# Development of a Landscape Integrity dataset for the Alaska Crucial Habitat Assessment Tool


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# Introduction

There is little debate that humans have impacted the landscape, particularly in the last 200 years. How we measure the impact, however, has been widely debated and discussed (Baldwin et al. , Steinitz 1990, Anderson 1991, Danz et al. 2007, Girvetz et al. 2008, Alberti 2010). Many attempts at mapping and quantifying the "human footprint" exist (Forman and Alexander 1998, Trombulak and Frissell 2000, Theobald 2001, Sanderson et al. 2002, Theobald 2004, 2005, 2010), but none have been developed specifically for Alaska. Additionally, it is largely recognized that merely the presence or absence of humans does not mean that the ecosystem is, or is not, operating in its peak condition. The presence or absence of human modification is only one of three criteria thought to define ecological integrity (Noss 2004). *Ecological resistance* (the ability to resist changes and stay intact regardless of the modification) and *resilience* (the ability to recover quickly, and without loss of function, following a disturbance) are equally important in quantifying the integrity of an ecosystem. Unfortunately, appropriate measures of resistance and resilience are difficult to identify, and often require intensive surveying and research effort. Human footprint on the other hand, is easily measurable. Further, human footprint is the one factor that land managers have the most control over.

The Crucial Habitat Assessment Tool (CHAT) was developed by the Wildlife Council of the Western Governors' Association (WGA) as a pre-planning tool to better inform both conservation and development projects at the landscape scale. This tool represents a cooperative effort among 16 Western states to provide the public and industry an overview of crucial wildlife habitat and corridors across the west. To this end, five categories of data were identified by the WGA for integration to the CHAT (WGA 2008). Native and unfragmented habitats represent one of the five Tier 1 data categories. The Alaska Department of Fish and Game (ADF&G) contracted the Alaska Natural Heritage Program (AKNHP) to compile a landscape integrity spatial dataset for Alaska to fulfill the requirement of identifying native and unfragmented habitat in Alaska. Using a modified Landscape Condition Model, the Alaska Natural Heritage Program has quantified, for the first time at the state level, the relative intactness of Alaska.

## Deliverables

Two geodatabases containing the below-detailed base and classified layers for landscape integrity in Alaska are provided to ADF&G in complement to this report. Geodatabase-level metadata is included as well. Datasets are provided in Albers Equal Area Conic projection for Alaska, referencing the North American Datum of 1983.

# Methods

## Human Land Use

Due to the unreliable quality of human footprint data in Alaska, we first developed our own comprehensive dataset representing all known and mapped human land uses (Table 1). Many data sources were used, and in some cases improved or augmented, using other available data. Specifically, the transportation dataset maintained by Alaska Department of Transportation and Department of

Natural Resources is out of date in many rural regions of Alaska. When feasible and prompted by external reviewers, we updated the dataset by removing features and digitizing new features using the Best Data Layer imagery made available by the Geographic Information Network of Alaska (www.gina.alaska.edu). All datasets used in this analysis are publically available, and were compiled into a single geodatabase for easy transferability and analysis.

| Dataset | Source | Description |
|---|---|---|
| **Pipe Lines** | ADNR | All industrial pipeline activity |
| **Power Lines** | ADNR | All power lines for Alaska |
| **Telephone Lines** | ADNR | All known telephone lines in Alaska |
| **AKEPIC** | AKNHP | Invasive species database, accessed January 2015 |
| **BLM Trails** | BLM | RS2477 trails linear features |
| **Ice and Rolligon Roads** | BLM | Seasonal winter roads, based on permits |
| **Major Rivers** | ADNR | Derived from the NHD |
| **Transportation** | ADNR | Includes highways, secondary roads, current and historical 4wd roads, major trails (like Iditarod) as well as foot trails |
| **Mining** | USGS | Slightly outdated estimate of current mining activity, limited to point data |
| **Logging** | USFS | Current estimate of logging operations |
| **National Land Cover Database** | USGS | Used for high, medium, and low density urbanization, as well as agriculture |

**Table 1: List of datasets used to compile comprehensive human footprint estimate for Alaska. ADNR = Alaska Department of Natural Resources, BLM = Bureau of Land Management, AKNHP = Alaska Natural Heritage Program, USGS = U.S. Geological Survey, USFS = U.S. Forest Service.**

## Landscape Condition Model

After compiling all human footprint data for the state, we modeled landscape integrity using a modified version of the NatureServe developed Landscape Condition Model (Comer and Hak 2009). The Landscape Condition Model is part of the Vista toolset that NatureServe provides to managers to aid in landscape-level conservation planning. The Landscape Condition Model (LCM) works by assigning an impact score and a decay distance to different types of land use and human modification. These impact scores are considered a relative measure of impact, as it is not focused on any particular ecological resource (species or habitat), but represents a scaled measure of the overall impact of human activities on the landscape. Values range from 0 (from lowest condition landscapes, limited function) to 1 (highest condition landscapes, fully functioning). Impact scores were developed for a suite of human activities by an exhaustive literature review combined with expert opinion, yielding an estimated impact for a full range of very intensive to minimal human modification to the landscape (Table 2). Additionally, the LCM recognizes that the level of impact is not limited to the precise location of the activity, and so included also is a decay score and distance. The decay score estimates how quickly the impact on the landscape degrades over space, and the decay distance estimates the maximum distance at which the impact is experienced. The combination of the decay score (scaled from 0 to 1) and the decay distance essentially creates a buffer around the activity to quantify the impact to the surrounding landscape of

the given activity (Table 2). When the impact score and distance decay are combined, the LCM creates a continuous surface representing relative landscape condition.

**Table 2: Original Landscape Condition Model (LCM) variables used to generate landscape integrity estimates in the contiguous U.S.**

| Theme | Data Source | Site Impact Score | Presumed Relative Stress | Decay Score | Impact Approaches Negligible |
|---|---|---|---|---|---|
| *Transportation* | | | | | |
| Dirt roads, 4-wheel drive | ESRI StreetMap 2010 | 0.7 | Low | 0.5 | 200m |
| Local and connecting roads | ESRI StreetMap 2010 | 0.5 | Medium | 0.5 | 200m |
| Secondary and connecting roads | ESRI StreetMap 2010 | 0.2 | High | 0.2 | 500m |
| Primary Highways with limited access | ESRI StreetMap 2010 | 0.05 | Very High | 0.1 | 1000m |
| Primary Highways w/out limited access | ESRI StreetMap 2010 | 0.05 | Very High | 0.05 | 2000m |
| *Urban and Industrial Development* | | | | | |
| Low Density Development | NLCD 2006 | 0.6 | Medium | 0.5 | 200m |
| Medium Density Development | NLCD 2006 | 0.5 | Medium | 0.5 | 200m |
| Powerline/Transmission lines | Platts (obtained under WGA agreement). | 0.5 | Medium | 0.9 | 100m |
| Oil /gas Wells | USGS/TNC | 0.5 | Medium | 0.2 | 500m |
| High Density Development | NLCD 2006 | 0.05 | Very High | 0.05 | 2000m |
| Mines | USGS/MRDS | 0.05 | Very High | 0.2 | 500m |
| *Managed and Modified Land Cover* | | | | | |
| Ruderal Forest & Upland | SW ReGAP, NW ReGAP, LANDFIRE EVT | 0.9 | Very Low | 1 | 0m |
| Native Veg. with introduced Species | SW ReGAP, NW ReGAP, LANDFIRE EVT | 0.9 | Very Low | 1 | 0m |
| Recently Logged | SW ReGAP, NW ReGAP, LANDFIRE EVT | 0.9 | Very Low | 0.5 | 200m |
| Managed Tree Plantations | SW ReGAP, NW ReGAP, LANDFIRE EVT | 0.8 | Low | 0.5 | 200m |
| Introduced Tree & Shrub | SW ReGAP, NW ReGAP, LANDFIRE EVT | 0.5 | Medium | 0.5 | 200m |
| Introduced Upland grass & forb | SW ReGAP, NW ReGAP, LANDFIRE EVT | 0.5 | Medium | 0.5 | 200m |
| Introduced Wetland | SW ReGAP, NW ReGAP, LANDFIRE EVT | 0.3 | High | 0.8 | 125m |

| | | | | | |
|---|---|---|---|---|---|
| Cultivated Agriculture | SW ReGAP, NW ReGAP, LANDFIRE EVT | 0.3 | High | 0.5 | 200m |

### Alaska LCM

Given that the LCM was originally parameterized for the contiguous U.S., where human activity is far more extensive and more pronounced on the landscape, we modified some of the LCM parameters to better represent the nature and extent of human activity in Alaska. Using the only other estimate of landscape integrity or intactness in the state (Strittholt et al. 2006), we modified the decay distance for several of the transportation land uses to better capture the effect of roads in Alaska. Additionally, although the impact score and decay distances are robust estimates of relative impact, there is been no ground-truthing of the LCM in Alaska (unlike the lower 48). This led us to drop the decay score and assume a simple linear decrease in impact for all land uses. Finally, we added several new transportation themes (mining trails, major rivers, sled dog trails, and ice and rolligon roads) to capture land uses that are not considered in the original LCM. These transportation themes were included based on extensive collaboration with BLM and other land management agencies during the development of the Rapid Ecoregional Assessments (REAs) in Alaska (Trammell et al. 2014, Trammell et al. 2015). We included mining trails separate from the trails database managed by the Alaska Department of Transportation because a) the mining trails are permitted by BLM and therefore not included in the DOT dataset and b) the level of impact can be quite high as small-scale mining operations have to move major equipment into relatively remote locations. Major rivers are included because the serve as an important transportation corridor between rural villages in the winter months. Similarly, sled dog trails were also included because their roles as important routes between rural villages, especially in the case of the Iditarod trail. Working closely with BLM on the North Slope, we were also able to include ice roads and rolligon trails as a transportation theme to develop a better understanding of human activity on the North Slope as part of the REA. A complete table of the themes, datasets, impact scores, and decay distances are presented in Table 3.

**Table 3: Landscape Condition Model variables used for estimating landscape integrity in Alaska.**

| Theme | Data Source | Site Impact Score | Presumed Relative Stress | Decay Distance |
|---|---|---|---|---|
| *Transportation* | | | | |
| Dirt roads, 4-wheel drive, historic tractor trails | Alaska DOT | 0.7 | Low | 500m |
| Mining Trails | BLM | 0.5 | Medium | 500m |
| Local and connecting roads | Alaska DOT | 0.5 | Medium | 500m |
| Secondary and connecting roads | Alaska DOT | 0.2 | High | 500m |
| Highways (including Dalton) | Alaska DOT | 0.05 | Very High | 5000m |
| Iditarod Trail | Alaska DNR | 0.7 | Low | 500m |
| Major Rivers | NHD | 0.7 | Low | 500m |
| Ice and Rolligon Roads | BLM | 0.7 | Low | 500m |

| | | | | |
|---|---|---|---|---|
| *Urban and Industrial Development* | | | | |
| Low Density Development | NLCD 2011 | 0.6 | Medium | 200m |
| Medium Density Development | NLCD 2011 | 0.5 | Medium | 200m |
| Powerline/Transmission lines | Alaska DNR | 0.5 | Medium | 100m |
| Oil /gas Wells | Alaska DNR | 0.5 | Medium | 500m |
| High Density Development | NLCD 2011 | 0.05 | Very High | 2000m |
| Mines | USGS ARDF | 0.05 | Very High | 500m |
| *Managed and Modified Land Cover* | | | | |
| Native Veg. with introduced Species | AKEPIC | 0.9 | Very Low | 200m |
| Recently Logged | USFS | 0.9 | Very Low | 200m |
| Cultivated Agriculture | NLCD 2011 | 0.3 | High | 200m |

All analyses were performed in ArcGIS 10.2.2 (ESRI 2015). Although the Landscape Condition Model is available through the NatureServe Vista package, we built a custom ArcGIS toolbox to generate the landscape integrity datasets for Alaska. This gave us flexibility in modifying the decay distances, as well as the analysis unit. Given the limitations of the data used in the analysis, we set the grid cells to 500 meters for this statewide dataset. The final LCM is delivered as both a continuous raster as well as a categorical dataset using the standard quintile bins from NatureServe. Additionally, we summarized landscape condition by ecoregion as defined by Nowaki et al (2001).

## Large Intact Blocks (LIB) and Landscape Integrity

We used the resulting statewide LCM to calculate Large Intact Blocks (LIBs) in order to fully define landscape integrity. Merely assessing condition without considering the landscape context may misrepresent the actual impact of different human activities on the overall landscape integrity. Most importantly, landscape condition should not be assessed at a particular location without some explicit consideration of the surrounding environment (Scott et al. 2004). We define "intact" as those areas with a LCM score of 0.8 or greater, representing the highest quintile of possible scores from the LCM. We then lumped all contiguous areas with a score of greater or equal to 0.8 and classified them in landscape integrity categories according to methodology established in the REAs in Alaska:

| Size | Classification |
|---|---|
| > 50,000 acres | Highest Integrity |
| 10,000-50,000 acres | High Integrity |
| < 10,000 acres | Vulnerable |

These categories are based on two assessments previously completed in Alaska. First, the Global Forest Watch (Stritthodt et al. 2006) identified areas greater than 50,000 acres as being highly intact. However, in a second analysis Geck (2007) identified areas greater than 10,000 acres as potential wilderness areas for BLM. Thus, we identified areas with both levels of landscape integrity according to the size of the LIB, and labeled anything less than 10,000 acres as potentially vulnerable to environmental perturbations.

# Results

## Human Footprint

We compiled all human footprint data into a single geodatabase (Figure 1). To date, this represents the only comprehensive attempt at compiling all human footprint data into a single analysis for the state. In total, there is approximately 3,156 km (1,961 mi) of highways, 17,180 km (10,675 mi) of secondary roads, 37,255 km (23,150 mi) of trails, and 6,120 km (3,803 mi) of 4WD/OHV roads. There is approximately 42 $km^2$ (16 $mi^2$) of high density urban development, 119 $km^2$ (46 $mi^2$) of medium density urban, and 1,224 $km^2$ (473 $mi^2$) of low density urban (including urban open space). Finally, there is 288 $km^2$ (111 $mi^2$) of agriculture in the state, and 2,446 $km^2$ (944 $mi^2$) of active logging.

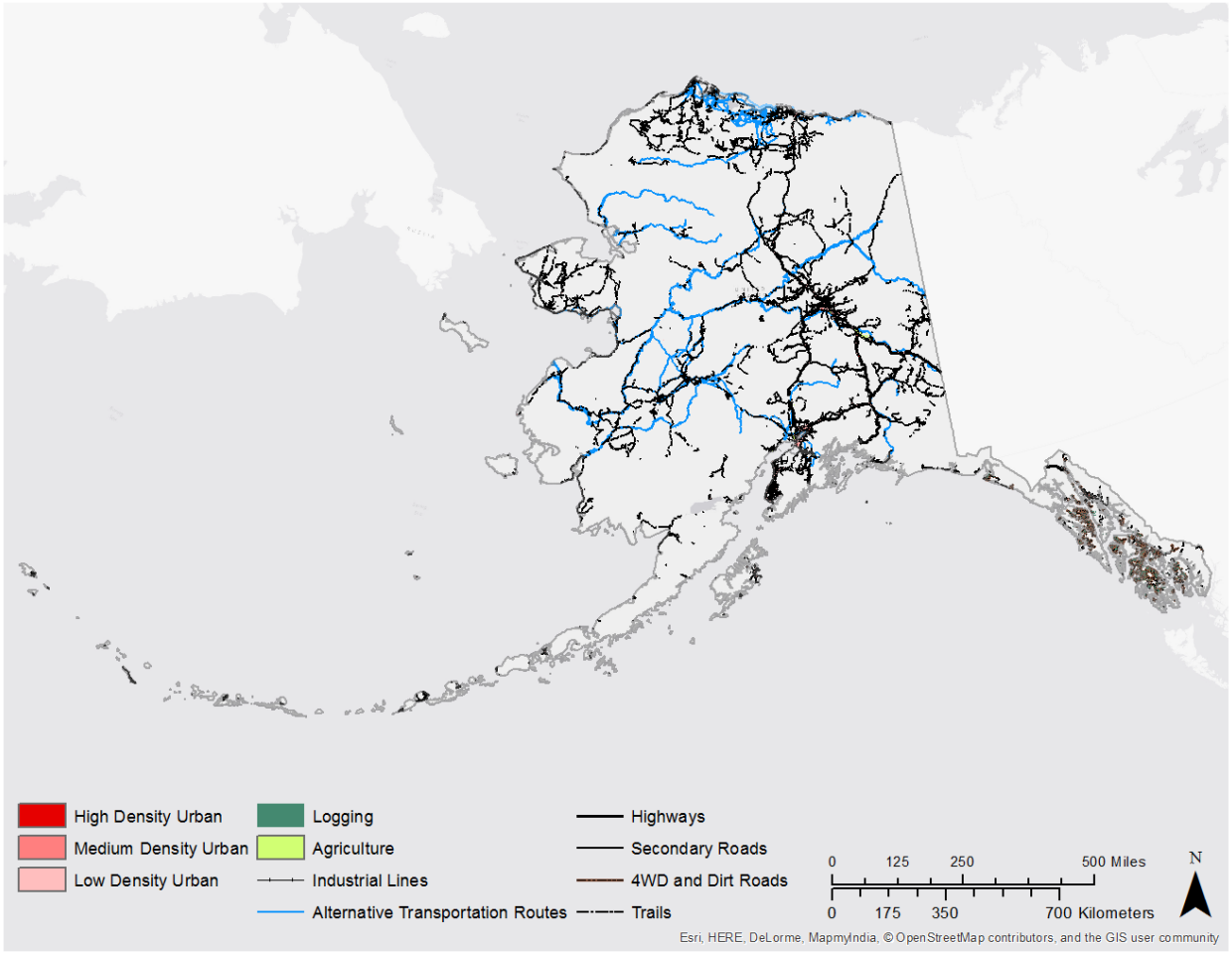


**Figure 1: Comprehensive human footprint datasets for the state of Alaska.**

## Alaska LCM

Overall landscape condition in Alaska is very high (Table 4, Figure 2). Using the NatureServe quintiles, over 95% of Alaska is considered in very high condition (LCM score of > 0.8). While approximately 2.6% of the state is considered to have moderate landscape condition, a little more than 1% is considered low or very low condition (Table 4). As expected, low and very low condition landscapes are found in and

around oil development on the North Slope (especially Prudhoe Bay), major cities (Anchorage, Fairbanks, the Kenai Peninsula and Juneau), and in the intensive forestry activities in southeast Alaska (Figure 2).

**Table 4: Landscape Condition for Alaska according to NatureServe categories.**

| CONDITION | AREA ($KM^2$) | PERCENTAGE OF STATE |
|---|---|---|
| **VERY LOW** | 6,835 | 0.4% |
| **LOW** | 12,719 | 0.8% |
| **MODERATE** | 39,297 | 2.6% |
| **HIGH** | 7,196 | 0.5% |
| **VERY HIGH** | 1,456,397 | 95.7% |

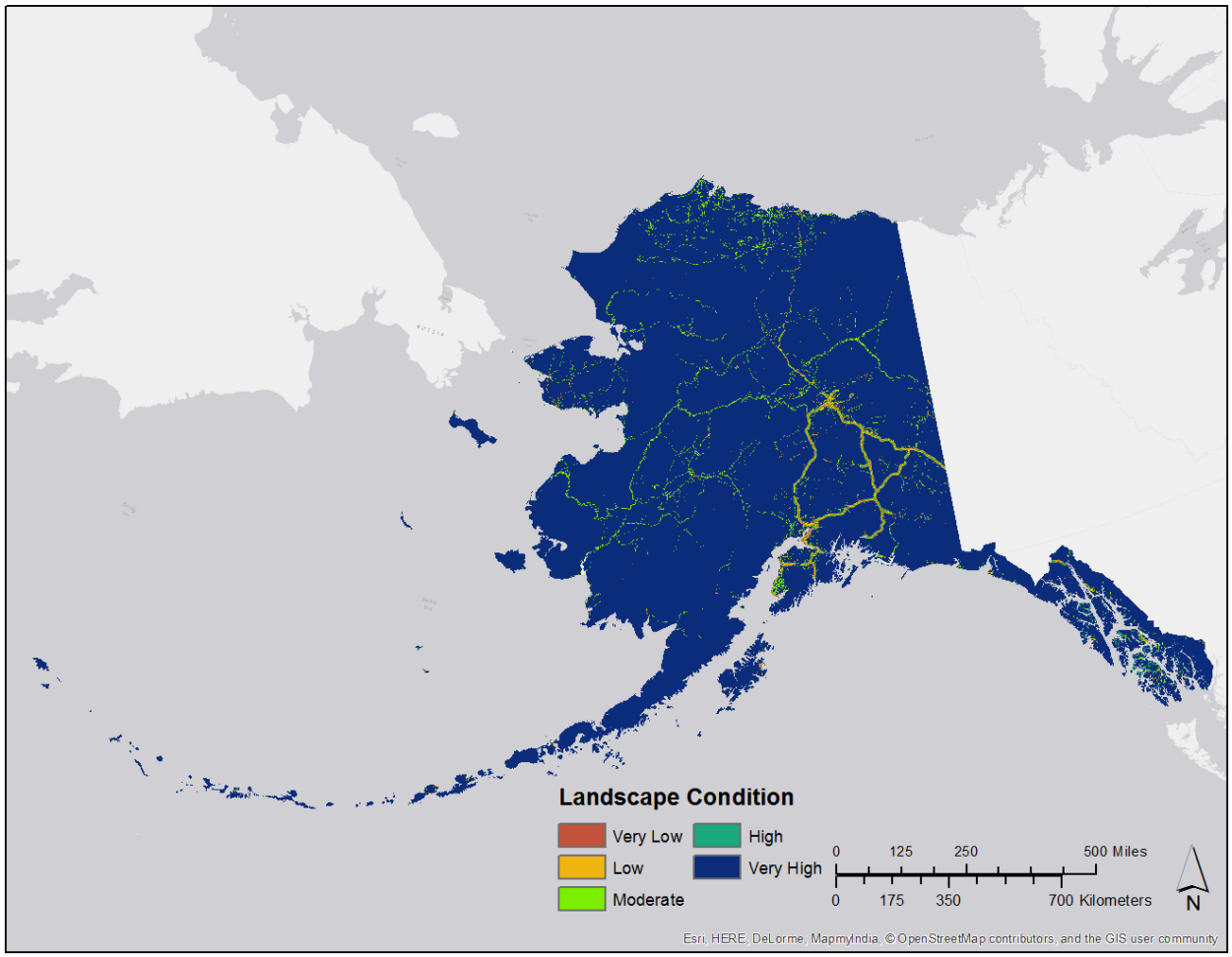


**Figure 2: Estimated current landscape condition for Alaska. Developed using the Landscape Condition Model from NatureServe, but modified to reflect more regionally relevant estimates of impact and distance decay.**

By summarizing the LCM by ecoregion, we can better understand the level of human development across the multitude of environments present in Alaska. The most impacted ecoregion (mean LCM score = 0.86; see Appendix) is the Cook Inlet Basin, home to Anchorage and over half of the human

population in the state. Second most impacted, however, is the Copper River basin (mean LCM score = 0.89). With a smaller geographic extent, the Copper River basin is at the intersection of three of the state's major highways, leading to a lower average condition. Of note, all ecoregions have a minimum score of 0.05, suggesting that there is evidence of human modification in every ecoregions in the state. However, all but the above mentioned ecoregions have an average LCM score of greater than 0.9. Four ecoregions (Bering Sea Island, Davidson Mountains, Alaska Peninsula and Lime Hills) have an average LCM score of 1, suggesting the even though there is some evidence of human land use, the overall impact to the ecoregion is undetectable.

## Landscape Integrity

Using the Large Intact Blocks methods described above, we find that of the 1.45 million square kilometers of very high condition lands, over 97% can be found in large blocks greater than 50,000 acres, representing the highest landscape integrity (Table 5; Figure 3). Of the high condition landscapes, 1.5% are between 10,000 and 50,000 acres, while 1% are considered to have low integrity since they occur in blocks less than 10,000 acres. Approximately 73,000 square kilometers, or 4.8% of the state, did not meet the minimum LCM score to be considered in the LIB analysis.

**Table 5: Landscape integrity categories for the state of Alaska.**

| LANDSCAPE INTEGRITY | AREA ($KM^2$) | PERCENT |
|---|---|---|
| **HIGHEST** | 1,419,726 | 97.5% |
| **HIGH** | 22,132 | 1.5% |
| **LOW** | 14,515 | 1.0% |

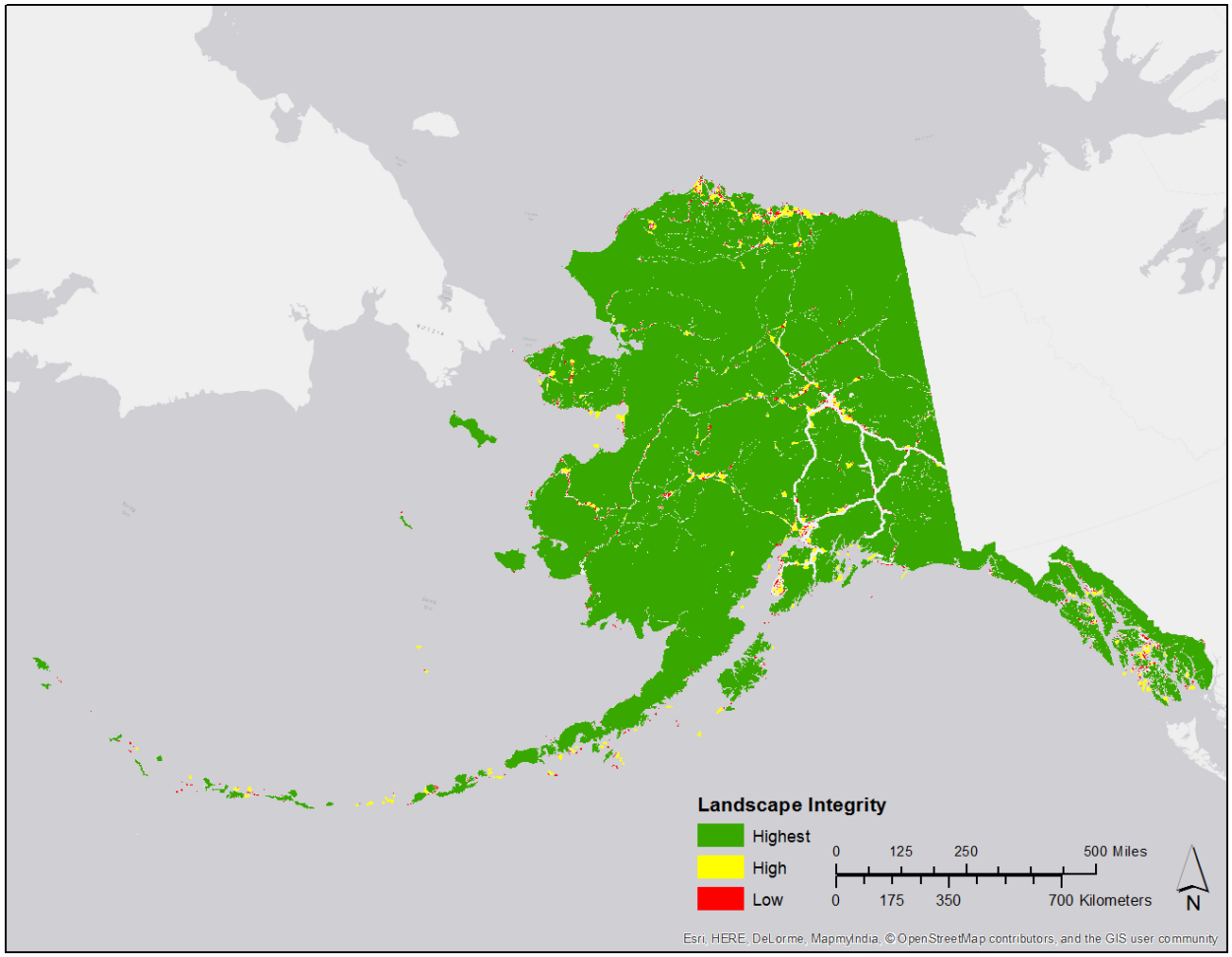


**Figure 3: Modeled landscape integrity for the state of Alaska.**

## Discussion

Alaska is known for its large, pristine landscapes and natural areas. Therefore, it is no surprise that our assessment confirms that the large majority of Alaska is indeed intact. In fact, most of Alaska far exceeds landscape condition values of even the most protected places (national parks and wilderness areas) in the contiguous United States (see Comer and Hak 2012). It is safe to say that the direct level of human modification to Alaskan landscapes is quite small.

Furthermore, areas with lower condition are restricted to relatively small geographical areas, leading to approximately 93% of the state falling into the highest landscape integrity category. However, while the majority of the state is indeed unimpacted by direct human modification, it is worth considering the implications of some of the low integrity landscapes. While they only represent 1% of the high condition landscapes, the low integrity areas are important because they are surrounded by development, which could impact the resilience of those landscapes to stochastic events or landscape stressors like climate change. In specific regions, these low integrity but high condition landscapes may serve as important migration corridors, or provide important ecosystem services to nearby communities. Thus, while it is

very safe to say that the majority of Alaska is not directly impacted by human land use and development, there are some regions that could be impacted and should be monitored to ensure they remain functional.

Additionally, the difference between "very high" and "high" landscape condition is a relative classification used in this broad-scale assessment, but could have important implications for sensitive species or habitats throughout the state. Arctic and subarctic systems are regularly exposed to extreme conditions, and many species that occur in Alaska also experience their range limit within the state. The sensitivity of species and ecological systems in Alaska therefore may be more sensitive to any degradation in landscape condition.

Similarly, it is important to distinguish between landscape integrity and ecological integrity. Ecological integrity encompasses more than just the structure of the environment, it accounts also for composition and function (Dale and Beyeler 2001; Tierney et al. 2009). Landscape integrity assesses only the structure of the landscape, and is modeled here as the landscapes that have not been physically modified by humans. While this is an important part of understanding ecological stability, and concepts related to ecological resilience and resistance, it is only one part of understanding the integrity of the broader ecosystem.

## Conclusion

It is no surprise that Alaska is largely seen as intact and pristine. Using the best available data, we estimate that 95% of the state shows very little physical disturbance by humans. However, the best available data is quite limited, and the implications of human development on systems in Alaska is uncertain. Regardless, understanding the baseline status of ecosystems is an important step in developing conservation plans, and this analysis provides a relatively simple, yet robust look at landscape integrity in Alaska.

## Limitations of Use:

The vast size of Alaska relative to other western states results in statewide data layers that are often inconsistently assembled and subsequently restricted in accuracy and utility. For example, trail data was assembled using Alaska Department of Transportation shapefiles, as well as from the Bureau of Land Management mining trails shapefile. While this layer is considered the best-available data, it is presumably less accurate than landscape integrity estimates for the lower 48. Additionally, although delivered at 500m resolution for the state, the accuracy of individual elements is unknown in many instances. This dataset should be used in regional-scale analyses only; if finer-level information is desired we suggest a reanalysis of the datasets and working with regional stakeholders to define the regionally-specific impact and distance decay scores.

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# Appendix

## Summary of Landscape Condition by Ecoregion

| ECOREGION NAME | MIN | MAX | RANGE | MEAN | STD |
|---|---|---|---|---|---|
| COOK INLET BASIN | 0.05 | 1.00 | 0.95 | 0.86 | 0.27 |
| COPPER RIVER BASIN | 0.05 | 1.00 | 0.95 | 0.89 | 0.24 |
| TANANA-KUSKOKWIM LOWLANDS | 0.05 | 1.00 | 0.95 | 0.94 | 0.19 |
| YUKON-TANANA UPLANDS | 0.05 | 1.00 | 0.95 | 0.95 | 0.17 |
| BEAUFORT COASTAL PLAIN | 0.05 | 1.00 | 0.95 | 0.96 | 0.15 |
| ALEXANDER ARCHIPELAGO | 0.05 | 1.00 | 0.95 | 0.96 | 0.14 |
| GULF OF ALASKA COAST | 0.05 | 1.00 | 0.95 | 0.97 | 0.15 |
| RAY MOUNTAINS | 0.05 | 1.00 | 0.95 | 0.97 | 0.14 |
| ALASKA RANGE | 0.05 | 1.00 | 0.95 | 0.97 | 0.14 |
| CHUGACH-ST. ELIAS MOUNTAINS | 0.05 | 1.00 | 0.95 | 0.97 | 0.13 |
| SEWARD PENINSULA | 0.05 | 1.00 | 0.95 | 0.97 | 0.12 |
| YUKON RIVER LOWLANDS | 0.05 | 1.00 | 0.95 | 0.97 | 0.11 |
| BOUNDARY RANGES | 0.05 | 1.00 | 0.95 | 0.98 | 0.12 |
| KLUANE RANGE | 0.05 | 1.00 | 0.95 | 0.98 | 0.11 |
| KOBUK RIDGES AND VALLEYS | 0.05 | 1.00 | 0.95 | 0.98 | 0.10 |
| YUKON-OLD CROW BASIN | 0.05 | 1.00 | 0.95 | 0.98 | 0.10 |
| NORTH OGILVIE MOUNTAINS | 0.05 | 1.00 | 0.95 | 0.98 | 0.10 |
| ALEUTIAN ISLANDS | 0.05 | 1.00 | 0.95 | 0.98 | 0.11 |
| KUSKOKWIM MOUNTAINS | 0.05 | 1.00 | 0.95 | 0.98 | 0.10 |
| KODIAK ISLAND | 0.05 | 1.00 | 0.95 | 0.98 | 0.10 |
| BROOKS FOOTHILLS | 0.05 | 1.00 | 0.95 | 0.98 | 0.09 |
| WRANGELL MOUNTAINS | 0.05 | 1.00 | 0.95 | 0.99 | 0.09 |
| YUKON-KUSKOKWIM DELTA | 0.05 | 1.00 | 0.95 | 0.99 | 0.08 |
| KOTZEBUE SOUND LOWLANDS | 0.05 | 1.00 | 0.95 | 0.99 | 0.06 |
| NULATO HILLS | 0.05 | 1.00 | 0.95 | 0.99 | 0.06 |
| BROOKS RANGE | 0.05 | 1.00 | 0.95 | 0.99 | 0.06 |
| BRISTOL BAY LOWLANDS | 0.05 | 1.00 | 0.95 | 0.99 | 0.06 |
| AHKLUN MOUNTAINS | 0.05 | 1.00 | 0.95 | 0.99 | 0.06 |
| BERING SEA ISLANDS | 0.05 | 1.00 | 0.95 | 1.00 | 0.05 |
| DAVIDSON MOUNTAINS | 0.05 | 1.00 | 0.95 | 1.00 | 0.05 |
| ALASKA PENINSULA | 0.05 | 1.00 | 0.95 | 1.00 | 0.05 |
| LIME HILLS | 0.05 | 1.00 | 0.95 | 1.00 | 0.05 |