Examining Ecological Characteristics of Populations of *Acer grandidentatum* Nutt. (Aceraceae, bigtooth maple) in Central Texas

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ABSTRACT

Part of the central Texas Edwards Plateau physiographic area was examined using satellite and drone photographs taken in autumn prior to leaf fall. This was done to identify and locate deciduous communities prior to ground truthing to identify overstory and understory woody species. Using satellite images, potential sites were identified for more careful examination. A drone was next flown over the potential sites and identified 26 most promising sites covering 174 ha. Based on community size and ease of access, nine sites were ground surveyed, eight with the quadrat procedure and the ninth visually. The mean of the deciduous communities was 1.2 ha (range=0.3-4.5 ha) surrounded by *Juniperus ashei* woodlands. All but one was in a steep limestone canyon. Seventeen overstory woody species were found in these deciduous plant communities. Mean overstory density was 559 plants/ha and mean basal area 25.5 m^2/ ha. Three species are relatively rare in central Texas including *Acer grandidentatum* Nutt. (Aceraceae, bigtooth maple, relative density 30%, relative basal area 38% in these communities). *Quercus muehlenbergii* Engelm. (Fagaceae, chinquapin oak) and *Tilia caroliniana* Mill. (Tiliacae, Carolina basswood), were also present but lower in both values. Thirty understory woody species were found with *Celtis laevigata* Willd. (Ulmaceae, Texas sugarberry) and *Q. laceyi* (Laceyi oak) having the highest densities. Recruitment into the adult population by juveniles of some of these overstory species seemed minimal or lacking because of low density. These communities were found in reduced light in steep limestone canyons, especially the north-south canyons and on deeper soils that could hold more water than the shallow upland soils. *Published on-line www.phytologia.org **Phytologia** 102(2): 27-40 (June 24, 2020). ISSN 030319430.*

KEY WORDS: populations; deciduous communities; rare species; overstory; understory; satellite photographs; drone; limestone canyons; recruitment.

A large part of Central Texas is called the Edwards Plateau physiographic region; it is not a plant community, but a large, heavily dissected, calcareous plateau (Hill 1892; Bray 1904; Tharp 1939; Gould 1962; Correll and Johnston 1979). It consists of about 9.7 X 10^6 ha or approximately 1 X 10^5 km^2. There are many different plant communities within this area including various grasslands, savannas, woodlands and forests (Amos and Gehlbach 1988; Gehlbach 1988; Riskind and Diamond 1988; Diamond et al. 1995; Van Auken 2018). The presence or unusual plants in this central Texas area were noted by early travelers and explorers (see Inglis 1962; Weniger 1988). The woody plants, specifically the timber was mentioned quite early (Bray 1904) as was the unusual flora present in some of these central Texas canyon communities (Palmer 1920). However, community structure and factors that seemed to promote or control the deciduous communities has only been examined recently (Van Auken et al. 1981; Nelson-Dickerson and Van Auken 2016; Van Auken et al. 2017).

The vast majority of the area in this central Texas Edwards Plateau physiographic region is private property and not well studied. Many of the private properties are fairly large with steep-sided hills and deep limestone canyons. Usually when these properties change hands the management strategy changes as well (Carpenter and Brandimarte 2014). Thus, it is very difficult to determine the plant communities of the past or what will happen in the future. In the past, domestic grazing and timber cutting were the main industries of the general area. Because of a reduction in the amount of grassland and savanna, caused by constant heavy grazing and the removal of light fluffy fuel by the cattle grazing, fire frequency was dramatically reduced promoting increased density of woody plants especially *Prosopis* (mesquite) and *Juniperus* (mountain cedar). Timber harvest has also been considerably reduced because of over harvest and slow re-growth (Riskind and Diamond 1988).

Some of these deciduous woodland communities have been shown to have populations of *Prunus serotina* (black cherry), *Quercus laceyi* (Lacey oak), *Q. buckleyi* (Texas red oak), *Aesculus pavia* (red buckeye) and other mostly deciduous species (Van Auken et al.1981). While others have populations of *Acer grandidentatum* (bigtooth maple, Nelson-Dickerson and Van Auken 2016; Van Auken and Taylor 2017; Van Auken et al. 2017). These later studies examined the structure and potential population changes of *A. grandidentatum* in two State Natural Areas. Thus, *A. grandidentatum* populations in central Texas have been studied more carefully for the past few years, but only in protected areas.

Many juvenile woody plants of this area are known to be sensitive to herbivory (Russell and Fowler 1999, 2002, 2004; Nelson-Dickerson and Van Auken 2016) and they appear to be plants capable of completing the early part of their life cycle in shade below a woodland canopy (Nelson-Dickerson and Van Auken 2016). These plants have slow growth in low light conditions. The niche of some of these deciduous woody plants seems to be deep, sheltered, limestone canyons or steep, north facing slopes. Some of these plants, in central Texas canyons, established approximately 300 years ago (Van Auken et al. 2017). However, only a few species in some of these deciduous communities have been carefully examined, and the cause of variation in community composition is mostly speculation.

Acer grandidentatum the main focus of this study is fairly widespread in the mountains of the southwestern United States, including mountain ranges in New Mexico and western Texas (Little 1944; Rice 1960; Hanks and Dick-Peddie 1974; Dent and Adams 1983; Alexander et al. 1984; Tollefson 2006; USDA-Plants 2019). However, isolated populations of *A. grandidentatum* are found in central Texas (Gehlbach and Gardner 1983; Nelson-Dickerson and Van Auken 2016) and in central and western Oklahoma (Rice 1960). *Acer grandidentatum* and some of the associated species in these deciduous communities are relatively rare and are part of the focus of this work. The present study was to locate and describe some of the current deciduous woodland communities in central Texas that contains *A. grandidentatum*. The most well-known site for viewing *A. grandidentatum* in Texas is the Lost Maples State Natural Area located just a few miles north of Vanderpool. This site has well documented *A. grandidentatum* populations and is a state property. However, not much is known about populations that may exist on private properties in central Texas.

PURPOSE

The primary objective of this project was to find and then gather baseline ecological information about *A. grandidentatum* and other low density deciduous woody plant populations in the Edwards

Plateau of central Texas. A secondary objective was to evaluate the potential use of satellite photography and unmanned aircraft to facilitate efficient identification and rapid assessment of deciduous woodlands that may have populations of *A. grandidentatum* and other low density woody species.

METHODS

The general area of interest in central Texas (Figure 1) is roughly bounded on the west by RM (ranch to market) road 187 and on the east by Texas State Highway 16. The north boundary is approximately RM road 39 and the south is bounded by RM road 476. This area is also commonly referred to as the "Swiss Alps of Texas". Study sites were established based on private property owner's willingness to allow access to their property. There were a total of five properties whose owners agreed to participate in the project.

Once confirmed, the properties were evaluated for deciduous woodlands using satellite imagery obtained in November 2016 during peak fall color change and freely available on Google Earth (Figure 2, example). Using the satellite imagery and conversations with the participating landowners, areas considered to be deciduous woodlands with a potential to have *A. grandidentatum* and other low density woody species were located (Figure 3). The possibility to have drone or un-manned aircraft (UA) flights were also established. Between November 13th and 25th, twenty-six drone flights were completed using a DJI Inspire 1 quadcopter flown at an altitude of 76.2 m (=250 ft AGL [above ground level] from the point of liftoff) in precise patterns across each area covering a total of 174 ha (430 acres). Upon completion 2,969 HD images were obtained to document areas thought to have deciduous woodlands and *A. grandidentatum* populations. Image resolution was approximately 1.0 inch per pixel.

Imagery was uploaded to Drone Deploy for stitching and then exported as a TIFF to ArcGIS 10 desktop software. Using the canopy color as a guide, the deciduous woodland communities were outlined then used to calculate the area of the deciduous woodlands using ArcGIS measurement tools. Areas were summed to get the total community area (ha). The images (JPGs) were used to determine where ground truthing should be done (Figure 4).

Next a matrix was established to rank the 26 areas based on the potential for *A. grandidentatum* presence and site accessibility. Ten were selected for ground-truthing and based on walk throughs, one of the 10 sites selected did not have any *A. grandidentatum* trees and another was inaccessible. This left 8 sites to be surveyed and all contained adult *A. grandidentatum* trees and all but one had *A. grandidentatum* juveniles. The ground surveys were conducted from April 6, 2018 through April 21, 2018. A total of 8900 m^2 (0.89 ha) in the eight sites were examined using the quadrat method (Van Auken et al. 2005). Although many more potential deciduous woodland communities were observed in the satellite imagery, the ability to fly the drone in these areas was limited because of FAA rules requiring visual line of sight at all times. One site was a north facing slope, and two sites were visually examined but no *A. grandidentatum* trees were found in one and the other was inaccessible. The communities were mostly located in deep, isolated, limestone canyons (Van Auken et al. 2017).

Domestic grazing was not occurring in the areas studied, but native herbivores were present. Elevation of the study area sites is approximately 480-620 m a. m. s. and soils were relatively deep calcareous silty clays (Mollisols over limestone bedrock, SCS 1979). Mean annual temperature is approximately 18.3°C, with a range from near 0.7°C in January to 34.1°C in August, and is highly variable. Mean annual precipitation is 72.4 cm/year with zero or very little in July and August and highly variable with May and September being wettest (World Climate 2011).

Density of all overstory trees found in these communities was determined in 5 m X 5 m or 25 m^2 quadrates (Van Auken et al. 2005). The number of 25 m^2 quadrats varied in each of the communities due to site conditions and topography. Adequate sampling was demonstrated by examining species and density stabilization curves but is not presented. For overstory woody plants, there were a total of 356, 25 m^2 quadrats or 0.89 ha sampled in the deciduous communities. All plants greater than 137 cm in height and 3 cm basal diameter were considered trees and part of the overstory. They were identified (Correll and Johnston 1979; USDA-Plants 2019), counted and basal area was measured. Five 1 m^2 sub-quadrats were established in each of the 25 m^2 quadrats or 5780 m^2 to count understory woody plants (one in each corner and one near the center). All woody plants less than 137 cm in height and/or 3 cm basal diameter were identified and counted as seedlings or juveniles. Identity, density, relative density, basal area, and relative basal area were calculated for each overstory tree species and identity, density and relative density was determined for the understory woody plants within each community (Van Auken et al. 2005). Next, means were determined, but only species density and basal area and relative values are presented for overstory species. For the understory woody species, the juveniles, density and relative density are presented. Species richness (number of species) and % occurrence (%O = [# of communities species found in / total # of communities studied] x 100 is also presented.

RESULTS

General ecological characteristics of eight deciduous communities were identified using drone images and then examined with the quadrat procedure. The deciduous communities ranged from 0.29 ha to 4.45 ha in area with a total area of 9.56 ha (Table 1). Communities were mostly in the bottom of deep calcareous north-south canyons, with one a north facing hillside. Overstory species richness ranged from 5 to 14 species with 17 total overstory woody species found (Table 1). There were 11 to 21 woody species in the understory of each community with a total of 30 woody species present.

Total overstory density ranged from 153 to 1024 plants/ha with a mean of 559 plants/ha (Table 1). Mean overstory tree basal area was 25.47 m^2/ha and ranged from 9.01 to 34.81 m^2/ha (Table 1). *Juniperus ashei* and *Acer grandidentatum* had 100 % occurrence in the overstory, and were found in all eight communities studied (Table 2). *Quercus laceyi* and *Juglands microcarpa* were found in five communities for an occurrence of 63 %. *Quercus muehlenbergii*, *Diospyros texana*, *Fraxinus albicans* and *Q. buckleyi* had 50 % occurrence and were present in four communities. Nine other species had occurrences of < 50 % (Table 2). *Juniperus ashei* and *A. grandidentatum* had the highest mean overstory density at 221 and 169 plants/ha respectively with the other 15 species having densities between 1 and 41 plants/ha (Table 2). *Acer grandidentatum* had the largest mean basal area at 9.57 m^2/ha. *Quercus muehlenbergii*, *Q. laceyi* and *J. ashei* had the next highest basal areas at 6.10, 4.37 and 1.30 m^2/ha. The other 12 species had basal areas < 1.00 m^2/ha (Table 2).

There were 30 juvenile woody plants found in the understories of some of the eight communities examined. There were five tree species found in the understory of every community (100 % occurrence) including *Celtis laevigata*, *Q. buckleyi*, *J. ashei*, *D. texana* and *Prunus serotina* (Table 3). An additional five species (three tree species) were present in the understory of seven of the communities (87 % occurrence) including *Q. laceyi, A. grandidentatum, Fraxinus albicans* and two vines. The other 20 woody species in the understory had occurrences of 75 % or less (Table 3).

Total understory woody plant density ranged from 3710 plants/ha to 17025 plants/ha depending on the community, with a mean of 7963 plants/ha (Table 1). *Celtis laevigata* had the highest density followed by *Q. buckleyi*, *Q. laceyi*, *J. ashei*, *Q. muehlenbergii*, *A. grandidentatum* and *D. texana* in descending order (Table 3). All had mean density values that ranged from 1201 down to 602 plants/ha. The other 23 species had lower density values.

Acer grandidentatum juveniles were found in seven of the eight communities (87 % occurrence) with a mean density of 642 ± 700 plants /ha (Table 3). The other woody species juveniles were scattered in various communities. In addition, the standard deviations for all of the species were relatively high. Almost all of the overstory trees had some seedlings or juveniles in the understory, but not all understory species had representatives in the overstory, for example. There were no *Celtis laevigata* trees.

DISCUSSION

The areas studied were steep, deep limestone canyons and one north facing hillside within the Edwards Plateau physiographic region of central Texas (Hill 1892; Bray 1904; Tharp 1939; Gould 1969; Correll and Johnston 1979; Amos and Gehlbach 1988). It is a physiographic region approximately 100,000 km^2 described by physical geology or geomorphology not one type of plant community. While it has been described simplistically as grasslands (Sims 1988**)** or Juniper woodlands (Amos and Gehlbach 1988), it is more accurately described as a diverse physiographic region that includes many plant communities that have a number of rare species and many endemic species (Pool et al. 2007; Van Auken 2018). Plant communities include several mixed juniper **-** oak woodlands as well as mesquite woodlands, shrublands, various types of savannas and grasslands in addition to riparian communities (Van Auken et al. 1979; Van Auken 1988; Diamond et al. 1995; Van Auken 2000; Van Auken and Ford 2017; Van Auken 2018).

Using satellite images and the drone ten deciduous woodland communities were identified. However, when examined on the ground one community did not have any *A. grandidentatum* plants and the second was inaccessible and neither were included in the present study. The current woodlands studied were similar to deciduous woodlands ecologically described over 40 years ago (Van Auken et al. 1981), and comparable to the communities reported in the upper canyons of this area (Palmer 1920). The current study was focused on *A. grandidentatum* populations within these deciduous woodland communities, but all of the woody species that were encountered were identified. Differences between the current study and the former study of these communities include 17 woody species (trees or shrubs) found in the current study while 19 were reported in the previous study (Van Auken et al. 1981). However, *Q. muehlenbergii, A. grandidentatum, Sideroxylon lanuginosum* and *Tilia caroliniana* were not found in the previous study. *Salvia ballotaeflora* (shrub) was reported in the previous study. Several species reported in the previous paper were only found in the understory of the current study.

Reasons for the large difference in woody plant density between the two studies (1851 vs. 8522 plants/ha, earlier study vs. current study) are probably in part location (the earlier study was more southern) and data collection times (late winter vs. late spring). In addition, in the earlier study, juveniles and mature plants were combined and reported as trees if their basal circumference was >3.0 cm, but if less they were not counted; but they were counted as juveniles in the current study. Also, *Aesculus pavia* was previously counted (per stem rather than per clump) thus having 296 ± 106 plants/ha versus 2 ± 4 plants/ha. *Diospyros texana* had a density ten times higher than the current studied, but why is uncertain. There was also a high density of *Q. laceyi* (= *Q. glaucoides*) and *Q. buckleyi* (= *Q. texana*) in these previously examined communities. The deciduous woodland communities in the current study were very open, with few understory shrubs. Understory density was high in most of the communities currently studied, but the woody plants were mostly less than 10 cm tall. In the understory of the current study there were 30 woody species including 16 juvenile tree species, 10 shrubs, and 4 woody vines whereas the understory was not reported in the previous study.

We were interested in the replacement dynamics of the species in the communities examined. However, little ecological or population information is available concerning the species present in these communities and communities dynamics was not part of the current study. Density values presented in the current document represent the mean number of woody plants found in the quadrates measured as overstory or understory plants/ha. We estimate the total area of the deciduous communities surveyed to be 9.56 ha. The mean density values presented in the current paper are per hectare and if the plants are equally found through the deciduous communities examined, the actual number of plants of a given species would be expected to be 9.56 times higher because of the area of the deciduous woodlands. However, the communities seem to be structured with species, density and basal area changing with elevation and aspect, but exactly how they are structured is not known.

The relatively large number of *A. grandidentatum* juveniles found in the current study suggests that recruitment into the adult population could be occurring. Unfortunately, the fate of the juveniles in these communities is unknown. Mortality of all of them could occur annually or over many or all years. Recruitment could be episodic and only occur periodically with the interim between recruitment cohorts unknown. For long-lived species this is very difficult to know. In addition, there is a large degree of variability of the number of overstory trees and the number of understory individuals of the same species with little known of recruitment success for any of the species. Two previous studies showed little or no recruitment of *A. grandidentatum* juveniles (Nelson-Dickson and Van Auken 2016; Van Auken et al. 2017). However, more recently it has been reported that *A. grandidentatum* juvenile success is dramatically increased when juveniles are protected from large herbivores (Van Auken and Taylor 2020),

Although many more potential deciduous woodland communities were observed in the satellite imagery, these areas were not examined on the ground for various reasons. Mature or adult *A. grandidentatum* were present in some of the other areas, but density seemed to be low and plants were not readily observed on satellite photographs or with drone flights.

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LITERATURE CITED

Alexander, B.G. Jr., Ronco, F. Jr., Fitzhugh, E.L. and Ludwig, J.A. 1984. A Classification of Forest Habitat Types of the Lincoln National Forest, New Mexico. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-104, Fort Collins, Colorado.

Amos, B.B. and Gehlbach, F.R. 1988. Edwards Plateau vegetation: plant ecological studies in central Texas. Baylor University Press, Waco, Texas.

Bray, W.L. 1904. The timber of the Edwards Plateau of Texas: Its relation to climate, water supply, and soil. United States Department of Agriculture, Bureau of Forestry, Bulletin No.47.

Correll, D.S. and Johnston, M.C. 1979. Manual of the Vascular Plants of Texas. Texas Research Foundation, Renner, Texas.

Carpenter, J. and Brandimarte, C. 2014. The Albert and Bessie Kronksky State Natural Area: A History of Lands and People. Historic Sites and Structures Program, State Parks Division, Texas Parks and Wildlife Department, Austin, Texas (Available on line TPWD as a draft).

Dent, T.C. and Adams, R.P. 1983. Relationships of two isolated groups of sugar maples (*Acer saccharum* Marshall ssp. saccharum) in west central Oklahoma to eastern and western species. Rhodora. 85:439-456.

Diamond, D.D., Rowell, G.A. and Keddy-Hector, D.P. 1995. Conservation of Ashe Juniper (*Juniperus ashei* Buchholz) Woodlands of the Central Texas Hill Country. Nat. Areas J.,15:189-197.

Gehlbach, F.R. and Gardner, R.C. 1983. Relationships of sugar maples (*Acer saccharum* and *A. grandidentatum*) in Texas and Oklahoma with special reference to relict populations. Tx. J. Sci. 35:231-238.

Gehlbach, F.R. 1988. Forests and woodlands of the northeastern Balcones Escarpment. Pp. 43-55. *In*: Amos, B.B. and Gehlbach, F.R. eds., Edward's Plateau vegetation: plant ecological studies in central Texas. Baylor University Press, Waco, Texas.

Gould, F.W. 1962. Texas plants-a checklist and ecological summary. Texas Agricultural Experiment Station Bulletin, MP-583.

Hanks, J.P. and Dick-Peddie, W.A. 1974. Vegetation Patterns of the White Mountains, New Mexico. Southwes. Nat. 18:71-382. https://doi.org/10.2307/3670295

Hill, R.T. 1892. Notes on the Texas-New Mexico region. Bull. Geol. Soc. Amer. 3:85-100.

Inglis, J. 1962. A History of Vegetation on the Rio Grande plain. Texas Parks and Wildlife Dept. Bull. 45, Austin, Texas.

Little, E.L. Jr. 1944. *Acer grandidentatum* in Oklahoma. Rhodora. 46:445-451.

Nelson-Dickerson, T. and Van Auken, O.W. 2016. Survival, Growth and Recruitment of Bigtooth Maple (*Acer grandidentatum*) in Central Texas Relict Communities. Nat. Areas J. 36:174-180. https://doi.org/10.3375/043.036.0209

Palmer, E.J. 1920. The canyon flora of the Edwards Plateau of Texas. J. Arnold Arb. 1:233-239.

Pool, J.M., Carr, W.R., Price, D.M. and Singhurst, J.R. 2007. Rare Plants of Texas. Texas A&M Nature Guides. Texas Parks and Wildlife. Everbest Printing Louisville, Kentucky.

Rice, E.L. 1960. The microclimate of a relict-stand of sugar maple in Devils Canyon in Canadian County, Oklahoma. Ecology. 41:445-453.

Riskind, D. H. and Diamond, D.D. 1988. An introduction to Environment and Vegetation. Pp. 1-15. *In*: Amos, B.B. and Gehlbach, F.R. eds., Edward's Plateau vegetation: plant ecological studies in central Texas. Baylor University Press, Waco, Texas.

Russell, F.L. and Fowler, N.L. 1999. Rarity of Oak Saplings in Savannahs and Woodlands of the Eastern Edwards Plateau, Texas. Southwest. Nat. 44:31-41.

Russell, F.L. and Fowler, N.L. 2002. Failure of Adult Recruitment in *Quercus buckleyi* Populations on the Eastern Edwards Plateau, Texas. Amer. Midl. Nat. 148:201-217.

Russell, F.L. and Fowler, N.L. 2004. Effects of White-Tailed Deer on Population Dynamics of Acorns, Seedlings, and Saplings of *Quercus buckleyi*. Plant Ecol. 173:59-72. https://doi.org/10.1023/B:VEGE.0000026329.47461.99

SCS, Soil Conservation Service. 1977. Soil survey interpretation for Kendal County, Texas. United States Department of Agriculture, Washington, DC.

Sims, P.L. 1988. Grasslands. Pp. 265-286, *In:* North American Terrestrial Vegetation. Eds. M.C. Barbour and W.D. Billings. Cambridge Univ. Press.

Tharp, B.C. 1939. The vegetation of Texas. Anson Jones Press, Houston, Texas.

Tollefson, J.E. 2006. *Acer grandidentatum*. In: Fire Effects Information System, USDA, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. http://www.fs.fed.us/database/feis/

USDA-Plants. 2019. Plants Database, USDA Natural Resources Conservation Service. http://plants.usda.gov/java/profile?symbol

Van Auken, O.W. 1988. Woody vegetation of the southeastern escarpment and Plateau. Pp. 43-55. *In*: Amos, B.B. and Gehlbach, F.R. eds., Edward's Plateau vegetation: plant ecological studies in central Texas. Baylor University Press, Waco, Texas.

Van Auken, O.W. 2000. Shrub invasions of North American semiarid grasslands. Ann. Rev. Ecol. Syst. 31:197-215.

Van Auken, O.W., Ford, A.L. and Allen, J.L. 1981. An ecological comparison of upland deciduous and evergreen forests of central Texas. Amer. J. Bot. 68:249-1256.

Van Auken, O.W., Ford, A.L. and Stein, A. 1979. A comparison of some woody upland and riparian plant communities of the southern Edwards Plateau. Southwest. Nat. 24:165-75.

Van Auken, O.W., Bush, J.K. and Elliott, S.A. 2005. Ecology-Laboratory Manual. Pearson Custom

Publishing, Boston, Massachusetts.
Van Auken, O.W. and Taylor, D.L. 2017. Using a Drone (UAV) to Determine the *Acer grandidentatum* (bigtooth maple) Density in a Relic, Isolated Community. Phytologia. 99:208-220.
Van Auken, O.W., Taylor, D.L., Shen, C. and Bush, J.K. 2017. Structure of isolated *Acer grandidentatum* (bigtooth maple) Communities and Potential Population Changes. Amer. J. Plant Sci. 8:232-240.
Van Auken, O.W. and Ford, A.L. 2017. Flood Caused Changes to the Upper Guadalupe River Riparian Forest of Central Texas. Phytologia. 99:226-237.
Van Auken, O.W. 2018. Ecology of plant communities of south-central Texas. Scientific research Publishing, USA.
Van Auken, O.W. and Taylor, D.L., 2020. Survival of Juvenile *Acer grandidentatum* Nutt. (Bigtooth Maple, Aceraceae) in Central Texas Woodlands. Amer. J. Plant Sci. 11:413-425.
Weniger, D. 1988. Vegetation Before 1860. Pp.17-23, *In*: Amos, B.B. and Gehlbach, F.R. eds., Edward's Plateau vegetation: plant ecological studies in central Texas. Baylor University Press, Waco, Texas.
World Climate. 2011. Climate Data for 29 N 98 W. http://www.worldclimate.com/cgi-bin/grid.pl?gr=N29W099

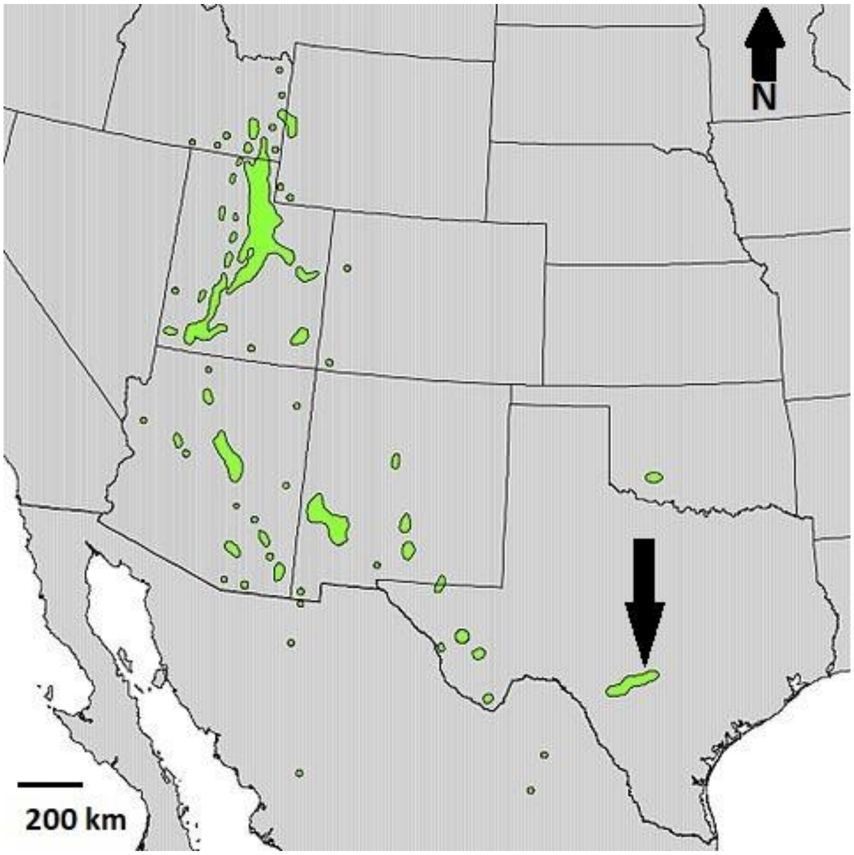

Figure 1. General locations of Bigtooth maple populations in central Texas and the western United States and Northern Mexico. The lower black arrow is the approximate location of the study sites of this project in central Texas.

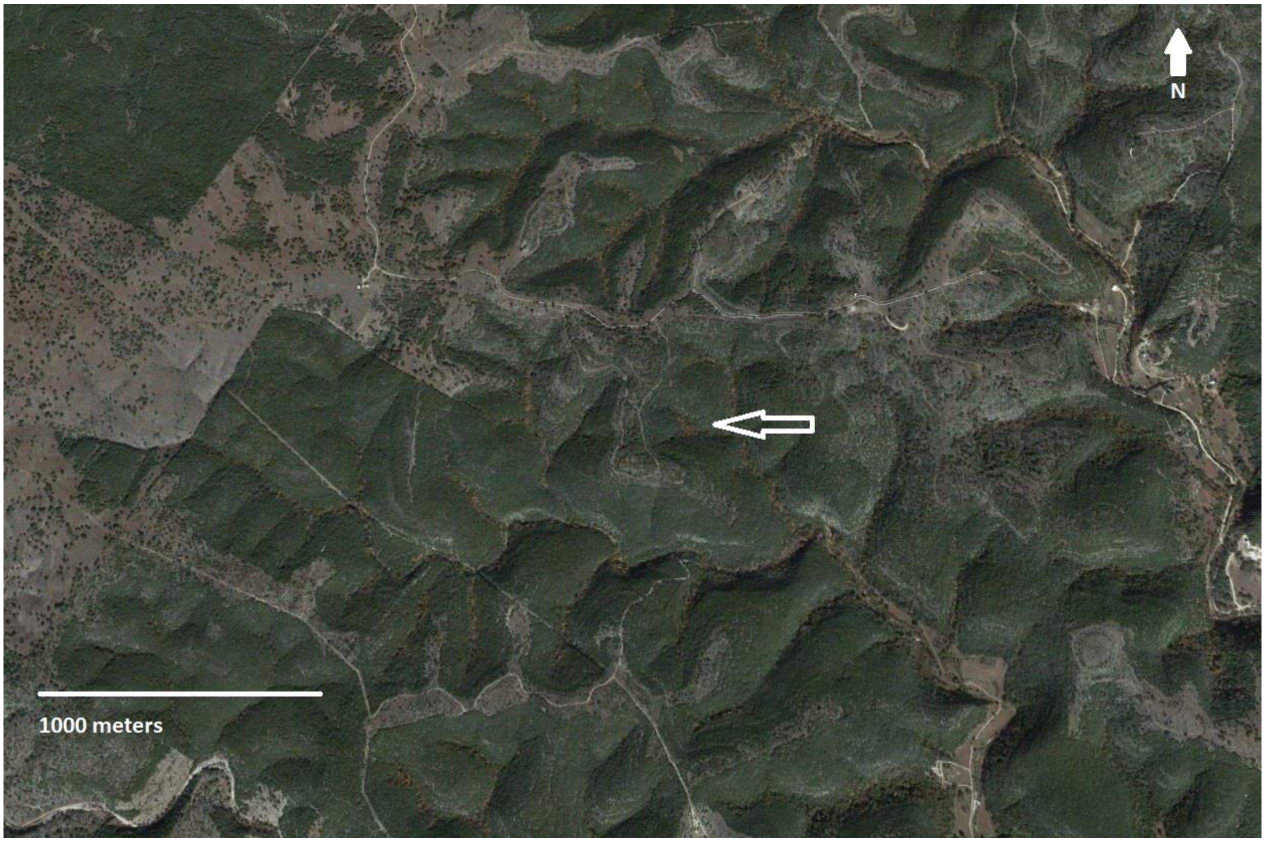

Figure 2. Example photograph from "Google Earth" of part of the study area taken in the fall of 2016 showing mostly the *Juniperus ashei* woodlands and various relatively deep limestone canyons where potential deciduous woodlands could occur. One of the deciduous communities is near the tip of the arrow but that part of the photograph has to be enlarged before the community can be easily seen.

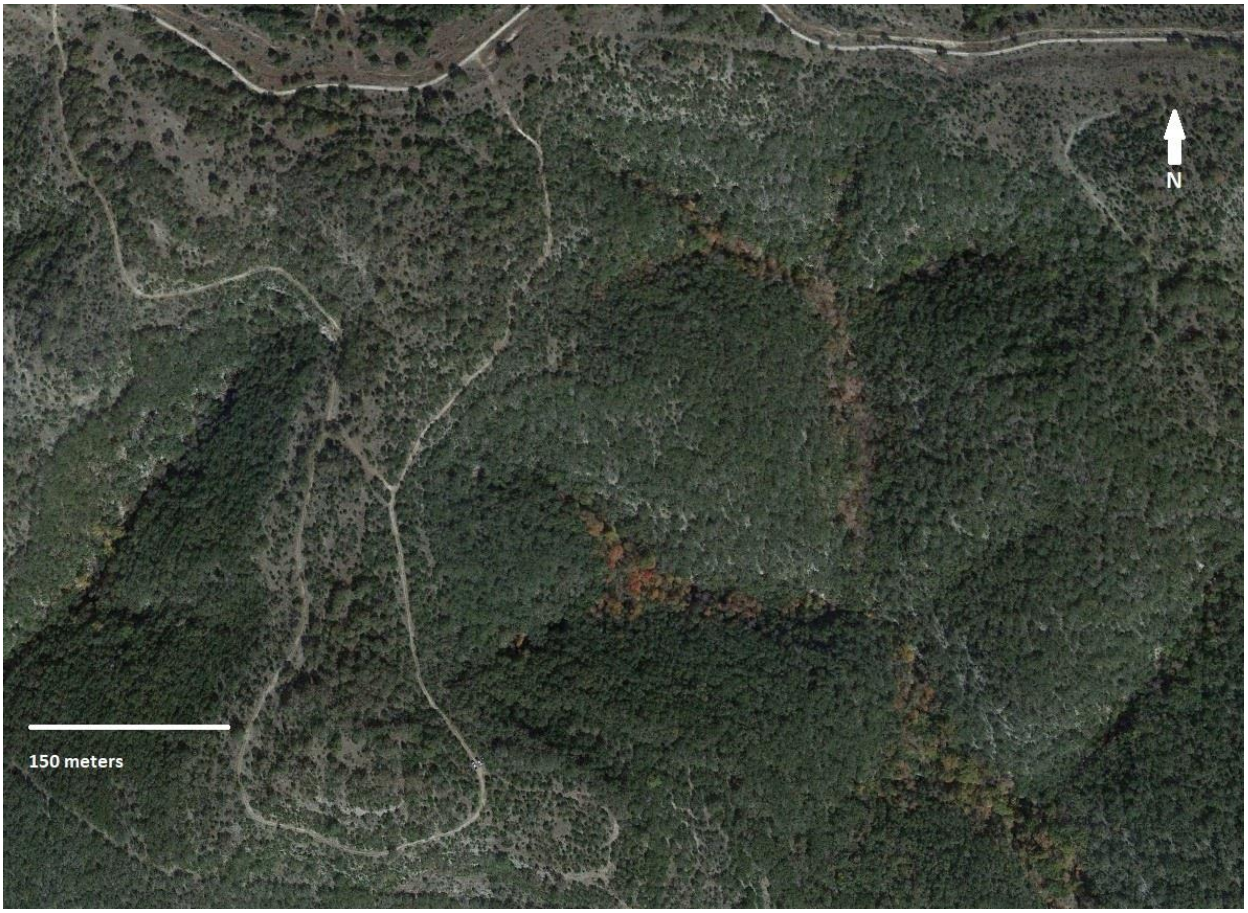

Figure 3. An example enlarged image of several potential deciduous woodlands with *Acer grandidentatum*. This picture was exported as a TIFF image and imported into ARCGIS-10.6 for assessment and characterizing the area of the deciduous woodland to determine if an *Acer grandidentatum* population was present. These deciduous woodlands can be easily seen because of the autumn colors of the leaves of some of the deciduous trees and include potential populations of *Acer grandidentatum.*

Figure 4. Example enlarged images of parts of two deciduous woodlands. These pictures were exported as TIFF images and imported into ARCGIS-10.6 for assessment and characterizing the area of the deciduous woodland to determine if *Acer grandidentatum* populations were present. These deciduous woodlands can be easily seen because of the autumn colors of the leaves of some of the deciduous trees and include potential populations of *Acer grandidentatum.* The large purple triangles indicate the approximate location of part of the ground quadrat transects.

Table 1. General measurements including the number of communities sampled, area of each community sampled, number of overstory and understory species as well as mean total overstory density and basal area and mean total understory density.

SAMPLE	AREA-ha	# OVER SPECIES	# UNDER SPECIES	DENSITY* OVER	DENSITY* UNDER	BASAL AREA**
1	0.96	5	15	153	5287	15.52
2	0.96	6	17	810	11895	28.96
3	4.45	5	21	183	17025	26.56
4	0.29	14	18	572	6021	23.42
5	0.29	9	15	645	5951	32.51
6	1.46	5	11	410	4372	32.97
7	0.79	7	12	675	3710	34.81
8	0.36	9	13	1024	9440	9.01
TOTAL or mean	9.56	17	30	559	7963	25.47

*plants/ha

**m²/ha

Table 2. Summary of the overstory woody species found in the communities surveyed including all their percent occurrences, mean and relative densities in plants per hectare and mean and relative basal areas in meters squared per hectare.

SPECIES	% OCC*	MEAN** DENSITY	% DENSITY	MEAN*** BASAL AREA	% BASAL AREA
Juniperus ashei	100	221	40	1.30	5.20
Acer grandidentatum	100	169	30	9.57	38.26
Quercus laceyi	63	41	7	4.37	17.47
Quercus muehlenbergii	50	26	5	6.10	24.41
Diospyros texana	50	20	4	0.02	0.07
Sophora secundiflora	38	23	4	0.01	0.04
Vitis arizonica	38	14	3	0.03	0.11
Juglans microcarpa	63	10	2	0.44	1.75
Fraxinus albicans	50	9	2	0.93	3.71
Prunus serotina	25	6	1	0.67	2.67
Ungnadia speciosa	25	5	1	0.11	0.43
Quercus buckleyi	50	5	1	0.28	1.11
Sideroxylon lanuginosum	25	5	1	<0.01	< 0.01
Juglans major	13	1	0	0.44	1.77
Celtis laevigata	13	1	0	0.06	0.25
Tilia caroliniana	13	1	0	0.24	0.97
Aesculus pavia	13	2	0	<0.01	<0.01
TOTAL		559	100	25	98.18

*OCCURRENCE

**PLANTS/ha

***m²/ha

Table 3. Summary of the understory woody species found in the communities surveyed including all their percent occurrences, mean and relative densities in plants per hectare.

UNDERSTORY SPECIES	% OCCURRENCE	MEAN DENSITY*	SD	% DENSITY
Celtis laevigata	100	1201	2450	15
Quercus buckleyi	100	1059	430	13
Quercus laceyi	87	926	941	12
Juniperus ashei	100	667	753	8
Quercus muehlenbergii	75	658	704	8
Acer grandidentatum	87	642	700	8
Diospyros texana	100	602	445	8
Parthenocissus quinquefolia	87	386	545	5
Sideroxylon lanuginosum	63	273	519	3
Vitis arizonica	75	257	307	3
Smilax bona-nox	87	249	234	3
Sophora secundiflora	50	241	370	3
Ungnadia speciosa	50	204	412	3
Fraxinus albicans	87	158	188	2
Prunus serotina	100	138	106	2
Ilex decidua	13	99	279	1
Juglans microcarpa	63	46	70	1
Ulmus crassifolia	13	37	104	<1
Mahonia trifoliolata	25	26	57	<1
Rhamnus caroliniana	25	24	50	<1
Toxicodendron radicans	25	12	30	<1
Ptelea trifoliata	13	11	31	<1
Tilia caroliniana	13	10	28	<1
Styphnolobium affine	13	7	19	<1
Ageratina havanensis	13	7	19	<1
Cercis canadensis	25	6	11	<1
Yucca rupicola	13	6	16	<1
Baccharis neglecta	13	6	16	<1
Rhus virens	13	4	10	<1
Styrax platanifolius	13	4	10	<1
Juglans major	13	<4	10	<1
Aesculus pavia	13	<4	10	<1
Eysenhardtia texana	13	<4	10	<1
Quercus fusiformis	13	<4	10	<1
Platanus occidentalis	13	<4	10	<1
Garrya ovata	13	<4	10	<1
TOTAL		7963		98

*PLANTS/ha