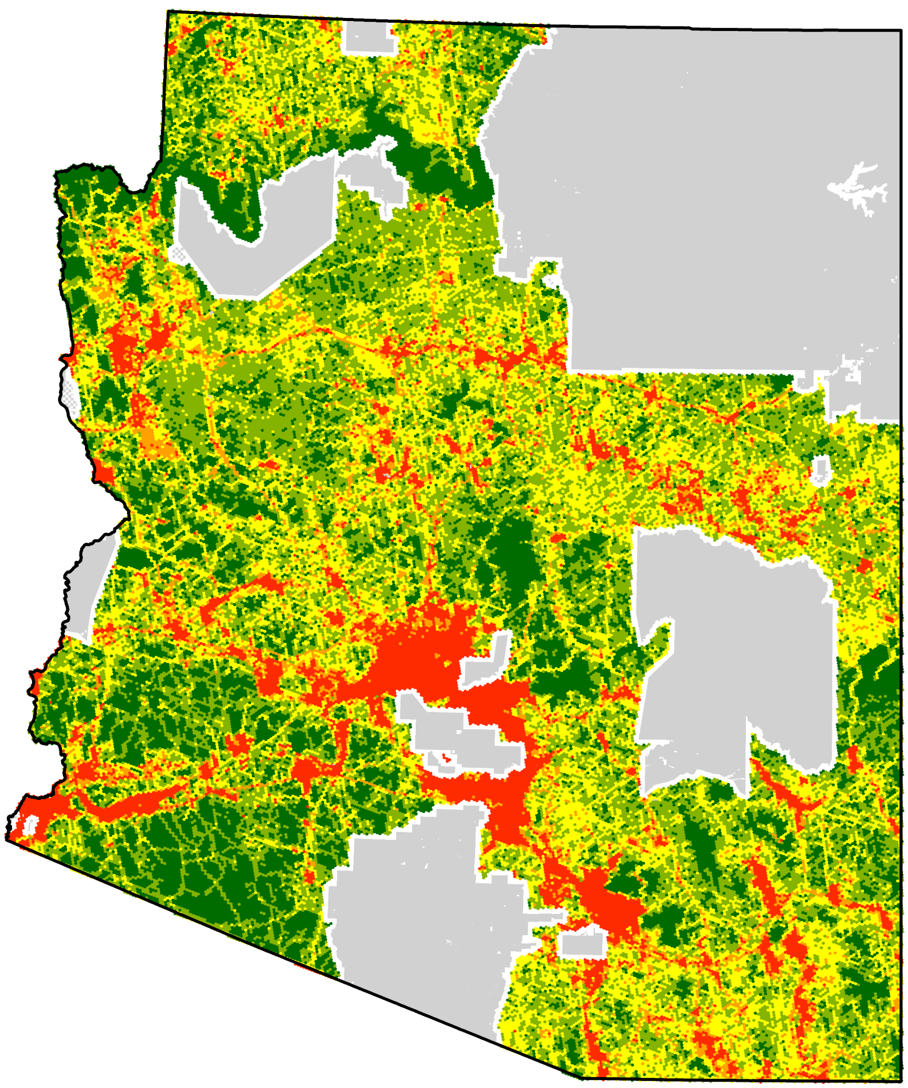
A Place for Human Modification and Intactness Data in Regional Mitigation:

A Case Study from Arizona



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Cover Photo

Human modification in Arizona from high (warm colors) to low levels (green colors). Tribal areas not included.

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A Place for Human Modification and Intactness Data in Regional Mitigation:
A Case Study from Arizona

A Report by

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Executive Summary

Regional mitigation policies in the United States increase the need to understand baseline conditions of natural resources to adequately compensate for adverse effects of infrastructure development. In this study, a new human modification dataset for Arizona derived from visual inspection of aerial imagery reveals that more than half of non-Tribal lands can be considered relatively intact and 17.5% have been heavily modified by humans. Using regional-scale contiguous intact blocks derived from this dataset, we evaluated a proposed interstate. The evaluation contributed to the removal of a proposed route that would have fragmented the 3rd largest intact landscape in the state. The methodology used to develop this dataset provides certain advantages related to new mitigation policies that call for increased transparency, including depiction of percent human modification without impact-score or decay-function modeling artifacts and identification of land uses and unique ecological features that are often not captured in existing geographic datasets.

Introduction

Balancing business and conservation interests to support nature and people is challenging given the projected global scale and rate of development (Oakleaf et al. 2015). To address this challenge, conservation organizations, natural resource agencies, and development proponents are using new mitigation policies and tools to evaluate infrastructure proposals and reduce their effects on natural resources (Kiesecker et al. 2009, Kiesecker et al. 2010, Clement et al. 2014). We present a type of data that can improve mitigation effectiveness.

Mitigation is not the only solution to biodiversity conservation, but applied effectively it can be a useful complement to traditional conservation efforts (Kiesecker et al. 2009). The goal of mitigation is zero loss or net benefit to wildlife and ecosystems (CEQ 2000) achieved through a hierarchy of steps: avoiding construction where natural values are irreplaceable, minimizing negative effects to key habitats, and restoring and offsetting negative effects to natural resources using compensatory off-site mitigation. In this framework, offsets are the last resort (Kiesecker et al. 2009, Kiesecker et al. 2011).

Offsets to mitigate biodiversity losses have been criticized as ineffective in meeting goals and for exacerbating environmental harm through eroding ethical barriers to destruction (Ives and Bekessy 2015). Mitigation evaluations and actions have generally occurred at the project scale limiting their ability to provide regional context, address cumulative effects, and provide adequate offset options (Kiesecker et al. 2009, Clement et al. 2014).

To address some of these concerns, many federal and state governments in the United States (U.S.) are beginning to address mitigation at regional scales. A consistent mitigation policy was recently established for the Departments of Defense, Interior, and Agriculture that includes use of the mitigation hierarchy and regional-scale planning (POTUS 2015). The U.S. Department of Interior Departmental Manual includes a chapter on landscape scale mitigation policies and implementation guidance (USDOI 2015). The U.S. Federal Highway Administration published mitigation guidance in 2006 (Brown 2006) and transportation legislation in 2012 encouraged the development of regional mitigation plans early in the planning process (MAP-21 2014).

These policies all rely upon knowledge of the degree to which humans have previously modified the land, often referred to by various terms: landscape integrity, naturalness, human footprint, ecological integrity, and landscape intactness. As described in the U.S. Department of Interior manual, mitigation should include "Protecting and restoring core, unfragmented habitat areas," (i.e., high intactness areas) and "Focusing development activities in ecologically disturbed areas when possible" (i.e., low intactness areas) (USDOI 2015). Mitigation policies also highlight the need for regional-scale conservation plans (USDOI 2015, POTUS 2015), which often use landscape intactness or fragmentation as surrogates for ecological integrity (Groves and Game 2016). Often land management agencies lack the resources necessary to develop multiple species habitat models and, under these conditions, modeling connectivity using landscape intactness data is a suitable alternative to focal species modeling (Krosby et al. 2015).

The need for robust landscape intactness datasets for mitigation and conservation is clear (Theobald 2013, Clement et al. 2014) and land managers have begun using such datasets to inform their mitigation decisions. Several datasets have been developed for the western U.S. with the explicit intent of supporting regional mitigation. Notable examples include the Western Governors' Association's Landscape Condition dataset (Comer and Hak 2012), Theobald's Human Modification Index dataset (Theobald 2013), the Arizona Game and Fish Department's Landscape Integrity dataset (Perkl 2013), and U.S. Bureau of Land Management's Sonoran Desert Terrestrial Intactness dataset (Strittholt et al. 2012). These and most available modification datasets (e.g., Leu et al. 2008, Theobald 2010) were developed using a similar modeling approach. Existing digitized spatial data on land cover and human use (e.g., roads, urban areas) were assembled, impact factors applied, and data combined into an index representing a human modification gradient.

The Nature Conservancy in Arizona found several conceptual and practical challenges in using such datasets for regional mitigation. Terms like landscape intactness are rarely defined. Models assume that existing human use datasets are accurate and complete which is not always the case in large western states and rural areas. Models often compute decay functions from existing infrastructure, apply impact scores or weighting schemes to different types of disturbances, and apply cross-scale aggregation methods, all of which are difficult to validate or understand.

To address these challenges, we developed an alternative dataset that characterizes previous human modifications based upon a visual examination of aerial imagery for non-Tribal Arizona lands. We estimated percent human modification within square-mile analysis units and then derived additional datasets by aggregating these into contiguous intact landscapes. We adopt the definition of landscape intactness as a measure of how contiguous a landscape is in conditions of low human modification (Trammell 2014). This definition acknowledges that the landscape can be viewed along a continuum from low to high human modification. In contrast to modeled products, it is not reliant on incomplete human use datasets or decay functions, does not use cross-scale aggregation, and is relatively simple to understand, validate, replicate, and compare across studies.

Here, we present our alternative approach to creating modification data and provide practical information on how to use these data in regional mitigation using a case study from Arizona: the proposed Interstate-11 and Inter-Mountain West Transportation Corridor (I-11) (ADOT and NDOT 2014). Most of the proposed I-11 routes would fragment areas of the Sonoran Desert, posing a potential threat to intact landscapes. Relatively little is known about the broad effects of fragmentation in desert and dryland ecosystems, but more specific studies show that fragmentation reduces pollination (Aizen and Feinsiger 1994), is detrimental to some species (e.g., fish (Fagan et al. 2002) and snakes (Rosen & Lowe 1994)), and that connectivity and dispersal play important roles for species living in "naturally fragmented" populations (e.g., bighorn sheep (Bleich et al. 1990) and toads (Bradford et al. 2003)). To address these and other concerns, we used our data along with other data (e.g., critical habitat, perennial waters, wildlife corridors) to provide recommendations to the Arizona Department of Transportation for their evaluation of potential routes (ADOT and NDOT 2014). Because the move to implement mitigation regionally is relatively new and applied science is needed to support its practice (Clement et al. 2014), the methodology and examples we provide here will be immediately useful to practitioners in the field.

METHODS

To create a comprehensive human modification dataset for use in regional mitigation and conservation planning, we adapted a methodology, based on human interpretation of aerial imagery (Randall et al. 2010), to identify landscape modification where it could be clearly attributed to humans. Our methods assume that the human eye can accurately detect and interpret human land modification from aerial images. We did not catalog invasive species or fires, given the difficulty in visually identifying these and other human-driven ecological disturbances. We developed our Human Modification (HM) dataset at the statewide scale, excluding land under the jurisdiction of the 21 Tribal Nations located in Arizona. We also created two derived datasets, Large Intact Blocks (LIB) and Ecological Systems LIBs. These two datasets consider spatial configuration, thereby using HM data to create intactness datasets that provide regional context.

Human modification (HM)

To create our HM data, we used aerial imagery current to the year 2010 (ESRI 2010, USDA 2010) and assigned a categorical value (0%, 1 – 5%, 5 – 25%, 25 –50%,or >50%) for the percent area visibly modified by humans to each of nearly 80,000 one square mile (2.59 km^2) hexagons (Fig. 1). We chose a sampling grid of hexagons because they are well recognized as an optimal unit for conservation planning (Nhancale and Smith 2011), perform better than rectangular grids for nearest-neighbor analyses that support connectivity and movement studies, and have advantages for data visualization (Birch et al. 2007). To determine the appropriate category for each hexagon, we applied the principle of convex hull theory (de Berg et al. 2000) to visually consolidate all signs of human modification within one area of the hexagon and to make a reasonable determination of the modification category. Reference datasets (e.g., topographic maps, land ownership) were used for assistance as needed (Appendix 1). To minimize observer bias, a standard set of interpretation guidelines were developed, and training runs were compared between observers to calibrate interpretations.

Large intact blocks (LIBs)

We used HM data to answer the question, "Where are contiguous areas of land that can be considered intact from a wildlife perspective?" We selected the term "Large Intact Blocks" for these data because it is already used by land managers (e.g., WGA 2013, Trammell 2014). Specifically, we defined LIBs across non-Tribal Arizona as areas of contiguous land greater than 5,000 acres (20.23 km^2) that were < 25% visibly modified per square mile by dirt roads and < 5% visibly modified per square mile by all other human modifications examined, and were more than 1,000 m from highways and major roads and 100 m from minor roads, railroads, and canals. We selected 5,000 acres as the threshold size because it is the minimum size requirement for wilderness designation under the U.S. Wilderness Act of 1964.

Ecological Systems LIBs

To evaluate mitigation offset options, we created an Ecological Systems LIB dataset for the Sonoran Desert. This dataset extended the definition of landscape intactness to specific ecological systems. We restricted this analysis to the Sonoran Desert because it is subject to many new infrastructure proposals, including I-11 and solar energy development. We used ecological systems data from the U.S. Geological Survey Southwest land cover dataset (Lowry et al. 2007) and extracted locations that overlapped 0 and 1 - 5% HM hexagons.

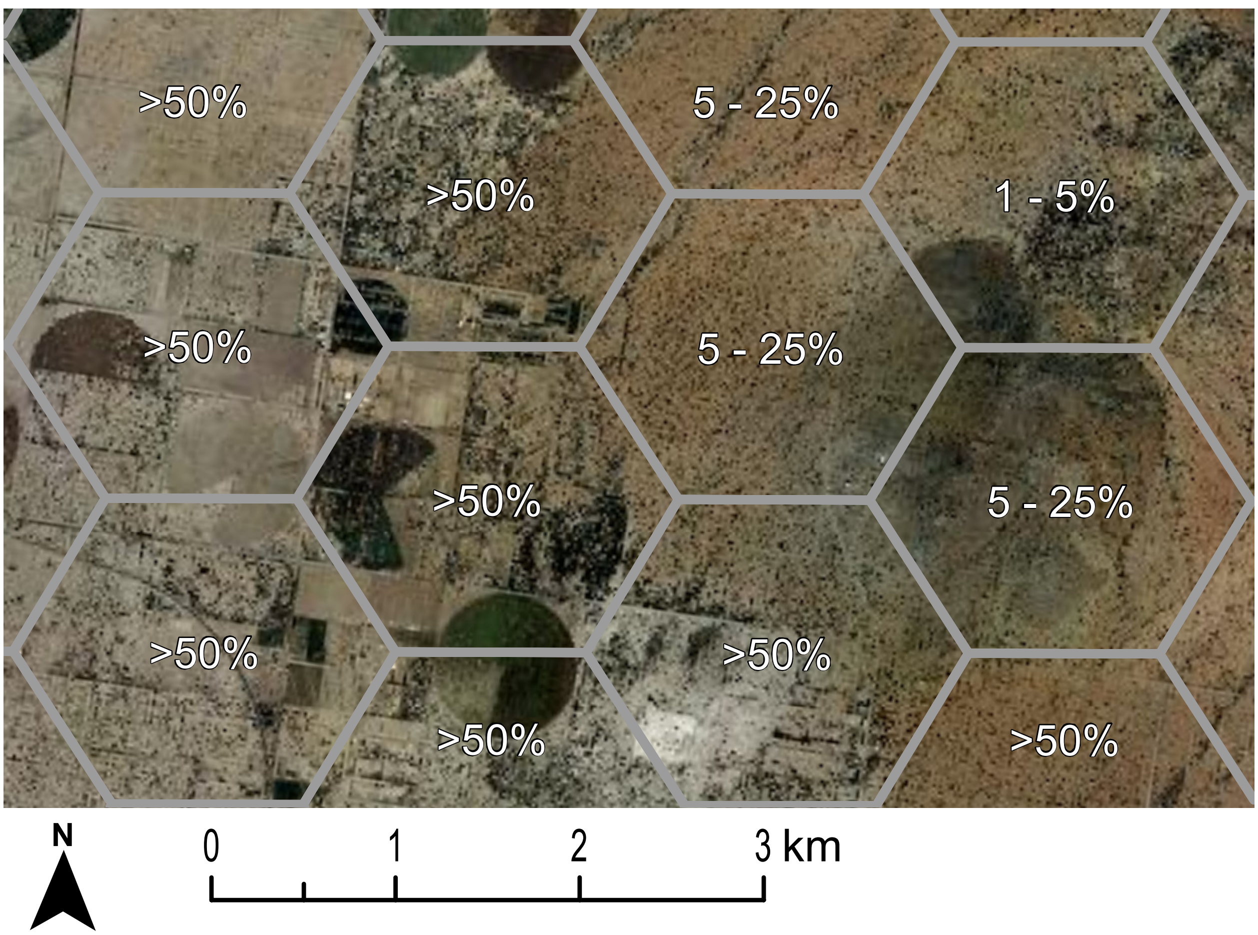

Figure 1. Categorization on the degree of visible human modification. Labels show one-square mile (2.59 km^2) sampling hexagon with the following estimates of visible modification: 1 – 5%, 5 – 25%, 25 – 50%, or >50%.

RESULTS

Our HM dataset shows that more than half of non-Tribal Arizona lands have had relatively low modification by humans (≤ 5% modified per sq mi) and 17.5% have been heavily modified by humans (> 25% modified per sq mi) (Fig. 2). At the state scale, overall patterns of modification were not surprising as many of the lands where hexagons of 0% modification were aggregated were within protected areas (e.g., the Grand Canyon) and clusters of highly modified lands primarily occurred within Arizona's urban centers (Phoenix and Tucson) and agricultural areas (Gila River, Yuma, Sulphur Springs Valley) (Fig. 2).

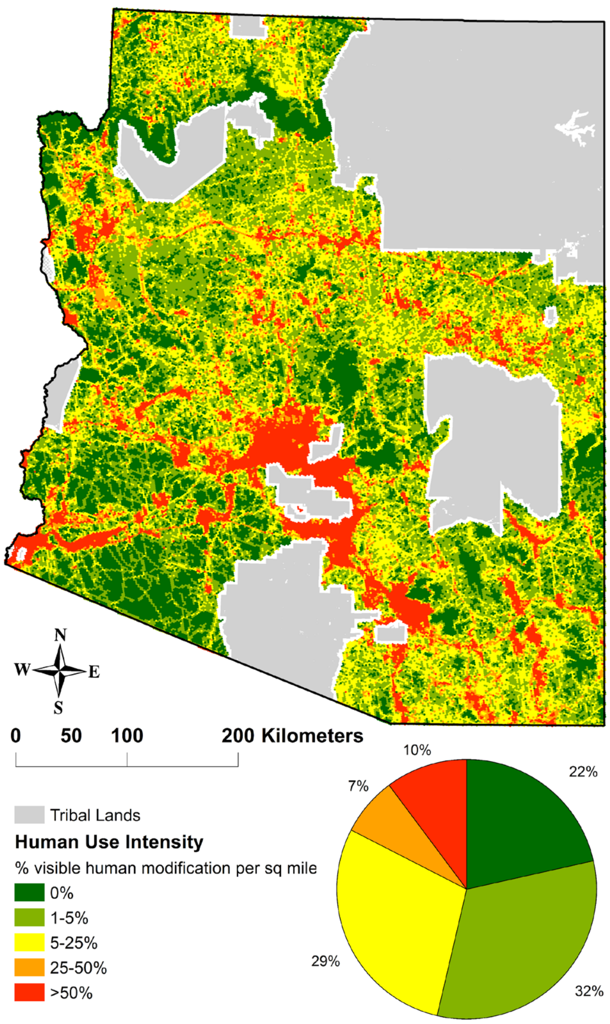

Figure 2. Human Modification (HM) dataset for non-Tribal Arizona, USA. Over 50% of lands in the state are less than or equal to 5% modified by humans per square mile (2.59 km^2) and 17% are greater than 25% modified per square mile. Highly modified urban and agricultural areas are noted, as is the largest intact area, the Grand Canyon.

Next, we present the use of this dataset in a real-world infrastructure project, the proposed I-11 that would traverse desert landscapes across Arizona, in which stakeholders were asked to apply the principles of the mitigation hierarchy - avoid, minimize, and offset - at a regional scale (ADOT and NDOT 2014). The first goal of the mitigation hierarchy is to avoid siting development where natural resources are irreplaceable (Kiesecker et al. 2010, Kiesecker et al. 2011). Large intact areas are considered important to maintaining viable wildlife populations (Haddad et al. 2015) and it would be difficult, if not impossible, to mitigate for fragmentation of these areas. Therefore, we used our LIBs to recommend that construction along a proposed route that would have fragmented the third largest LIB in non-Tribal Arizona be avoided (Fig. 3). Along with similar input from other stakeholders, these results persuaded the Arizona Department of Transportation to remove this route from further consideration (ADOT and NDOT 2014).

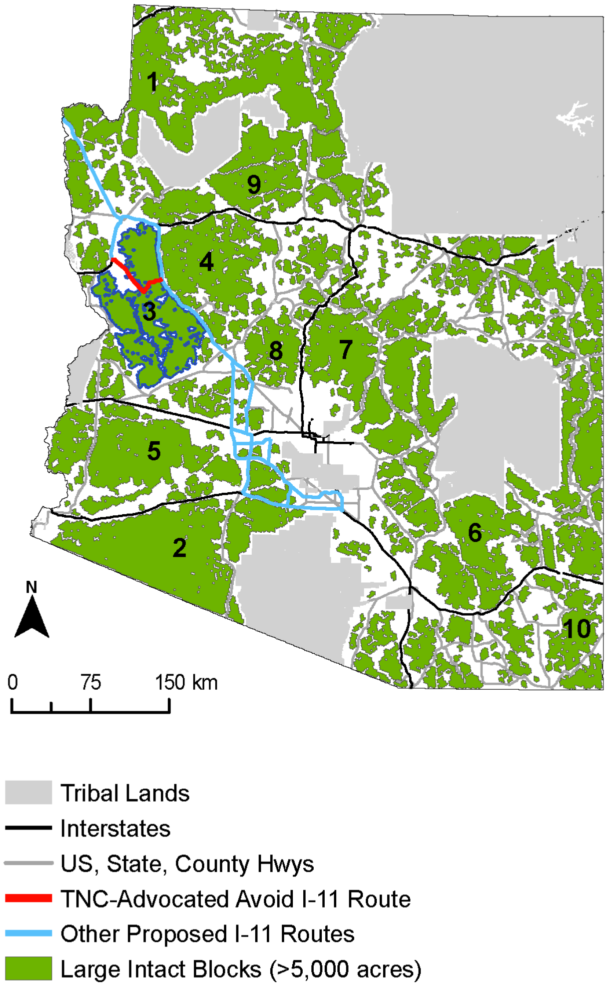

Figure 3. Large Intact Blocks (LIBs) in non-Tribal Arizona, USA. Top 10 LIBs in size labeled (all are greater than 2,000 km^2). New I-11 freeway routes shown, including the freeway route (red line) that The Nature Conservancy recommended be avoided so that the 3rd largest LIB in non-Tribal Arizona (highlighted blue polygon) would not be fragmented.

We also used our intactness data to inform minimization and offset recommendations for other proposed routes. For example, our Ecological Systems LIBs informed our recommendation to minimize and offset potential negative effects from a proposed route near the Hassayampa River in central Arizona. Although the majority of this area is somewhat modified, the fifth largest Paloverde-Mixed Cacti Desert Scrub Ecological System LIB is found there (Fig. 4) and represents natural resources for which adverse effects should be adequately compensated. The Hassayampa route was eventually included in the pre-NEPA scoping report (ADOT and NDOT 2014). However, our analysis set the stage for mitigation action beyond the project-level because it focused on natural resources targeted in new mitigation policies and was set at a scale appropriate to understand regional effects on those resources.

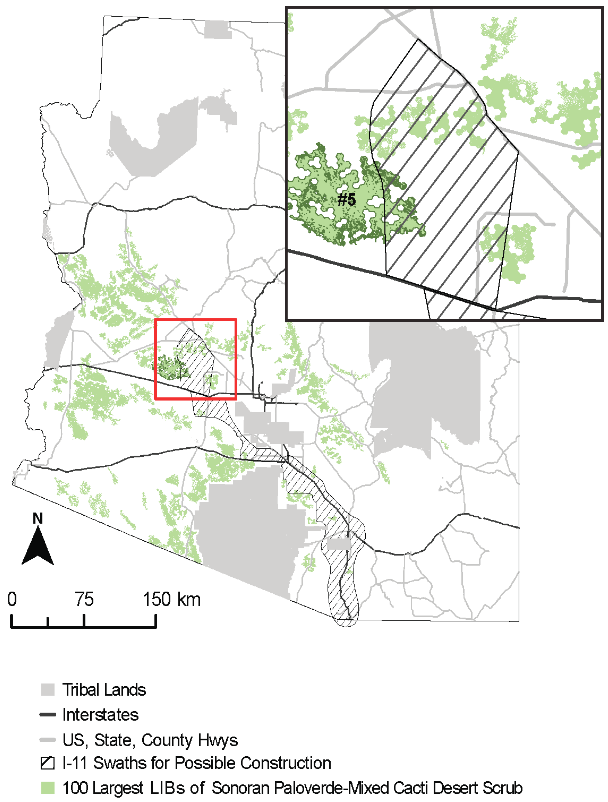

Figure 4 Ecological intactness northwest of Phoenix, USA. Large Intact Blocks (LIBs) of Paloverde-Mixed Desert Cacti Scrub in the Sonoran Desert represent options for mitigation offset locations. The 5th largest of these crosses the potential I-11 development footprint near the Hassayampa River area (inset map).

DISCUSSION

Applying a regional approach to mitigation is quickly becoming an imperative and federal and state land managers are looking for ways to implement mitigation at this scale. Understanding baseline conditions of natural resources (i.e., modification and intactness data) is essential for applying the mitigation hierarchy and achieving no net loss or conservation gain (USDOI 2015). Many human modification datasets have value and several are already being used for mitigation. We do not propose that our data and methodology are the best fit for every use. However, to provide transparent science for mitigation (USDOI 2015, POTUS 2015), it is important for all data sets to provide clarity in terms of assumptions, uncertainties, and methodology.

We believe our methodology adds value and can be considered complimentary to existing landscape modification models. At present, there is no published quantitative analysis comparing human modification to model interpretations of modification. However, in practice, human interpretation of aerial imagery is used to validate or refine spatial models (e.g., Theobald 2013, Theobald 2014). In this context, our HM data are 'ground-truthed' data. Human interpretation confers additional advantages, in that the human eye and mind can still perform better than computer algorithms at interpretation of novel landscape features (Blaschke 2010) and, thus, better classify natural vs. anthropogenic causes of modification. For example, our dataset correctly identified an area set aside for wilderness protection that other models characterized as disturbed or degraded (Fig. 5).

Additionally, we detected use types (e.g., rural and ex-urban development, small dirt roads/trails, forest thinning, and livestock grazing) that have been difficult to distinguish using land cover data derived via models (Lowry et al. 2007, Theobald 2014). Thus, we avoided propagating error and uncertainty associated with land cover data. Further, traditional infrastructure datasets can be incomplete and/or inaccurate, especially in large western states where the majority of land ownership is public. For example, the Arizona Game and Fish Department's landscape integrity data (Perkl 2013) show three linear modification features across a wilderness area where aerial imagery and in-person site inspection show no human-built infrastructure (Fig. 5). Approaches that rely on such data present a challenge to interpretation and recommendations for mitigation. For example, interpretation of the Theobald dataset (Theobald 2013) might suggest development be avoided in the I-11 Hassayampa area in contrast to The Nature Conservancy dataset, which, because of the degree of modification in the region, suggests an offset strategy is appropriate (Fig. 6).

Our HM data displays degrees of modification as categories related directly to the percent human modification observed. In this way, our data are relatively straightforward to communicate and provide the transparency sought in mitigation policies (USDOI 2015, POTUS 2015). In contrast, modeling approaches often apply various techniques and algorithms that are difficult to interpret and add modeling artifacts. For example, decay functions create smooth gradients of high to low modification with dis-

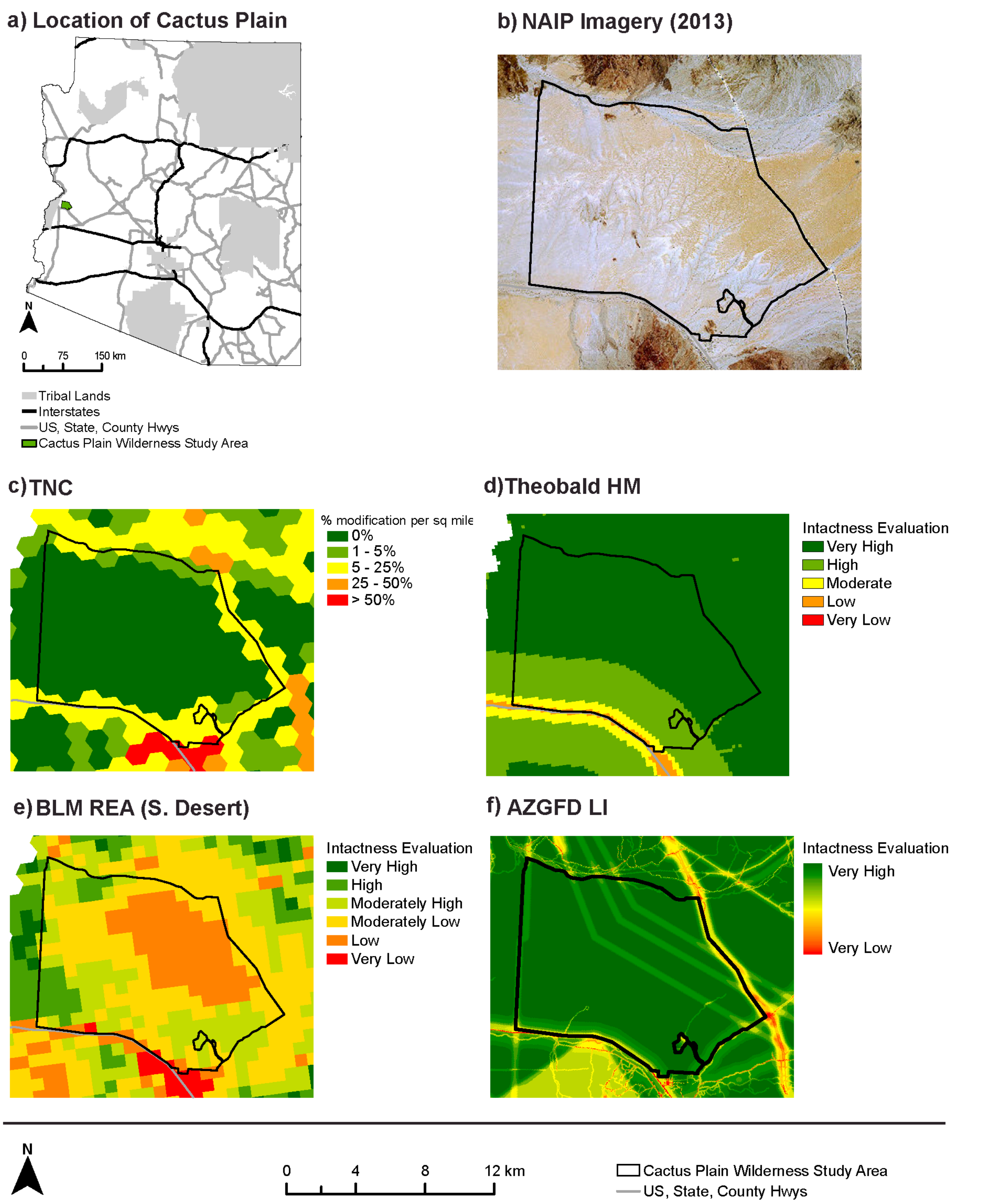

Figure 5 Dataset comparison within Cactus Plain Wilderness Area in western Arizona, USA. a) The location of the Cactus Plain Wilderness Study area on the west-central Arizona within the Sonoran Desert; b) Recent aerial imagery of the area; the dunes are visible as the tan formations and the white areas represent gravel-covered badlands; c) The Nature Conservancy's human modification (HM) dataset (this study); d) Theobald's Human Modification Index dataset (Theobald 2013); e) the U.S. Bureau of Land Management's Sonoran Desert Rapid Ecological Assessment Terrestrial Intactness dataset (Strittholt et al. 2012); and f) the Arizona Game and Fish Department's Landscape Integrity dataset (Perkl 2013) within the Cactus Plain area. Color gradients from very low to very high intactness levels reflect threshold values provided by each data producer.

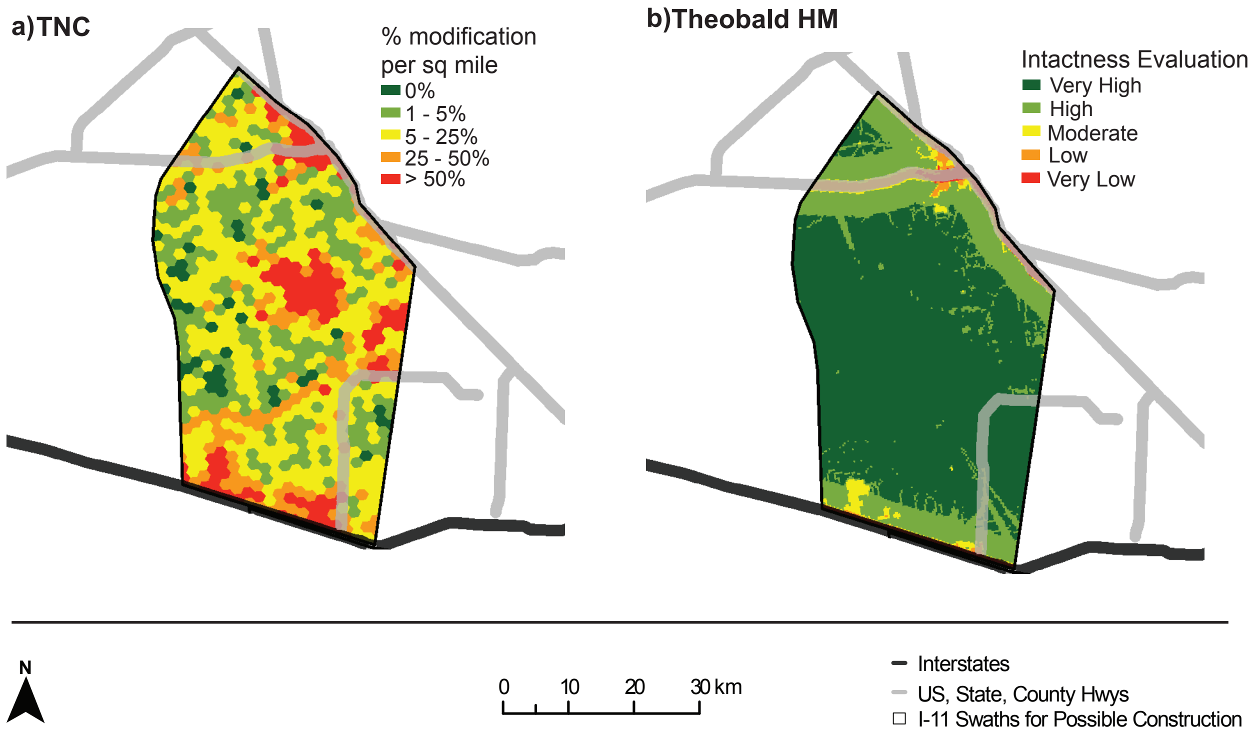

Figure 6. Human modification northwest of Phoenix, USA. a) The Nature Conservancy's human modification (HM) dataset (this study) and b) Theobald's Human Modification Index dataset (Theobald 2013) near the Hassayampa River area proposed for a new freeway interstate, I-11.

tance from defined features (e.g., highways, Figs. 5d, 5f, 6b). These functions attempt to represent effects on ecological integrity; they do not represent actual modifications. Modeled datasets also use multiple input data that vary in spatial and temporal extent and resolution and applying weighting and other functions to produce a modification "score" for each pixel (often on 0 -1 or 0 -100 scale). These scores are normalized to the full extent of the dataset. Therefore, in datasets created for the contiguous U.S. (e.g., Theobald 2013), the West is perhaps accurately displayed as more intact than the East, but when the same data are used to evaluate infrastructure within western states, the model may not discriminate between previously disturbed and relatively undisturbed areas. To communicate how scores should be interpreted, divisions along the scoring scale are used to represent relative levels of modification. These divisions are established using quantitative analysis or best professional judgement. Mapped results are a combination of all these factors making it challenging for users to discern which factor is most significant or whether crucial data are missing. More explicit guidance on how to use and interpret these data for mitigation is needed to meet the policy need for transparent science (USDOI 2015, POTUS 2015).

Our HM, LIB, and Ecological Systems LIB datasets were critical components of our response to the I-11 freeway proposal and are applicable to other types of infrastructure. For example, we also used these data to provide input to the U.S. Bureau of Land Management on suitable location of solar installations on public lands that would help increase renewable energy production while minimizing infrastructure impacts to the fragile desert environment.

Our dataset also had key limitations, including the fact that we did not complete an accuracy assessment although methods are available to do so (Yuan et al. 2005). It did not depict all disturbances associated with human activities, including invasive species and fire; and, it had limited applications for fine-scale infrastructure projects (e.g., < 10 miles). It was also a static product that is human-generated and, therefore, may be relatively more expensive to update when compared to modeled datasets derived from algorithms. It is our hope that the case study and discussion offered here will add to the discussion of ways to advance transparent science and application of the mitigation hierarchy at regional scales.

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Appendix 1. Reference data sets used in creating TNC's human modification dataset.

Data Source Name	Data Source	Description	Use in Project
Miscellaneous Sources			
EAUSA_AZ_STATEWIDE_ DIST_ HEX_FINAL_05_24_13	TSSW	Square mile hexagon polygons covering Arizona.	Defines the study area with each polygon defining the area of interpretation for disturbance percentage and type.
NAIP 2010 Imagery	State of Arizona	1-meter color imagery service flown by the USGS in 2010.	The main and authoritative source for interpreting disturbance percentage and type.
Bing Aerials	Microsoft	1-meter or better color imagery service from a variety of sources.	An ancillary source of imagery for interpreting disturbance percentage and type.
USA_Topo_Maps	National Geographic Society	Digital images of topographic maps from various sources and scales.	To verify roads, mines and vegetation patterns related to topography.
Geologic Map of Arizona	AzGS	Geologic Map of Arizona	Used to determine different areas of rock outcrops, fault lines, etc.
EAUSA_AZ_STATEWIDE_ DIST_ HEX_FINAL_05_24_13	TSSW	Square mile hexagon polygons covering Arizona.	Defines the study area with each polygon defining the area of interpretation for disturbance percentage and type.
The Nature Conservancy			
TNC Statewide Disturbance Index	TNC	Hex dataset containing TNC generated Disturbance Index.	Used as guideline for percent disturbance.
Arizona Land Resource Information System			
active_MSW_landfills2	ALRIS	Active landfills	To overlay and verify hexes with landfill disturbances.
allot	ALRIS	ASLD grazing allotments.	Used to determine areas of possible grazing.
ALRIS_own_IndianRes _dis_category	ALRIS	Geodatabase; Indian Reservations identified in ALRIS "own. shp"	Identification of Indian Reservation lands for hex exclusion in project
AZBoundary_ALRIS	ALRIS	Geodatabase; State of AZ boundary	Reference.
interstates.shp	ALRIS	Interstate highways represented as line features.	To overlay and verify hexes with major road disturbances.
lakes_adeq.shp	ALRIS	ADEQ lakes	Reference
mines.shp	ALRIS	Point locations of mines with type and status.	To verify mining activity.

own	ALRIS	Statewide land ownership.	Used to determine Indian Reservations and areas such as Military Use (Yuma Test Range, Luke Williams Range, Goldwater Range), Forest, BLM land
streets.shp	ALRIS	All public roads in Arizona	To overlay and verify hexes with road disturbances.
tigpower	ALRIS	Power lines represented as line features.	To overlay and verify hexes with power line disturbances.
tigrails	ALRIS	Railroads represented as line features.	To overlay and verify hexes with railroad disturbances.
Pima County			
lfil_ex.shp	Pima County	Landfill data	Identify landfills in Pima County
lfilfdaz.shp	Pima County	Landfill data	Identify landfills in Pima County
lfilspc.shp	Pima County	Landfill data	Identify landfills in Pima County
pipeline.shp	Pima County	Pipeline	Identify pipelines in Pima County
TerraSystems Southwest			
PIPELINE_TSSW	TSSW	Identified pipelines from topo maps	
POWER_TSSW	TSSW	Identified power lines not included in tigpower	
US Forest Service (USFS)			
AZ_2010_Forest_Health	USFS	Forest Health for State of AZ	Identifies areas of poor forest health (infestations, etc.)
USFS Apache Sitgreaves National Forest			
Admin_Forest.shp	USFS	Forest boundary	
Constructed_Feature_ln.shp	USFS	Forest constructed feature	Used to identify areas for disturbance.
Constructed_Feature_pt.shp	USFS	Forest constructed feature	Used to identify areas sites for disturbance.
Fire_History_pl.shp	USFS	Apache-Sitgreaves NF fire history	To overlay and verify hexes with burn area disturbances.
Recreation_Site_pl.shp	USFS	Recreation sites	Used to identify recreation sites for disturbance.
Recreation_Site_pt.shp	USFS	Recreation sites	Used to identify recreation sites for disturbance.
Road_Route.shp	USFS	Apache-Sitgreaves roads	Used to identify known roads in NF.
Trails.shp	USFS	Apache-Sitgreaves trails	Used to identify the trails versus roads. Some trails were large enough to equal that of a road disturbance.

Wilderness.shp	USFS	Forest defined wilderness	
USFS Coconino National Forest			
Admin_Forest.shp	USFS	Forest boundary	
Fire_History_pl.shp	USFS	Coconino NF fire history	To overlay and verify hexes with burn area disturbances.
rmu_unit.shp	USFS	Grazing allotments	Used to identify possible grazing
Road.shp	USFS	Coronado roads	Used to identify known roads in NF.
Trails.shp	USFS	Coconino trails	Used to identify the trails versus roads. Some trails were large enough to equal that of a road disturbance.
Wilderness.shp	USFS	Wilderness areas	Used to identify wilderness areas.
USFS Coronado National Forest			
Constructed_Feature_ln.shp	USFS	Forest constructed feature	
Constructed_Feature_pt.shp	USFS	Forest constructed featur	
COR_Fire_History_pl.shp	USFS	Coronado NF fire history	To overlay and verify hexes with burn area disturbances.
Recreation_Site_ln.shp	USFS	Recreation sites	Used to identify recreation sites for disturbance
Recreation_Site_pl.shp	USFS	Recreation sites	Used to identify recreation sites for disturbance
Recreation_Site_pt.shp	USFS	Recreation sites	Used to identify recreation sites for disturbance
Road.shp	USFS	Coronado roads	Used to identify known roads in NF.
Trail.shp	USFS	Coronado trails	Used to identify the trails versus roads. Some trails were large enough to equal that of a road disturbance.
Water_Body	USFS	Bodies of water	
Wildland_Urban_Interfeace	USFS	Areas surrounding NF with urban land use	
Wilderness	USFS	Wilderness areas	Used to identify wilderness areas.
USFS Kaibab National Forest			
Admin_Forest.shp	USFS	Forest boundary	
AllotmentJoin.shp	USFS	Grazing allotments	Used to determine areas of possible grazing.
KAI_Fire_History_pl.shp	USFS	Kaibab NF fire history	To overlay and verify hexes with burn area disturbances.

PastureJoin.shp		Pastures	Used to determine areas of possible grazing.
Road.shp	USFS	Kaibab roads	Used to identify known roads in NF.
Trail.shp	USFS	Kaibab trails	Used to identify the trails versus roads. Some trails were large enough to equal that of a road disturbance.
Wilderness	USFS	Wilderness areas	Used to identify wilderness areas.
USFS Prescott National Forest			
Admin_Forest.shp	USFS	Forest boundary	
Fire_History_pl.shp	USFS	Prescott NF fire history	To overlay and verify hexes with burn area disturbances.
Road.shp	USFS	Prescott roads	Used to identify known roads in NF.
Surface Ownership	USFS	Land ownership	Used to identify areas of private ownership for disturbance.
Trail.shp	USFS	Prescott trails	Used to identify the trails versus roads. Some trails were large enough to equal that of a road disturbance.
Wildland_Urban_Interfeace	USFS	Areas surrounding NF with urban land use	
Wilderness.shp	USFS	Wilderness areas	Used to identify wilderness areas.
USFS Tonto National Forest			
Admin_Forest.shp	USFS	Forest boundary	
Recreation_Site_pt.shp	USFS	Recreation sites	Used to identify recreation sites for disturbance
Road.shp	USFS	Tonto roads	Used to identify known roads in NF.
rmu_unit.shp	USFS	Grazing allotments	Used to identify possible grazing
Trail.shp	USFS	Tonto trails	Used to identify the trails versus roads. Some trails were large enough to equal that of a road disturbance.
TON_Fire_History_pl.shp	USFS	Tonto NF fire history	To overlay and verify hexes with burn area disturbances.
Water_Body.shp	USFS	Bodies of water	
Wilderness.shp	USFS	Wilderness areas	Used to identify wilderness areas.