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Ashe Juniper Reference Document

This document is intended to be a resource to help provide a more positive perspective and dispel some of the myths about the Ashe juniper tree and Ashe juniper-oak woodlands and forests. It provides brief synopses and talking points with supporting citations. This is a "living document," and thus should be continually updated as additional information becomes available.

1. Ashe juniper is not a cedar.

- Although commonly referred to as "cedar," junipers are actually part of the Cypress family (Cupressaceae), while true cedars belong to the Pine family (Pinaceae).

- Ashe juniper (*Juniperus ashei*) was first described in 1930 by John Buchholz.[1,2] He named the species in recognition of William Willard Ashe[3], a forester with the U.S. Forest Service who first collected it from Arkansas and noted differences from other juniper species.

2. Ashe juniper is a native species.

- Fossilized juniper pollen from Friesenhahn Cave in northern Bexar County date to the last ice age, 14,000-20,000 years ago.[4] This finding is especially significant, given that juniper pollen is fragile and does not preserve well in the alkaline soils of the Edwards Plateau.[5,6]

- Juniper wood charcoal has been found in burned rock middens dating up to 6,500 years old on the Edwards Plateau.[7,8,9]

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[1] Buchholz, J. 1930. The Ozark White Cedar. Botanical Gazette 90:326-332.
[2] Other scientific names have been used for Ashe juniper (e.g., see Little, E.L. 1944. American Journal of Botany 31(9):587-596; https://www.fs.fed.us/database/feis/plants/tree/junash/all.html). For example, the cedarwood oil industry still refers to Ashe juniper as *Juniperus mexicana*.
[3] http://www.herbarium.unc.edu/Collectors/ashe.htm
[4] Hall, S. and S. Valastro. 1995. Grassland vegetation in the southern Great Plains during the last glacial maximum. Quaternary Research 44:237-245.
[5] Shaw, R.B., K.C. Volman, and F.E. Smeins. 1980. Modern pollen rain and vegetation on the Edwards Plateau, Texas. Palynology 4(1):205-213.
[6] Bryant, V.M. and R.G. Holloway. 1985. A late-quaternary paleoenvironmental record of Texas: an overview of the pollen evidence. Pages 39-70 *in* Pollen records of late-quaternary North American sediments (V.M. Bryant and R.G. Holloway, eds.). American Association of Stratigraphic Palynologists Foundation. Dallas, Texas.
[7] Black, S.L. and D.G. Creel. 1997. The Central Texas burned rock midden reconsidered. Pages 269-305 *in* Hot rock cooking on the greater Edwards Plateau: four burned rock midden sites in west central Texas, Vol. 1 (S.L. Black, L.W. Ellis, D.G. Creek and G.T. Goodes). Studies in Archaeology 22, Texas Archeological Research Laboratory, University of Texas at Austin, Austin, Texas.
[8] Houk, B.A., K.A. Miler, and E. R. Okansen. 2008. The Gatlin Site (41KR621): investigating archaic lifeways on the southern Edwards Plateau of central Texas. Index of Texas Archaeology: Open Access Gray Literature from the Lone Star State 2008(1): https://doi.org/10.21112/ita.2008.1.1
[9] https://www.texasbeyondhistory.net/ethnobot/images/juniper.html

- Written accounts of juniper trees in the Texas Hill Country date as far back as the early 1700s.[10,11]

- The endangered golden-cheeked warbler has evolved to depend on the Ashe juniper tree and nests exclusively in the mature Ashe juniper-oak woodlands/forests of central Texas.[12,13]

3. Early explorers of the Texas Hill Country reported extensive forests dominated by juniper and other woody species prior to European settlement.

- Primary eyewitness accounts of early explorers, settlers, and scientists from 1700 to 1900 consistently reported extensive woodlands/forests dominated by juniper, oaks, and other woody species in the Texas Hill Country, especially in along the Balcones Escarpment from Austin to San Antonio as well as the Colorado River and other riparian corridors.[14,15 ,16,17]

- These eyewitnesss accounts are supported by other documents, including field survey notes from original land grants, maps, and photographs.[18]

- Many claims that the Hill Country was primarily grassland prior to European settlement, or that the eastern Edwards Plateau was a live oak savannah, appear to be based on observations during the 20th century and/or misinterpretations of where the early explorers' observations took place on the landscape.[19,20] Major European settlements (Austin, San Marcos, New Braunfels, San Antonio) were established along the Blackland Prairie, at the base of the Balcones Escarpment. Several accounts of extensive grasslands interspersed with the occasional live oak have been erroneously placed in the Hill Country but in fact took place on or near the Blackland Prairie or Cross Timbers.

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[10] Weniger, D. 1984. Explorer's Texas: the land and waters. Eakin Press, Austin, Texas.
[11] O'Donnell, L. 2019. Historical ecology of the Texas Hill Country: historical accounts of vegetation communities from 1700-1900, with an emphasis on the eastern edge of the Edwards Plateau. City of Austin, Wildland Conservation Division, Austin, Texas. https://www.researchgate.net/publication/331582514_HISTORICAL_ECOLOGY_OF_THE_TEXAS_HILL_COUNTRY
[12] Pulich, W. 1976. The golden-cheeked warbler: a bioecological study. Texas Parks and Wildlife Department. Austin, Texas.
[13] U.S. Fish and Wildlife Service. 1992. Golden-cheeked warbler recovery plan. Albuquerque, New Mexico.
[14] Weniger, D. 1984.
[15] O'Donnell, L. 2019.
[16] Nelle, S. 2012. The great grassland myth of the Texas Hill Country. Texas Wildlife (July 2012):46-51. http://www.hillcountryalliance.org/uploads/HCA/News041014.pdf
[17] McGreevy, E. In prep. Mountain cedars: wanted dead and alive, volume one. http://landsteward.net/
[18] O'Donnell, 2019.
[19] Weniger, D. 1984.
[20] O'Donnell, L. 2019.

4. Ashe juniper has a restricted range.

- Disjunct populations of Ashe juniper occur on limestone in the Ozark Mountains along the Missouri and Arkansas border, the Arbuckle Mountains in south-central Oklahoma, central Texas, and Coahuila, Mexico. The largest stands are found in the Hill Country of central Texas, particularly along the Balcones Escarpment and river corridors.[21]

- A common claim is that Ashe juniper has expanded its range (and invaded former grasslands) over the past 150 to 200 years due in part to fire suppression. However, based on the historic accounts, the size and intensity of fires appeared to increase during the mid to late 1800s, following European settlement.[22,23,24] Tree ring analyses within the Balcones Canyonlands Preserve and Balcones Canyonlands National Wildlife Refuge document the continuation of fires through the 1900s.[25,26]

5. Ashe juniper was once considered a valuable asset and commodity.

- Ashe juniper was extensively logged for fuel, fence posts, railroad ties, building construction, and telegraph poles beginning in the mid to late 1800s. By the early 1900s, many stands of Ashe juniper were already being cleared a second time.[27]

- Ferdinand Roemer, a German geologist, wrote of the juniper forests near New Braunfels in 1849: "The cedars here are not the stunted shrub-like plants found in the Northern States of the Union, but are stately trees with straight trunks, seldom more than twenty to twenty-five feet in height and one and one-half feet thick. They have a uniformly spreading crown. This cedar forest is a treasure to the colonists of New Braunfels, since the wood was preferred above all others on account of its durability when used in building houses and fences."[28]

- An article in the Austin Daily Democratic Statesman (precursor to the Austin American Statesman) in 1874 observed that "The cedar tie business has contributed largely to the growth and prosperity of the 'Hill City' in the last two years, more especially the last twelve months. A gentleman connected with the Central Railroad says that two hundred thousand cedar ties have been shipped from this city during the last two years, and when it is remembered that these ties

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[21] https://www.fs.fed.us/database/feis/plants/tree/junash/all.html
[22] Weniger, D. 1984.
[23] Bray, W.L. 1904. The timber of the Edwards Plateau of Texas: its relation to climate, water supply, and soil. U.S. Department of Agriculture, Bureau of Forestry – Bulletin No. 49. Government Printing Office, Washington.
[24] O'Donnell, L. 2019.
[25] City of Austin, Balcones Canyonlands Preserve, unpublished data provided by Dr. Joseph White, Baylor University.
[26] Murray, D.B., J.D. White, and J. Yao. 2013. Loss of neighbors, fire, and climate effects on Texas red oak growth in a juniper-dominated woodland ecosystem. The American Midland Naturalist 170(2):348-369.
[27] Bray, W.L. 1904.
[28] Roemer, Ferdinand. 1849. Texas with particular reference to German immigration and the physical appearance of the country. Translated by Oswald Mueller. Eakin Press (1995), Austin, Texas.

bring from sixty to ninety cents each, the reader will readily comprehend the vastness of the revenue from this source…."[29]

- William Bray, an early forester who wrote extensively about the Edwards Plateau forests in 1904, noted "With the exception of cedar, the hill timber finds a market chiefly as fuel, of which enormous quantities are consumed….Cedar likewise is extensively consumed as fuel and in charcoal burning; but its great value lies in its yield of railway ties, poles, posts, sills, and innumerable other articles which utilize its great durability." "[Cedar] is, in fact, one of the most valuable assets of the region, as well as the most characteristic feature of the hill timber."[30]

- "Cedar chopping" became such a big business during the early 1900s, a special axe was created specifically for this purpose.[31] The clearing of vast areas and subsequent regrowth of Ashe juniper likely contributed to the myth that it is invasive and not native.

- Cedar oil extraction plants and lumber yards still exist in the Hill Country.

6. Ashe juniper is dioecious (separate male and female trees).

- Females trees produce "berries" (not a true berry, but cones that have a berry-like appearance), and male trees produce pollen, which is typically released in December through February. Juniper pollen, like the pollen of many native and non-native plants (grasses, forbs, trees), can cause allergic reactions.[32] While "cedar fever" is frequently reported today, no references have been found in the historical accounts.[33]

7. Ashe juniper grows slowly.

- While Ashe juniper may re-establish quickly, their diameter growth rates are slow. For example, a photo of 25-year old stand along Dry Creek in Bray (1904) shows juniper trees that appear to be about 3 inches in diameter. Bray noted the slow growth: "Of course there was very little, if any, tie or post timber in this, and no clear heart cedar."[34]

- Diameter growth rates of Ashe junipers on the Balcones Canyonlands National Wildlife Refuge from 1998-2010 averaged 0.6 inches per decade.[35] Growth rates on Balcones Canyonlands Preserve have averaged 0.6 to 1 inch per decade.[36]

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[29] Austin Daily Democratic Statesman, September 10, 1874.
[30] Bray, W.L. 1904.
[31] Hollon, G. 1946. Kerrville cedar axe. The Southwestern Historical Quarterly 50(2):241-250.
[32] White, J.F. and D.I. Bernstein. 2003. Key pollen allergens in North America. Annals of Allergy, Asthma & Immunology 91(5):425-435.
[33] McGreevy, E. In prep.
[34] Bray, W.L. 1904.
[35] http://biodiversityworks.org/wp-content/uploads/2016/02/Hatfield-Link.pdf
[36] O'Donnell 2019.

8. Ashe juniper is drought-tolerant and thus helps to conserve water.

- Ashe junipers are well-adapted to the central Texas climate and are ideal for xeric landscapes, where plants are selected for their ability to conserve water. It is one of the few species that can grow on dry caliche slopes.

- Current research indicates Ashe juniper does not consume more water than other native trees.[37,38,39] The amount of water used by any plant varies depending on many factors, including its age and growth form, topography, soils, precipitation, surrounding vegetation, time of day, time of year, etc. For example, recent studies estimate that Ashe junipers transpire more water than live oaks in open savannahs, but considerably less water in closed-canopy woodlands/forests.[40,41,42]

- Another myth is that Ashe juniper has deep roots that suck up groundwater supplies. However, the root systems of Ashe juniper trees do not appear to be deeper than other native trees.[43,44] Further, the water storage capacity of the root zone appears to be limited, with little evidence that deeper roots extract significant amounts of water than what is available to shallow roots.[45]

9. Ashe juniper contributes to water quality and quantity.

- Ashe juniper plays a key role in the maintenance of groundwater by reducing evaporation during drought[46] and increasing infiltration.[47,48,49]

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[37] Elkington, R.J., K.T. Rebel, J.L. Heilman, M.E. Litvak, S.C. Dekke, and G.W. Moore. 2014. Species-specific water use by woody plants on the Edwards Plateau. Ecohydrology 7(2):278-290.
[38] Dammeyer, H.C., S. Schwinning, B.F. Schwartz, and G.W. Moore. 2016. Effects of juniper removal and rainfall variation on tree transpiration in a semi-arid karst: evidence of complex water storage dynamics. Hydrological Processes 30(24):4568-4581.
[39] McGreevy, E. In prep.
[40] Bendevis, M., M.K. Owens, J.L. Heilman, and K.J. McInnes. 2010. Carbon exchange and water loss from two evergreen trees in a semiarid woodland. Ecohydrology 3:107-115.
[41] Owens, K. 2008. Juniper tree impacts on local water budgets. Pages 188-201 *in* Western North American *Juniperus* communities: a dynamic vegetation type (O.W. Van Auken, ed.). Springer Science+Business Media, LLC, New York, New York.
[42] McGreevy, E. In prep.
[43] Jackson, R.B., L.A. Moore, W.A. Hoffman, W.T. Pockman, and C.R. Linder. 1999. Ecosystem rooting depth determined with caves and DNA. Ecology 96:11387-11393.
[44] McGreevy, E. In prep.
[45] Heilman, J., K.J. McInnes, J.F. Kjelgaard, M.K. Owens, and S. Schwinning. 2009. Energy balance and water use in a subtropical karst woodland on the Edwards Plateau, Texas. Journal of Hydrology 373:426-435.
[46] Hauwert, N. M., and J. M. Sharp. 2014. Measuring autogenic recharge over a karst aquifer utilizing eddy covariance evapotranspiration. Journal of Water Resource and Protection 6:869-879.
[47] Slaughter, J. D. 1997. Throughfall, stemflow, and infiltration rates for *Juniperus ashei* on the Edwards Plateau, Texas. Thesis. University of Texas, Austin, Texas.
[48] Lindley, A. L. 2005. The hydrologic function of small sinkholes in the Edwards Aquifer recharge zone. Thesis. University of Texas, Austin, Texas.
[49] Dasgupta, S., B. P. Mohanty, and J. M. Köhne. 2006. Impacts of juniper vegetation and karst geology on subsurface flow processes in the Edwards Plateau, Texas. Vadose Zone Journal 5(4):1076-1085.

- A 2010 study found that springflows in four major river basins of the Edwards Plateau doubled over the previous 85 years, while woodlands/forests expanded and rainfall remained constant during the same time period.[50]

- In the northern Edwards Aquifer, some of the largest populations of Jollyville Plateau salamanders coincide with the highest densities of golden-cheeked warblers, providing another example of how Ashe juniper-oak woodlands/forests and water quality/quantity are not mutually exclusive.

- As a pioneer and climax species, decomposition of the needles dropped by Ashe juniper builds soils. Organic matter is higher in soils under Ashe juniper canopies than in adjacent deforested sites[51] and increases with increasing stand age (Figure 1).[52] Organic matter increases soil fertility and water holding capacity, which reduces erosion and improves water quality.[53]

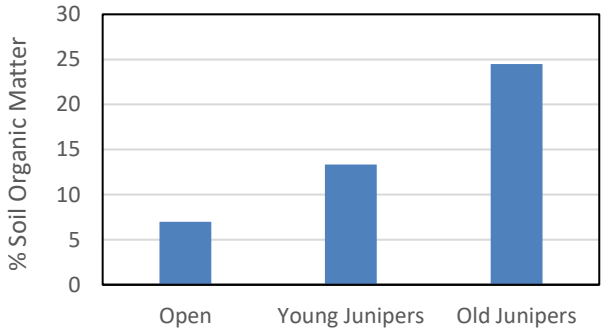

Figure 1. Soil organic matter increases with stand age in Ashe juniper-oak forest, Balcones Canyonlands Preserve

10. Ashe junipers help to control flooding and soil erosion.

- Central Texas is the most flash-flood prone area in the United States and has become known as "flash flood alley." [54] Both the evergreen canopy of Ashe juniper and its leaf litter intercept and reduce the volume and velocity of rainfall events.[55, 56,57,58] This rainfall interception provides

[50] Wilcox, B. and Y. Huang. 2010. Woody plant encroachment paradox: rivers rebound as degraded grasslands convert to woodlands. Geophysical Research Letters 37:1-5.
[51] O'Donnell, L., B.J. Pickles, C.M. Campbell, L.L. Milton, N.M. Hauwert, M.A. Gorzelak. 2020. Native tree and shrub canopy facilitates oak seedling regeneration in semiarid woodland. Ecosphere 11(2):e03017.
[52] City of Austin, Balcones Canyonlands Preserve, unpublished data.
[53] Bot, A. and J. Benites. 2005. The importance of soil organic matter: key to drought-resistant soil and sustained food production. FAO Soils Bulletin 80. http://www.fao.org/3/a-a0100e.pdf
[54] https://twri.tamu.edu/publications/txh2o/2016/fall-2016/do-you-live-in-flash-flood-alley/
[55] Owens, M. K., R. K. Lyons, and C. L. Alejandro. 2006. Rainfall partitioning within semiarid juniper communities: effects of event size and canopy cover. Hydrological Processes 20: 3179-3189.
[56] Owens, K. 2008.
[57] Bray, W.L. 1904.
[58] Marsh, W.M. and N.L. Marsh. 1992. Juniper trees, soil loss, and local runoff processes. Pages 4-1 – 4-14 *in* Soil, landforms, hydrologic processes, and land-use issues – Glen Rose limestone terrains, Barton Creek watershed, Travis County, Texas (C.I. Woodruff, Jr., W.M. Marsh, and L.P. Wilding, eds.). Society of Independent Professional Earth Scientists, Central Texas Chapter, Austin, Texas.

both erosion and flood control, which plays an essential role in reducing runoff and soil loss, particularly on steep slopes.[59,60] The interception rate varies depending on the location, duration, amount, and intensity of the rainfall event.[61, 62]

- The force of unobstructed rain on bare soil can be extremely destructive, rapidly eroding soil away. The foliage of Ashe juniper is particularly effective at breaking the momentum of raindrops. When juniper needles fall to the ground, they also prevent erosion, absorbing sediment-bearing water as it moves over the surface. The deposited sediment then forms small berms that further retard the flow of water downhill.[63,64]

- Soil erosion has been severe and episodic in the Hill Country since the latter part of the 1800s following successive waves of juniper clearing, burning, and overgrazing.[65]

- The importance of the Edwards Plateau forests for "checking floods, collecting soil, preventing erosion, promoting the entrance of water into the earth, and maintaining a longer and more constant flow of springs and streams…." was documented as far back as 1904.[66]

11. Ashe juniper-oak woodlands/forests tend to be low wildfire risk areas.

- Models of fire risk within Ashe juniper-oak woodlands/forests of the Balcones Canyonlands Preserve[67] found that:
  - Woodlands/forests within and adjacent to the preserve have the lowest risk of wildfire potential and effects compared to grasslands and shrub/savannahs.
  - Presence of woodland/forest canopies with diverse species composition reduces fire spread and lowers probability of burn. Tree species within the juniper woodlands/forests, such as deciduous oaks, constrain the spread of canopy fires.
  - Active canopy fires in juniper-oak woodlands/forests are potentially very rare.
  - Ignitions and fire originating in juniper-oak woodlands/forests have slow rates of spread that could be effectively handled by emergency responders.
  - Canopy fires can occur in Central Texas juniper communities, but only under very unique meteorological and ignition conditions.[68]

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[59] Bray, W.L. 1904.
[60] Marsh, W.M. and N.L. Marsh. 1992.
[61] Owens, M. K. et al. 2006.
[62] Owens, K. 2008.
[63] Marsh, W.M. and N.L. Marsh. 1992.
[64] McGreevy, in prep.
[65] Marsh, W.M. and N.L. Marsh. 1992.
[66] Bray, W.L. 1904.
[67] White, J. and J. Thomas, D. Murray, M. Sides, and J. Yao. 2009. The Balcones Canyonlands Preserve fire risk and management: characterization of woodland fuels and simulated fire behavior in the wildland-urban interface. Spatial Ecology Laboratory, Baylor University, Waco, Texas.
[68] Reemts, C.M. and L.L. Hansen. 2008. Slow recolonization of burned oak-juniper woodlands by Ashe Juniper (*Juniperus ashei*): ten years of succession after crown fire. Forest Ecology and Management 255:1057-1066.

- Based on known wildfires within and near the Balcones Canyonlands Preserve (1961-2020), the frequency and rate of spread of fires in Ashe juniper-oak woodland/forest is very low compared to grassland and shrubland.[69]

- Ashe juniper is sensitive to fire, as its thin bark is easily damaged and it does not resprout. Small trees in grasslands are most vulnerable, while large trees in moderate to dense stands tend to be fire-resistant. Fine fuels in such stands are usually not sufficient to carry fire, and the trees are usually far enough apart to prevent fire being carried from crown to crown. Dead Ashe juniper trees are highly volatile fuels and must be treated with caution.[70]

- Because of its fire resistance, mature juniper woodlands/forests can be an effective fire break, provided the leaf moisture remains above 60 percent and sustained winds are below 20 mph.[71]

12. Ashe juniper-oak woodlands/forests support a unique community of plants and animals, many of which are found nowhere else.

- The uniquely rich and well-draining soil that builds up as juniper leaves fall and decompose is ideal for several native plants, some of which tend to occur almost exclusively in association with it, including cedar sage, cedar sedge, and cedar rosette grass. Texas madrone, Texas red oak, Texas smoke tree, white limestone honeysuckle, Lindheimer's silktassel, and zexmenia also germinate and grow well in association with Ashe juniper, refuting the rumor that nothing grows under these trees.[72] Rare orchids grow under the canopies of juniper-oak woodlands/forests and depend on fungi from the tree roots for nutrients. Several other species of plants endemic to Texas, or nearly so, are associated with juniper-oak woodlands/forests, including Heller's marbleseed, two-flower anemone, twistleaf yucca, sycamore-leaf snowbell, bracted twistflower, canyon mock-orange, Buckley tridens, Texabama croton, and Lindheimer crownbeard.

- Despite claims that Ashe juniper suppresses plant growth, greenhouse experiments do not indicate reduced survival or poorer health of plants (including little bluestem, sideoats grama, and tomato) grown in Ashe juniper soils compared to conventional potting soil.[73]

- Ashe juniper woodlands/forests support biologically rich terrestrial and aquatic ecosystems, including cave and spring ecosystems of the Edwards Plateau. Historically, black bear were abundant in these woodlands/forests.[74] The berries are eaten by most mammals (including

[69] City of Austin. 2020. History of fire incidents on and near Balcones Canyonlands Preserve, western Travis County, Texas (April 1961-April 2020). City of Austin, Austin Water, Wildland Conservation Division, Balcones Canyonlands Preserve. Austin, Texas.
[70] https://www.fs.fed.us/database/feis/plants/tree/junash/all.html
[71] Armstrong, Bill. 2004. Conducting cool season prescribed fires: the Kerr Wildlife Management Area experience. Texas Parks and Wildlife Department report, PWD BK W7000-2065 (3/04). Austin, Texas.
[72] http://www.wildflower.org/plants/result.php?id_plant=JUAS
[73] City of Austin, Balcones Canyonlands Preserve, unpublished data.
[74] Weniger, D. 1997. The Explorers' Texas: The Animals They Found. Eakin Press, Austin, Texas.

white-tailed deer, raccoons, fox, rabbits), many birds (including American robins, cedar waxwings, yellow-rumped warblers), and some insects. The Ashe juniper is a larval host for the juniper hairstreak butterfly. And, of course, the golden-cheeked warblers, which raise their young nowhere else but mature juniper-oak woodlands/forests in central Texas, make their nests of the bark from mature Ashe junipers. Ashe junipers also provide shelter, nest substrate, and a supply of food (invertebrates) for adult and young golden-cheeked warblers.

13. Ashe junipers restore its woodland/forest ecosystems and reduce the spread of invasive species.

- The low branches of Ashe junipers can serve as "nurse trees" for woodland/forest plants by protecting seedling and sapling hardwoods and other plants from browsing deer. One study showed that Texas red oak seedlings and saplings growing near junipers were more likely to survive than those growing away from junipers. The unsustainably high deer population in central Texas has decimated several generations of oaks[75], making this protection all the more important.

- In addition to protection from herbivory, Ashe juniper-oak woodlands/forests facilitate oak regeneration by providing shade during hot summer months and higher organic matter than adjacent deforested sites. They also support beneficial fungi that enhance plant survival (for example, nutrient uptake and protection from pathogens).[76] Competition with junipers for sunlight or water does not appear to be a major factor in the growth of oak seedlings, since oaks can grow up in dense thickets under junipers where deer numbers are low.[77]

- Ashe juniper is one of the first trees to return to cleared or degraded land. Since overgrazing, burning, and other land management practices can influence natural plant succession, this allows for a high rate of juniper establishment in some areas. This "legacy effect" of past land use has likely contributed to the belief that nothing grows under Ashe junipers and that Ashe junipers outcompete other woody plants.

- Maintaining contiguous Ashe juniper woodlands/forests tends to reduce the invasion and proliferation of non-native species that thrive in open, sunny, and/or disturbed areas, such as King Ranch bluestem and other exotic plants, oak wilt, and red-imported fire ants.

- Ashe juniper bark and leaves support endophytes (a type of fungus that lives in plant tissue without causing visible signs of harm), some of which have antimicrobial properties, including antifungal activity against the oak wilt fungus.[78]

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[75] Russell, L. and N. Fowler. 2004. Effects of white-tailed deer on the population dynamics of acorns, seedlings and small saplings of *Quercus buckleyi*. Plant Ecology 173:59-72.
[76] O'Donnell et al. 2020.
[77] O'Donnell et al. 2020.
[78] Sandy, M., M. Bao, A. Jamal, and J. Raj. 2019. Endophytic fungi of *Juniperus ashei*. Report provided to City of Austin, Austin Water, Wildland Conservation Division. University of Texas, Austin, Texas.

14. Ashe junipers help to reduce the heat island effect.

- Shade from forest canopies shields the ground from the sun and drying winds, reducing the temperatures of the air and soil and also reducing evaporation from the soil beneath the trees.[79] Transpiration from the leaf surfaces also lowers the air temperature. For this reason, urban planners recommend planting trees to help control cooling costs in urban environments.[80,81,82]

15. Ashe juniper-oak forests and woodlands/forests help combat global warming.

- Carbon dioxide contributes to greenhouse gases that can cause global warming. The New York Times published an extensive article summarizing the role of forests in reducing carbon dioxide and the effects of climate change on forests.[83]

- Evergreen Ashe junipers capture and hold large amounts of carbon dioxide[84]and the soils store high levels of organic carbon.[85]

- Other research has found that daily carbon gain is significantly greater for Ashe juniper than for live oak.[86] However, both trees have the capability of sequestering a greater amount of carbon than grasslands.[87,88]

- While climate science tends to focus on carbon, the role of forests in the hydrologic cycle should also be considered.[89] A recent theory posits that forest evapotranspiration creates low-pressure systems that draw moisture from oceans to continental interiors.[90] Forests may also play a role

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[79] Nagra, G., P. C. Treble, M. S. Andersen, I. J. Fairchild, K. Coleborn, and A. Baker. 2016. A post-wildfire response in cave dripwater chemistry. Hydrology and Earth System Sciences 20:2745-2758.
[80] https://www.epa.gov/heatislands/using-trees-and-vegetation-reduce-heat-islands
[81] Texas Trees Foundation. 2015. State of the Dallas urban forest. Dallas, Texas. https://www.texastrees.org/wp-content/uploads/2019/04/Urban-Forest-report.pdf
[82] Nowak, D.J., A.R. Bodine, R.E. Hoehn, C.B. Edgar, D.R. Hartel, T.W. Lister, T.J. Brandeis. 2016. Austin's urban forest, 2014. U.S. Forest Service, Delaware, Ohio. www.itreetools.org/documents/300/Austins_Urban_Forest_report.pdf
[83] http://www.nytimes.com/2011/10/01/science/earth/01forest.html?pagewanted=all
[84] Bendevis et al. 2010.
[85] City of Austin, Balcones Canyonlands Preserve, unpublished data.
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in cloud formation through the release of tiny particles that provide a surface for the condensation of water vapor, enabling the growth of cloud droplets.[91,92,93] Below ground, tree roots and mycorrhizal networks sequester and transport carbon[94] and water through the forest community.[95,96]

16. Ashe juniper produces aromatic compounds that benefit human health.

- Like other conifers, Ashe juniper leaves contain essential oils (terpenes), including camphor, pinene, and limonene.[97] Recent research has shown that inhaling these "forest aerosols" promotes physical and mental well-being, including relaxation, improved cognitive performance and mood, improved immune system, and anti-inflammatory, antioxidant, and anti-tumor activity.[98,99] "Forest therapy" is a health-promoting practice in many countries; Japan has coined the term "shinrin-yoku" for this activity and has led much of the research.[100,101]

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