

# **Mapping Threats to Wilderness Character in the Saguaro National Park Wilderness**

James Tricker, Becky MacEwen, Ray O'Neil, Peter Landres

April 2016

**Author's note**

Owing to staff turnover of key members of the project core team and the tight time constraints for completing this project, this report is an abbreviated version of previous wilderness character mapping reports (Tricker et al. 2012; Tricker et al. 2014). Specifically, all sections have been shortened to cover only the essential elements of this project. For more detail on measure descriptions, data sources, processing techniques, and associated caveats, please contact Ray O'Neil, Saguaro National Park Chief Ranger.

## **Acknowledgements**

Special thanks to Patrick Gregerson and the NPS Park Planning and Special Studies division for providing the funding to undertake this project. Thanks also to the SAGU superintendent Darla Sidles for supporting this project. We are also indebted to the project core team and other SAGU staff who were always available to provide their expert opinion on all aspects of this project—we thank them for their continued passion and commitment to protecting the Saguaro wilderness and for supporting the wilderness ideal. Thanks are also extended to those from other land management agencies and research facilities/entities for providing data and consultation. Lastly, we want to thank Elizabeth Mejicano for formatting and editing the report.

## **List of Roles and Contributors**

### **Principle Contact**

Ray O’Neil  
Chief Ranger  
Division of Visitor and Resource Protection  
Saguaro National Park  
Phone: 520-733-5110, Email: [ray\\_o'neil@nps.gov](mailto:ray_o'neil@nps.gov)

### **Aldo Leopold Wilderness Research Institute**

Peter Landres – Ecologist/Research Application Program Leader  
James Tricker – GIS Analyst

### **Saguaro National Park Project Core Team**

Jesse Engebretson – SAGU Wilderness Fellow  
Becky MacEwen – GIS Specialist  
Ray O’Neil – Chief Ranger

### **Saguaro National Park Staff Consultation**

Kara O’Brien – Biological Science Technician  
Natasha Kline – Biologist  
Paul Austin – Former Chief Ranger

### **External Consultation**

Dan Duriscoe – Physical Scientist, Natural Sounds and Night sky Division, Natural Resource Stewardship and Science Directorate, National Park Service  
Dan Mennitt – Research Scientist, Department of Electrical and Computer Engineering, Colorado State University (in partnership with the Natural Sounds and Night sky Division, Natural Resource Stewardship and Science Directorate, National Park Service)

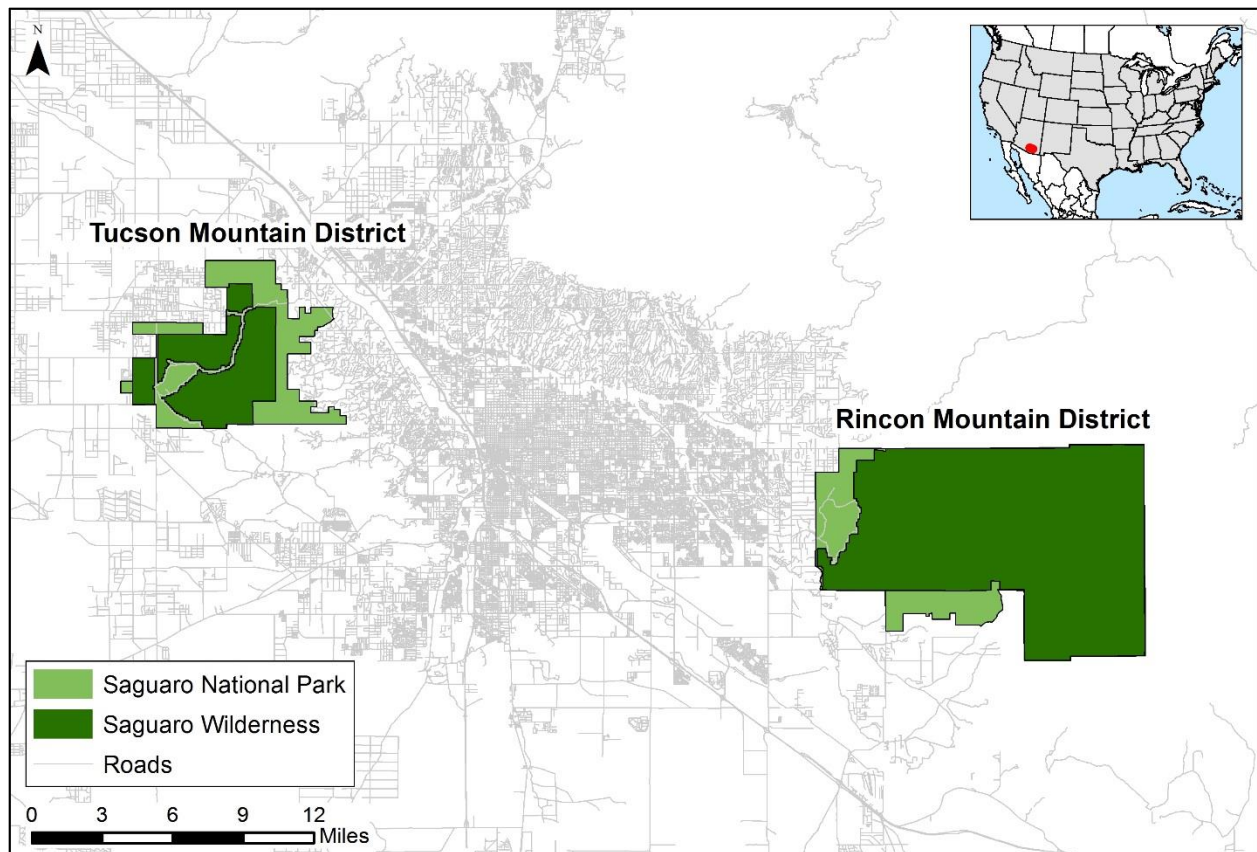
## **Introduction**

The Wilderness Act of 1964 (Public Law 88-577) established the National Wilderness Preservation System (NWPS) “for the protection of these areas, [and] the preservation of their wilderness character” (Section 2(a)). In congressional testimony clarifying the intent of wilderness designation, Howard Zahniser (1962) said, “The purpose of the Wilderness Act is to preserve the wilderness character of the areas to be included in the wilderness system, not to establish any particular use”; legal scholars (Rohlf and Honnold 1988; McCloskey 1999) subsequently confirmed that preserving wilderness character is the Act’s primary legal mandate. Furthermore, the policies of all four wilderness managing agencies state that they are to preserve wilderness character in all areas designated as wilderness.

Wilderness character is an inherent part of a wilderness, and varies across the landscape just as elevation, vegetation, and other landscape features vary from one place to the next. Maps that depict how wilderness attributes vary across the landscape from least to most wild have been produced at a variety of scales: globally (Sanderson et al. 2002), continentally (Carver 2010), nationally (Aplet et al. 2000), and locally (Carver et al. 2008). Adding to this body of work, a recent study for the Death Valley Wilderness (Tricker et al. 2012; Carver et al. 2013) has provided a spatially explicit description of impacts to wilderness character for all lands falling within a particular National Park Service (NPS) wilderness. This approach has been strongly supported by the NPS, and further studies have been conducted for wildernesses within Olympic, Denali, Sequoia and Kings Canyon, and now Saguaro National Park (SAGU).

### ***The Saguaro Wilderness***

SAGU was first established as a national monument in 1933 in order to preserve the saguaro cacti native to the region. In 1976, Congress designated the majority of the area as the Saguaro Wilderness. The monument was given national parkland status in 1994 and became Saguaro National Park. Today, the park comprises of 91,442 acres in Arizona, of which 70,905 acres are designated wilderness (Figure 1). One of the more urban parks and wildernesses managed by the National Park Service, SAGU is divided into two districts located approximately 20 miles east and 15 miles west of central Tucson. The western Tucson Mountain District (TMD) is just over 21,000 acres with relatively flat terrain; traversed by well-maintained dirt roads, the TMD receives mostly day-use visitors. The eastern Rincon Mountain District (RMD) is almost 63,000 acres with elevations ranging from 2,800 feet to 8,666 feet on Mica Mountain. Bordered to the east by the Forest Service administered Rincon Mountain Wilderness, the RMD is primarily roadless and attracts both overnight backpackers and day-use hikers. While SAGU contains approximately 127 miles of maintained trails split between the two districts, overnight camping is permitted only in six designated campgrounds located in the RMD.



**Figure 1.** Saguaro National Park

***Purpose of this mapping project***

The purpose of this project was to develop an approach that spatially depicts threats to wilderness character and how they vary across the Saguaro Wilderness. This mapping effort:

- Shows the current extent and magnitude of threats to wilderness character in the Saguaro Wilderness and how they vary across the landscape.
- Provides a measurement baseline from which future monitoring can show how threats to wilderness character change spatially over time.
- Allows SAGU to analyze the potential impacts of different management actions on wilderness character.
- Identifies areas within the wilderness where resource managers should make an effort to control or mitigate impacts. These efforts may include monitoring conditions, establishing thresholds, or taking direct action.
- Identifies specific activities or impacts outside the wilderness that may pose a substantial risk of degrading wilderness character inside wilderness.
- Improves internal staff communication about wilderness and wilderness character and improves external communication between the park and the public on related issues.
- Identifies and fills data gaps by collecting information from local staff and digitizing new spatial data.

In addition to the immediate benefits described above, this project improved and consolidated existing spatial datasets and generated new datasets. These datasets, and the maps produced by

this project, lay the groundwork for future wilderness character mapping efforts in the Saguaro Wilderness. When and if the park is able to conduct future iterations of the map of threats to wilderness character, the maps in this report can serve as the baseline for assessing how threats to wilderness character change spatially over time.

### ***Project overview***

This wilderness character mapping project used a Geographic Information System (GIS) to spatially describe and assess impacts to wilderness character in the Saguaro Wilderness. With this approach, it is essential to understand the variety of activities and influences that “threaten” wilderness character, as well as the role of wilderness managers in mitigating or responding to such threats. In the Saguaro Wilderness, there has been, and continues to be, a substantial amount of human influence—ranging from a long history of human use and resource extraction, to current high visitation levels, to reasonably foreseeable future impacts from climate change. Although the Saguaro Wilderness is far from being considered a “pristine” or “pure” wilderness, managers are nevertheless tasked with protecting and preserving its wilderness character from further degradation. Only by understanding the myriad human influences that affect—or “threaten”—wilderness character can managers meet wilderness stewardship goals.

For this report, “threats” to wilderness character are defined as a combination of:

- Historical activities that continue to degrade wilderness character (e.g. resource extraction, departure from natural fire regimes).
- Current actions or influences that degrade wilderness character (e.g. non-native invasive species, administrative motorized/mechanized use).
- Impending issues that are likely to degrade wilderness character into the future (e.g. climate change impacts, night sky obfuscation).

By identifying and depicting threats to wilderness character, the maps produced in this report provide managers with a tool to better understand the extent and magnitude of impacts to wilderness character in the Saguaro Wilderness and thereby improve wilderness stewardship.

This project adheres to the interagency strategy for monitoring wilderness character, as described in *Keeping It Wild: An Interagency Strategy for Monitoring Wilderness Character Across the National Wilderness Preservation System* (Landres et al. 2008a)<sup>1</sup>. The *Keeping it Wild* monitoring strategy was formally endorsed in 2009 by the Interagency Wilderness Policy Council (which is composed of the highest policy-level personnel responsible for wilderness in each of the four wilderness managing agencies). Therefore, by adhering to the interagency strategy, this project is consistent with National Park Service and interagency policies, terminology<sup>2</sup>, and monitoring protocols for wilderness character.

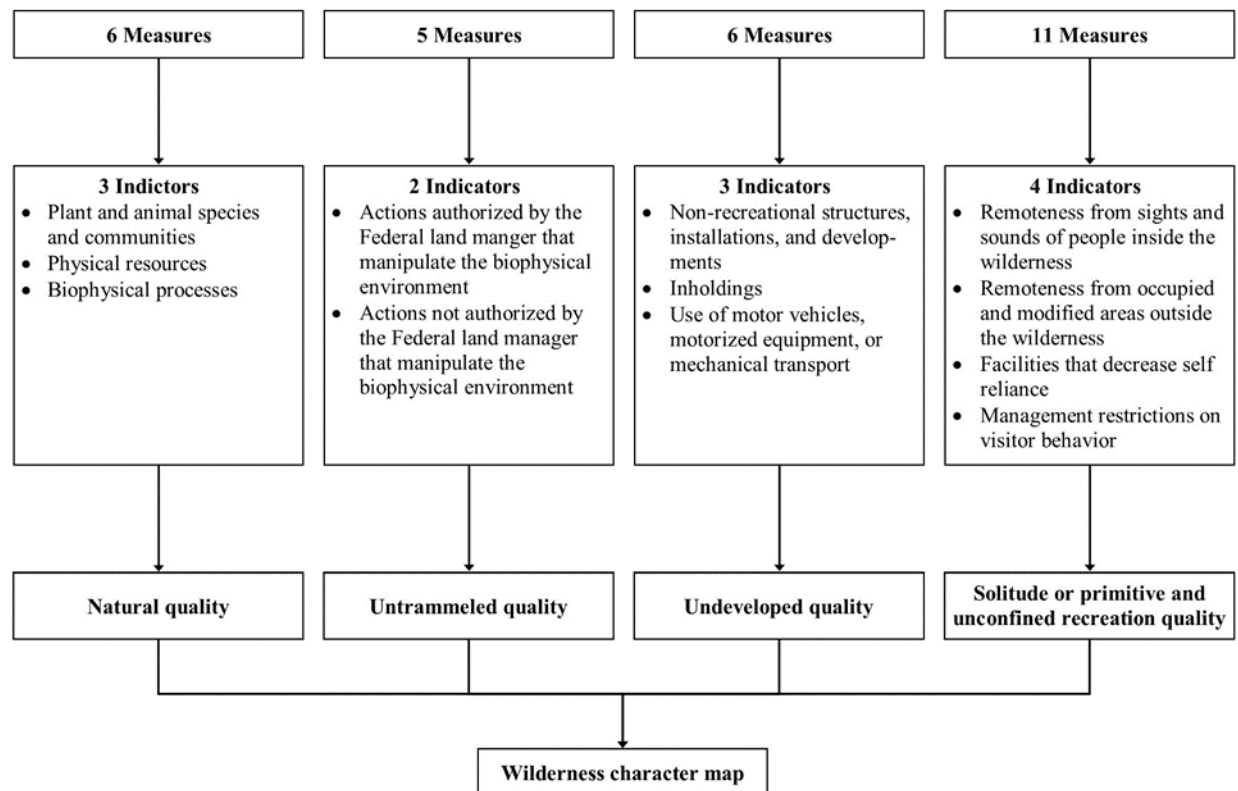
---

<sup>1</sup> An updated interagency wilderness character monitoring strategy, described in *Keeping it Wild 2: An Updated Interagency Strategy to Monitor Trends in Wilderness Character Across the National Wilderness Preservation System* (Landres et al. 2015), was released prior to the publication of this report but after the completion of the mapping project. While this project was based on the original *Keeping it Wild*, early and final drafts of *Keeping it Wild 2* were used for additional clarification and guidance.

<sup>2</sup> Terminology used in this report to describe threats to wilderness character—including “degraded,” “negative impact,” “significant,” etc.—reflects common vocabulary used in laws, policies, and interagency wilderness character monitoring documents. These terms do not imply an analysis of impacts or determination of significant effects, such as required by the National Environmental Policy Act or other agency decision-making processes.

### ***The mapping framework***

*Keeping It Wild* provides a tangible definition of wilderness character and identifies four qualities of wilderness character that apply uniquely to every wilderness: untrammeled, natural, undeveloped, and solitude or primitive and unconfined recreation. These qualities apply to all designated wilderness areas because they are based on the legal definition of wilderness from the Wilderness Act (Section 2(c)). The four qualities of wilderness character form the foundation of the interagency monitoring strategy, and are the first level of the hierarchical monitoring framework. As described in *Keeping it Wild*, this framework divides wilderness character into successively finer components: the qualities of wilderness character are divided into a standard set of indicators<sup>3</sup>, which are monitored in turn through a set of locally relevant measures<sup>4</sup>. For this project, measures were selected by the project core team to represent threats to wilderness character in the Saguaro Wilderness. Individual measures were mapped using spatial datasets and weighted to reflect their respective influences on wilderness character. Maps of the measures were then added accumulatively using these weights to create maps of the indicators and qualities, as well as an overall map of threats to wilderness character in the Saguaro Wilderness (Figure 2).



**Figure 2.** Flow chart of the framework used for mapping threats to wilderness character.

<sup>3</sup> Indicators are distinct and important elements within each quality of wilderness character. They have measurable attributes that can be the focus of wilderness character monitoring efforts.

<sup>4</sup> Measures are specific and tangible aspects of an indicator that can be measured to gain insight into the status of the indicator and to assess trends over time.

At first glance, it could appear inappropriate or meaningless to combine measures into a single overall map since each measure captures a unique and distinct impact to wilderness character. For example, it may seem counterintuitive to combine the areal extent of invasive plants with the probability of encounters with other visitors. However, since all measures quantify threats to wilderness character, combining measures is both appropriate and important for understanding and recording the magnitude of their cumulative effects. Additional information on the rationale and methods for accumulatively combining disparate measures to produce an overall map of threats to wilderness character are described by Carver et al. (2013). While data and maps for individual measures are relevant for local management purposes, the intent of this mapping project is also to understand and report on the big picture—to represent the cumulative spatial pattern and variation of threats to wilderness character. This big picture is a powerful and effective tool for communicating wilderness issues within the agency and with external audiences (Landres et al. 2008b).

The maps produced through this project depict the Saguaro Wilderness' current degree of departure or degradation from an "optimal condition" of wilderness character. This optimal condition reflects an ideal manifestation of wilderness character as expressed in the Wilderness Act—in other words, a state in which there are no threats to wilderness character. Each measure is depicted across the wilderness on a scale from its "optimal condition" (i.e. no threat) to its most "degraded condition" (i.e. highest current threat level). When the measures are combined accumulatively, therefore, the overall map of threats to wilderness character is similarly depicted on a scale from its optimal condition (i.e. no threats to wilderness character) to its most degraded condition (i.e. highest cumulative threat level from all measures). The optimal conditions depicted in the map products do not represent the condition of wilderness character in the Saguaro Wilderness in 1976, and therefore cannot be used to determine if threats to wilderness character have increased or decreased since the time of designation.



## Methods

Selecting measures under each indicator of the four qualities was an iterative and collaborative decision-making process. Possible measures were first identified by the project core team, and then evaluated for both their relevance to the indicator and the availability and quality of the required data. SAGU staff assessed data quality for each dataset using two metrics: accuracy (how well the dataset represents the measure) and completeness (how complete the dataset is across the wilderness). In general, only measures that were relevant, and that had readily available data of sufficient quality, were included. For certain measures this involved developing new datasets based on institutional knowledge. In some cases, potential measures had insufficient or non-existent data but were acknowledged by SAGU staff for their significance to their respective indicators; these “data gap” measures are described below after the four qualities. As data improve or become available, the data gap measures should be reevaluated for inclusion in future iterations of the map of threats to wilderness character.

### *Weighting measures*

Once all measures were selected, each was evaluated independently to determine the magnitude of its effect on wilderness character. Some measures have a greater impact to wilderness character than others; for example, the mine safety barrier measure has a relatively smaller impact (because the barriers are only found at a few locations), whereas the departure from natural fire regimes measure has a relatively greater impact (because fire suppression is widespread and causes unnatural fuel build up). To accurately portray the variable magnitudes of the measures’ effects, each measure was assigned a “weight”—a value from 1 (low impact) to 10 (high impact)—by the project core team. The project core team then reviewed the map outputs and modified the weighting scheme to reflect their knowledge of the condition of wilderness character on the ground. While this interactive process runs the risk of allowing staff to “game the system” to produce a desired outcome, staff experience has been shown to be highly accurate in judging resource conditions (Cook et al. 2009). The project core team used caution and consensus-driven oversight to ensure accuracy in the maps produced.

Specific rationales for weights assigned to each measure can be found in Tables 1-4 under their respective qualities. The following questions were used to help determine weights for all measures:

- Is the measure specific to a particular area or spread throughout the wilderness?
- Does the measure represent a major management issue (e.g. suppressed fires) or is it something relatively benign (e.g. mine safety barriers)?
- Does the measure depict an emerging threat that requires intensive management (e.g. the spread of non-native invasive species) or does it depict an issue that has largely been solved and is no longer of high concern to management (e.g. mine safety barriers)?
- Is the measure relevant to a particular time of year or season or is it an issue year-round?
- Are the data representing the measure accurate and complete or are they lower in quality?
- Are the data qualitative or quantitative?

### *Data sources and processing techniques*

Measures were mapped by applying GIS-based techniques to their respective datasets. A variety of datasets were used for measuring and delineating threats to wilderness character in the

Saguaro Wilderness. These datasets were obtained from a number of sources and comprised local, regional, and national spatial data at varying scales, accuracy, and completeness. This variation placed limitations on how the map products were developed and necessitated the use of adaptable data processing methods, as described below. All data and metadata were organized and stored on a network drive to ensure accessibility and facilitate use in future analyses.

Datasets included:

- Commonly-used data layers that are stored in the SAGU GIS database.
- Existing data layers associated with previous or on-going SAGU projects.
- Existing datasets that were edited, combined, or refined as a prerequisite for use in this project.
- Original datasets that were developed from local sources (including records, reports, and expert knowledge) and converted into a geospatial format.

A number of basic processing tasks were performed using ArcGIS<sup>5</sup> for datasets before they were used as measures to create the map of threats to wilderness character. All datasets were projected in ArcGIS using the NAD 1983 UTM Zone 12N coordinate system. For vector<sup>6</sup> datasets, a value was assigned to each feature by the project core team to represent its spatial impact in the Saguaro Wilderness. Some of the vector datasets had features with a range of values because of the data they represent; for example, under the inholdings measure, lands were assigned a value of 1 for the presence of trails, a value of 3 for dirt roads, a value of 5 for paved roads, and a value of 10 for buildings. The vector datasets were then converted to raster grids<sup>7</sup> whereby locations of the features or their associated effects were represented by the assigned values; unaffected areas of the wilderness (i.e. where no degradation occurs) were set to a value of 0.

The values for all raster grid layers were normalized<sup>8</sup> by stretching them to a standardized range of values (0–255). This normalized range of values allows datasets, and therefore measures, to be evaluated together on a common relative scale (Carver et al. 2008). For example, the soundscape and night sky measures use different units (decibels vs. anthropogenic light ratio) and cannot be directly compared without normalization. Lower values of normalized measures were used to represent optimal conditions (i.e. no threat) and higher values to represent degraded conditions (i.e. high threat level).

In the following section, the measures, weights, and rationales are listed for each of the four qualities of wilderness character. For additional information on data sources, processing, and cautions for each of the measures, please contact Ray O’Neil, SAGU Chief Ranger. The maps represent a grid of values (approximately 320,000 pixels at a 30m resolution) and use a green-brown color ramp and the “minimum-maximum” stretch method<sup>9</sup> to enhance the color contrast; areas of optimal condition (no threat) are shown in green, while areas of degraded condition (high threat level) are shown in brown.

---

<sup>5</sup> GIS software developed by Environmental Systems Research Institute.

<sup>6</sup> Vector data type uses points, lines, and polygons to represent features.

<sup>7</sup> Raster data type consists of rows and columns of cells, with each cell storing a single value.

<sup>8</sup> Normalization of measures was achieved using a linear rescaling of the input values (slicing) onto a 0–255 scale on an equal interval basis.

<sup>9</sup> The stretch method defines the type of histogram stretching that was applied to raster datasets to enhance their appearance. The minimum-maximum stretch applies a linear stretch on the output minimum and output maximum pixel values, which were used as endpoints for the histogram (ESRI 2015).

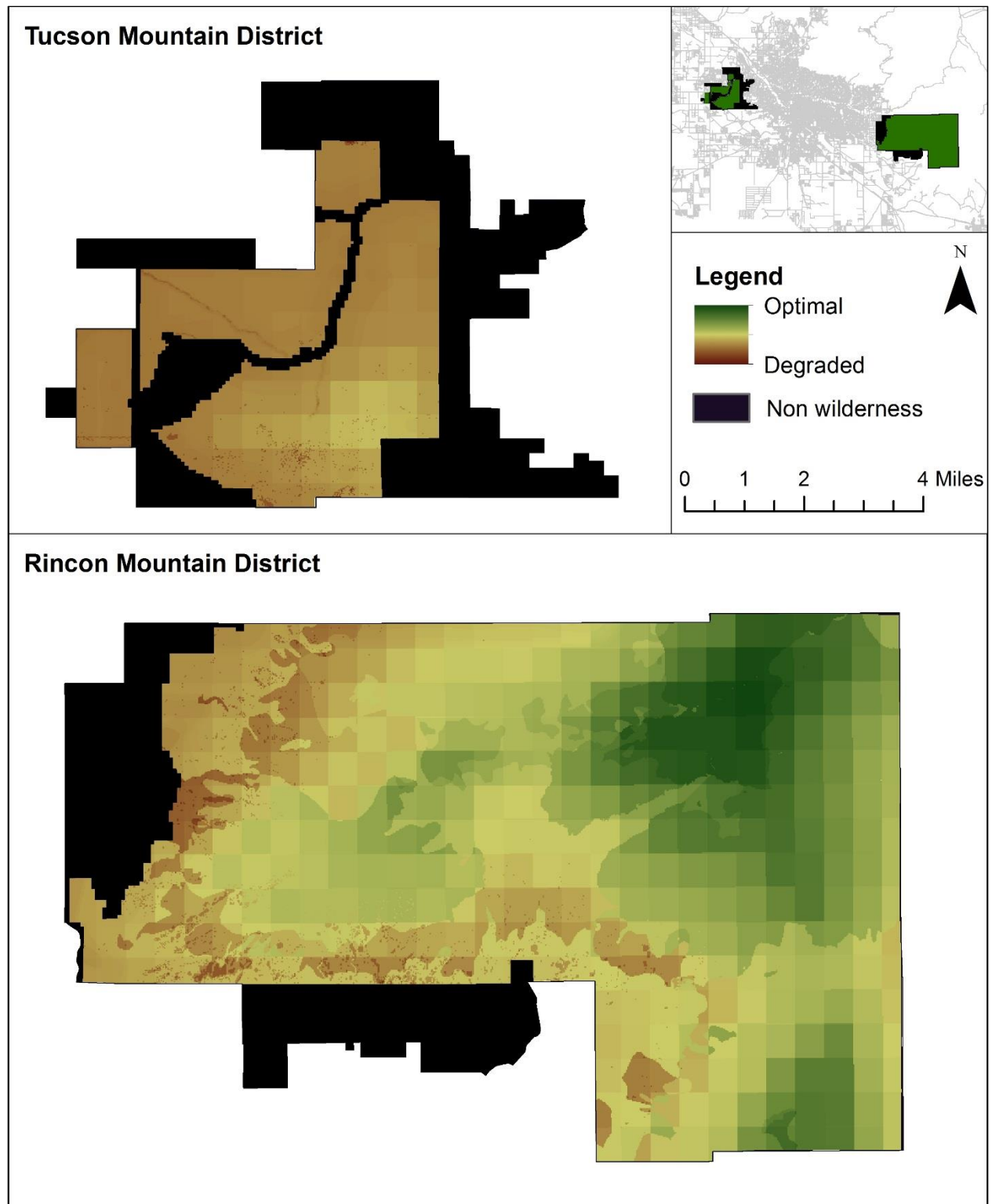
## Natural Quality

The natural quality centers on the idea that wilderness contains ecological systems that are substantially free from the effects of modern civilization. This quality is degraded by the intended or unintended effects of modern people on ecological systems inside wilderness (Landres et al. 2008a; Landres et al. 2015). *Keeping it Wild* delineates three indicators under the natural quality. The measures selected for each indicator, along with their weights (on a scale of 1 to 10) and the corresponding rationale, are listed below (Table 1). The weighted measures were added together using a raster calculator to create the natural quality map (Figure 3).

**Table 1.** Measure weights and rationales for the natural quality.

Indicator	Measure	Weight	Rationale
Plant and animal species and communities	Exotic Plants	8	Exotic plants highly threaten the Sonoran desert ecosystem due to increased competition and fires. Its weighting reflects the salience of the threat's impact on the other measurements.
	Landscape integrity	8	Mapping the vegetation of SAGU can help with understanding the impact of climate change (are communities moving to higher elevations as it gets warmer?) and other factors. The relative lower weight is indicative of the lack of accuracy in the current data. See Perkl, 2013 for additional information.
Physical resources	Departure from fire return interval	6	Measuring the departure from the fire return interval documents the departure from the nature fire regime, an important component in SAGU's diverse biomes.
Biophysical processes	Climate change: mean temperature of warmest quarter	8	SAGU is a crossroads of ecosystems; within the Sonoran Desert but influenced by the Chihuahuan Desert, Rocky Mountains, and Sierra Madre Mountains. Many plant and animal species are at the edge of their range. Small changes in climate can have significant influences on those species and those species are particularly impacted by changes at the warmest and coldest times of the year.

Indicator	Measure	Weight	Rationale
	Climate change: mean temperature of coldest quarter	8	SAGU is a crossroads of ecosystems; within the Sonoran Desert but influenced by the Chihuahuan Desert, Rocky Mountains, and Sierra Madre Mountains. Many plant and animal species are at the edge of their range. Small changes in climate can have significant influences on those species and those species are particularly impacted by changes at the warmest and coldest times of the year.
	Climate change: annual precipitation	8	SAGU receives low levels of precipitation. Slight increases or decreases in levels can result in large impacts to many species.



**Figure 3.** Map of the natural quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

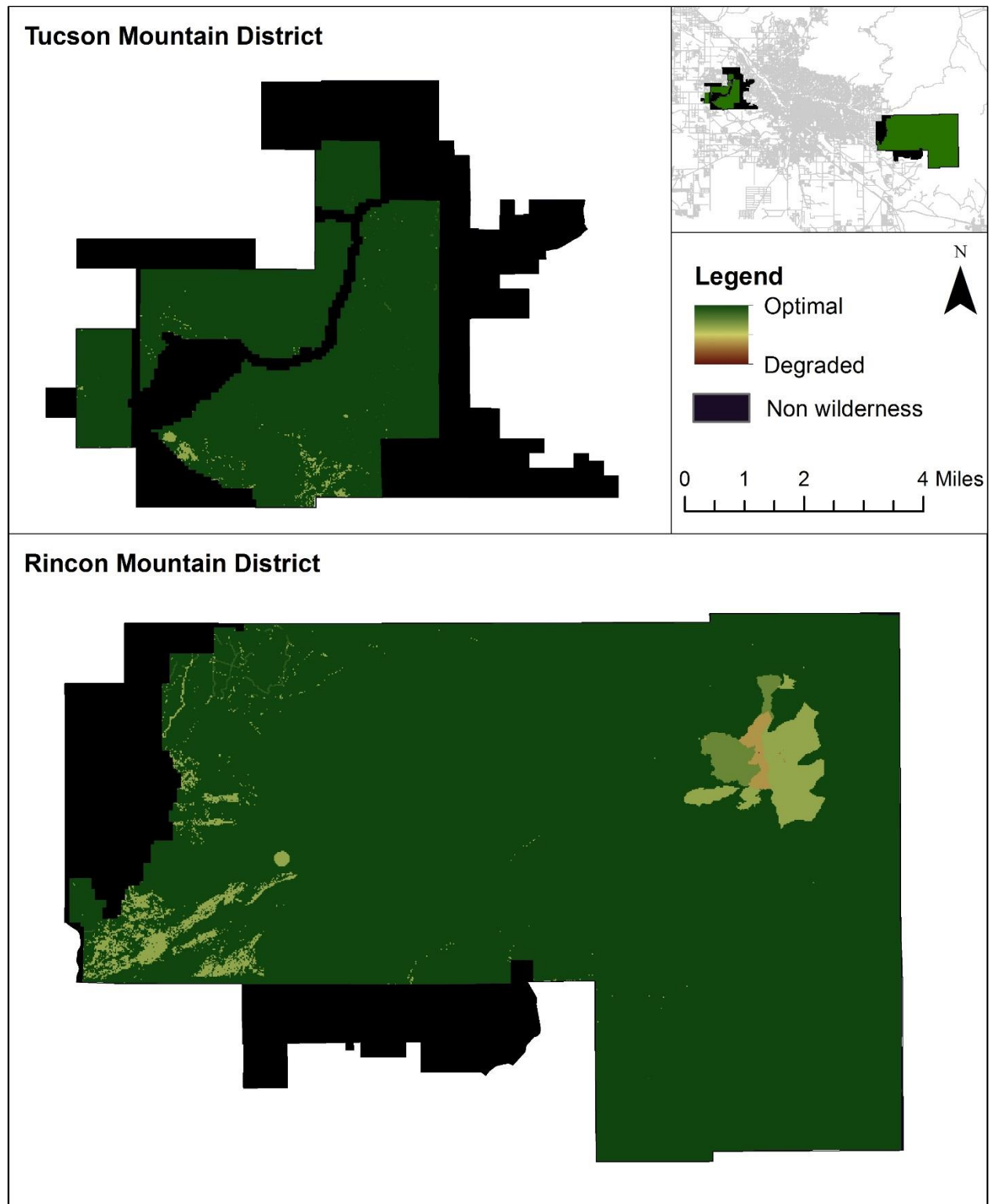
## Untrammelled Quality

The untrammelled quality focuses on the degree to which wilderness is unhindered and free from modern human control or manipulation. The untrammelled quality is degraded by actions that intentionally manipulate or control ecological systems (in contrast to the natural quality, which is degraded by the *effects* of modern civilization) (Landres et al. 2008a; Landres et al. 2015).

*Keeping it Wild* delineates two indicators under the untrammelled quality. The measures selected for each indicator (all under the authorized trammeling actions indicator), along with their weights (on a scale of 1 to 10) and the corresponding rationale, are listed below (Table 2). The weighted measures were added together using a raster calculator to create the untrammelled quality map (Figure 4).

**Table 2.** Measure weights and rationales for the untrammelled quality.

Indicator	Measure	Weight	Rationale
Actions authorized by the Federal land manager that manipulate the biophysical environment	Treated exotics	7	Treating exotics is a major part of management at SAGU and degrades the untrammelled quality significantly.
	Fire suppression	7	Suppression in higher elevations severely alters the natural fire regime and is a deliberate manipulation of natural fire processes.
	Prescribed Fires	5	Intentionally burning is a deliberate manipulation of the landscape.
	Disturbed-lands restoration (trails, roads, motor vehicle damaged areas, line camps, mine reclamation)	2	Despite the benefits to the natural quality, reclamation is a major trammeling on the landscape and because of the small amount of current reclamation, its weighting was low.
	Mine safety barrier	1	Placing barriers in front of mines is a conscious manipulation of an existing habitat for fauna living in the mines.



**Figure 4.** Map of the untrammeled quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

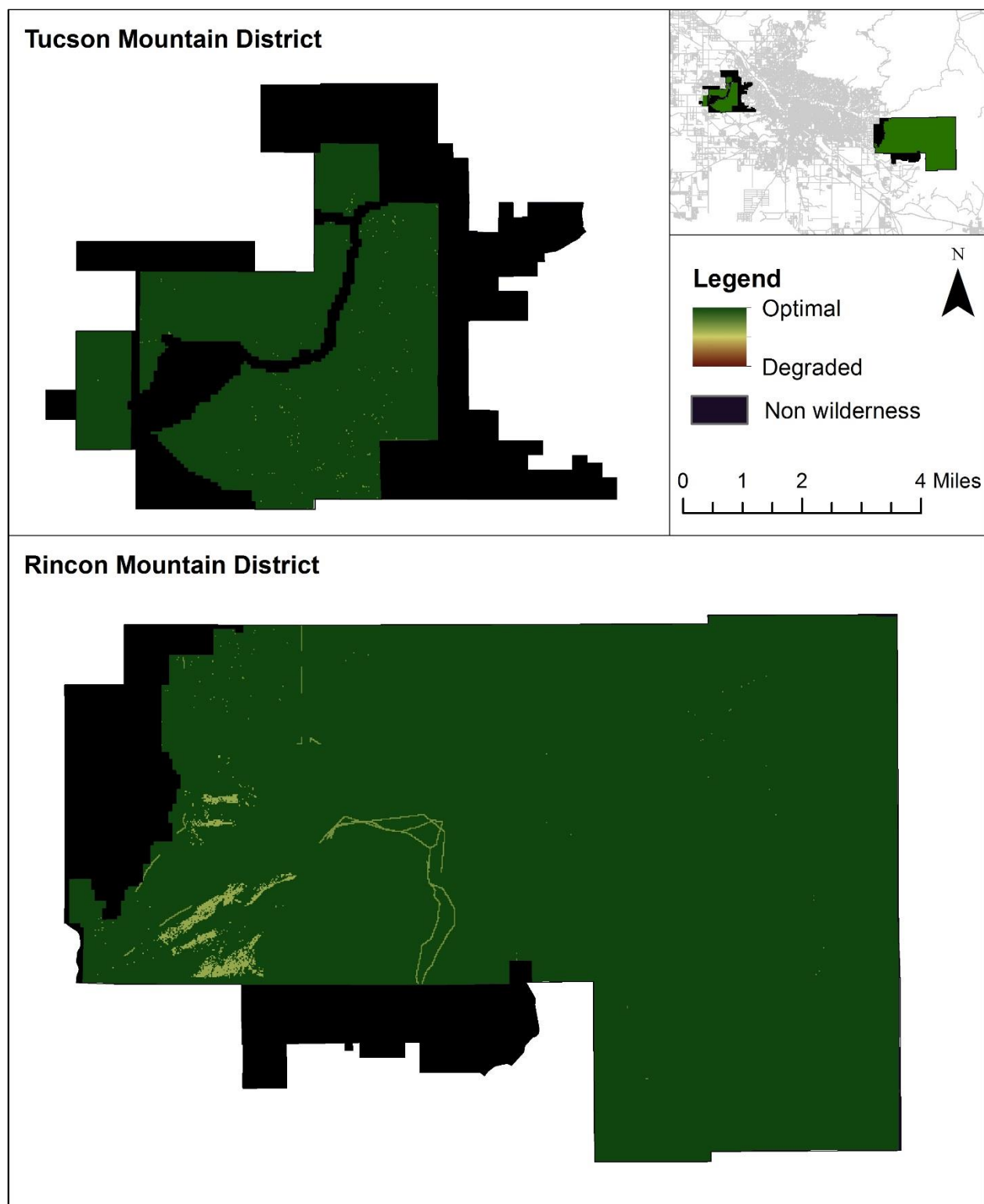
## Undeveloped Quality

The undeveloped quality centers on the idea that wilderness is without permanent improvements or modern human occupation. This quality is degraded by the presence of structures and installations, as well as the use of motor vehicles, motorized equipment, and mechanical transport, because these increase people's ability to occupy or modify the environment (Landres et al. 2008a; Landres et al. 2015). The measures selected for each indicator, along with their weights (on a scale of 1 to 10) and the corresponding rationale, are listed below (Table 3). The weighted measures were added together using a raster calculator to create the undeveloped quality map (Figure 5).

**Table 3.** Measure weights and rationales for the undeveloped quality.

Indicator	Measure	Weight	Rationale
Non-recreational structures, installations, and developments	Installations	4	There are a good number of installations which directly degrade the undeveloped quality at SAGU.
	Utilities	4	The presence of utility lines and their continual maintenance are signs of modern human presence.
	Science installations	4	Scientific installations are signs of modern human presence, but, their impact is smaller than other measures.
	Mines	4	Mines are a sign of modern human occupation and exist in high numbers at SAGU.
Inholdings	Private, State, County inholdings	6	The presence of inholdings degrades the undeveloped quality because of developments or the potential for development on the lands. An eligibility study has not been completed for inholdings at SAGU so they are not included on the wilderness character maps.
Use of motor vehicles, motorized equipment, or mechanical transport (on the surface)	Administrative use (sling water for herbicide, trail maintenance, outhouse fans, repeater installation/maintenance, Pima Cty weather station supplies, wheel barrow/water cart at Manning, trail maintenance)	5	Administrative use of motorized vehicles, motorized equipment, and mechanical transport degrades the undeveloped quality, and, because there is greater flexibility in their use opposed to emergencies, it was given a slightly higher weight.





**Figure 5.** Map of the undeveloped quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

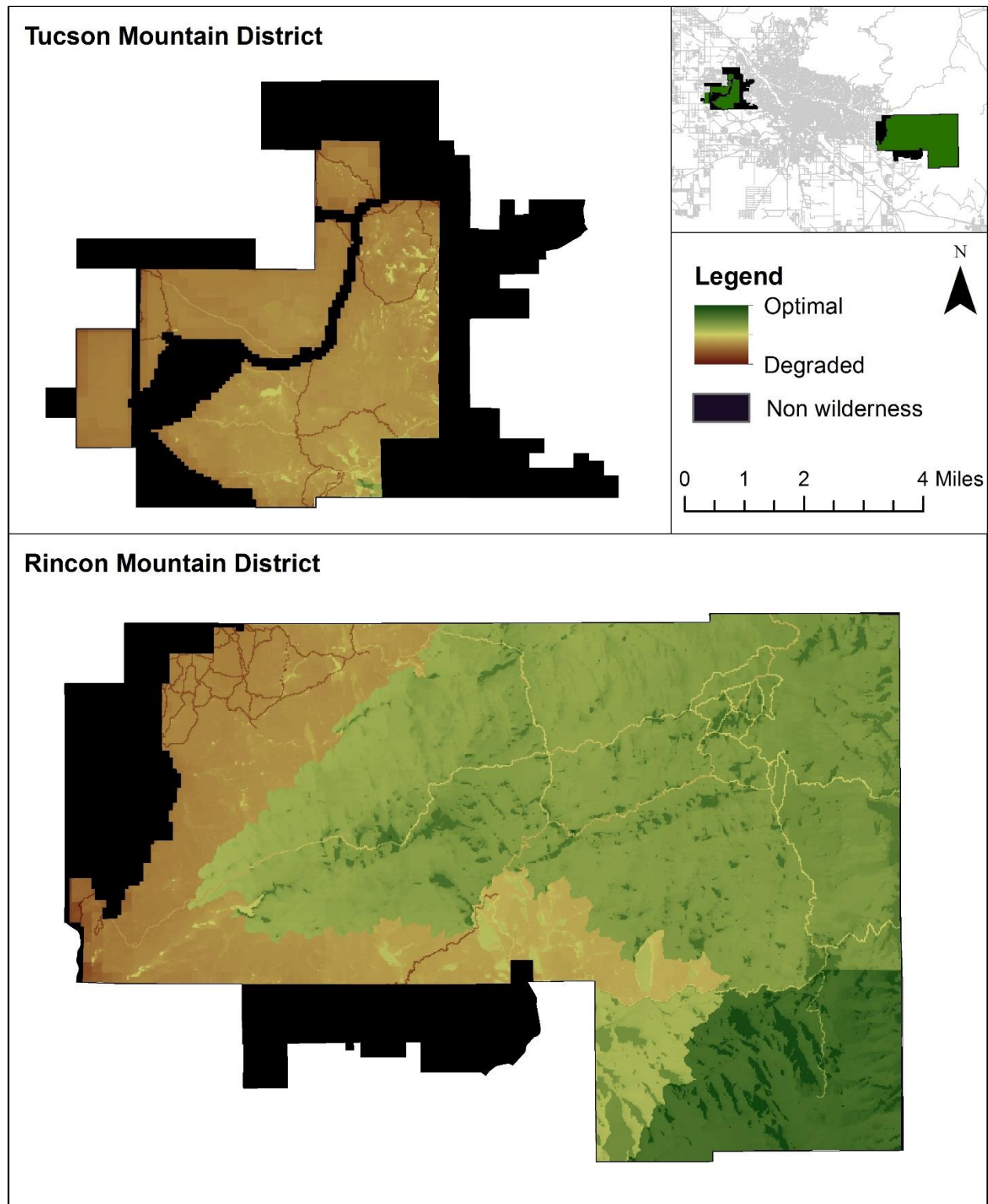
## Solitude or Primitive and Unconfined Recreation Quality

The solitude or primitive and unconfined recreation quality focuses on the outstanding opportunities that exist in wilderness to experience solitude, remoteness, and primitive recreation free from the constraints of modern society. This quality is degraded by tangible attributes of the setting that reduce these opportunities, such as visitor encounters, signs of modern civilization, recreation facilities, and management restriction on visitor behavior (Landres et al. 2008a; Landres et al. 2015). The measures selected for each indicator, along with their weights (on a scale of 1 to 10) and the corresponding rationale, are listed below (Table 4). The weighted measures were added together using a raster calculator to create the solitude or primitive and unconfined recreation quality map (Figure 6).

**Table 4.** Measure weights and rationales for the solitude or primitive and unconfined recreation quality.

Indicator	Measure	Weight	Rationale
Remoteness from sights and sounds of people inside the wilderness	Increased use of lower elevation trails	7	There is significantly more impact on the solitude for the lower elevation trails because of the larger number of visitors compared to higher elevation trails.
	Travel Time	2	Calculates a person's (adult of average fitness carrying an overnight pack of 35lbs) travel across the landscape from various access points, taking into account vegetation and elevation.
	Arizona Trail (increased use)	2	There has been an increase in hiker traffic in the park because of the new route of the Arizona Trail through the park. There has been an increase in hiker traffic in the park because of the new route of the Arizona Trail through the park. The amount of use is still significantly less than the amount of use that lower elevation trails receive.
Remoteness from occupied and modified areas outside the wilderness	Viewshed	9	Urban development outside of the park greatly impacts the viewshed from many vantage points inside wilderness – this nearly constant reminder of human habitation and modern development highly degrades opportunities for solitude and a primitive and unconfined experience.

Indicator	Measure	Weight	Rationale
	Soundscape (overflights, highway, ATV)	8	Soundscape indicative of human presence outside the park which degrades the opportunity for solitude.
	Night Sky	4	Shows visual loss of the astronomical features, an important element of the solitude and primitive and unconfined experience.
Facilities that decrease self-reliant recreation	Trails, trail features	6	Developed and maintained trails concentrate visitor use which degrades opportunities for solitude. It is given the most weight because of its relative frequency compared to other measures.
	Campgrounds (6 locations with 3 camping sites each)	6	Vault toilets, campsites and picnic areas decrease self-reliant recreation by providing utilities that are not needed in a wilderness area.
	Manning Camp	3	Manning Camp has a decreases the self-reliance of park users because of water availability and the perception that a wilderness backcountry ranger is always at the camp among park users.
Management restrictions on visitor behavior	Use Restrictions	8	Agency restrictions that modify visitor behavior degrades the opportunity for unconfined recreation.
	Access Restrictions	8	Agency restrictions that modify visitor behavior degrades the opportunity for unconfined recreation.



**Figure 6.** Map of the solitude or primitive and unconfined recreation quality of wilderness character. Green depicts optimal condition and brown depicts degraded condition.

## Data Gap Measures

Additional measures under two of the four qualities were identified by SAGU staff but were excluded from this mapping project due to insufficient data (Table 5).

**Table 5.** Data gap measures and reasons for dismissal

Quality/Indicator	Data gap measure	Weight	Rationale
Natural/ Plant and animal species and communities	Extirpated Species	5	Spatially representing the loss of species is usefully shows a departure from the park's natural flora and fauna. Rather than threatening the ecosystem, it is simply a shows the manifestations of the threats.
Natural/ Biophysical processes	Soil loss due to large, high intensity fire	3	Considering the importance of water and soil resources to the park, this measure was chosen. However, it seemed to be an impacted by high-intensity fires, which is due to fire suppression.
Natural/ Biophysical processes	Connectivity	8	Connectivity is a major issue at SAGU because of its close proximity to a highly developed urban area which degrades the natural quality in remarkable ways.
Undeveloped/ Use of motor vehicles, motorized equipment, or mechanical transport (on the surface)	Emergency use	3	Emergency use of motorized equipment and motor vehicles degrades the undeveloped quality, but, the number of incidents is not high enough to significantly degrade the undeveloped quality

## Map of Wilderness Character

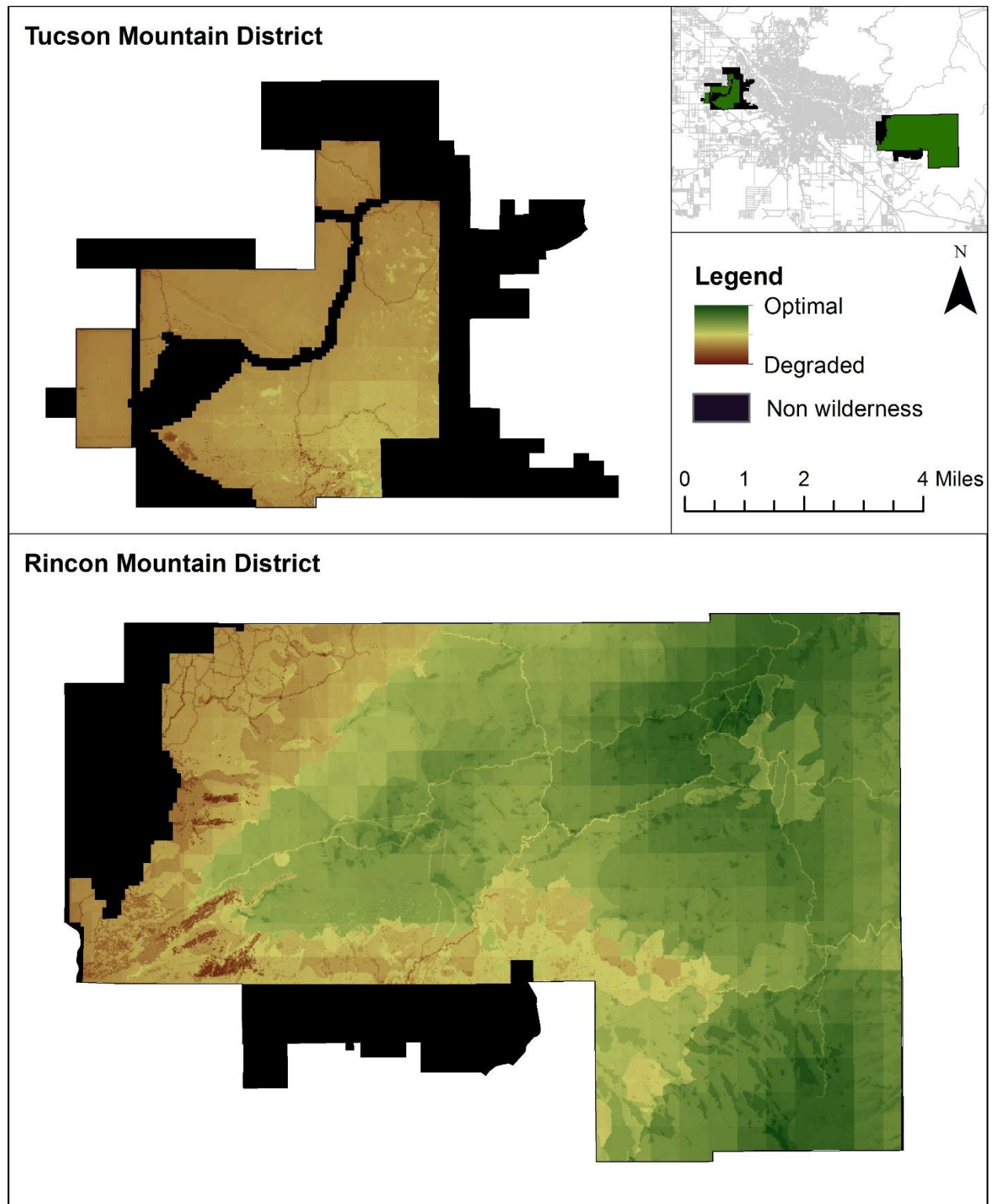
Interpreting the map products generated by this project requires a clear understanding of the methods that were used and their associated limitations. For example, the maps for the natural and solitude or primitive and unconfined recreation qualities used both vector and continuous raster data sources and are distinctly different in appearance from the maps for the qualities that only used vector data sources. In addition, it is important to bear in mind that the maps were generated through the analysis of a multitude of datasets: to understand why certain areas are degraded one must “drill down” into the individual qualities, indicators, and measures.

The methodology described in the previous sections produced maps for each of the 28 weighted measures; these were then added together accumulatively to produce a single map of threats to wilderness character in the Saguaro Wilderness (Figure 7). The map of threats to wilderness character represents a grid of values (approximately 320,000 pixels at a 30m resolution), and uses a green-brown color ramp and the “minimum-maximum” stretching technique to best represent those values for display and discussion. An equal interval reclassification<sup>10</sup> of the overall map was performed to transform the range of values for all pixels onto a scale of 0 (most degraded condition, highest cumulative threat level from all measures) to 100 (optimal condition, no threats to wilderness character). These values were then split into ten equal categories (i.e. 0-10, 11-20, 21-30, etc.) to clearly emphasize the variation in the magnitude of threats to wilderness character across the Saguaro Wilderness (Figure 8).

The histogram of the distribution of pixel values (Figure 9) shows that the magnitude of threats to wilderness character varies widely across the Saguaro Wilderness. Overall, the map depicts that wilderness character is less impacted by threats in the RMD than in the TMD; while most pixels in the RMD fall into the 61-70 and 71-80 categories (indicating a smaller impact from threats and higher quality wilderness character), most pixels in the TMD fall into the 31-40 category (indicating a relatively greater impact from threats). The least degraded areas (categories 71-80, 81-90, and 91-100) are found exclusively within the RMD in the higher elevations on the eastern side of the wilderness. These high quality areas are more difficult for visitors to access, and are furthest from the impacts associated with the city of Tucson. In addition, these areas are abutted to the north, east, and south by the Forest Service administered Rincon Mountain Wilderness, which protects them from further degradation from outside pressures. The next highest category (61-70) also falls almost entirely within the RMD in mid-elevation areas, with a very small portion located in the southeast corner of the TMD. Approximately 75% of the TMD and the majority of lower elevation areas in the RMD fall into the second largest category (31-40). In both districts, the most degraded areas (categories 0-10, 11-20, and 21-30) are associated with high impact sites, including the lower elevation trail network and locations where invasive species are present or have been eradicated.

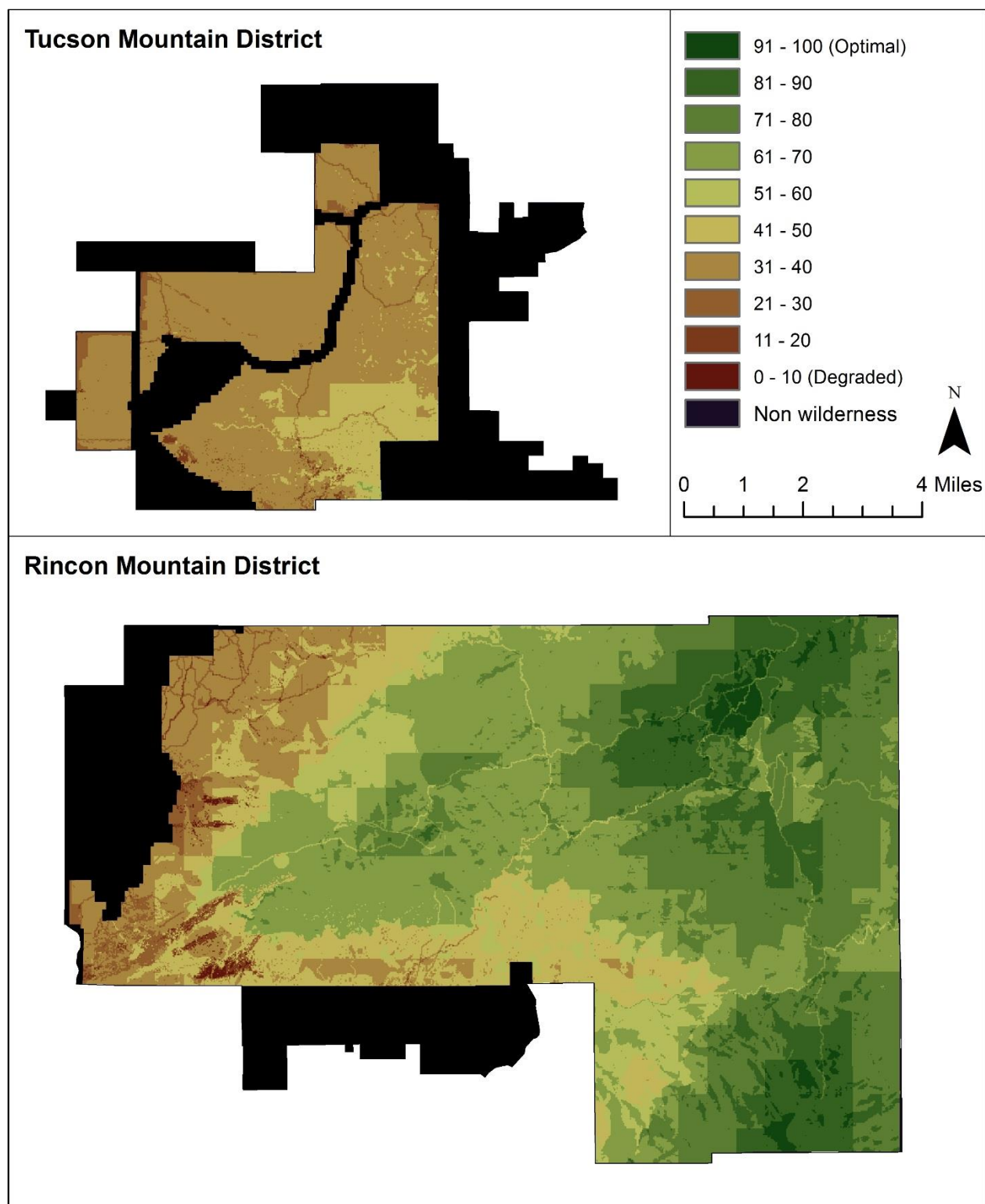
---

<sup>10</sup> This reclassification scheme divides the range of attribute values into equal-sized sub-ranges, allowing the user to specify the number of intervals while ArcMap determines where the breaks should occur (ESRI 2015).



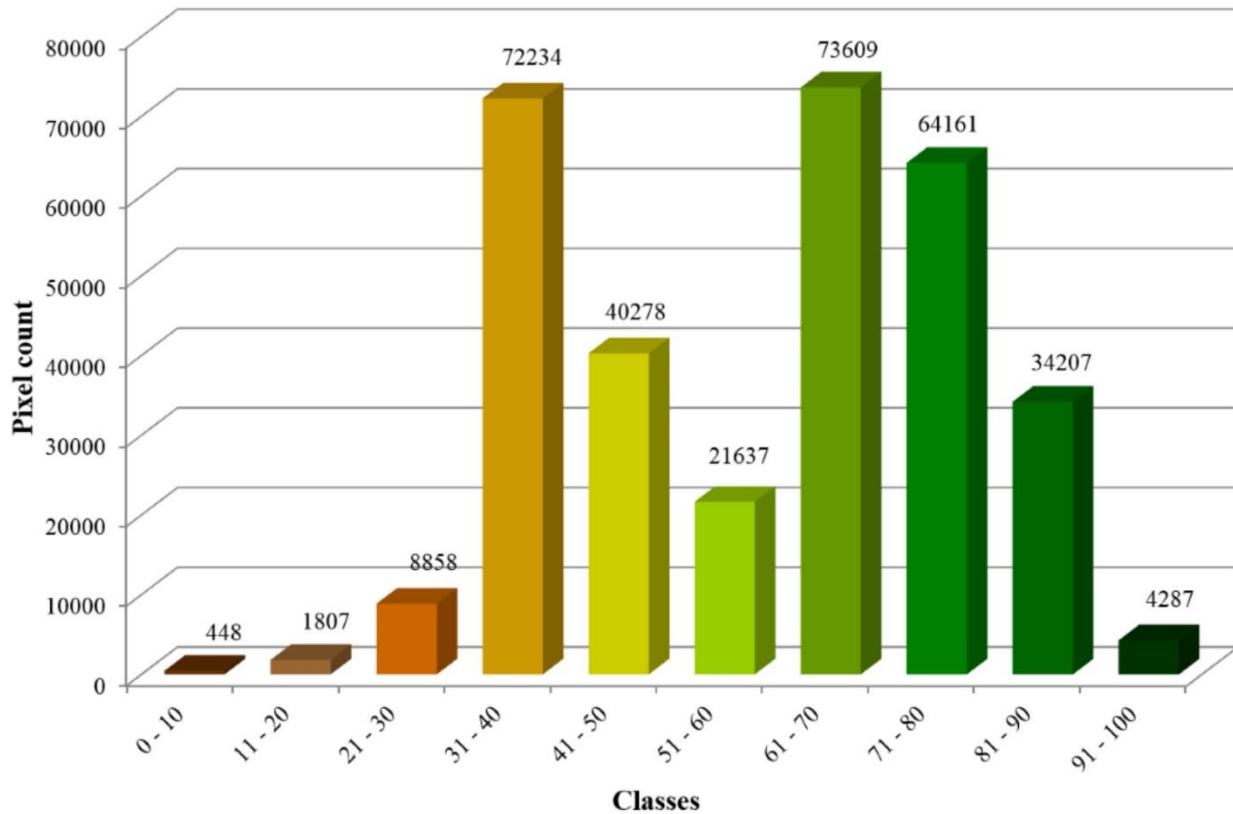
**Figure 7.** Map of threats to wilderness character in the SAGU wilderness. Green depicts optimal condition and brown depicts degraded condition.





**Figure 8.** Map of threats to wilderness character in the BWCAW reclassified into ten equal categories. Green depicts optimal condition and brown depicts degraded condition.





**Figure 9.** Histogram of the values of the map of threats to wilderness character. Green depicts optimal condition and brown depicts degraded condition.

### ***Final concerns and cautions***

There are a number of potential concerns about producing maps of threats to wilderness character. Despite these concerns, managers have recognized these maps as the best available tool for spatially representing impacts to wilderness character. Major cautions about this overall effort include:

- *Creating sacrifice zones* – The map may facilitate the inappropriate creation of “sacrifice zones” or internal buffers within the wilderness, directly contravening congressional and agency mandates to preserve wilderness character across an entire wilderness. For example, if the map shows that some areas are “better” or of “higher quality” than others, the tendency may be to focus efforts on preserving wilderness character only in these specific areas while allowing wilderness character to degrade in “lower quality” areas. By showing the current extent and magnitude of threats to wilderness character and how they vary across the entire wilderness, the intent of the map is to help staff maintain high quality areas while improving lower quality areas.
- *Comparing wilderness character among wildernesses* – Since this approach has been used for other wilderness areas, the map may facilitate inappropriate comparisons of wilderness character among different wildernesses. These maps show the current extent and magnitude of threats to wilderness character in different colors (representing pixel values), and it would be easy for users to compare the quantity of a given color from one wilderness to another. Comparing these maps among different wildernesses, however, is

neither valid nor appropriate because each map is built with data from the unique context of a particular wilderness.

- *Assuming that the resulting map completely describes wilderness character* – The map may be misconstrued as an accurate and precise description of wilderness character. While the tendency to attribute higher levels of reliability and precision to maps because they look accurate is common to almost all GIS analyses, the map is instead only an estimate of selected threats to wilderness character for which spatial data were available for this particular wilderness. As an approximate representation of threats to wilderness character, the map should not be considered an absolute and complete description. In addition, the map does not portray the threats to the symbolic, intangible, spiritual, or experiential values of wilderness character. In short, while this map is useful for the purposes outlined above, it does not describe the complexity, richness, or depth of wilderness character.
- *Updating datasets in the future such that maps are not directly comparable* – As datasets are updated over time, future iterations of the map may not be comparable with the original map. Each map is a product of both the best available spatial data and the locally defined methods for processing those data. Improving the data quality of the existing datasets (by improving data accuracy or completeness) or adding datasets for the data gap measures would benefit future iterations of the maps. As with all long-term monitoring efforts, changes in the type and quality of data or in the data processing techniques can make comparisons between original and subsequent data invalid. Therefore, proposals to use new or altered data, or to change data processing methods, need to be assessed carefully to ensure the comparability of map products over time.

## References

- Aplet, G.; Thomson, J.; Wilbert, M. 2000. Indicators of wildness: using attributes of the land to assess the context of wilderness. In: McCool, S.F.; Cole, D.N.; Borrie, W.T.; O'Loughlin, J., comps. Wilderness science in a time of change conference—Volume 2: wilderness within the context of larger systems; 1999 May 23-27; Missoula, MT. Proc. RMRS-P-15-VOL-2. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 89-98.
- Carver, S.; Comber, L.; Fritz, S.; McMorran, R.; Taylor, S.; Washtell, J. 2008. Wildness study in the Cairngorms National Park. Final Report, commissioned by the Cairngorms National Park Authority and Scottish Natural Heritage. March, 2008. Available at: <http://www.wildlandresearch.org/Cairngorm2008.pdf>.
- Carver, S. 2010. 10.3 Mountains and wilderness in European Environment Agency: Europe's ecological backbone: recognising the true value of our mountains. EEA Report No 6/2010: 192-201.
- Carver, S.; Tricker, J.; Landres, P. 2013. Keeping it wild: mapping wilderness character in the United States. *Journal of Environmental Management*. 131: 238-255.
- Cook, C.N.; Hockings, M.; Carter, R.W. 2009. Conservation in the dark? The information used to support management decisions. *Frontiers in Ecology and the Environment*. 8(4): 181-186.
- ESRI. 2015. ESRI Support. Redlands, CA: Environmental Systems Research Institute. Retrieved from <http://support.esri.com>.
- Landres, P.; Barns, C.; Dennis, J.G.; Devine, T.; Geissler, P.; McCasland, C.S.; Merigliano, L.; Seastrand, J.; Swain, R. 2008a. Keeping it wild: an interagency strategy to monitor trends in wilderness character across the national wilderness preservation system. Gen. Tech. Rep. RMRS-GTR-212. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 77 p.
- Landres, P.; Hennessy, M.B.; Schlenker, K.; Cole, D.N.; Boutcher, S. 2008b. Applying the concept of wilderness character to National Forest planning, monitoring, and management. Gen. Tech. Rep. RMRS-GTR-217. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 45 p.
- Landres, P.; Barns, C.; Boutcher, S.; Devine, T.; Dratch, P.; Lindholm, A.; Merigliano, L.; Roeper, N.; Simpson, E. 2015. Keeping it wild 2: an updated interagency strategy to monitor trends in wilderness character across the National Wilderness Preservation System. Gen. Tech. Rep. RMRS-GTR-340. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 114 p.
- McCloskey, M. 1999. Changing views of what the wilderness system is all about. *Denver University Law Review*. 76: 369-381.

- Perkl, R. 2013. Arizona Landscape Integrity and Wildlife Connectivity Assessment. The University of Arizona and the Arizona Game and Fish Department. Tucson, AZ.
- Rohlf, D.; Honnold, D. L. 1988. Managing the balance of nature: the legal framework of wilderness management. *Ecology Law Quarterly*. 15(2): 249-279.
- Sanderson, E.W.; Jaiteh, M.; Levy, M.A.; Redford, K.H.; Wannebo, A.V.; Woolmer, G. 2002. The human footprint and the last of the wild. *Bioscience*. 52(10): 891-904.
- Tricker, J.; Landres, P.; Dingman, S.; Callagan, C.; Stark, J.; Bonstead, L.; Fuhrman, K.; Carver, S. 2012. Mapping wilderness character in Death Valley National Park. Nat. Res. Rep. NPS/DEVA/NRR-2012/503. Fort Collins, CO: National Park Service.
- Tricker, J; Landres, P, Fauth, G; Hardwick, P; Eddy, A. 2014. Mapping wilderness character in Sequoia and Kings Canyon National Parks. Nat. Res. Tech. Rep. NPS/SEKI/NRTR – 2014/872. Fort Collins, CO: National Park Service.
- Wilderness Act of 1964; 16. U.S.C. 1121 (note), 1131-1136.
- Zahniser, H. 1962. Hearings before the Subcommittee on Public Lands of the Committee on Interior Affairs, House of Representatives, 87th Congress, 2nd session, May 7-11, serial no. 12, part IV.