



Climate Risk Analysis of Tucson Tree Species

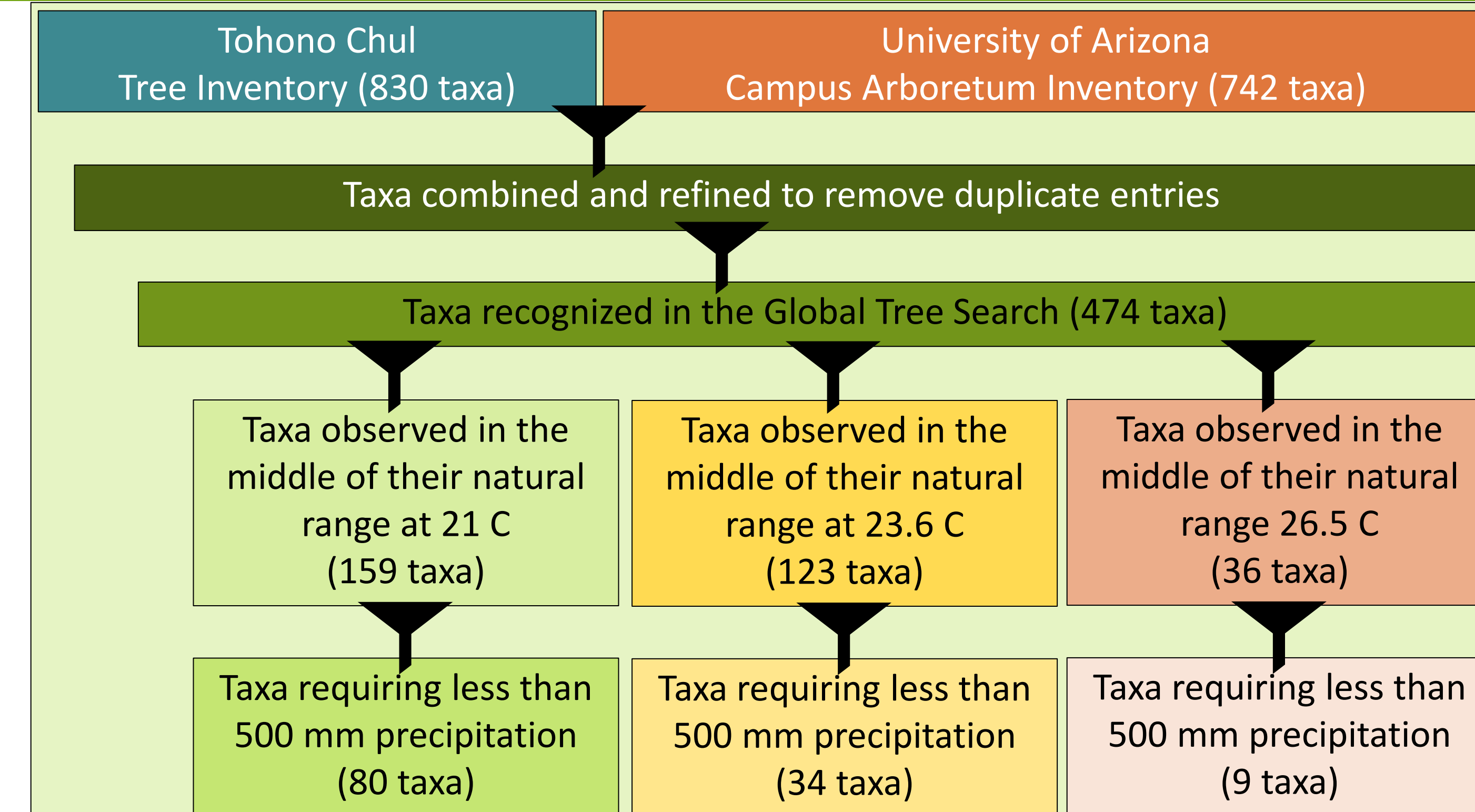
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With supervision by Dr. Tanya M. Quist

Abstract

Trees can play a significant role in mitigating and adapting to global climate change, especially in urban environments. As such, urban greening initiatives are emerging at the forefront of community strategies for a changing climate. However, anticipated increases in global temperature will subject plants to temperatures never experienced before. As such, it is increasingly important to evaluate tree climate adaptation to ensure they are selected based on potential to survive and thrive in both the current and projected future climate. The University of Arizona Campus Arboretum and the Tohono Chul Park, are living collections of arid-adapted trees, situated within an urban center in the Sonoran Desert. These gardens provide a wide array of tree species to evaluate for potential performance in projected climate scenarios. With the 2017 release of the Global Tree Search, a database of 60,000 known tree species observed globally, and the subsequent development of the Climate Assessment Tool by Botanic Gardens Conservation International (BGCI) in 2022, we determined to evaluate climate ratings of 474 species in our collections under current and future predicted climate scenarios for Tucson, AZ including: "Current Climate" (based on climate data from 2020), an "Emissions Limited" (EL) scenario (SSP2/RCP4.5) and a "Business as Usual" (BU) scenario (SSP3/RCP7.0). The EL and BU scenarios are based on models developed by the Intergovernmental Panel on Climate Change (IPCC). By comparing the taxa in two local arboresecent plant collections with global observations of those species in regions around the world with mean annual temperature (MAT) equal to that in Tucson currently, and the MAT predicted for Tucson under the EL and BU scenarios, we generated a list of species with potential to be climate-adapted. We further refined the list to select only species known to survive in climates with specific MATs with less than 500 mm of precipitation, as this is a constraint dictated by the Campus Arboretum's collection policy. The initial results highlight species with the greatest promise for performing well within Tucson's current/future climate, though they also reflect an overall decline in the collection's biodiversity with rising temperatures unless additional adapted species are identified and planted. A subset of the species analyzed were identified with potential to perform better in warmer climate scenarios including one species with potential to survive in all three climate scenarios. These findings inform curation decisions and sustainability of both arboreta collections and may be relevant for tree planting recommendations in the surrounding community. Before ranking and recommending species for production and planting, we will further refine the list of adapted species based on known temperature (high and low) thresholds and based on input of urban forestry, and nursery practitioners.

Approach & Methodology

The complete tree inventories from both the University of Arizona Campus Arboretum and Tohono Chul Gardens were generated and merged. The combined inventories from the two gardens included 831 taxa. Duplicate entries were removed, then further refined by eliminating any species not represented in the Global Tree Database resulting in 474 unique species. The resulting 474 species, were then entered into the Botanical Garden Conservation International Climate Assessment Tool (CAT) found online at: <https://cat.bgci.org/> This tool compares the taxa entered with observations of those species in regions around the world with a mean annual temperature (MAT) equal to the region selected given the climate scenario selected (Tucson, AZ). Based on observations of these species globally, the CAT ranks species from 0-11, corresponding to whether the species were observed growing in the near edge, shoulder, or middle of its natural or urban range (0-Not known and not likely, 1-Not known but possible, 2-Not known but likely, 3-Near edge of botanical garden range, 4-Near edge of urban range, 5-Near edge of natural range, 6-Shoulder of botanical garden range, 7-Shoulder of urban range, 8-Shoulder of natural range, 9-Middle of botanical garden range, 10-Middle of urban range, 11-Middle of natural range), respectively. We established that only species ranking 11, (the species is considered in the middle of its natural range at the specified MAT) would be included. Additionally, we restricted our search for climate adapted species further by eliminating species that required more than 500 mm of precipitation to survive at the specified MAT. This limit corresponds to the Campus Arboretum's collection policy limits for selecting drought adapted trees. This process was repeated with The University of Arizona Campus Arboretum selected as the location for three climate scenarios: Current Climate (with a MAT of 21.0°C), SSP2/RCP4.5 Emissions Limited (MAT 23.6°C) and SSP3/RCP7.0 Business as Usual (MAT 26.5°C).



Graphic (Above): Outline of the process used to create the initial species list for the present evaluation and the selection criteria used to filter results in this final analysis.

Results

Current Climate Scenario:

Of the 474 taxa analyzed, 80 species were identified that fell within the current mean annual temperature of Tucson, AZ (without consuming more than 500 mm precipitation per the Campus Arboretum's Collection Policy's). This represents 16.9% of our current collections. Of these 80 species identified, 14 species go on to appear in the Emissions Limited Scenario as retaining these same rankings per the MAT of the Emissions Limited Scenario.

Emissions Limited Scenario:

Of the 474 taxa analyzed, 34 species were identified that fell within the mean annual temperature predicted for Tucson, AZ in the Emissions Limited Scenario (without consuming more than 500 mm precipitation per the Campus Arboretum's Collection Policy's). This represents 7.2% of our current collections. As noted, 14 of these species matched those identified in the middle of the current mean annual temperature of Tucson. Alternatively, of these 34 species identified, 3 species go on to appear in the Business as Usual Scenario retaining these same ranking per the MAT of the Business as Usual Scenario.

Business as Usual Scenario

Of the 474 taxa analyzed, 9 species were identified that fell within the mean annual temperature predicted for Tucson under the Business as Usual Scenario (without consuming more than 500 mm precipitation per the Campus Arboretum's Collection Policy's).. This represents 1.9% of our current collections. As noted, 3 of these species matched those identified in the middle of the Emissions Limited mean annual temperature of Tucson.

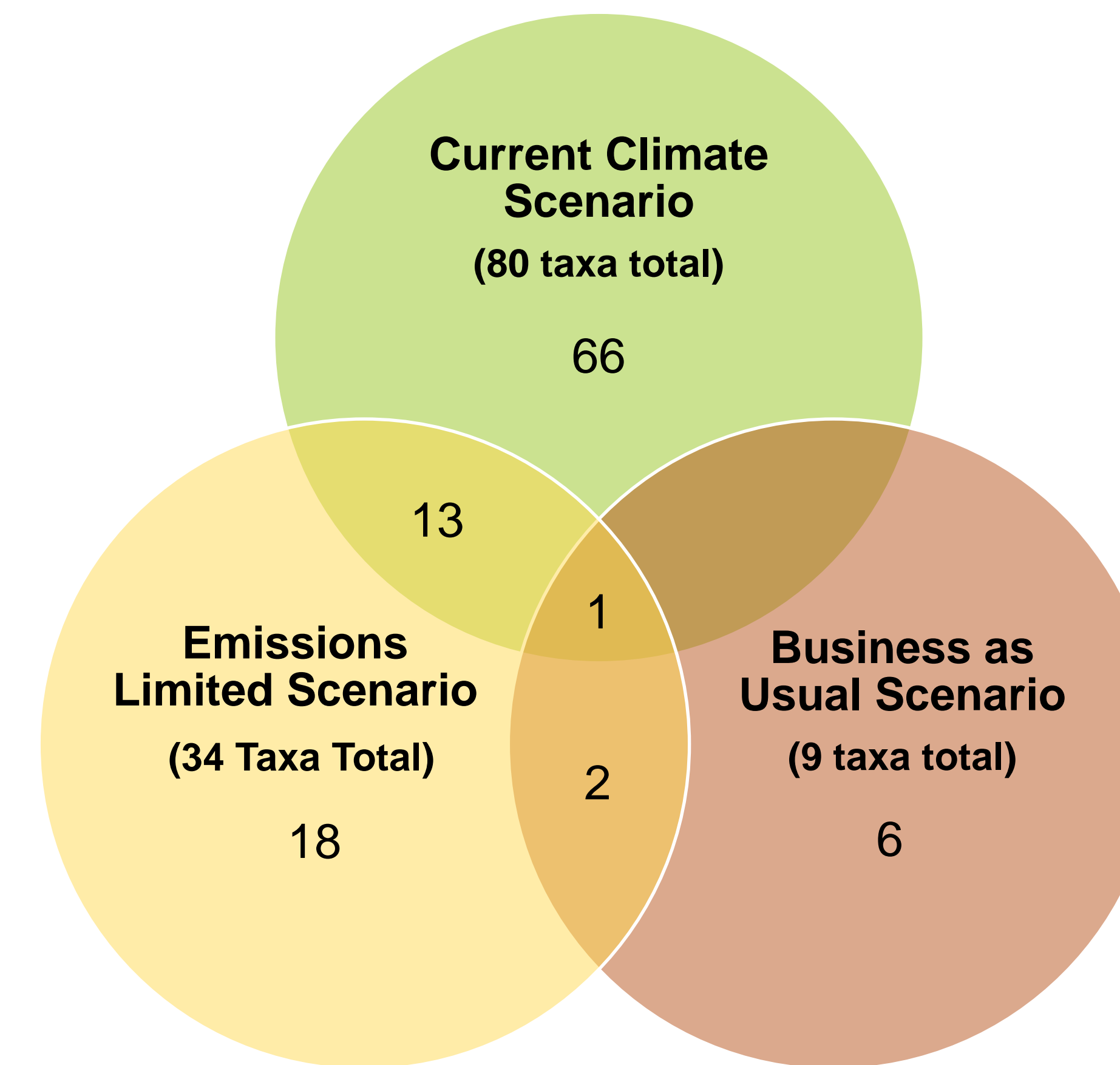


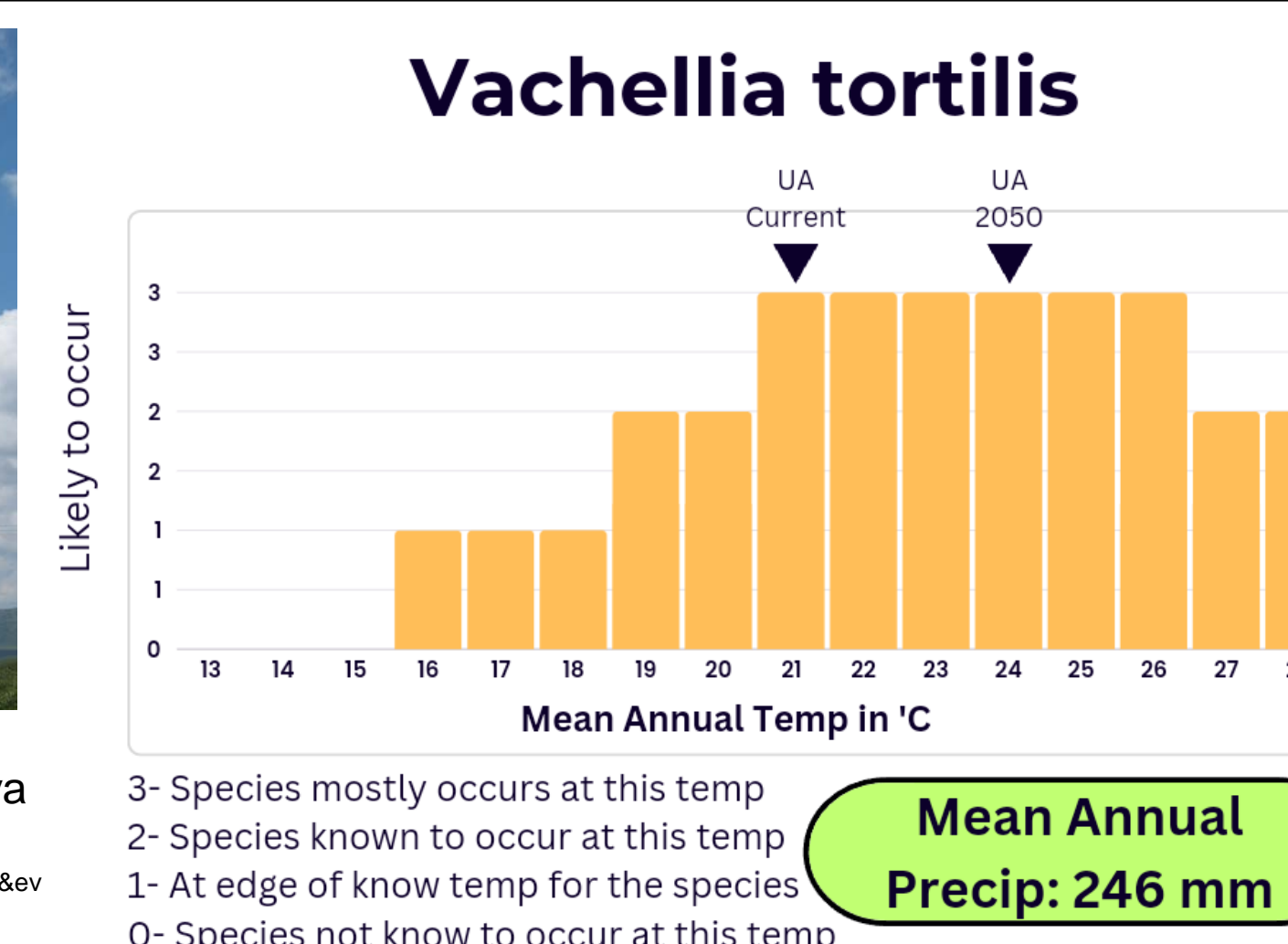
Figure (Above): This diagram displays the number of species that have been observed in the middle of their natural range at the MAT of each given climate scenario, while adhering to the 500mm precipitation limit, as well as any overlap of the same species occurring in multiple climate scenarios.

Species Spotlight: *Vachellia tortilis*

Of the 474 species analyzed, *Vachellia tortilis* was the only specimen that has been observed occurring in regions around the world with mean annual temperatures equivalent to that observed in Tucson currently and in both Emissions Limited and Business as Usual scenarios



Vachellia tortilis photographed in Isolo, Kenya by Maria Vorontsova, 2012. Source: <https://www.flickr.com/photos/18photo/531411310>



3- Species mostly occurs at this temp
2- Species known to occur at this temp
1- At edge of know temp for the species
0- Species not know to occur at this temp

Conclusions

The BGCI Climate Assessment Tool uses observation data from the Global Tree Database to predict tree species performance based on presence of those species in global regions of the same mean annual temperature (MAT). Using MAT as an initial parameter followed by a precipitation limit of 500mm, we identified 80 taxa which are or have been grown in the Campus Arboretum or Tohono Chul collection that fall within the mean annual temperature of Tucson, 34 that fall within the predicted MAT of Tucson under the Emissions Limited Scenario, and 9 that fall with the predicted MAT of Tucson under the Business as Usual Scenario. These represent a potential reduction in collection diversity of 83.1%, 92.8%, and 98.1% under current, LE and BU scenarios – suggesting many trees currently grown in Tucson are at risk based on current or predicted MAT in the region. As such, the project illustrated opportunities to improve the tree selection criteria.

Future Work

We consider the use of MAT as a valid initial parameter to evaluate potential species performance. As such, those species observed in regions with the same MAT as Tucson currently, or in the two predictive climate change scenarios considered, may include a subset of species with better temperature performance than other species evaluated. For this reason, we tentatively point to the promise of these 16 taxa to perform well under current and/or future climate in Tucson, AZ. However, while the mean temperature may correlate with plant performance generally, it is the temperature extremes that better predict survival. As the high and low temperatures used to derive the mean are not known, we would like to further refine the list based on the breadth of temperatures experienced in the regions where these trees have been observed. This data may be obtained from the Global Tree Database, other online records and from global practitioners reporting performance based on their use/experience cultivating those species. Given the temperature range experienced in Tucson historically is approximately 15°F to 115° F, we would like to refine the list of species we've collected by comparing the full span of temperatures in their range with that observed in Tucson to better evaluate potential performance. For species with a similar span, we might recommend prioritizing planting in the Tucson area. For species adapted to regions where temperatures fall below 15°F, we might recommend planting those in a cooler or protected Tucson microclimates. For species adapted to temperatures hotter than 115° F, we might recommend those be planted in warmer microclimates or areas where supplemental water can be provided. Further, recognizing the 474 taxa evaluated are limited to those previously grown in Tucson (and also limited by those appearing in the Global Tree Database), we will compliment our work by evaluating additional species in the Campus Arboretum's "Wishlist", which are tree species not commonly cultivated in Tucson. Climate Assessment will be repeated using the same criteria (MAT and precipitation <500mm) and the resulting species list will be refined as described above. As a guide to planting and curation, The University of Arizona Campus Arboretum Collections Policy will be updated to include the recommended species which fall within the temperature range and below the precipitation threshold defined in the standard. We also hope the work will yield a broader range of tree species to recommend for planting or production in the nursery trade given their superior potential to perform well in Tucson.

Acknowledgements

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Taxa	Current (MAT 21°C)	Emissions Limited (MAT 23.6°C)	Business as Usual (MAT 26.5°C)
<i>Vachellia tortilis</i>	✓	✓	✓
<i>Coursetia glandulosa</i>	✓	✓	X
<i>Fouquieria formosa</i>	✓	✓	X
<i>Havardia pallens</i>	✓	✓	X
<i>Parkinsonia praecox</i>	✓	✓	X
<i>Senegalia occidentalis</i>	✓	✓	X
<i>Vallesia glabra</i>	✓	✓	X
<i>Bursera laxiflora</i>	✓	✓	X
<i>Fouquieria purpusii</i>	✓	✓	X
<i>Jatropha cordata</i>	✓	✓	X
<i>Maytenus phyllanthoides</i>	✓	✓	X
<i>Sabal uresana</i>	✓	✓	X
<i>Vachellia erioloba</i>	✓	✓	X
<i>Vallesia laciniata</i>	✓	✓	X
<i>Boswellia sacra</i>	X	✓	✓
<i>Faidherbia albida</i>	X	✓	✓

Table (Above): This table displays any overlap of taxa observed in the middle of their natural range across each of the climate scenarios assessed, while adhering to the 500mm precipitation limit, as indicated with a check mark (✓). Those which have not been observed in the middle of their natural range per each climate scenario were indicated with an (X). For a complete list of taxa in each climate scenario, visit: <https://arboretum.arizona.edu/research/evaluating-climate-adaptation-tucson>