**LAST GREAT PLACES -- RESEARCH AND ASSESSMENT METHODS**

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**Overview**

For almost a century, many ecologists and institutions have called for a network of protected areas to conserve the diversity of ecosystems, species and natural features. Toward this goal, three potential “portfolios” of conservation areas in the conterminous U.S. were assessed -- National Audubon’s Important Bird Areas (IBAs); The Nature Conservancy’s ecoregional assessments (TNCs); and the U.S. Protected Areas inventory (PAs). Sites with a minimum size of 10,000 acres in each portfolio (~1,250, ~4,100, and ~9,000 sites respectively) were assessed for seven conservation factors using datasets with coverage of the conterminous United States: ecological land units; terrestrial ecosystems; rare species’ richness; human modification; vegetation condition; ecological resilience; and conservation manage­ment status. Sites were ranked using standardized normal distributions for these factors, and the top-ranked 1000 sites in each of the 3 portfolio sets were collated. Sites were selected using both national and ecoregional weights to include representation from all 69 ecoregions. The assessment included coastal areas, but not offshore marine sites, for which the evaluation data were not available.

ArcGIS Desktop 10.8.1 with Spatial Analyst license was used as the primary evaluation tool for mapping and spatial assessments. Microsoft Excel 2010, programmed using Visual Basic, was used as a non-relational database to capture results, calculate z-scores, tabulate and analyze other statistics, and produce scorecards with site rankings.

**Sites**

Three place-based datasets were used to evaluate potential conservation areas. Each dataset provided geospatial boundaries as polygon shapefiles for the respective sites, as well as varied non-spatial data in their associated attribute tables.

Sites for analysis in each dataset were filtered to include sites 10,000 acres or larger in size. Many papers have been written on minimum reserve size, and it is not our intention to expand upon that discussion. 10,000 acres was selected as a conservative and pragmatic minimum size based upon the following considerations:

* America’s National Parks are often considered premier places for biodiversity conservation, and hence can be informative about potential minimum conservation area size. Excluding two “urban” parks -- the 192-acre Gateway Arch National Park in St. Louis and 5,500-acre Hot Springs National Park which include a substantial built environment -- the smallest national park is Indiana Dunes National Park at 15,000 acres, followed by Congaree National Park at approximately 26,500 acres.
* TNC’s ecoregional assessment for the Central Appalachian ecoregion selected 15,000 acres as the minimum size for the matrix forest blocks in the ecoregion, which constituted the core of the portfolio and the vast majority of its acreage. This decision was based upon an assessment of “minimum dynamic area,” which considered 4 times the historic severe-destruction patch size and 25 times the mean female home range of selected focal species.
* A 10,000 acre minimum area size captured an extremely large percentage of the total acreage of all sites each dataset. For example, the sites larger than 10,000 acres comprised over 98% of the area for all IBAs and TNCs in the Lower 48 states.
* Data management and calculation limitations for the extremely large PA database, with ~358,000 total sites, required establishing a minimum site size for practical considerations. Even a 1 km2 minimum size (247 acres) resulted in ~61,000 records for the Lower 48 states. The 10,000 acre minimum size created a manageable database of slightly over 9000 units.

*IBAs*

The National Audubon Society’s Important Bird Area dataset of the United States was provided in January 2021 per a data request form.

The full set of IBAs included 2759 sites in all 50 states, ranging from less than 1 acre (several sites, such as Adams County Jackpines in Wisconsin) to 89,497,056 acres (Northwestern Hawaii Islands) in size. 239 sites were smaller than 1 sq km (247 acres). Offshore marine and pelagic areas are included in the data layer. Non-spatial data included the state, size in hectares and/or acres, and global priority ranking. Each IBA is ranked as being of Global, Continental or State significance.

The evaluation data were analyzed for 1240 sites over 10,000 acres.

Audubon’s caveats regarding its site data include the following, among other:

* The IBA boundaries should not be perceived as absolute, definite boundaries. Rather, the boundaries should be considered approximates of the critical habitat areas.
* These data should not be considered a substitute for on-site surveys that may be required for an environmental assessment, environmental impact statement, or conservation planning.
* The information and data associated with the boundaries are continually growing as new data are acquired. Therefore, the data released may become outdated.

*TNCs*

TNC’s dataset of the United States was provided in 2021 per a data request to TNC’s Geospatial Systems Team. Data include a geodatabase with two GIS feature files -- U.S. ecoregional portfolio and ecoregion boundaries, and two table files -- elements (e.g. species and ecological systems) and intersections (elements by ecoregion).

TNC’s total U.S. ecoregional portfolio includes 8,261 conservation areas in 69 ecoregions. Several ecoregions extend across the U.S. borders; cross-border sites were included in the assessment if their centroid fell into the United States.

Acres were calculated for TNC portfolio sites using ArcGIS. Site sizes ranged from less than 1 acre (e.g. Jerry Smith Farm Park near Kansas City) to over 12.0 million acres (Sandhills Prairie in Nebraska); the next largest site was Crown of the Continent at ~4.3 million acres. Sandhills Prairie site was excluded from the analysis as an outlier, in that 11 other large sites -- several individually larger than 100,000 acres -- were contained within the Sandhills Prairie “mega-site.” TNC’s portfolio, excluding Sandhills Prairie, totaled 618,138,530 acres, but approximately 1% of the TNC sites comprise approximately 23% of the total TNCs area. 571 sites were smaller than 1 sq. km (247 acres).

The evaluation data were analyzed for 4,122 sites over 10,000 acres.

TNC’s database also included tables on the varied “elements” or “conservation targets” captured by the portfolio sites. The majority of the 15,163 targets are species of plants or animals. Approximately 6500 (43%) of the targets are communities, associations, alliances, assemblies or ecological systems.

*PAs*

The Protected Areas Database (PAD-US ) is the official national inventory of U.S. terrestrial and marine protected areas that are dedicated to the preservation of biological diversity and to other natural, recreation and cultural uses, managed for these purposes through legal or other effective means.  Lands in PAD-US are mainly open space/resource lands owned in fee by public agencies and nonprofits. Conservation easements in the public domain are also included.  The fundamental areas included in the PAD-US database are called “units.” PAD-US includes a total of 60,891 units greater than 1 km2, including fee ownership, designation and conservation easements. Each unit has a named manager - either a federal, state, regional, or local agency or private conservation organization.

Most units are clearly defined and/or managed *sites* (e.g. parks, refuges, grazing allotments, wilderness areas) but units also include *administrative entities* that we excluded from the place-based analysis.

* Entire National Forest administrative areas are tallied in PAD-US as “units,” even though they are typically very large, often sprawling or dispersed management assemblages. For example, “National Forests in North Carolina” is considered a single unit, even though this unit is comprised of four distinct National Forests ranging across the state from the coast to the mountains (Croatan, Uwharrie, Nantahala and Pisgah), which total ~1.2 million acres.
* Similarly, State Trust lands sprawling across the west (totaling over 40 million acres) are tallied as a single unit for each given state, even though they include many small, widely-dispersed lands based upon one square mile sections. The widely dispersed NC Department of Transportation Mitigation lands were similarly excluded.
* Bureau of Land Management administrative field office entities are responsible for managing large and dispersed expanses of lands; 140 BLM offices collectively managing over 170 million acres are tallied as single units.

On the other hand, over 29,000 designated areas totaling over 400 million acres within these Forest Service and BLM administrative “units” are also inventoried as “units” -- including Wilderness Areas, Wilderness Study Areas, Inventoried Roadless Areas, Research Natural Areas, Areas of Critical Environmental Concern, Wildlife Management Areas, Grazing Allotments and other designations. The largest of these designated areas is the Frank Church River of No return Wilderness in Idaho at over 2.3 million acres, followed by BLM’s Rock Springs Grazing Allotment in Wyoming at over 2.1 million acres.

The 10,000 acre minimum size and exclusion of BLM and USFS administrative units and State Trust lands created a database of 9,883 PA units that were evaluated.

We used Protected Areas Database (PAD-US) 2.0. Much analysis for this project was done prior to the release of PAD 2.1 in late 2020, which added 75,000 local parks and nearly 5,000 local land trust areas altogether totaling ~ 3 million acres. Almost all of these additional local sites would have been excluded by the 10,000 acre minimum threshold for site evaluation. Additionally, American Indian reservation lands were also added, but these administrative areas would also have been excluded from the analysis, as were the Forest Service and BLM administrative areas.

*Ecoregions*

In developing its portfolio, TNC used ecoregions as a fundamental unit of stratification to capture the ecological and genetic variability of species, ecological communities, and ecological systems. Of the TNC ecoregions occurring within the conterminous United States, 52 fall completely within the U.S. borders (e.g. Great Basin, Mid-Atlantic Coastal Plain), 17 ecoregions cross the border into either Canada (e.g. Great Lakes) or Mexico (e.g. Chihuahuan Desert). The original Willamette Valley ecoregion was split into two subsets. We used TNC’s ecoregions to stratify our analysis of sites from all three portfolios.

**Evaluation Factors**

The three “portfolios” were each assessed for seven conservation factors. All seven datasets provided coverage of the conterminous United States at a minimum. The seven datasets were: ecological land units; terrestrial ecosystems; rare species’ richness; human modification; vegetation condition; ecological resilience; and conservation management status.

*Ecological Land Units*

“Conserving Nature’s Stage” has been a recurring theme in conservation biology for over two decades Fundamentally, it calls for the use of geo-diversity as a “coarse filter” strategy for conserving biodiversity, especially in the face of a changing climate. This coarse filter strategy conserves representative samples of broadly defined ecological and/or geophysical environments as a way to conserve most species. An entire special section of Conservation Biology with multiple articles was devoted to “Conserving Nature’s Stage” in 2015.

To evaluate the geodiversity of the portfolio areas, we used ecological land units as the dataset. ELUs reflect a stratification of the earth into unique physical environments and their associated vegetation. The mapping approach first characterizes the Earth’s climate regime, the landforms, the geology (lithology), and land cover, and then models terrestrial ecosystems as a combination of those four geophysical characteristics. As such, the work is a physical geography approach to classifying ecological diversity. We used the global map and database of ELUs developed by Roger Sayre, USGS, and Esri (Sayre, 2014). Source: <https://www.esri.com/~/media/Files/Pdfs/library/whitepapers/pdfs/introducing-the-global-elu.pdf>

The data was based upon 3,923 terrestrial ELUs mapped at a resolution of 250 meters. Each ELU is based upon consideration of the four geophysical characteristics (see table below). Every point in the ELU spatial dataset is symbolized by a combination of values for each of these fields.

An example of an ELU is thus: “Cold Moist Hills on Mixed Sedimentary Rocks with Mostly Deciduous Forest.”

|  |  |  |  |
| --- | --- | --- | --- |
| **Bioclimate** | **Landforms** | **Lithology** | **Land Cover** |
| Arctic | Plains | Undefined | Bare Area |
| Cold Dry | Hills | Unconsolidated Sediment | Sparse Vegetation |
| Cold Semi-Dry | Mountains | Carbonate Sedimentary Rock | Grassland, Shrub, or Scrub |
| Cold Moist |  | Mixed Sedimentary Rock | Mostly Cropland |
| Cold Wet |  | Non-Carbonate Sedimentary Rock | Mostly Needleleaf/Evergreen Forest |
| Cool Dry |  | Evaporite | Mostly Deciduous Forest |
| Cool Semi-Dry |  | Pyroclastics | Swampy or Often Flooded |
| Cool Moist |  | Metamorphic Rock | Artificial or Urban Area |
| Cool Wet |  | Acidic Volcanics | Surface Water |
| Hot Dry |  | Acidic Plutonics | Undefined |
| Hot Semi-Dry |  | Non-Acidic Volcanics |  |
| Hot Moist |  | Non-Acidic Plutonics |  |
| Hot Wet |  |  |  |
| Warm Dry |  |  |  |

Source: Esri, World Ecological Land Units Map 2015

A second step by Sayre et al involved a spatial combination of the four inputs into a single, new integrated raster dataset where every cell represents a combination of values from the bioclimate, landforms, lithology, and land cover datalayers. This combined worldwide raster datalayer contains 48,872 unique, more detailed combinations of the four inputs – these are called ecological facets (EFs).

An example a distinct EF above would be: “Hot Wet Flat or Nearly Flat Plains on Unconsolidated Sediment with Needle-leaved evergreen forest closed to open (>15%)” – which is a common and broadly distributed EF in the U.S. southeastern and gulf coastal plains. An uncommon and much more localized example is “Hot Wet Smooth Plains with some local relief on Siliciclastic Sedimentary Rock with Shrub or herbaceous vegetation, flooded, fresh/saline/brackish water.”

For purposes of analyzing the portfolio sites, we clipped the 2015 ELU geospatial data to the conter­minous United States. We then eliminated all “non-natural” ELUs/EFs falling under two ELU land cover types -- Artificial/Urban and Mostly Cropland. This resulted in a total of 18,743 “natural” EFs in the lower 48 states. Among the EFs, surface water land facets and water body land cover types were retained, capturing 330 distinct EFs of lakes, large rivers and other varied water bodies and wetlands.

We then used Spatial Analyst Tools/Zonal/Zonal Statistics as Table to tally the Variety of natural EFs within all portfolio sites.

*Terrestrial Ecosystems*

Ecological systems have long been held as a recommended “coarse filter” for capturing biological diversity. Ecological systems represent recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. They are intended to provide a classification unit that is readily mappable and readily identifiable in the field.

The interagency LANDFIRE program and NatureServe worked to classify and map the terrestrial ecological systems of the United States, as well as develop ecological models for each system. Of NatureServe’s initial classification (2003), some 381 ecological systems are upland types, 183 are wetland types, and 35 are complexes of uplands and wetlands. Considering prevailing vegetation structure, 322 systems are predominantly forest, woodland, or shrubland, 166 systems are predominantly herbaceous, savanna, or shrub steppe, and 74 systems are sparsely vegetated or “barren.”

We used LANDFIRE's Existing Vegetation Type (EVT)  LANDFIRE Remap 2016 Existing Vegetation Type (EVT) CONUS at a 30-meter grid resolution to capture the current distribution of the terrestrial and riparian ecological systems.  EVT is mapped using decision tree models, field data, Landsat imagery, elevation, and biophysical gradient data. From the EVT dataset we excluded all “non-natural” types, which includes ruderal vegetation, cropland and developed areas. Data Source: <https://landfire.gov/evt.php>

We then used Spatial Analyst Tools/Zonal/Zonal Statistics as Table to tally the Variety of natural ecological systems within all portfolio sites.

*Habitat Suitability for Imperiled Species*

Rare and imperilled species of plants and animals have long been considered as the “fine filter” for capturing biological biodiversity. TNC’s portfolio sites are heavily represented by species. Over half of the ~15,000 conservation targets found across TNC’s portfolio sites are plant and animal species.

The State Natural Heritage Programs collectively, and NatureServe as a central repository, capture the occurrences of rare and imperilled species. For our analysis, we used NatureServe’s national geospatial dataset (updated 2021) of “Richness of Imperiled Species in the United States,” which displays numbers of species in the lower 48 United States that are protected by the Endangered Species Act and/or considered to be in danger of extinction (categorized by [NatureServe](https://www.natureserve.org/conservation-tools/conservation-status-assessment) as “G1” Critically Imperilled or “G2” Imperiled). Source: <https://www.arcgis.com/home/item.html?id=6e90cefddb634e6a949838e7efff55fb>

The NatureServe maps were built upon habitat suitability models for 309 vertebrates (birds, mammals, amphibians, reptiles, freshwater fishes); 228 freshwater invertebrates (mussels and crayfishes; 43 pollinators (bumblebees, butterflies, and skippers; and 1636 vascular plants. High values identify areas where more imperiled species are most likely to occur.

We used these data which focused on rare species richness instead of two other possible datasets: Range-size rarity places greater emphasizes species with limited ranges (whereby presence of a single range-restricted species could increase the mean score for a site) and “Map of Biodiversity Importance” which takes protection status into account in rankings (we are using protection status as a separate evaluation factor.

We used Spatial Analyst Tools/Zonal/Zonal Statistics as Table to tally the mean of species richness within all portfolio sites. Higher mean scores represented a higher level of rare species richness for the site as a whole.

*Human Modification*

The human modification framework reflects two dimensions: the degree to which natural processes are free or controlled, and the degree to which landscape patterns are natural or artificial. Lightly modified landscapes, such as wilderness areas, have natural patterns such as diverse composition and age structure and natural processes such as wildfire are allowed to operate. Also, lightly modified landscapes are typified by low levels of fragmentation and higher connectivity. (Theobald 2010)

To capture the degree of human modification, we used the global Human Modification (HM) map, which provides a cumulative measure of human modification of terrestrial lands at a 1-km resolution. A continuous 0-1 metric reflects the proportion of a landscape modified based on modeling the physical extents of 13 anthropogenic stressors and their estimated impacts with a median year of 2016. Stressors include: extent of human settlement (population density and built-up areas); agriculture (cropland and livestock); transportation (major roads, minor roads, two tracks, and railroads); mining; energy pro­duction (oil wells and wind turbines); and electrical infrastructure (powerlines and night-time lights). The HM map was developed by scientists at The Nature Conservancy and Conservation Science Partners. Source: Theobold et al. <https://doi.org/10.5281/zenodo.5338803>

We used Spatial Analyst Tools/Zonal/Zonal Statistics as Table to tally the mean of human modification within all portfolio sites. Lower mean scores represented a lower degree of modification for the site as a whole.

*Vegetation Condition*

Vegetation models and description documents, collaboratively developed by more than 800 experts around the country through the interagency LANDFIRE Program, synthesize fundamental ecological information about ecosystem dynamics, structure, composition, and disturbance regimes for all of the mapped terrestrial and wetland ecosystems. These products establish the first comprehensive national baseline for measuring vegetation change in the USA. Using these models, the LANDFIRE program mapped “vegetation departure” (previously called fire regime condition) to determine the degree to which current ecological systems have been altered in their composition and structure, as compared to a set of modeled reference conditions pre-European settlement. As such, vegetation departure (also called ecological departure) is an integrated, landscape-level measure of ecological condition. This methodology determines the dissimilarity between an ecological system’s current condition and its natural range of variability (NRV), based on a score of 0% departure to 100% departure.

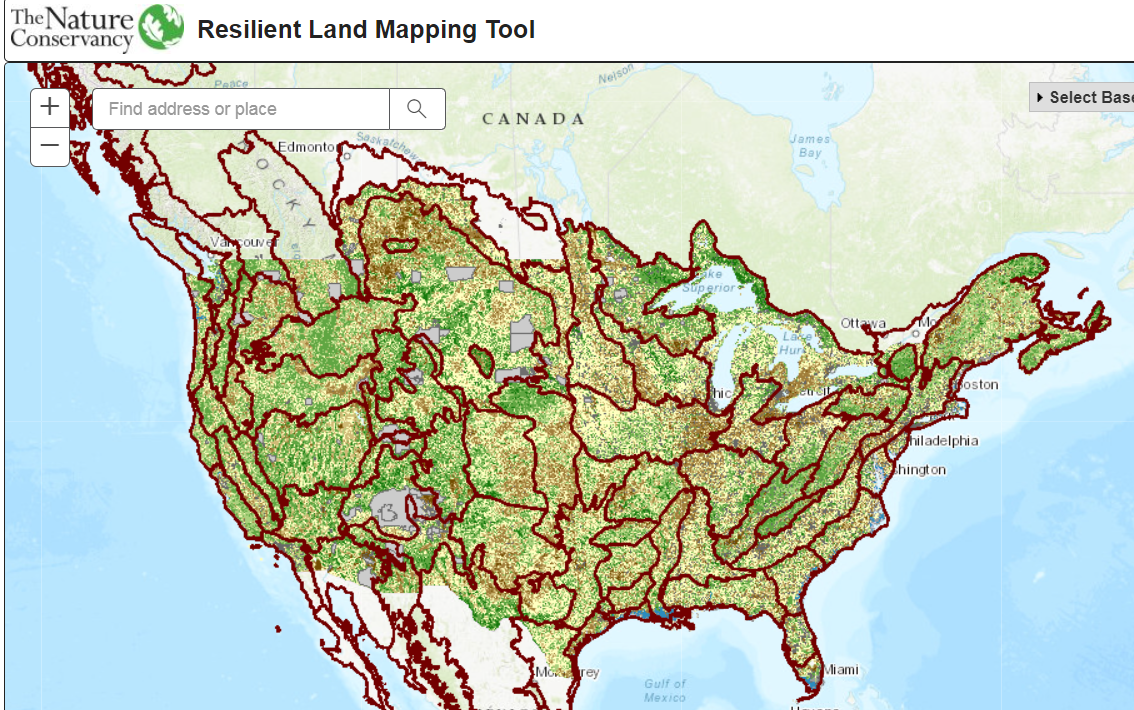
We used the LANDFIRE 2016 Vegetation Departure Index dataset, based on 30-meter pixels. We re-classified Urban and Agriculture pixels as 100 departure (i.e. they will negatively affect site scores); we classified Water, Snow/Ice, and Barren/Sparsely Vegetated all as “no data” (i.e., they will not positively or negatively affect site scores). Vegetation departure, a landscape metric, is scale dependent. Every pixel representing a unique ecological system type in a summary unit (geographic zones somewhat similar to ecoregions) has the same vegetation departure value. For example, if invasive species have broadly overtaken the Wyoming Big Sagebrush ecosystem in the Great Basin, resulting in a high departure score for this ecological system, this score would be captured wherever Wyoming Big Sagebrush occurs in that region. While likely to be broadly accurate over larger landscapes, smaller sites may in actuality have greater or lesser departure. Data source: <https://landfire.gov/vdep.php>

We used Spatial Analyst Tools/Zonal/Zonal Statistics as Table to tally the mean of vegetation departure within all portfolio sites. Lower mean scores represent a lower degree of departure from the natural range of variability, and thus better vegetation condition for the site as a whole.

*Resilience*

TNC sought to identify areas where nature’s own natural resilience is the highest. Thanks to the land’s diverse topography, bedrock, soil and micro-climates, these areas are deemed more likely to sustain native plants, animals, and natural processes into the future, as climate changes.

TNC mapped at 30-meter resolution distinct geophysical settings based on geology and elevation. **Geophysical Settings are somewhat similar to Land Facets as described above in ELUs – i.e. b**roadly defined landscape types with similar geology and elevation that support distinctive plants, animals and natural communities). As climate changes, each geophysical setting will continue to support species and communities that thrive in the conditions defined by its physical properties, although the species in the future may differ from those currently present. Within each geophysical setting, TNC identified areas that were both connected by natural cover and that had relatively more microclimates indicated by diverse topography and elevation gradients. (Anderson, 2014, 2016)

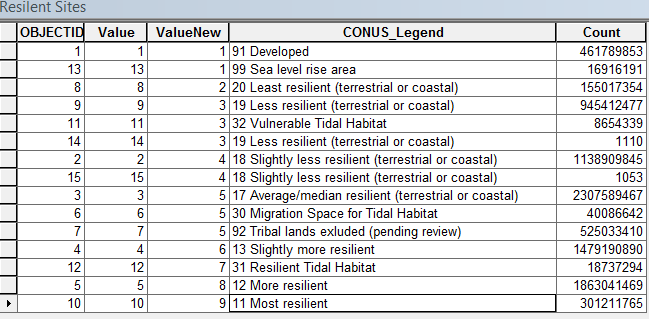


TNC’s Resilient Land Mapping Tool displays the data ttps://maps.tnc.org/resilientland/

A pixel’s Resilience Score was calculated within ecoregions based on all cells of the same geophysical setting (similar to the approach for LANDFIRE vegetation departure scores). For example, cells of granite bedrock were compared with all other cells of granite bedrock, and coastal plain sands were compared with other coastal plain sands.

We used TNC”s resilient Sites dataset for the ecoregions in the lower 48 states. Data source: <http://www.conservationgateway.org/ConservationPractices/ClimateChange/Pages/RCN-Downloads.aspx>

Using ArcGIS, we re-classified 15 values along a 1 to 9 scoring gradient (see ValueNew in Table below), with lower scores being less resilient and higher scores more resilient. Developed pixels retained a value of 1 (i.e. the very least resilient; average/median resilient retained a value of 5; most resilient was assigned a value of 9. Sea level rise areas were assigned a value of 1, vulnerable tidal areas a value of 3, migration tidal space a value of 5 and resilient tidal lands a value of 7. Pixels in tribal lands were assigned a temporary average/ median value of 5, as they were pending review by the respective indigenous authorities at the time of the analysis. (Note: We tested assigning NoData to tribal lands, but this skewed results for many sites).



We used Spatial Analyst Tools/Zonal/Zonal Statistics as Table to tally the mean of resilience scores within all portfolio sites. Lower mean scores represent a lower degree of resilience to climate change for the site as a whole; higher scores indicate greater resilience.

*Conservation Management*

A common approach to categorizing the level of conservation protection has been through categories based on whether land is managed for permanent biodiversity maintenance through some legal or institutional mechanism, or both. Both the World Conservation Union (IUCN) and the U.S. Geological Survey’s (USGS) Gap Analysis Program (GAP) use this approach, though their protection categories differ somewhat.

The USGS GAP program stewardship classification has four status classes:

Status 1: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a natural state within which disturbance events (of natural type, frequency, intensity, and legacy) are allowed to proceed without interference or are mimicked through management.  Examples of Status 1: National Parks, Wilderness Areas

Status 2: An area having permanent protection from conversion of natural land cover and a mandated management plan in operation to maintain a primarily natural state, but which may receive uses or management practices that degrade the quality of existing natural communities, including suppression of natural disturbance.  Examples of Status 2: National Wildlife Refuges, State Parks, The Nature Conservancy Preserves

Status 3: An area having permanent protection from conversion of natural land cover for the majority of the area, but subject to extractive uses of either a broad, low-intensity type (e.g., logging, Off Highway Vehicle recreation) or localized intense type (e.g., mining). It also confers protection to federally listed endangered and threatened species throughout the area.  Examples of Status 3: National Forests, BLM Lands, State Forests, some State Parks

Status 4: There are no known public or private institutional mandates or legally recognized easements or deed restrictions held by the managing entity to prevent conversion of natural habitat types to anthropogenic habitat types. The area generally allows conversion to unnatural land cover throughout

or management intent is unknown. Examples of Status 4: Unknown areas, private lands, developed or agriculture areas.

These GAP Management Status rankings have been assigned to every site in the PAD-US database, thereby making them spatially explicit for all PAs. Thus each PA has a de facto conservation management ranking in its entirety. Many IBAs and TNCs include all or portions of PAs within their boundaries, thereby making it possible to extrapolate a GAP status class based on spatial analysis of the PAs within the IBAs and TNCs. To do so, we separated the master PA polygon layer into four separate GAP 1, 2, 3 and 4 polygon layers, created Unions for these layers with IBAs and TNCs respectively, and calculated the acres of for each GAP status category within each IBA and TNC site. These acres were assigned scores of 1 to 4 according to their GAP status; any remaining area not covered by a PA was assigned a score of 5 (not a PA and no known protection). The percentage of area in each of the five categories was then calacuated for each IBA and TNC site, and an overall “GAP score” for the site calculated accordingly. For example, if a site had 25% of its area in GAP 2 (State Park), 50% in GAP 3 (National Forest) and 25% not in public land (i.e., “category” 5), its average GAP score would be 3.25 (25% x 2 + 50% x 3 + 25% x 5).

Data source: <https://www.usgs.gov/programs/gap-analysis-project/science/pad-us-data-overview>

We tallied the GAP scores for all portfolio sites. Lower scores represent a greater degree of conservation management.

**Scoring and Ranking the Sites**

Excel workbooks were developed for each of the three portfolio sets – IBAs, TNCs and PAs. Each Excel workbook had worksheets that included the core information provided for each site, such as its database ID, name, and acres. For those sites for which acres were not provided, they were calculated using Cylindrical Equal Area projections on ArcGIS. The ecoregion information was provided for all TNC sites, and was determined for IBAs and PAs using ArcGIS Analysis Tools/Statistics/Tabulate Intersection to calculate the percentage of unit within an ecoregion; if a site was in more than one ecoregion, the ecoregion with the largest percentage of area was selected.

In each of the three Excel workbooks, worksheets were maintained for each of the seven evaluation factors, where the scoring data (e.g. Variety of ELUs, mean Human Modification scores) was imported from the respective ArcGIS Spatial Analyst Tables. The Mean and Standard Deviation was determined for each evaluation dataset. Excel’s STANDARDIZE function was used to return a  z-score based on the mean and standard deviation.  Z-scores were calculated for each evaluation factor for all sites within each respective portfolio. Z-scores were then converted via Excel’s Norm.S.Dist function (Cumulative) which returns output for the standard normal cumulative distribution, and then multiplied by 100 to produce a scoring scale of 0 to 100 for each factor for each site, with 0 being the lowest potential score and 100 the highest.

A master scoring worksheet was maintained for each of the three portfolio sets. The VLOOKUP function was used to carry over the raw data and the calculated scores to the list of sites. An overall score for each site was calculated by averaging the seven scores. A worksheet with a table of weights was added to allow users to assign a higher or lower weight any of the seven evaluation factors (e.g. ELUs weight could be doubled, and/or Conservation Management could be zeroed out), and a weighted average automatically recalculated. For purposes of the core analysis, equal weights were assigned to each of the seven factors. Excel filters were used to sort overall scores from highest to lowest. [Note: for some sites, statistical values were not generated for some evaluation factors; if data was provided for any six factors, an average overall score was calculated. This affected a small number of site scores. If a site had data for fewer than six evaluation factors, the site was not scored.]

This process thus produced a scorecard for all sites within each of the three portfolios.

It is possible using these scorecards to simply generate overall, national priority lists within each of the three portfolios. However, doing so would fail to account for the variation of natural diversity across ecoregions, and would overly “reward” sites in those ecoregions with the greatest number of ELU gradients, the least human disturbance, etc. These ecoregions, such as the Colorado Plateau and the Arizona-New Mexico Mountains, are disproportionately found in the western United States. The ecoregional portfolio principles of *representation and replication/redundancy* requires that a national portfolio of priority sites be representative of all ecoregions.

We therefore developed macros using Visual Basic in three new workbooks to extract and rank the top 30 sites (or up to 30 sites if fewer present) in every ecoregion for each of the three portfolio sets. PAs were found in all 69 ecoregions; TNCs in 67 ecoregions and IBAs in 65 ecoregions. This process resulted in 1002 top ranked IBAs; 1271 top ranked TNCs; and 1238 PAs. A number of duplicate units in the PAs were consolidated (e.g., Grand Canyon National Park had five separate shapefiles; Great Dismal Swamp was split between VA and NC), and weighted average scores were calculated for these sites.

The final step involved consolidating the three portfolios into one “master” portfolio. The top 1000 sites were selected from each portfolio, using a scoring system that assigned equal weight to a site’s overall national percentile rank and its percentile rank within its ecoregion. This process assured the repre­senta­tion of all ecoregions in the final portfolio. The Excel workbooks were designed so that users could assign alternative weights to the national and ecoregional rankings, if desired.

This data was copied into a final Excel workbook, producing a new “master” portfolio of 3000 sites, all of which were then re-scored (z-scores) in comparison with their new “peers,” thus producing a final ranking of the “Last Great Places” in the lower 48 states. There was considerable spatial overlap among many sites from the three separate portfolios - e.g. the Canyonlands area of Utah was represented in all three portfolios, but in different configurations. These overlaps will be discussed in the Results and Discussion sections which follow.

October 2021 (updated April 2022)