Section 2C. Spatial Analysis

All spatial data for selected final indicators were compiled into the Madrean Database for reference and analysis (Appendix 2Ca).

i. Spatial data were selected to match the indicators as closely as possible (Appendix X). For riparian indicators, and most stream indicators, analysis was postponed until a future project. For springs, a detailed examination of springs in the U.S. can be found in the Sky Island Spring Prioritization Tool 1.0, from which we pulled several variables to include in spatial analysis. Some indicators did not have any currently available corresponding spatial data.

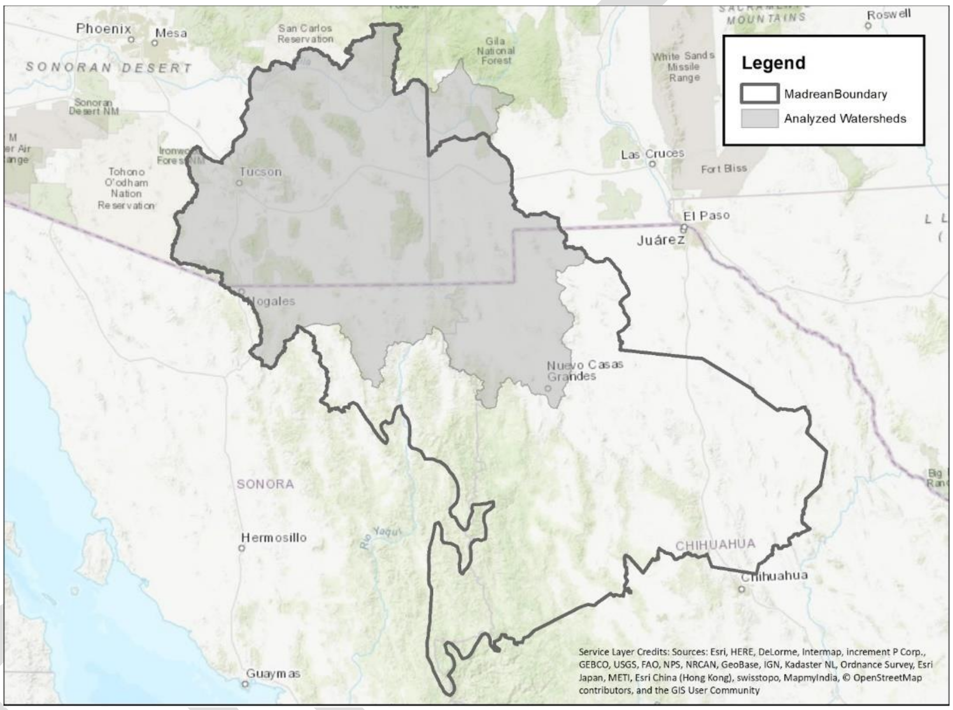

Figure X. Madrean Pilot Area and smaller area in which HUC12 watersheds were analyzed.

Spatial data were summarized at the HUC12 watershed (a small geographic unit bound by topographic and hydrological influence), Forest Core, and Grassland Core scales. HUC12 watersheds were only available for a portion of the pilot area in Mexico, so that analysis is limited to a smaller area than the original pilot area (Figure X). For connectivity areas, we created one ArcGIS shapefile that contains not only the Connectivity Areas described in Section X, but also all mapped linkages and corridors known in the pilot area. This includes data from Wilbor (2014), Atwood et al (2011), the AZ Missing Linkages Project, the AZGFD Pima County Wildlife Connectivity Assessment, Menke (2008), Hass (2001), and Majka (AZ Missing Linkages Project). Table X indicates to which indicator spatial data variables correspond, and at which scale the variable was analyzed. All variables are available in four spreadsheets - the HUC12 database, the Forest Cores database, the Grassland Cores database, and the Connectivity Areas database, as well as in shapefile format (Appendix 2Ca link, Sciencebase link). To enable comparisons and combinations of variables, we rescaled all data to a scale of 0-100, except trend data, which was rescaled from -100 to +100. For each analysis unit (watersheds and cores), we analyzed the combination of a subset of selected variables to provide insight into specific management concerns.

Forest Cores

In forested areas of the Madrean Watersheds pilot area, permanent loss of forest core to high severity wildfire is a major concern. To understand which Forest Cores are most threatened by high severity wildfire, we combined the BurnRisk (percent of the core at risk for high severity fire) and MEWMeanArea (average size of forest patches in the core) variables. We divided cores into four groups:

- *High Burn Risk, Small Patches:* cores in the top 25% of BurnRisk and bottom 50% of MEWMeanArea
- *High Burn Risk, Large Patches:* cores in the top 25% of BurnRisk and top 50% of MEWMeanArea
- *Low Burn Risk, Small Patches:* cores in the bottom 75% of BurnRisk and bottom 50% of MEWMeanArea
- *Low Burn Risk, Large Patches:* cores in the bottom 75% of BurnRisk and top 50% of MEWMeanArea

Some cores also have no risk of high severity fire (BurnRisk here represents the percent of the core at risk of high severity fire. Cores with high burn risk and small patches may be most in danger of losing significant portions of forest habitat, while those with low or no burn risk and large patches may be in the least danger. We also did the same analysis for HUC12 watersheds with ≧ 5% forest cover (Figure X). This analysis shows which watersheds have forest at high risk.

Grassland Cores

In the grasslands of the pilot area, woody encroachment and human modification (agricultural expansion and other development) are major threats. To examine woody encroachment, we looked at GrassTreeTREND, which is the trend in the average percent tree cover from 2000-2016, calculated as the slope of the best-fit line to all yearly data points. We divided cores into quartiles of GrassTreeTREND, including four quartiles for positive trends (top 25, top 50, bottom 50, and bottom 25), and one category for a negative trend in tree cover (trees decrease). Cores in the top 25 are the most likely to be experiencing invasion by woody plants, while cores in the trees decrease category may be increasing in grassland cover.

To examine human modification, we first averaged GrassMeanArea (the average size of grassland patches) and GrassHerb2016 (the percent of grassland that was not tall trees or bare ground) to obtain a measure of grassland quality (GoodGrass). This calculation assumes that larger patches of grassland with higher non-tree vegetation cover are better quality. However, it does not contain any information about grass species, so is inherently limited. We then combined this measure of grassland quality, GoodGrass, with PerGrassMo, the percent of the core that humans had converted to urban or built-up areas, or cropland. We divided cores into four groups:

- *Good Grassland, High Modification:* the top 25% of GoodGrass and top 25% of PerGrassMo
- *Good grassland, Low Modification:* cores in the top 25% of GoodGrass and bottom 75% of PerGrassMo
- *Poor to Moderate Grassland, Low Modification:* cores in the bottom 75% of GoodGrass and bottom 75% of PerGrassMo
- *Poor to Moderate Grassland, High Modification:* cores in the bottom 75% of GoodGrass and top 25% of PerGrassMo

Cores with good grassland and high modification may be most in danger of losing significant areas of high quality grassland habitat. We also did the same two analyses for HUC12 watersheds with $\geqq$ 5% grassland cover. This analysis shows which watersheds have grassland suffering from woody invasion and high quality grassland at high risk of loss to human modification.

Water Scarcity

In the Madrean Watersheds pilot area, water availability and maintaining perennial stream and spring flow are major concerns. Within the HUC12 watersheds, we assessed water scarcity. For all watersheds, we used the TotPerWi_m (the total length of perennial stream in the watershed, rescaled from 0-100) to display perennial stream scarcity (Figure X). Using this calculation, watersheds with lower values have greater perennial stream scarcity. Streams in watersheds with scores very close to but greater than zero may be especially worth protecting, as they are very rare water sources in their area.

For only watersheds in the US, we also calculated a water scarcity score by averaging TotPerWi_m (the total length of perennial stream in the watershed, rescaled from 0-100), and SpringDens (the number of springs per square km, rescaled from 0-100). This value was not calculated for watersheds in Mexico, due to the lack of mapped springs in the country. Using this calculation, watersheds with lower values have greater water scarcity. Streams and springs in watersheds with scores very close to but greater than zero may be especially worth protecting, as they are very rare water sources in their area.

Sonoran Desert Scrub

For Sonoran Desert Scrub (SDS), major threats include the conversion of bare ground and native vegetation to herbaceous invasives, including buffelgrass (*Cenchrus ciliaris*), Sahara mustard (*Brassica tournefortii*), and others, as well as conversion of intact SDS to human built-up areas or cropland. For all SDS analyses, we only analyzed watersheds in which Brown and Lowe (citation) mapped SDS, and the percent of tropical or sub-tropical shrubland from the 2010 NALCMS (citation) was $\geqq$ 5. To examine the conversion of bare ground and native vegetation to herbaceous invasives, we combined SDSHerbTrend (within Brown & Lowe's "Arizona Upland Subdivision" in the HUC12, the trend in average percent non-tree cover from 2000-2016, calculated as the slope of the best-fit line to all yearly data points) and SDSBGTrend (within Brown & Lowe's "Arizona Upland Subdivision" in the HUC12, the trend in average percent bare ground from 2000-2016, calculated as the slope of the best-fit line to all yearly data points). We divided watersheds into four groups:

- *Strong Herbaceous to Bare ground Trend:* watersheds with the 50% most negative SDSHerbTrend and 50% most positive SDSBGTrend
- *Strong Bare ground to Herbaceous Trend:* watersheds with the 50% most positive SDSHerbTrend and 50% most negative SDSBGTrend
- *Weak Herbaceous to Bare ground Trend:* watersheds with the 50% least negative SDSHerbTrend and 50% least positive SDSBGTrend
- *Weak Bare ground to Herbaceous Trend:* watersheds with the 50% least positive SDSHerbTrend and 50% least negative SDSBGTrend

Some watersheds had another combination of trends. Watersheds with a strong bare ground to herbaceous trend may be experiencing invasion of buffelgrass or nonnative annuals. To examine the risk of conversion from native SDS to human modification, we combined PerSDS (Percent of HUC12 that is "Tropical or sub-tropical shrubland", according to the 2010 NALCMS) and SDSMod (within Brown & Lowe's "Arizona Upland Subdivision" in the HUC12, the percent "Cropland" and "Urban and built-up" combined , according to the 2010 NALCMS). We divided watersheds into four groups:

- *Abundant SDS, High modification:* watersheds in the top 50% of PerSDS and top 25% of SDSMod
- *Less SDS, High modification:* watersheds in the bottom 50% of PerSDS and top 25% of SDSMod
- *Abundant SDS, Low modification:* watersheds in the top 50% of PerSDS and bottom 75% of SDSMod
- *Less SDS, Low modification:* watersheds in the bottom 50% of PerSDS and bottom 75% of SDSMod

Watersheds with abundant SDS and high modification may be most in danger of losing significant areas of high quality SDS habitat.

Connectivity Areas

For connectivity areas, one of the greatest concerns is loss of connectivity due to human use of the area. To look at which corridors were most at risk, we calculated the mean value of the Human Influence Index (HII, citation) within each Connectivity Area. Areas with higher HII values are at greater risk of loss of connectivity.

ii. Products

Forest Cores -

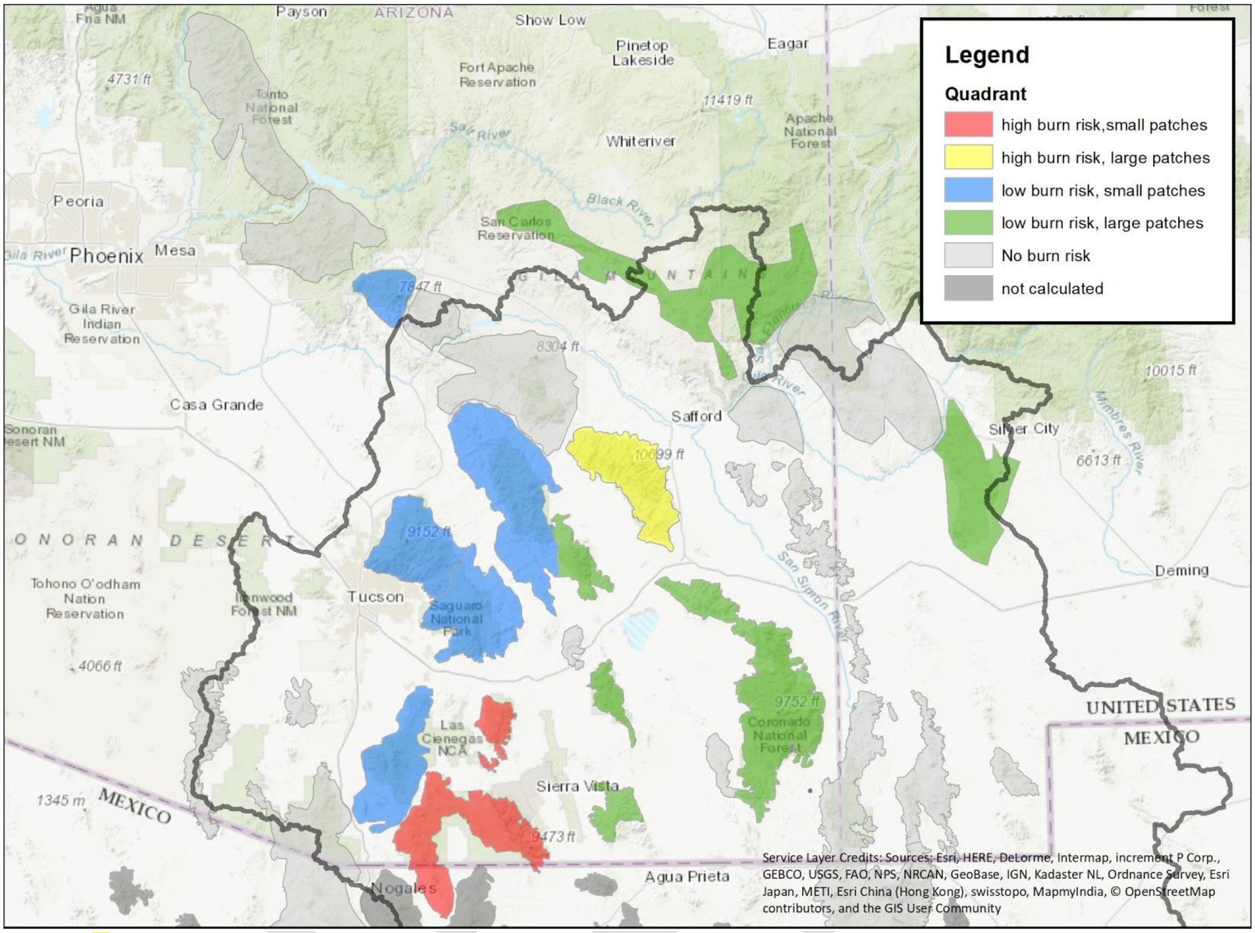

Figure X. Forest Cores, color coded by burn risk/patch size category:

- *High Burn Risk, Small Patches:* cores in the top 25% of BurnRisk and bottom 50% of MEWMeanArea
- *High Burn Risk, Large Patches:* cores in the top 25% of BurnRisk and top 50% of MEWMeanArea
- *Low Burn Risk, Small Patches:* cores in the bottom 75% of BurnRisk and bottom 50% of MEWMeanArea
- *Low Burn Risk, Large Patches:* cores in the bottom 75% of BurnRisk and top 50% of MEWMeanArea

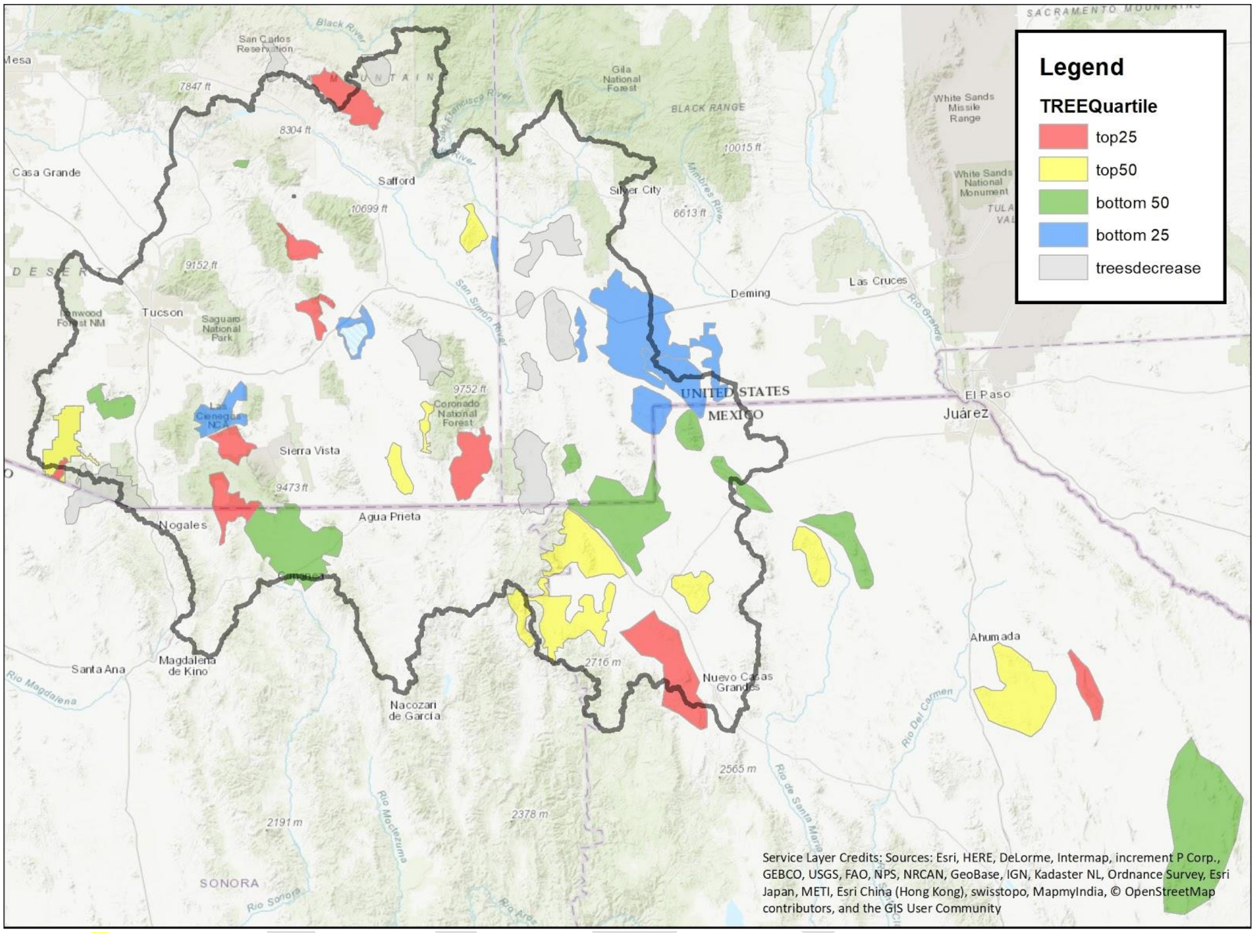

Figure X. Grassland Cores, color coded by tree trend quartile. The quartiles represent the trend in the average percent tree cover from 2000-2016, calculated as the slope of the best-fit line to all yearly data points. We divided cores into quartiles of GrassTreeTREND, including four quartiles for positive trends where tree cover is increasing (top 25 - 25% increasing most strongly, top 50 - increasing strongly, bottom 50 - increasing moderately, and bottom 25 - increasing slightly), and one category for a negative trend in tree cover (trees decrease).

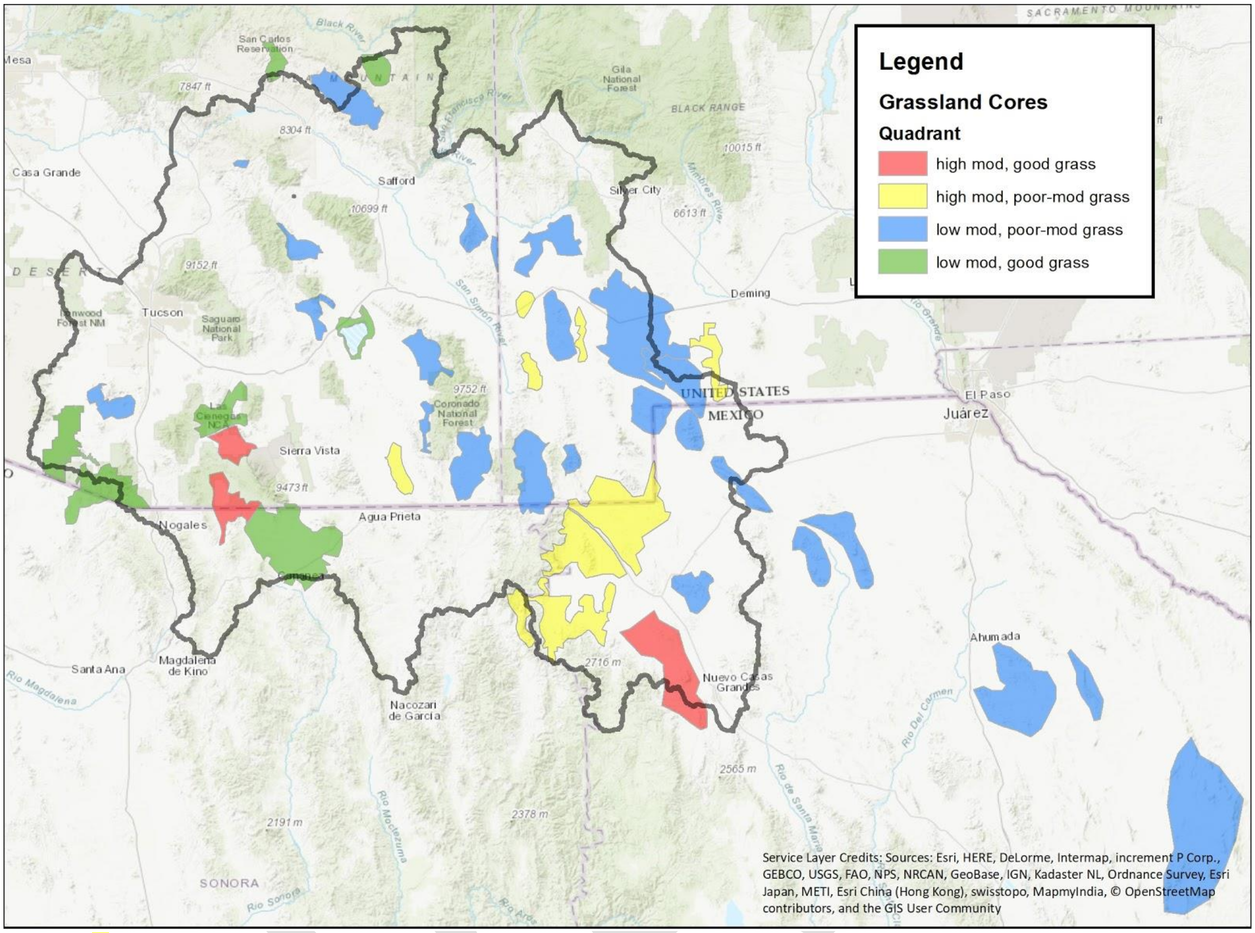

Figure X. Grassland Cores, color coded by human modification/grassland quality category:

- *Good Grassland, High Modification:* the top 25% of GoodGrass and top 25% of PerGrassMo
- *Good grassland, Low Modification:* cores in the top 25% of GoodGrass and bottom 75% of PerGrassMo
- *Poor to Moderate Grassland, Low Modification:* cores in the bottom 75% of GoodGrass and bottom 75% of PerGrassMo
- *Poor to Moderate Grassland, High Modification:* cores in the bottom 75% of GoodGrass and top 25% of PerGrassMo

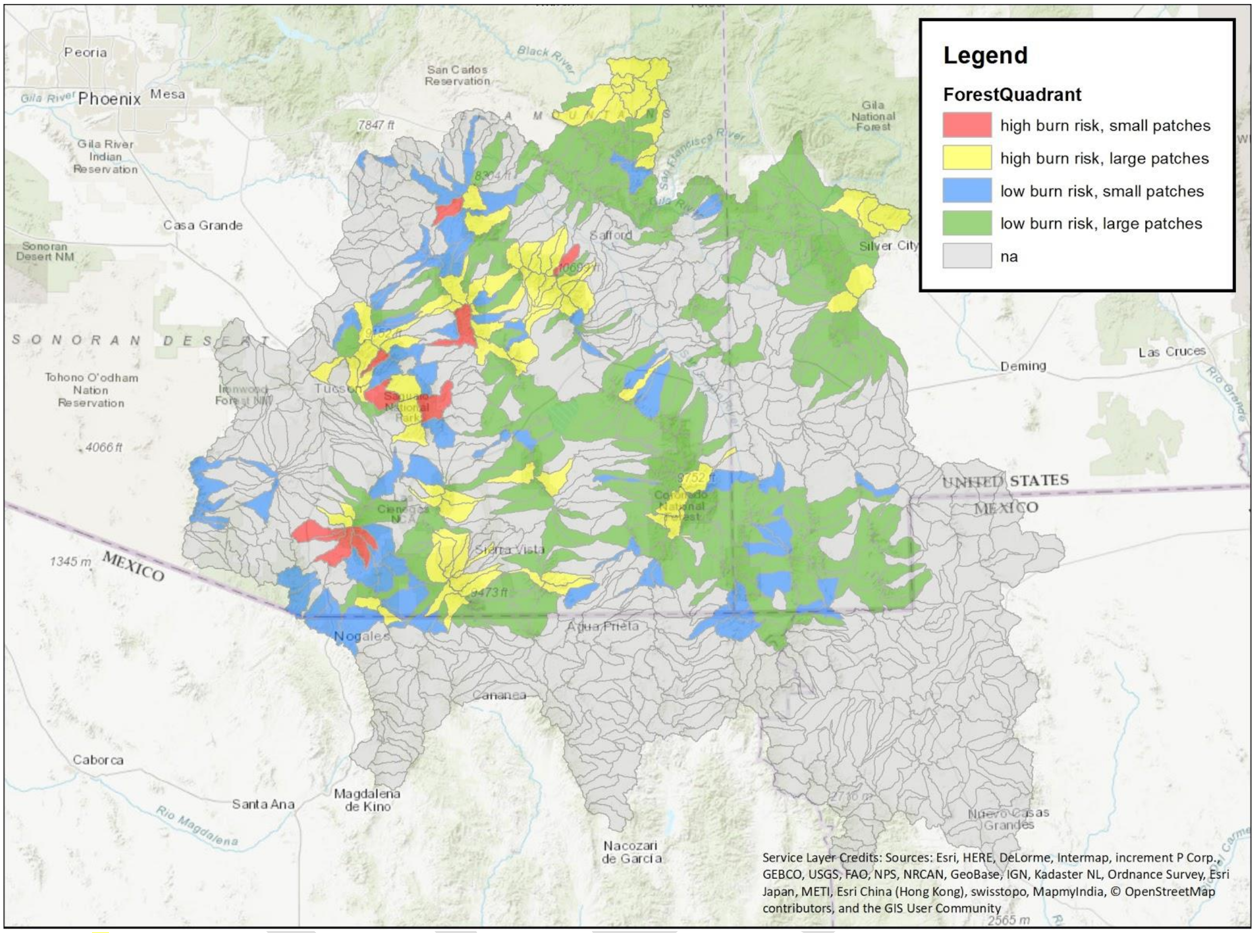

Figure X. HUC12 watersheds, color coded by burn risk/patch size category:

- *High Burn Risk, Small Patches:* watersheds in the top 25% of BurnRisk and bottom 50% of MEWMeanArea
- *High Burn Risk, Large Patches:* watersheds in the top 25% of BurnRisk and top 50% of MEWMeanArea
- *Low Burn Risk, Small Patches:* watersheds in the bottom 75% of BurnRisk and bottom 50% of MEWMeanArea
- *Low Burn Risk, Large Patches:* watersheds in the bottom 75% of BurnRisk and top 50% of MEWMeanArea

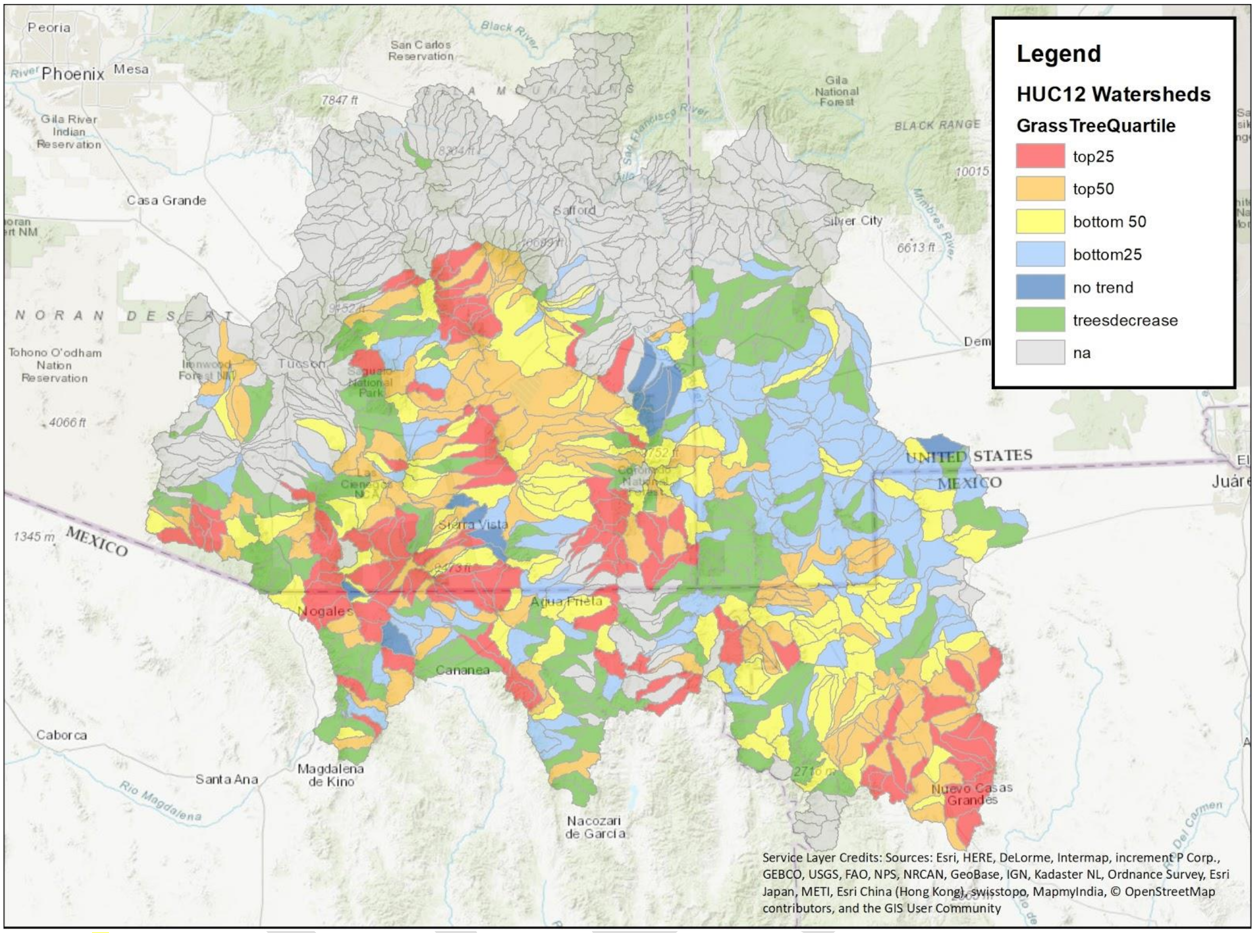

Figure X. HUC12 watersheds, color coded by tree trend category within their grasslands. The quartiles represent the trend in the average percent tree cover from 2000-2016, calculated as the slope of the best-fit line to all yearly data points. We divided cores into quartiles of GrassTreeTREND, including four quartiles for positive trends where tree cover is increasing (top 25 - 25% increasing most strongly, top 50 - increasing strongly, bottom 50 - increasing moderately, and bottom 25 - increasing slightly), and one category for a negative trend in tree cover (trees decrease).

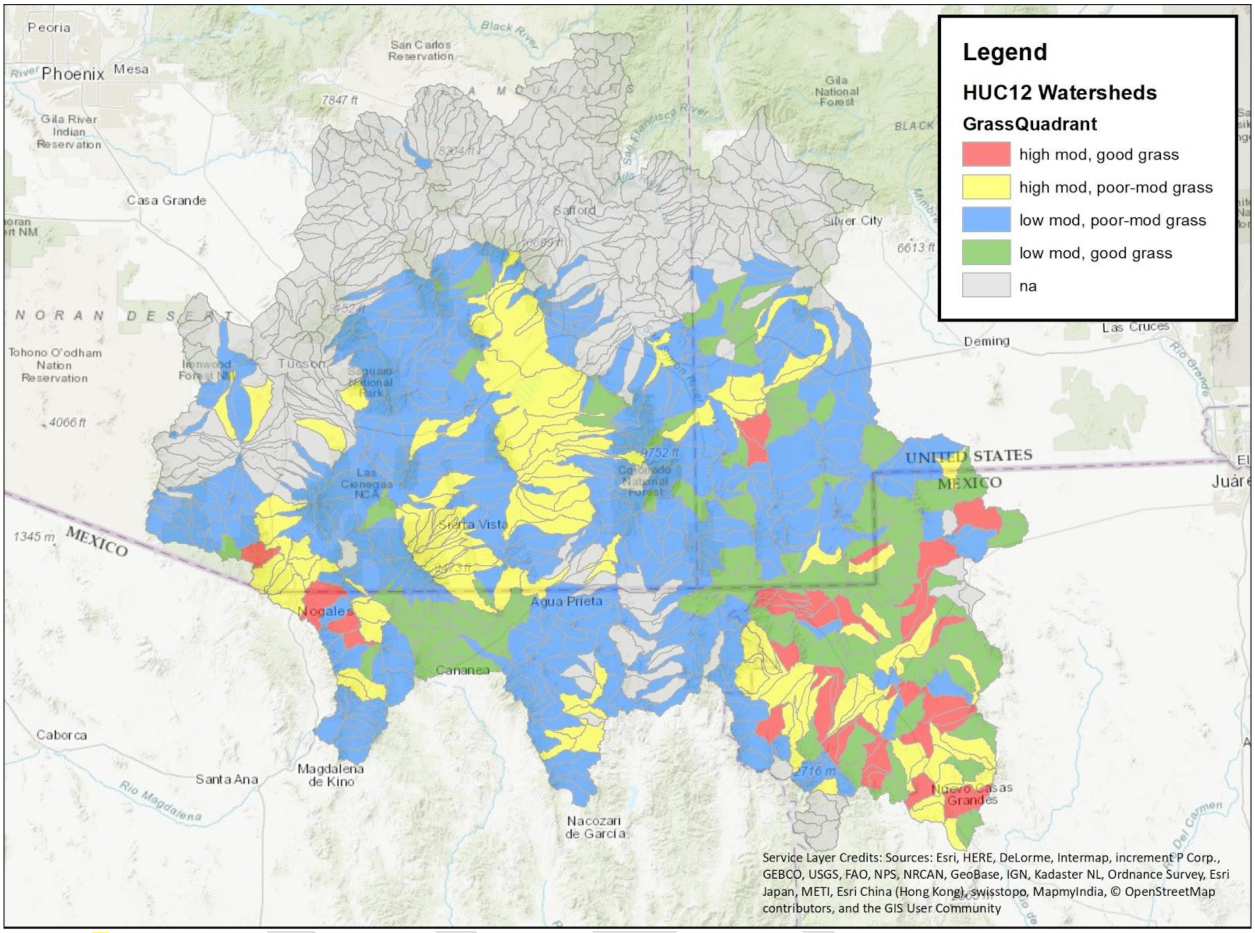

Figure X. HUC12 watersheds, color coded by human modification/grassland quality category within their grasslands:

- *Good Grassland, High Modification:* the top 25% of GoodGrass and top 25% of PerGrassMo
- *Good grassland, Low Modification:* cores in the top 25% of GoodGrass and bottom 75% of PerGrassMo
- *Poor to Moderate Grassland, Low Modification:* cores in the bottom 75% of GoodGrass and bottom 75% of PerGrassMo
- *Poor to Moderate Grassland, High Modification:* cores in the bottom 75% of GoodGrass and top 25% of PerGrassMo

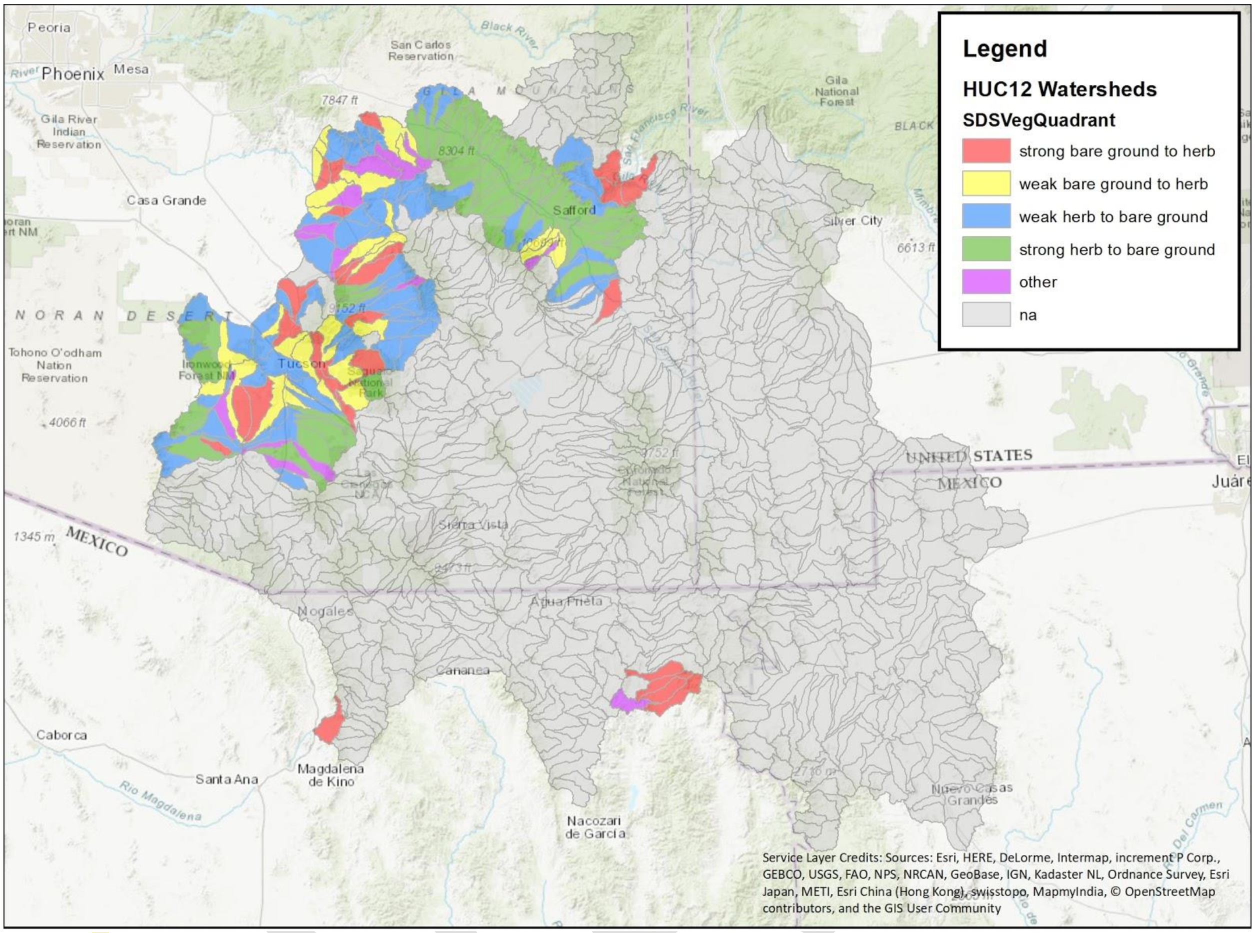

Figure X. HUC12 watersheds, color coded by bare ground/herbaceous cover trend category within their Sonoran Desert Scrub:

- *Strong Herbaceous to Bare ground Trend:* watersheds with the 50% most negative SDSHerbTrend and 50% most positive SDSBGTrend
- *Strong Bare ground to Herbaceous Trend:* watersheds with the 50% most positive SDSHerbTrend and 50% most negative SDSBGTrend
- *Weak Herbaceous to Bare ground Trend:* watersheds with the 50% least negative SDSHerbTrend and 50% least positive SDSBGTrend
- *Weak Bare ground to Herbaceous Trend:* watersheds with the 50% least positive SDSHerbTrend and 50% least negative SDSBGTrend

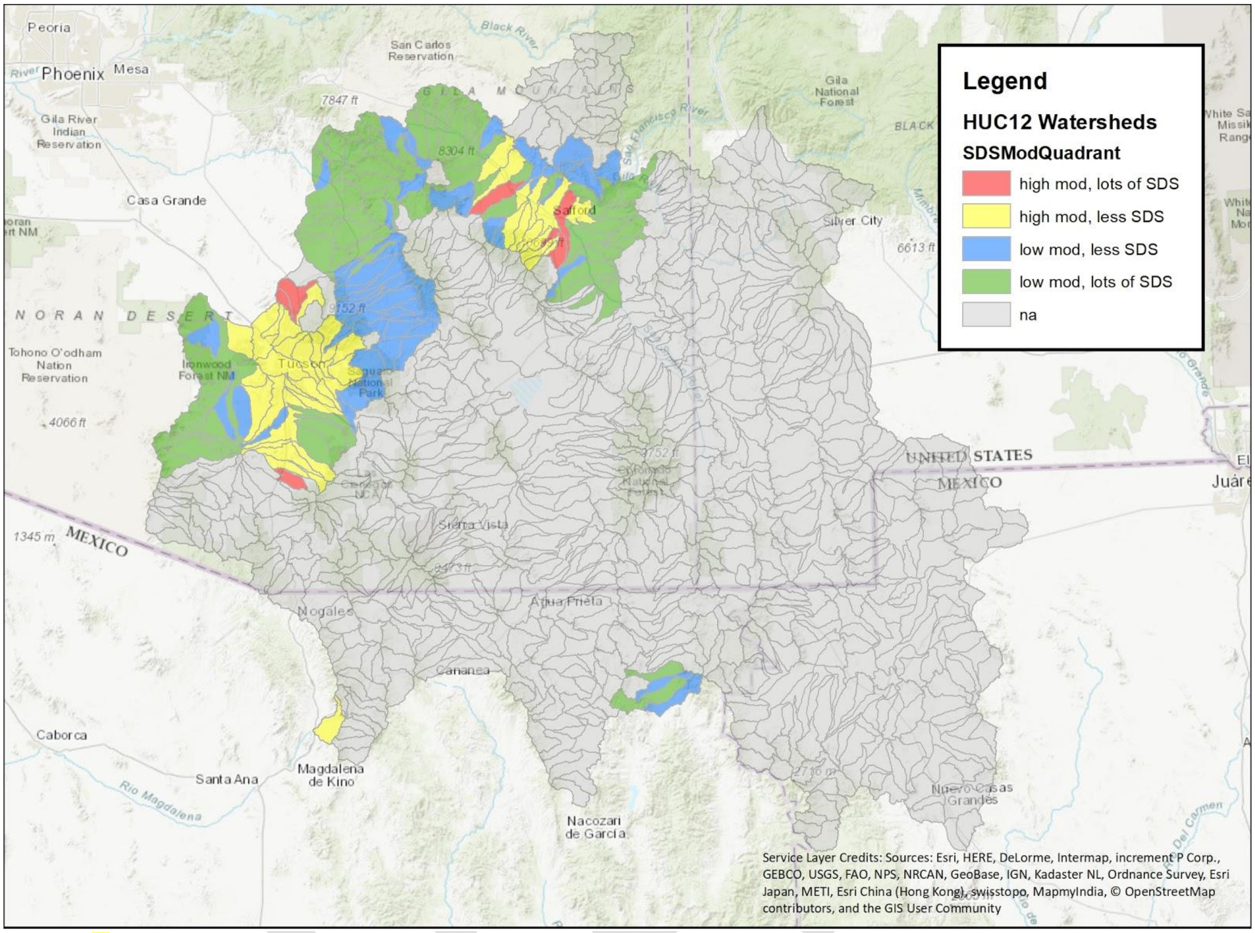

Figure X. HUC12 watersheds, color coded by percent desertscrub/percent modified category within their Sonoran Desert Scrub:

- *Abundant SDS, High modification:* watersheds in the top 50% of PerSDS and top 25% of SDSMod
- *Less SDS, High modification:* watersheds in the bottom 50% of PerSDS and top 25% of SDSMod
- *Abundant SDS, Low modification:* watersheds in the top 50% of PerSDS and bottom 75% of SDSMod
- *Less SDS, Low modification:* watersheds in the bottom 50% of PerSDS and bottom 75% of SDSMod

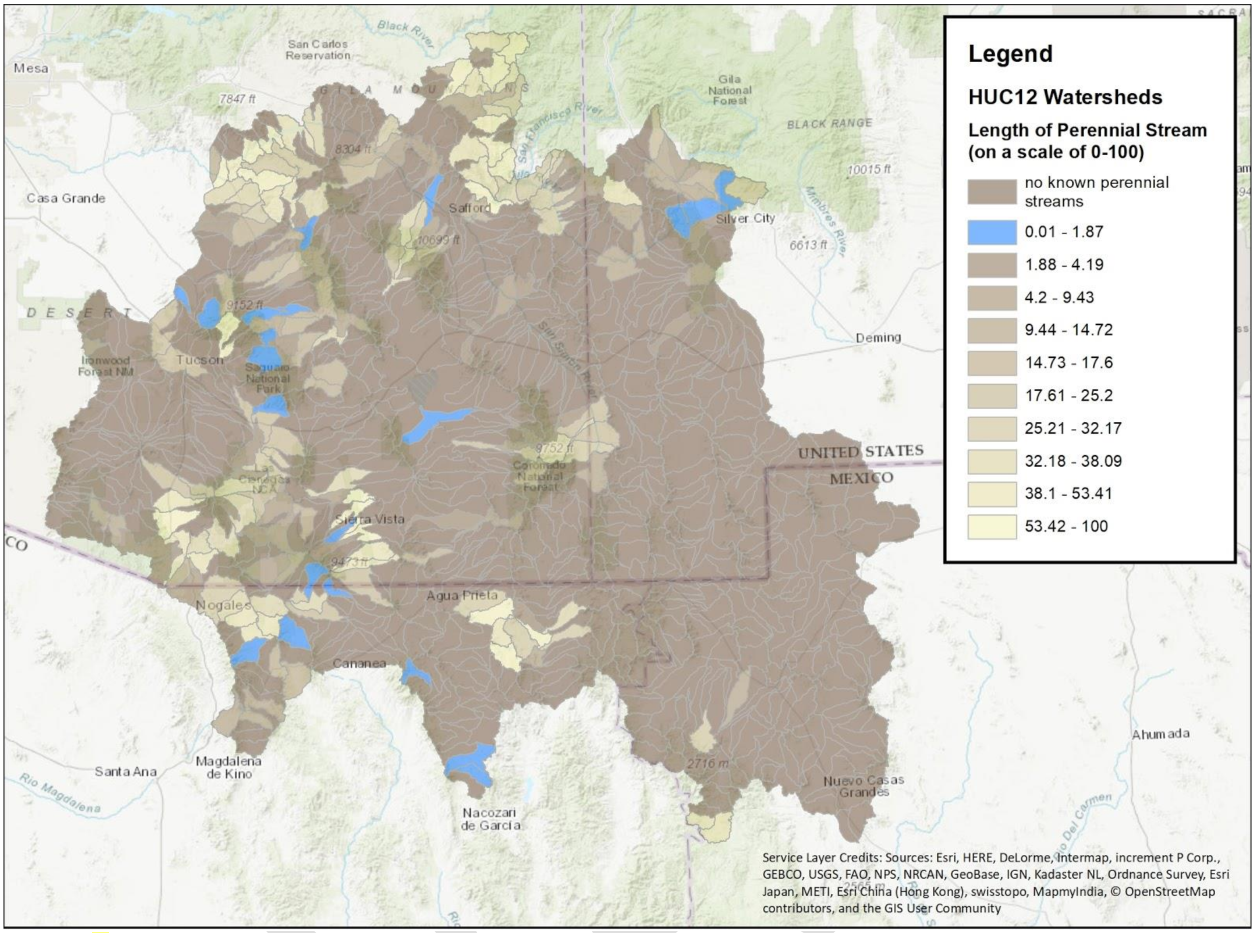

Figure X. HUC12 watersheds, color coded by mapped perennial stream scarcity. Watersheds with some mapped water, and the highest scarcity (low Water_Scarce score) are highlighted in blue.

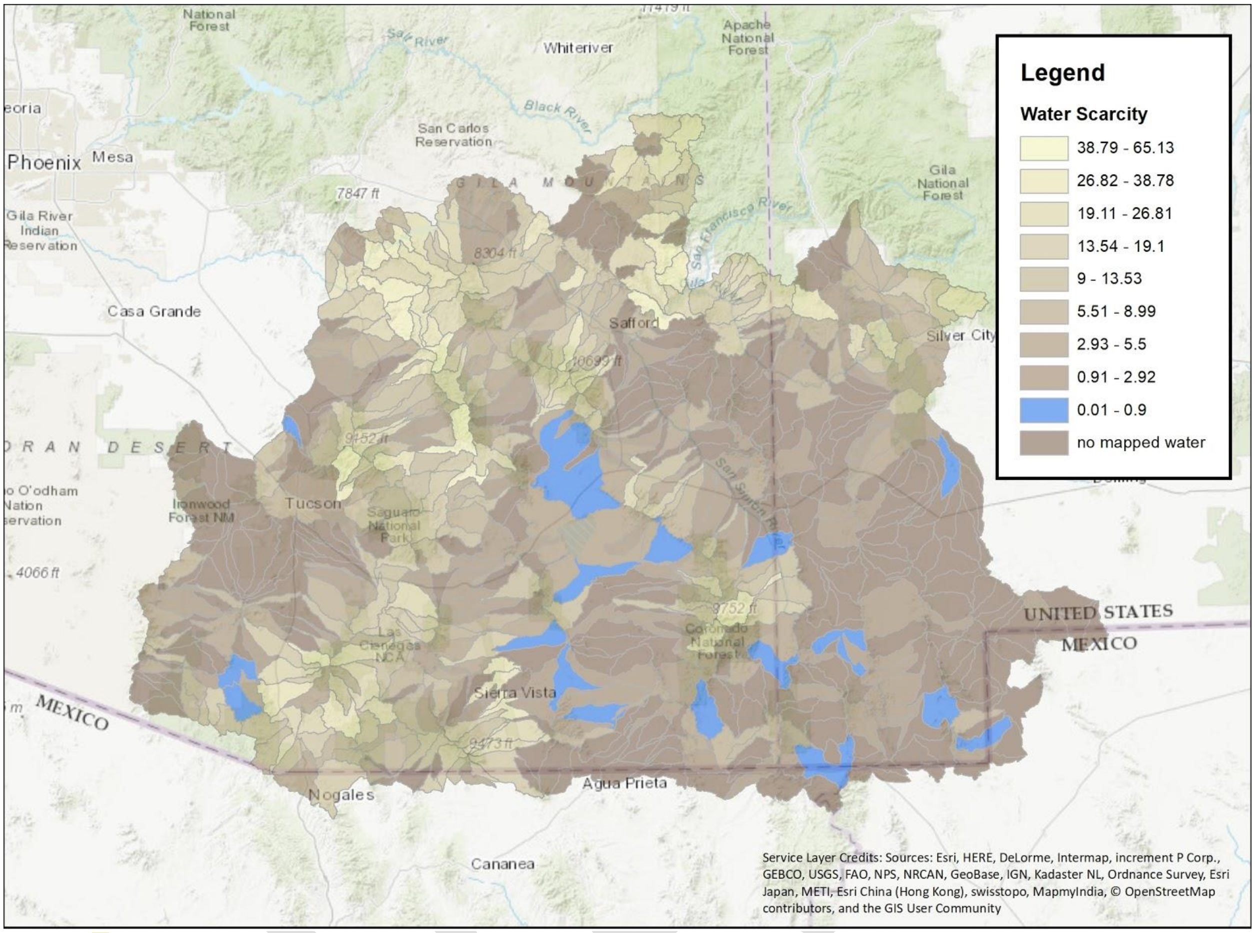

Figure X. HUC12 watersheds, color coded by mapped surface water scarcity. Water scarcity was calculated only for US watersheds, due to the lack of available data on springs in Mexico. Watersheds with some mapped water, and the highest scarcity (low Water_Scarce score) are highlighted in blue.

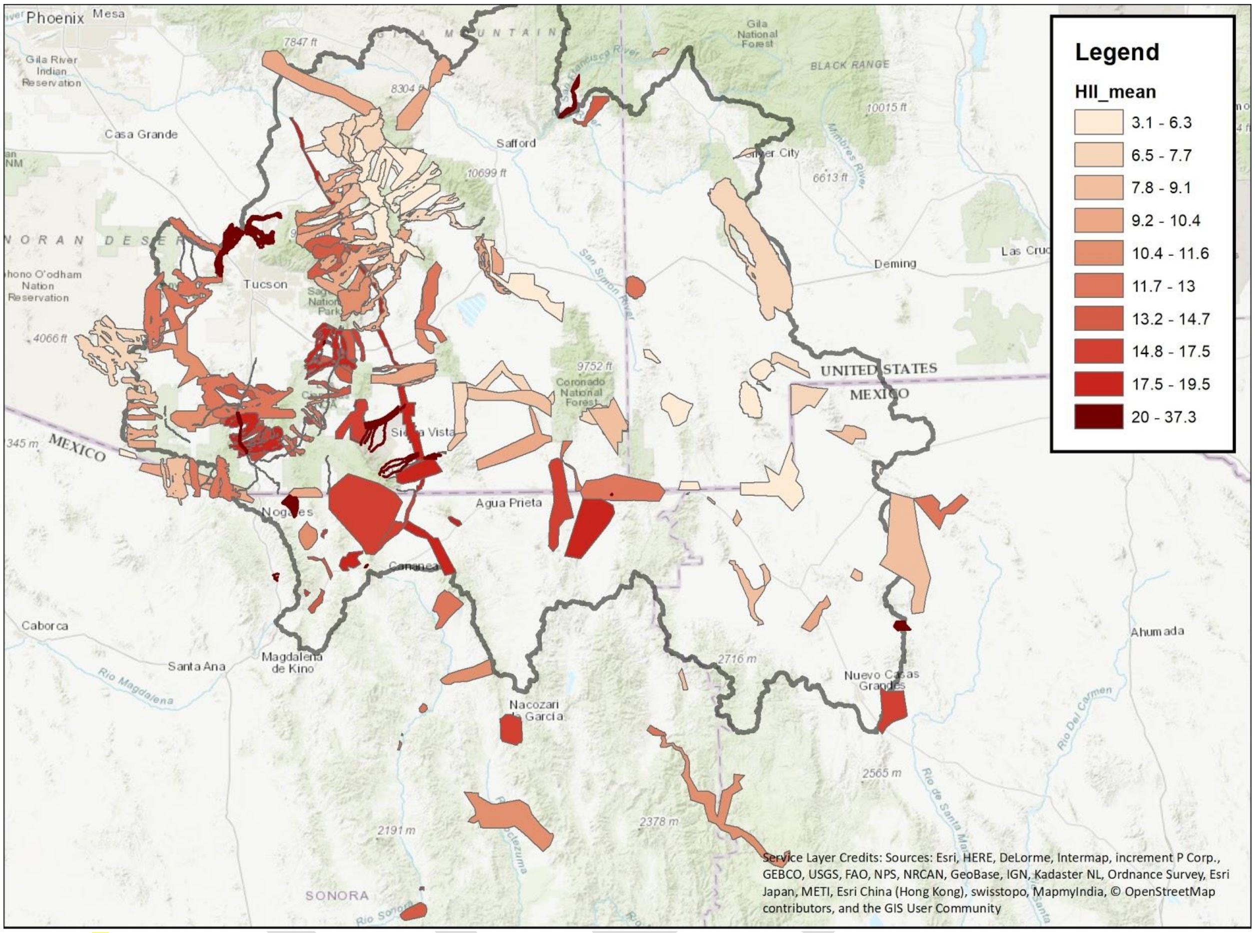

Figure X. Connectivity Areas, color coded by degree of human influence (higher values = greater human influence).

iii. Results and Interpretation

Forest Cores -

To be in the top 25% of BurnRisk, cores had to have >3% at risk of high burn severity. To be in the bottom 50% of MEWMeanArea, the average patch size had to be <154 square meters. Fifty Forest Cores (63%) were solely in Mexico, so had no BurnRisk score available and were excluded from the analysis. Fifteen Forest Cores partially or wholly in the US had no risk of high severity fire, based on the spatial data we used to calculate fire risk (Figure X). It is unlikely that these cores truly have no risk of high severity fire, but they are probably the cores that managers can be least worried about. Two cores, the Huachuca-Patagonia core and the Whetstone core, were in the category of most concern - high burn risk and small patches. These cores have larger areas at risk of high severity fire and smaller patches of forest, making them most at risk of losing forest to fire. The distribution of cores in each category is in Table X.

Table X. Distribution of Forest Cores in fire risk and patch size categories. Cores solely in Mexico were excluded due to lack of data.

Category	Count	Percent (of analyzed)
High burn risk, small patches	2	7%
High burn risk, large patches	1	3%
Low burn risk, small patches	5	17%
Low burn risk, large patches	6	21%
No high severity burn risk	15	52%

Grassland Cores -

To be in the top 25% of woody encroachment, Grassland Cores had to have > +7.5% GrassTreeTrend; to be in the tp 50%, > +3% GrassTreeTrend, and to be in the bottom 25%, < +1.7% GrassTreeTrend. The nine cores with the greatest increases in tree cover were the Buenos Airies NWR Grassland, Severin Canyon, Galiuro Oak Creek, Janos Valley South, Bonita Creek, Sierra del Fierro, San Rafael Valley, San Bernardino Valley, and South Sonoita Valley (Figure X). Two of these cores are in Mexico, while the rest are in the US. Nine (20%) of the Grassland Cores had decreasing trends in tree cover, so are likely of least concern. These core were Animas Valley Mid, Animas Valley I10, Pyramid, Antelope Flats, S of the Gila, Animas Valley, Big Prairie, Pajarita Mountain Grassland, and Pinery Creek.

To be in the top 25% of grassland quality (GoodGrass), cores had to have an average GrassMeanArea (rescaled from 0-100, the average size of grassland patches) and GrassHerb2016 (rescaled from 0-100, the percent of grassland that was not tall trees or bare ground) >36. To be in the top 25% of PerGrassMo, the percent of the grassland modified by humans had to be > 1%. Three cores, South Sonoita Valley, San Rafael Valley, and Janos Valley South, were in the category of most concern - good grassland with high modification (Figure X). These cores have higher non-tree vegetation cover, larger patches, but greater human modification, making them potentially most at risk of losing quality grassland to human development. All three of these cores were also in the top quartile of tree encroachment. The distribution of cores in each category is in Table X.

Table X. Distribution of Grassland Cores in grassland quality and human modification categories.

Category	Count	Percent
Good grassland, high modification	3	7%

Poor to moderate grassland, high modification	8	18%
Poor to moderate grassland, low modification	25	57%
Good grassland, low modification	8	18%

HUC12 Watersheds -

Forests -

In HUC12 watershed analysis of forests, 238 watersheds in Mexico were excluded due to lack of burn severity data in the country. Another 189 watersheds in the US were excluded because they were < 5% forested. For the remaining 359 watersheds, to be in the top 25% of BurnRisk, watersheds had to have >0.4% at risk of high burn severity. To be in the bottom 25% of MEWMeanArea, the average patch size had to be <85.63 square meters. Eleven watersheds, primarily in the Santa Rita Mountains and Rincon Mountains, with one watershed in each of the Galiuro Mountains, Santa Teresa Mountains, and Pinaleño Mountains, were in the category of most concern - high burn risk and small patches (Figure X). These watersheds have larger areas at risk of high severity fire and smaller patches of forest, making them most at risk of losing forest to fire. The distribution of watersheds in each category is in Table X.

Table X. Distribution of watersheds in fire risk and patch size categories. Watersheds with a BurnRisk of zero are included in the low burn risk category. Those solely in Mexico were excluded due to lack of data.

Category	**Count**	**Percent (of analyzed)**
High burn risk, small patches	11	2%
High burn risk, large patches	79	14%
Low burn risk, small patches	79	14%
Low burn risk, large patches	190	35%

Grasslands -

We excluded 293 watersheds because they were < 5% grassland.

To be in the top 25% of woody encroachment, watersheds had to have > +7.29742% GrassTreeTrend; to be in the top 50%, > +3.435% GrassTreeTrend, and to be in the bottom 25%, < +1.52% GrassTreeTrend. The top 25% of watersheds with the strongest trends in increasing tree cover comprised 110 watersheds (Figure X). No trend was seen in 12 watersheds. One hundred forty-three (24%) of the watersheds had decreasing trends in tree cover in their grasslands, so are likely of least concern. The distribution of watersheds in each category is in Table X.

Table X. Distribution of watersheds in tree invasion trend categories.

Category	**Count**	**Percent**
Top 25% trees increasing trend	110	18%
Top 50% trees increasing trend	110	18%
Bottom 50% trees increasing trend	110	18%
Bottom 25% trees increasing trend	111	19%
No Trend	12	2%
Trees decreasing	143	24%

To be in the top 25% of grassland quality (GoodGrass), watersheds had to have grasslands with an average GrassMeanArea (rescaled from 0-100, the average size of grassland patches) and GrassHerb2016 (rescaled from 0-100, the percent of grassland that was not tall trees or bare ground) > 29.54. To be in the top 25% of PerGrassMo, the percent of the grassland in the watershed modified by humans had to be > 2.92%. Thirty-seven watersheds were in the category of most concern - good grassland with high modification (Figure X). Most of these were in Mexico, in the state of Chihuahua, where the primary threat is conversion to agriculture. These watersheds have higher non-tree vegetation cover, larger patches, but greater human modification, making them potentially most at risk of losing quality grassland to human development. The distribution of watersheds in each category is in Table X.

Table X. Distribution of HUC12 watersheds in grassland quality/human modification categories.

Category	**Count**	**Percent**
Good grassland, high modification	37	6%
Poor to moderate grassland, high modification	112	19%
Poor to moderate grassland, low modification	335	56%
Good grassland, low modification	112	19%

Sonoran Desert Scrub -

We excluded 709 watersheds because they did not have any SDS mapped by Brown and Lowe (citation), or they had some mapped but were < 5% desertscrub according to the NALCMS (2010). This left 180 watersheds to analyze.

Overall, trends in bare ground and non-tree vegetation (herbaceous) cover were highly correlated (Figure X, r^2=0.92). To be in the top 50% most negative SDSHerbTrend, watersheds had to have a value of < -14.5%; to be in the top 50% most positive SDSHerbTrend, watersheds had to have a value of > +12%. To be in the top 50% most negative SDSBGTrend, watersheds had to have a value of < -9.7%; to be in the top 50% most positive SDSBGTrend, watersheds had to have a value of > +18.3%. Twenty-seven watersheds were in the category of most concern - a strong bare ground to herbaceous trend (Figure X). These watersheds have strong decreasing bare ground and strong increasing non-tree vegetation cover, highlighting them as potentially experiencing invasion of non-native herbaceous plants. The distribution of watersheds in each category is in Table X.

Figure X. Correlation between trends in bare ground and non-tree vegetation (herbaceous) cover. Points in the upper left box represent watersheds with a strong bare ground to herbaceous trend, while points in the lower right box represent watersheds with a strong herbaceous to bare ground trend.

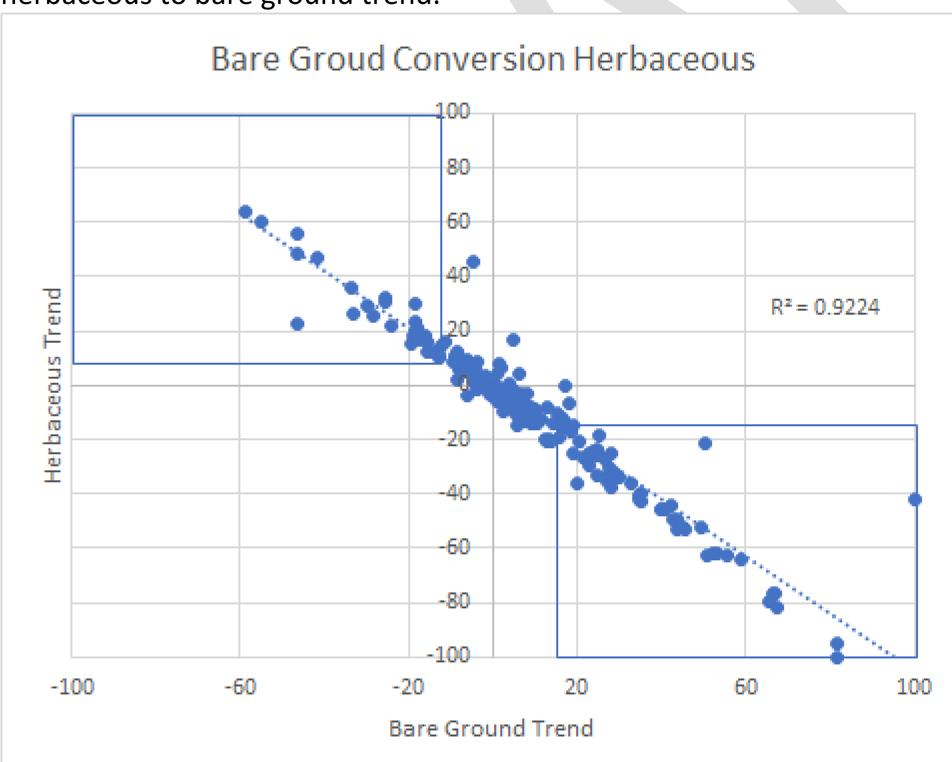

Table X. Distribution of watersheds in herbaceous/bare ground trend categories.

Category	Count	Percent
Strong bare ground to herbaceous trend	27	15%
Weak bare ground to herbaceous trend	27	15%
Weak herbaceous to bare ground trend	58	32
Strong herbaceous to bare ground trend	54	30%
Other trend	14	8%

To be in the top 50% of PerSDS, the percent cover of “tropical or sub-tropical shrubland" had to be >85.9%. To be in the top 25% of SDS_Mod, the percent cover of “urban or built-up" or “cropland” had to be >9%. Six watersheds in the Santa Cruz River and Gila River Valleys were in the category of most concern - high modification and abundant SDS (Figure X). These watersheds have higher cover of Sonoran Desert Scrub, but also high levels of human development, potentially making them most at risk of large intact patches of SDS. Eighty-four watersheds had abundant SDS and low modification, primarily in the Lower Gila Valley, Lower San Pedro Valley, and Lower Avra Valley - these may be areas most likely to keep large amounts of SDS. The distribution of watersheds in each category is in Table X.

Table X. Distribution of watersheds in percent desertscrub/percent modified categories.

Category	Count	Percent (of analyzed)
Abundant SDS, high modification	6	3%
Less SDS, high modification	39	22%
Less SDS, low modification	51	28%
Abundant SDS, low modification	84	47%

Water -

Out of 889 total watersheds, 442 (50%) did not have any mapped perennial streams or springs. However, this likely includes a substantial number of watersheds in Mexico that do in fact have springs - we simply don’t have a mapped record of them. The 10% (45) of watersheds that have the least mapped water may be places where that water is particularly valuable to both the environment and humans. Water in those watersheds may be a priority for protection (Figure X).

Connectivity Areas -

Our final compiled shapefile contains 171 mapped Connectivity Areas, some of which overlap. The file contains 94 from the LCD process, 20 from Wilbor (2014), 19 from Atwood et al (2011), 14 from the AZ Missing Linkages Project, 9 from the AZGFD Pima County Wildlife Connectivity Assessment, 8 from Menke (2008), 7 from Hass (2001), and 3 from Dan Majka. The nineteen (10%) Connectivity Areas with the highest human influence are listed in Table X. Most (14) are in the San Pedro River and Santa Cruz River Valleys in the US, 4 are in Mexico, and 1 is in the Upper Gila River in Arizona (Figure X).

Table X. Connectivity Areas in the top 10% of Human Influence Index.

Name	**HII mean**
Slaughterhouse Cyn, Huachuca Cyn, Babocomari River	37.3
Rock Spring Canyon	32.6
Upper Santa Cruz River Corridor	30.7
Babocomari corridor	29.9
Santa Catalina Oracle X-Tortolita Hwy 77 break	29.7
Tucson to Tortolita	26.8
San Francisco River Corridor	25.5
Tortolita-Santa Catalina	24.6
Escondida to Capulin Hidalgo la Campana break	23.6
Blacktail Canyon	22.5
Tucson-Tortolita	22.2
Las Cienegas Fleming-Cienega Creek I-10 break	22.0
San Luis-Guadalupe Peloncillo Hwy 2 break	22.0

Ramsey Cyn and Carr Cyn	21.8
Miller Cyn	21.5
El Pinito to San Antonio Hwy break	20.6
San Pedro to Mule	20.2
Atascosa-Cibuta to El Pinito Hwy 15 break	20.0
Marquita-Elenita Hwy 2 break	20.0

iiii. Data Gaps and Future Improvements

We had to drop the greatest number of indicators due to lack of species-specific information (Appendix X). While there are isolated pockets of information about particular plant and animal species, that information is very rarely available across the entire pilot area. In grassland and Sonoran Desert Scrub, this is a particular shortcoming. While we could infer something about the quality of grassland or invasion of herbaceous plants in SDS from vegetation structure information (tree, non-tree, and bare ground cover), not knowing plant species composition is a major hindrance to fully understanding the quality or condition of these environments. Similarly, managers need to understand how different bird guilds are doing in each ecosystem, as well as certain indicator species like pronghorn and mule deer, but we could not find comprehensive data on these species.

We dropped many stream indicators, and had originally planned to analyze riparian areas across the pilot area. However, stream data is sparse in this region, as is groundwater data. Riparian areas by their nature are a zone around streams. We would need to define polygons of riparian areas within which to analyze riparian or stream indicators. However, these have not been defined for the entire study area, and doing so would represent a substantial undertaking. Future iterations of this LCD may well be able to analyze riparian areas, as the Arizona Game and Fish Department is currently in the process of defining riparian polygons across the entire state. However, the data is still missing for Mexico and New Mexico.

Another gap was yearly data on loss of ecosystems to development. The closest product we could find for both Mexico and the U.S. was the NALCMS, which is a newer product and only available for 2005 and 2010. Creating yearly data is possible, but would require a separate effort.

There were two major gaps that we weren't able to bridge for data in Mexico - lack of information on fire and fuels, and spring locations. There is some burn severity information for fires in Mexico (Villareal and Poitras 2018), but it is only available through 2011 and does not classify dNBR into burn severity classes. For springs, we were not able to find data on locations, other than a limited number of surveys available in the SSI database (citation). Assuming the spring density in the Mexican portion of the pilot area is similar to the U.S., there are likely at least 750 springs in Mexico that we were not able to account for.

Lack of survey data for springs was another major gap. While over 300 springs have been surveyed in the US portion of the pilot area, and several dozen in Mexico, that represents fewer than 10% of all the springs in the region. Furthermore, surveys are not randomly distributed across the landscape. This meant that we could make few inferences about springs, so we limited the analysis to simple metrics like the density of springs (in the U.S. only). Groundwater data is even more patchy than spring data, and only available in the US.

Furthermore, our decision to use HUC12 watersheds as the primary unit of analysis limited the area which we could analyze in Mexico to a relatively small region near the border with the U.S., where watersheds were already delineated. Future iterations of this LCD should either delineate similarly-sized watersheds in Mexico, or reanalyze the entire region using a different units of analysis, such as hexagons.

Similarly, future iterations should consider more careful definition of forest and grassland cores, and perhaps connectivity areas. For forest cores, we began with an existing dataset (Deyo et al. 2013), and added cores based on plant community and mountain ranges between the Mogollon RIm and the Sierra Madre Occidental. More detailed criteria should be created for how to define forest cores. Potential criteria could be change in slope, change in vegetation, change in ruggedness, etc. Should cores be based on mountain ranges, or simply blocks of forest habitat? Grassland cores would benefit from a similar examination. This would improve comparisons of different core areas and make tracking changes over time more meaningful.

Other suggestions for future versions include adding data on vegetation cover from prior to 2000, as far back as it is available, and changing the method for understanding Summer NDVI values. The current calculation is the average value in each watershed for the summer monsoon season (July, August, and September). It may be more meaningful to subtract the maximum NDVI values for this period from the NDVI values in June, the driest time of year. This would allow us to understand the relative green-up between different areas of the landscape.

Villarreal, M.L., and Poitras, T.B., 2018, Differenced Normalized Burn Ratio (dNBR) data of wildfires in the Sky Island Mountains of the southwestern US and Northern Mexico from 1985-2011: U.S. Geological Survey data release, https://doi.org/10.5066/P9P3NIXR.