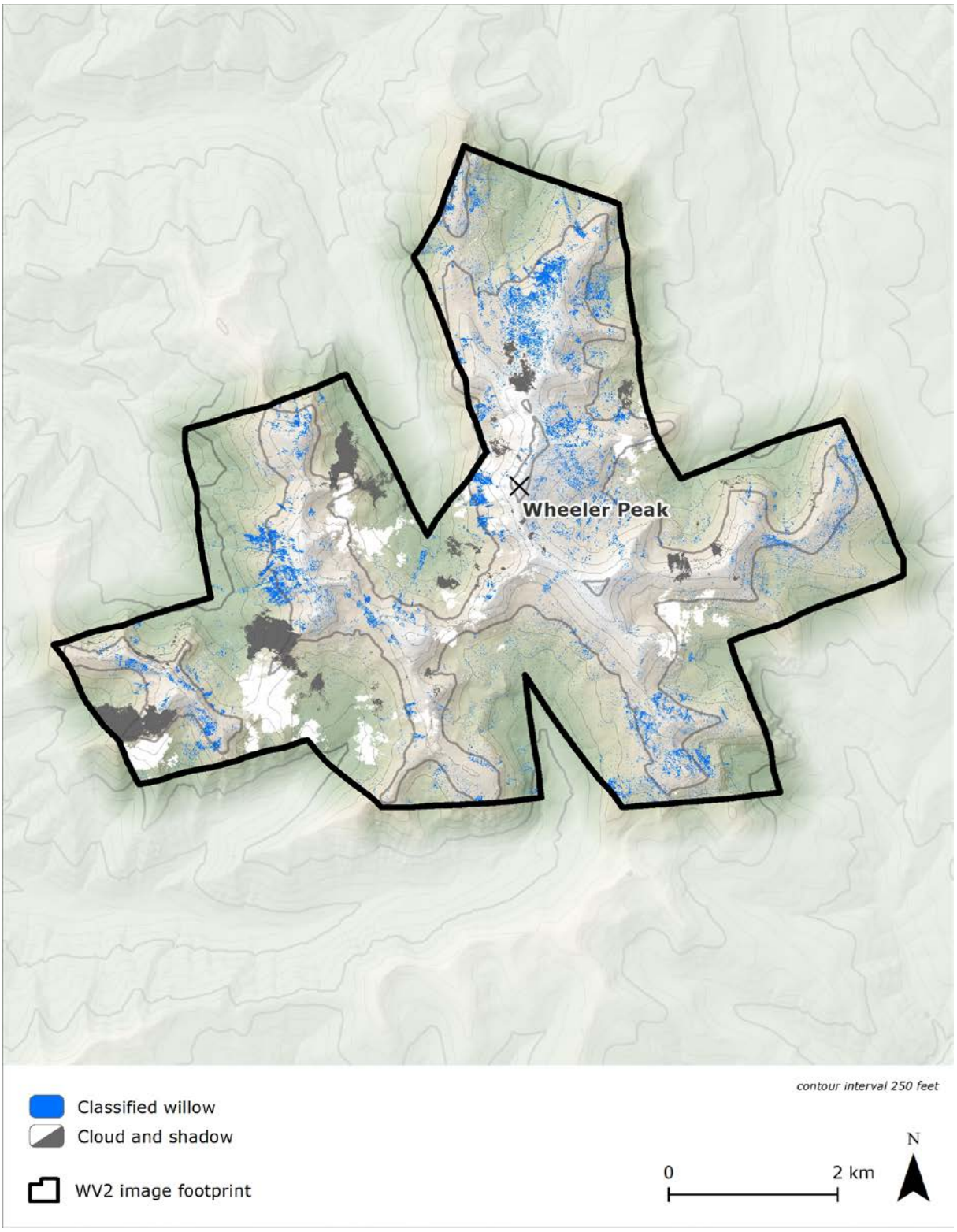

Figure 12 – Wheeler Peak Wilderness Area, Taos County. 8.5% willow extent. Derived from WorldView-2 (WV2) image.

Table 2 – Predators and other species of interest observed during survey and mapping efforts. W.P.W.A. = Wheeler Peak Wilderness Area; L.P.W.A = Latir Peak Wilderness Area; V.P.R. = Vermejo Park Ranch.

Date	Species	Location	County	Time (MDT)	Obs.	Latitude (WGS 84)	Longitude (WGS 84)	Elevation (feet)	Number observ.
26-Jun-17	American Pika	Gold Hill	Taos	13:50	DHW	36*38.120	105*27.613	12191	1
26-Jun-17	American Pipit nest	Gold Hill	Taos	14:22	DHW	36*38.047	105*27.776	12209	3 eggs
26-Jun-17	American Pika	Gold Hill	Taos	15:28	DHW	36*38.170	105*28.144	12067	1
12-Jul-17	American Pipit nest	W.P.W.A	Taos	13:10	DHW	36*34.318	105*24.726	12703	3-4 young
12-Jul-17	American Pika	W.P.W.A	Taos	15:29	DHW	36*34.509	105*24.259	11626	1
12-Jul-17	American Pika	W.P.W.A	Taos	15:35	DHW	36*34.543	105*24.259	11552	1
14-Jul-17	American Pika	L.P.W.A	Taos	10:59	DHW	36*47.863	105*28.710	12685	
15-Aug-17	Red-tailed Hawk	V.P.R.	Taos	11:27	ECC	36*54.273	105*19.928	12905	1 adult
16-Aug-17	American Pika	V.P.R.	Taos	12:10	DHW	36*56.452	105*19.628	12448	1
16-Aug-18	Prairie Falcon	V.P.R.	Taos	15:28	DHW	36*57.646	105*20.150	12843	1
17-Aug-17	American Pika	V.P.R.	Taos	11:41	ECC	36*55.796	105*19.642	12269	1
17-Aug-17	American Pika	V.P.R.	Taos	12:30	DHW	36*54.889	105*19.705	12183	2
17-Aug-17	American Pika	V.P.R.	Taos	12:52	DHW	36*54.900	105*19.742	12224	1
17-Aug-17	American Kestrel	V.P.R.	Taos	14:02	DHW	36*55.187	105*19.713	12713	1 male
18-Aug-17	Red-tailed Hawk	V.P.R.	Taos	11:59	DHW	36*55.758	105*19.734	12345	1 adult
18-Aug-17	Red-tailed Hawk	V.P.R.	Taos	12:58	DHW	36*55.561	105*19.880	12601	1 juvenile
18-Aug-17	Long-tailed Weasel	V.P.R.	Taos	13:28	DHW	36*55.332	105*19.823	12672	1