Environmental Science and Policy 147 (2023) 267–278

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Integrating equity, climate risks, and population growth for targeting conservation planning

Deidre Zoll[a,*], Katherine Lieberknecht[b], R. Patrick Bixler[c], J. Amy Belaire[d], Shalene Jha[e]

[a] Department of Integrative Biology, The University of Texas at Austin, USA
[b] School of Architecture, The University of Texas at Austin, USA
[c] LBJ School of Public Affairs, The University of Texas at Austin, USA
[d] The Nature Conservancy Texas, Houston, TX 77098, USA
[e] Department of Integrative Biology, The University of Texas at Austin, USA

ARTICLE INFO

Keywords:
Conservation planning
Social vulnerability
Climate adaptation
Conservation prioritization
Environmental justice

ABSTRACT

Where landowners, non-profit organizations, and government agencies prioritize conservation activities has significant implications for people, ecosystems, and climate resilience. Our study builds on conservation decision-making scholarship by analyzing the relationships between biodiversity priorities, social vulnerability, climate risks, and projected population growth in Texas to identify geographies that simultaneously support multiple goals. Drawing from publicly available datasets, we show the potential for existing conservation priorities to exacerbate the inequitable distribution of environmental goods and services, especially for lower-income residents, communities of color, and socially vulnerable populations. Using bivariate local indicators of spatial autocorrelation, we demonstrate effective ways to avoid negative social impacts by identifying synergistic locations with high levels of social vulnerability and biodiverse landscapes. We overlay these locations with climate risks to further prioritize areas that could meet biodiversity, social vulnerability, and climate adaptation needs. Lastly, we consider how future population growth may inform the urgency of conservation activities given potential development pressures. Our study contributes to academic and policy debates seeking to jointly address biodiversity conservation, climate change, and environmental justice concerns.

1. Introduction

In 2021, the Biden-Harris Administration committed to conserving 30% of U.S. lands and waters by 2030 (America the Beautiful Interagency Working Group, 2021), offering an important opportunity to expand upon the 13% of currently conserved lands (USGS, 2018). The “America the Beautiful Initiative” encompasses a broad array of objectives, including using multi-sectoral locally-led efforts to protect biodiversity, sustain ecosystem services, address social inequalities, and reduce the impacts of climate change (America the Beautiful Interagency Working Group, 2021). How and where non-profit organizations, private landowners, and local government agencies prioritize conservation efforts over the next eight years will likely have major implications for people and ecosystems in the face of climate change.

Emerging research seeks to understand where conservation actions could provide "win-win-win" opportunities to meet multiple objectives associated with biodiversity conservation, reducing social vulnerability, and adapting to climate change (Albert et al., 2019; Arkema et al., 2017; Belote et al., 2021; Pineda-Pinto et al., 2022). Yet, few studies concurrently examine the connections between these three objectives, especially in locations with high population growth and land use conversion where habitats may be most at risk (Gourevitch et al., 2021; Sims et al., 2022). In this study, we build on conservation decision-making scholarship by analyzing the relationships between biodiversity conservation priorities, social vulnerability, and climate risks in Texas to identify potential synergistic geographies on the ground.

The United States is predicted to grow by 47 million people by 2040, with approximately 70% of that growth occurring in the Sun Belt, a rapidly urbanizing but climatically stressed region stretching across the southern U.S. (University of Virginia Weldon Cooper Center, 2018). The Sun Belt is home to over 60% of the U.S. population and multiple global and national biodiversity hotspots. The region faces interconnected socio-ecological challenges, including population growth, large-scale land use change, increasing social inequality, and biodiversity loss

* Correspondence to: Department of Integrative Biology, The University of Texas at Austin, 2415 Speedway #C0930, Austin, TX 78712, USA.
E-mail address: deidrezoll@utexas.edu (D. Zoll).

https://doi.org/10.1016/j.envsci.2023.06.015
Received 2 February 2023; Received in revised form 4 May 2023; Accepted 24 June 2023
Available online 4 July 2023

(Economic Policy Institute, 2016, 2016; Frey, 2021; Fulton et al., 2020; Sohl et al., 2016; Stein et al., 2000). Specifically, Sun Belt states have experienced the highest number of billion-dollar weather and climate disasters and contain many of the areas most at risk for future impacts (Hsiang et al., 2017; Smith, 2020a). Those risks include increases in temperature and heatwaves, droughts, wildfires, heavy precipitation and associated flooding, sea level rise, and more intense and frequent storm events (Jones et al., 2015; Mazdiyasni and AghaKouchak, 2015; USGCRP, 2018).

Climate change and future population growth pressures in the Sun Belt will likely drive further land use conversion and have repercussions for biodiversity and ecosystem services, especially in states with fewer conserved lands (Fulton et al., 2020; Hamilton et al., 2022; Jenkins et al., 2015; Sohl et al., 2016; Stein et al., 2000; USGCRP, 2018). Climate impacts, particularly changing precipitation patterns, rising seas, and increasing temperatures, require many species to move to adapt, but habitat fragmentation limits species' ability to track suitable locations resulting in species decline (Fischer and Lindenmayer, 2007; Foley et al., 2005; McGuire et al., 2016).

Furthermore, disaster and environmental justice scholarship provides evidence that climate risks are not equally distributed and often disproportionately impact lower-income residents, people of color, and other groups subjected to various forms of structural oppression (Hsu et al., 2021; USGCRP, 2018; Wilson et al., 2010). Research suggests that these groups are often relegated to living in locations with greater exposure to risks, possess fewer resources to reduce threats, incur greater impacts from disaster events, and have longer and more difficult recovery processes (Drakes et al., 2021; Howell and Elliott, 2019; Rufat et al., 2015; Schmeltz et al., 2016; Thomas et al., 2019). Social vulnerability has emerged as a term and concept to explore how multiple social processes converge to produce inequitable risk exposure and disaster recovery trajectories (Cutter et al., 2003; Emrich and Cutter, 2011; Jacobs, 2019) and to design programs to reduce those harms and inequalities (Rufat et al., 2015; Tate et al., 2021). While considering social vulnerability in program design does not address the underlying power structures that drive those inequalities, researchers argue that programs that do not focus on populations or locations with high social vulnerability are likely to maintain or amplify those inequalities (Tate et al., 2021; Van Sant et al., 2021).

Efforts to address these interconnected issues include multi-sector and multi-scalar conservation activities encompassing infrastructure investments, property buyouts, development regulations, incentives for private landowners for voluntary conservation efforts, nature-based solutions like land conservation and green infrastructure, and more (Lempert et al., 2018). However, many of these solutions have documented inequalities in terms of which places and people benefit from these interventions and how they may amplify unequal climate risks (Anguelovski et al., 2016; Hino et al., 2017; Keenan et al., 2018; Shokry et al., 2020). For example, while understudied in the U.S., research by Villamagna et al., (2015, 2017) indicates that conserved lands disproportionately benefit white residents by providing ecosystem services that could support climate adaptation. In response, researchers have begun to investigate where and how "win-win-win" conservation opportunities might emerge (Albert et al., 2019; Arkema et al., 2017; Belote et al., 2021; Pineda-Pinto et al., 2022). Similarly, government entities and non-profit organizations are working to embed equity into climate resilience and biodiversity conservation efforts (Brune, 2020; Bruno and Jepson, 2018; Bowan, 2020; California Senate Bill 535, 2012; Exec. Order No. 8, 14008, 2021; Harris County Flood Control District, 2018; Kohl, 2021; Pellow, 2001; Rudd et al., 2021).

To contribute to academic and policy debates on the potential for targeting conservation actions in high-impact locations to achieve the greatest amount of co-benefits, our study evaluates relationships between conservation priorities, measures of social vulnerability, and climate risks in Texas. Here, we ask three questions. First, are there differences in measures of social vulnerability and climate risks between census tracts with and without biodiverse landscapes? Second, do tracts with higher levels of biodiverse landscapes and social vulnerability spatially coincide in Texas? Third, where do high climate risks and population growth areas overlap with clusters of high biodiverse landscapes and social vulnerability? We answer these questions using two-tailed student's t-tests, bivariate local indicators of spatial autocorrelation, and spatial analysis techniques. This study extends previous research establishing conservation priorities based on biodiversity hotspots or climate impacts on species dispersal and parallel work integrating social inequality analyses into conservation outcomes and future prioritization considerations (Anderson et al., 2016; Jenkins et al., 2015; Simkin et al., 2022; Sims et al., 2022; Van Sant et al., 2021; Villamagna et al., 2017). Our results highlight areas that potentially meet multiple land management objectives related to biodiversity conservation, social vulnerability, and prioritizing areas most at risk from climate impacts.

2. Data and methods

2.1. Site

We focused our analysis on census tracts in Texas, the second-largest state by size (695,000 km^2) and population (29.7 million residents). We selected Texas because it is the Sun Belt state with the highest number of high-impact climate-related extreme events and has the largest projected population growth for the Sun Belt region (Smith, 2020b; University of Virginia Weldon Cooper Center, 2018). Texas also has substantial racial and economic segregation, high levels of biodiversity and endemism, and more than 95% private land ownership, making the state an important location for identifying synergistic conservation opportunities (Stein, 2002; Taylor and Fry, 2012; USGS, 2018).

2.2. Data

To evaluate potential win-win-win conservation opportunities in Texas we brought together publicly available datasets on biodiversity, social vulnerability, climate risks, and population growth to provide a prioritization approach that accounts for concurrent threats and opportunities in multiple social and ecological dimensions (Table 1).

2.2.1. Biodiverse landscapes

We used The Nature Conservancy's Resilient & Connected Network (RCN) as our proxy for biodiversity priorities. The RCN identifies areas with a high degree of climate resilience, confirmed biodiversity, and connectivity (Anderson et al., 2016). The RCN defines a resilient site as "an area of land where high microclimatic diversity and low levels of human modification provide species with connected, diverse climatic conditions they will need to persist and adapt to changing regional climates" (The Nature Conservancy, 2022). Biodiversity represents areas with "rare species population, exemplary natural communities, or intact habitat" (The Nature Conservancy, 2022). Connectivity includes locations where species can "disperse, migrate and adapt to a changing climate" and was derived from "wall-to wall flow analysis that simulated species moving along climate gradients while avoiding anthropogenic barriers" (The Nature Conservancy, 2022).

We used the simple RCN layers, which divide Texas into 30-meter cells, representing areas with four mutually exclusive categories: areas with resilience, biodiversity, and connectivity; areas with resilience and connectivity; areas with resilience and biodiversity; and other areas. We compiled the first three categories into one measure for biodiverse landscapes, which we divided by the total land area to obtain the percent of land area in a census tract that contains biodiverse landscapes.

We selected the RCN because it is one of the few publicly available datasets that incorporates climate change and associated impacts on species movement and refugia in identifying priority conservation landscapes across the contiguous United States (Anderson et al., 2016). The RCN has been extensively peer-reviewed and used by federal and state policymakers, land trusts, and NGOs to guide conservation strategies (Anderson et al., 2023). By design, the RCN identifies large, connected, natural habitat patches, and therefore, predominantly excludes geographies with higher levels of anthropogenic land uses (Anderson et al., 2016). While our study focuses on spatial analysis to identify larger-scale conservation opportunities, significant research has shown cities contain important biodiversity and ecosystem services and therefore this study may miss relevant urban priorities (Gómez-Baggethun et al., 2013; Nowak, 2010; Shaffer, 2018). We are unaware of urban conservation priority datasets that are publicly available, cover Texas or the contiguous United States, and incorporate climate change. Future research could develop a complementary approach for urban areas or use local-level biodiversity datasets to understand conservation opportunities at the city-scale.

2.2.2. Social vulnerability

We measured social vulnerability using the Centers for Disease Control's (CDC) estimates at the census tract (Centers for Disease Control and Prevention, 2016). The CDC methodology uses 15 demographic variables to create a normalized score of 0–1 to rank overall vulnerability, with 0 being the least vulnerable and 1 being the most. The 15 variables include measures such as unemployment, poverty, race/-ethnicity, educational status, housing types, and vehicle access. These variables draw from disaster and hazard research that finds positive correlations between social factors and uneven exposure and impacts from disaster or hazard events, and more difficult recovery processes (Cutter et al., 2003; Fatemi et al., 2017; Otto et al., 2017). We converted the 0–1 rank to 0–100 to have a common numerical range for study variables.

Research and policymakers predominantly use two social vulnerability index (SVI) models, the CDC model used here, and the University of South Carolina's SoVI (Cutter, Boruff and Shirley, 2003; Rufat et al., 2019). The SoVI model incorporates 29 variables linked to disaster impacts and recovery. The most recent free, compiled, and publicly available SoVI dataset is at the county level and uses 2014 data (SoVI, 2023). A temporally updated or smaller scale analysis requires users to create an index through principal component analysis. Here, we used the CDC model because the accessibility, temporality, spatial scale, and non-technical requirements ease replication for practitioners wanting to undertake a similar approach.

Our use of social vulnerability as a decision-making criterion aligns with policy and planning efforts across multiple levels of government; however, social vulnerability as a concept and modeling tool has been critiqued (Centers for Disease Control and Prevention, 2016; Cutter et al., 2013; FEMA, 2022; Harris County Flood Control District, 2018; Jacobs, 2019; Ribot, 2014). Criticisms include concerns that social vulnerability concepts bypass engagement with larger systems of oppression that manufacture vulnerability, as well as emerging research questioning the empirical correlations between the indices with actual disaster impacts (Fazel-Zarandi et al., 2018; Jacobs, 2019; Kehler and Birchall, 2021; Méndez et al., 2020; Rufat et al., 2019; Spielman et al., 2020). In a partial response to these concerns, we also evaluated race, ethnicity, and poverty rates; however, future research could use other established quantitative environmental justice methods.

2.2.3. Climate risks

We created four variables to estimate flood, heat, drought, and combined climate risk at the census tract scale. Climate risks were selected based on the Texas State Climatologist's 2021 assessment of extreme events with the greatest human and economic impacts, and risks with publicly available data at the census tract scale across Texas (Nielsen-Gammon et al., 2021). For *flood risks*, we calculated the percent of a census tract covered by the 100-year floodplain (inland and coastal) to estimate flood exposure. The 100-year floodplain was derived from the Environmental Protection Agency's (EPA) EnviroAtlas floodplain map for the Conterminous United States (Pickard et al., 2015; Woznicki et al., 2019). EnviroAtlas estimates were used in place of the Federal Emergency Management Agency's (FEMA) National Flood Hazard Layer maps, as FEMA has not evaluated most of west and northwest Texas. While the EnviroAtlas estimates are not as accurate as FEMA layers, they provide complete state coverage. We used the percent of a census tract covered by the 100-year floodplain and calculated a percentile rank to compare relative flood risk across the state. The percentile rank is used for the figures in the paper.

Exposure to *heat risk* was measured as the average number of days per year (between 2010 and 2020) over 100°F (approximately 38 °C) using data from the CDC's National Environmental Public Health Tracking Network (Centers for Disease Control and Prevention, 2022). The CDC calculates days over 100°F by combining North American Land Data Assimilation System measures of surface air temperature, humidity, and surface pressure into temperature estimates at the census tract scale. We used the average number of days and a calculated percentile rank to compare relative extreme heat risk across the state. The percentile rank is used for the figures in the paper.

Drought risks were calculated as the annualized frequency of drought risk at the census tract scale, which was derived from the FEMA National Risk Index (FEMA, 2022). FEMA calculates annualized frequency by averaging the number of days per year (2000–2018) a census tract overlaps with areas experiencing either an "Extreme" or "Exceptional" drought event as declared by the U.S. Drought Monitor (Zuzak et al., 2021). We used the average number of days and a calculated percentile rank to compare relative drought risk across the state. The percentile rank is used for figures in this paper.

We ranked census tracts within Texas to create a combined relative *climate risk index*. Existing research often examines individual climate risks; however, there is a growing body of scholarship and practice that attends to concurrent threats to better prepare for compounding climate impacts (Arneth et al., 2020; Bixler et al., 2021; ; Ciurean et al., 2018; Drakes and Tate, 2022; Mazdiyasni and AghaKouchak, 2015; Piontek et al., 2014). To contribute to this literature, we used the percentile rank calculated for flood, heat, and drought risks at each tract. We added those values together and percentile-ranked the tracts from 0 to 1, with 1 indicating relatively higher climate risks. We converted the 0–1 rank to 0–100 to have a common numerical range for study variables. This approach follows the CDC's social vulnerability index methodology (Centers for Disease Control and Prevention, 2016).

Lastly, we compiled 2020–2060 *population growth* estimates from the Texas Water Development Board's (TWDB) 2021 Population and Water Demand Projections (Texas Water Development Board, 2021). TWDB projections were derived from the Texas State Demographer and provided at the county level, which were then assigned to census tracts based on their county location. We used the percent growth and a calculated percentile rank to compare relative population growth predictions. The percentile rank is used for figures in the paper.

Table 1
Summary table of dependent and independent variables in Texas at the census tract level (n = 5202).

Variable	Mean	Std. Dev	Min.	Max.
Biodiverse Land (%)	8.8	17.9	0.0	95.2
Social Vulnerability	58.6	29.6	0.0	100.0
Poverty (%)	16.8	12.0	0.0	83.4
White (%)	43.2	27.6	0.0	100.0
Black (%)	11.6	15.6	0.0	99.0
Latinx (%)	39.2	28.1	0.0	100.0
Asian (%)	3.9	6.9	0.0	70.6
Floodplain (%)	12.4	16.2	0.0	100.0
Days over 100ºF	37.1	20.8	0.0	85.6
Drought Rate (yr)	38.8	18.1	12.1	127.9
Climate Risk Index	50.0	28.9	0.0	100.0

2.3. Methods

We used a two-tailed student's t-test to assess if there are differences in measures of social vulnerability and climate risks between census tracts with and without biodiverse landscapes. Dependent variables included the overall social vulnerability score, race, ethnicity, poverty rates, flood, heat, drought, and the climate risk index. Similar research used comparison of means tests or spatial overlays to assess potential environmental justice issues related to race and income and proximity to conservation areas with different land managers (i.e., public and private) (Sims et al., 2022; Van Sant et al., 2021; Villamagna et al., 2017). Our work extends those approaches by assessing future conservation priorities, climate risks, and socio-demographics together. This approach allows us to understand if tracts with biodiverse lands have higher climate risks and could offer high-impact opportunities for land protection, nature-based solutions for climate adaptation, or similar conservation activities. It also provides initial insights on potential environmental injustices if future conservation activities concentrate in areas with less social vulnerability, lower poverty, or fewer people of color.

Following our t-tests, we completed exploratory spatial analysis using bivariate local indicators of spatial autocorrelation (LISA) to understand if census tracts with higher levels of biodiverse landscapes and social vulnerability spatially coincide, which can help identify areas that may address joint socio-ecological goals. Recent efforts to incorporate issues of social inequality into conservation priority setting have used traditional statistics and suitability analyses to identify locations that could address both needs (Gourevitch et al., 2021; Sims et al., 2022). While overlay analysis is an important approach to visually understanding associations, it does not assess the statistical relationship between variables. In contrast, bivariate LISA describes the statistical relationship between both variables and how those relationships vary over space (Anselin, 1995).

Spatial statistics are increasingly used in evaluating climate or disaster risks and spatial relationships with socio-demographic variables or measures of social vulnerability (Cutter and Finch, 2008; Koks et al., 2015; Mennis and Jordan, 2005; Tate et al., 2021). For example, Gaither and colleagues used bivariate LISA to assess the relationships between social vulnerability and wildfire plumes in the southeast United States (2015), while Tate et al., evaluated social vulnerability and flood risk hotspots across the contiguous United States (Tate et al., 2021). Both studies used bivarate LISA methods to identify statistically significant areas where high social vulnerability spatially coincided with high risk and therefore indicated priority locations for risk reduction strategies (Gaither et al., 2015; Tate et al., 2021). Here, we are using a similar analysis but shifting the focus to identifying locations where positive or negative spatial autocorrelation exists between social vulnerability values in a census tract and a spatially lagged measure of biodiverse landscapes in neighboring tracts (Anselin, 1995).

After generating a number of spatial weights including first-order queen's contiguity and K-nearest neighbor ($k = 2$–6), we selected the first-order queen based on the autocorrelation coefficient (Chi and Zhu, 2008). Our global bivariate Moran's I was 0.0083 ($p < 0.05$, 999 permutations), indicating low but positive spatial autocorrelation. We used the same queen's first-order spatial weights matrix for the bivariate LISA. Analysis outcomes identified tracts with positive spatial autocorrelation, or clustering, where high levels of social vulnerability are surrounded by high values of biodiverse landscapes (High-High) or low observations of both (Low-Low). Areas identified as High-Low or Low-High have negative spatial autocorrelation.

Following our bivariate LISA analysis, we selected tracts where high values of social vulnerability were surrounded by high values of biodiverse landscapes (High-High) and used those as a baseline map. The baseline map provides insights into locations where conservation activities may offer opportunities to improve both human and ecological well-being. We then overlaid existing climate risks (flood, heat, drought) and the climate risk index to identify areas that could have triple-win opportunities for biodiversity, vulnerability, and climate adaptation. Lastly, we overlaid the biodiversity, social equity, and climate resilience map with projected high population growth areas where urban expansion may increase habitat conversion or fragmentation and where increases in impervious cover may impact local flooding, heat, and drought risks. By overlaying synergistic clusters with climate risks and population growth we further refined areas that may offer time-sensitive opportunities to meet multiple land management objectives. We conducted all analyses in R Statistical Software with final mapping in QGIS (QGIS Development Team, 2020; R Core Team, 2021; RStudio Team, 2020).

3. Results

3.1. Socio-demographics and climate risks in locations with and without biodiverse landscapes

We found that 37% of all census tracts intersected with biodiverse landscapes and had higher combined climate risks (53 vs. 48) including greater floodplain exposure (15% vs. 11%), more days over 100ºF (38 days vs. 36 days), and lengthier drought events (42 days vs. 37 days) compared to tracts without biodiverse landscapes ($p < 0.05$ for all comparisons) (Table 2).

Results also indicated that tracts with biodiverse landscapes had lower social vulnerability scores (57 vs. 60), levels of poverty (14% vs. 18%), and fewer Black (9% vs. 13%), Latinx (30% vs. 45%), and Asian American residents (2% vs. 5%) ($p < 0.05$ for all comparisons) (Table 2).

3.2. Social vulnerability and biodiverse landscapes

Our bivariate LISA analysis revealed three patterns of synergies and tradeoffs where locations for conservation activities might address both biodiversity and social vulnerability, or be in conflict. First, we found a concentration of synergies (dark blue), defined here as census tracts with high levels of social vulnerability surrounded by high levels of biodiversity, along the southern border (Fig. 1). Second, in many of the larger urban areas, we found clusters of low social vulnerability and low biodiversity (red), along with urban tradeoffs, defined as tracts with high levels of social vulnerability surrounded by low levels of biodiversity (light blue). Third, synergies were also present in central and northwest Texas (dark blue) but were often interspersed with tradeoffs, represented by tracts with low levels of social vulnerability surrounded by high levels of biodiversity (pink).

We used a two-tailed student's t-test to compare synergy and tradeoff clusters with high biodiverse landscapes (i.e., clusters of high levels of social vulnerability surrounded by high levels of biodiversity compared to clusters of low levels of social vulnerability surrounded by high levels of biodiversity). The amount of biodiverse landscapes in the clusters

Table 2
Two-tailed t-statistics results for census tracts with and without biodiverse landscapes in Texas ($n = 5202$).

Variable	Census Tracts with Biodiverse Land	Census Tracts without Biodiverse Land	t	p-value
Social Vulnerability	56.7	59.7	3.6	0.000
Poverty (%)	14.4	18.1	11.9	0.000
White (%)	57.5	34.8	-31.1	0.000
Black (%)	8.5	13.5	12.0	0.000
Latinx (%)	29.7	44.7	20.1	0.000
Asian (%)	2.2	5.0	15.6	0.000
Floodplain (%)	14.7	10.6	-8.5	0.000
Days over 100ºF	37.9	36.6	-2.3	0.012
Drought Rate (yr)	42.0	36.9	-9.6	0.000
Climate Risk Index	52.9	48.3	-5.6	0.000

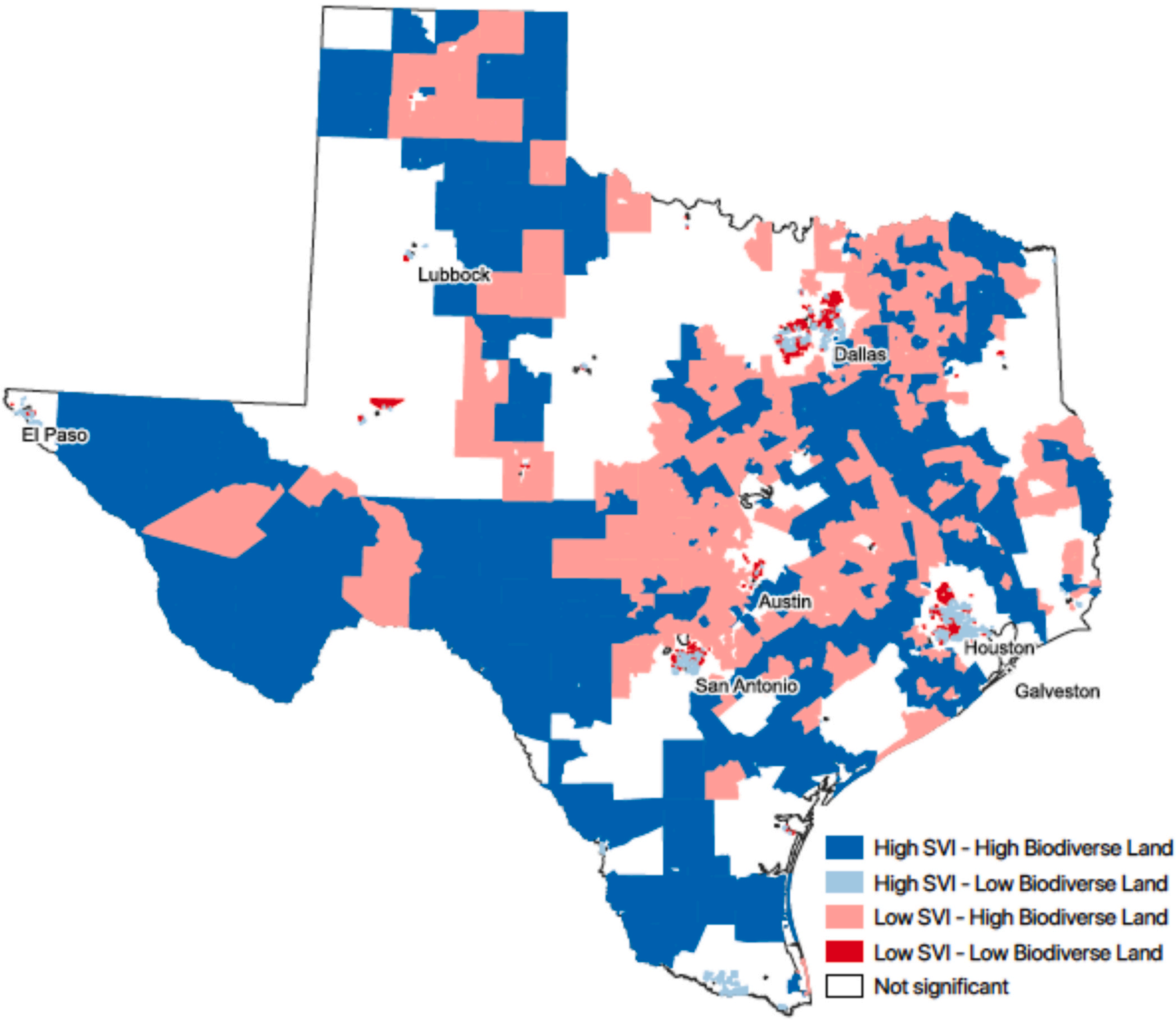

Fig. 1. Bivariate local indicators of spatial autocorrelation between social vulnerability and biodiverse landscapes.

(40.5% vs. 43.5%) were not statistically different ($p > 0.05$), but measures of social vulnerability (77.3 vs. 38.0), poverty (18.6% vs. 9.4%), and Black (9.6% vs. 4.5%) and Latinx residents (31.6% vs. 16.1%) were approximately two times higher in the synergy clusters ($p < 0.05$) (Table 3).

Table 3
Two-tailed t-statistics results for census tracts with high social vulnerability and high biodiversity clusters compared to low social vulnerability and high biodiversity clusters in Texas ($n = 745$).

Variable	Synergies: High Social Vulnerability and High Biodiversity Clusters	Tradeoffs: Low Social Vulnerability and High Biodiversity Clusters	t	p-value
Biodiverse Land (%)	40.5	43.6	-1.9	0.063
Social Vulnerability	77.3	38.0	39.6	0.000
Poverty (%)	18.6	9.4	17.9	0.000
White (%)	56.0	76.2	-14.8	0.000
Black (%)	9.6	4.5	7.7	0.000
Latinx (%)	31.6	16.1	11.7	0.000
Asian (%)	0.7	1.2	-2.2	0.005
Days over 100°F	37.8	41.8	-3.2	0.001
Drought Annual Rate	43.0	45.3	-1.5	0.141
Floodplain (%)	14.1	12.5	1.4	0.171
Climate Risk Index	53.2	55.2	-1.0	0.302

3.3. Climate risks and population growth

Our third analytical approach found that areas with the greatest overlaps between biodiverse landscapes, social vulnerability, and high drought and heat risks (> 90th percentile) occurred in the more arid or semi-arid regions of the state, whereas the highest flood risks were more dispersed (Fig. 2).

In addition to the individual climate risk information provided by our analysis, we overlaid a combined climate risk index and identified 49 census tracts with high biodiverse landscapes, social vulnerability, and the highest (> 90th percentile) combined climate risks (dark purple) (Fig. 3). These tracts were spread across the state, but there was a strong concentration along the southern border.

Lastly, we included population growth predictions through 2060 and classified the 49 census tracts identified above by the level of urgency given expected development pressures (Fig. 4). Three census tracts in central Texas emerged as priority areas where high biodiversity, social vulnerability, climate risks (> 90th percentile), and future population growth (> 90th percentile) coincided (red) (Fig. 4). There were also seven census tracts with above median (50th-90th percentile) (orange) population growth projections. Together, these ten census tracts are located in rapidly growing exurban communities in major metropolitan statistical areas. The last two future population growth categories covering the 30th-50th percentile (yellow) and the 0–30th percentile (green) indicated areas that still address biodiversity, social vulnerability, and climate adaptation goals but are less likely to face the same land use pressures.

4. Discussion

4.1. Socio-demographic and climate disparities in biodiverse landscapes

Our initial two-tailed student's t-test comparing tracts with and without biodiverse landscapes offers insights for land managers seeking to jointly address climate change and environmental justice concerns. Finding that tracts with biodiverse landscapes had statistically significant higher values for flood, heat, drought, and overall climate risks suggests targeting biodiversity conservation activities in these areas could have potential co-benefits for climate adaptation. A growing body of evidence supports this type of integrated nature-based solution for managing ecosystems for climate mitigation and adaptation and the synergistic potential for conserving biodiversity and providing additional ecosystem services (Frantzeskaki et al., 2019; Girardin et al., 2021; Seddon et al., 2020). Nature-based solutions are increasingly featured in biodiversity conservation strategies along with climate mitigation and adaptation efforts across multiple sectors and scales (Fargione et al., 2018; Mawdsley et al., 2009; Seddon et al., 2020). Given the predicted increases in climate risks in this geography and globally, especially related to extreme rainfall, heat, and droughts, it will be essential to manage conservation actions for both biodiversity and climate adaptation (USGCRP, 2018).

Our t-test analysis also emphasized the potential for environmental

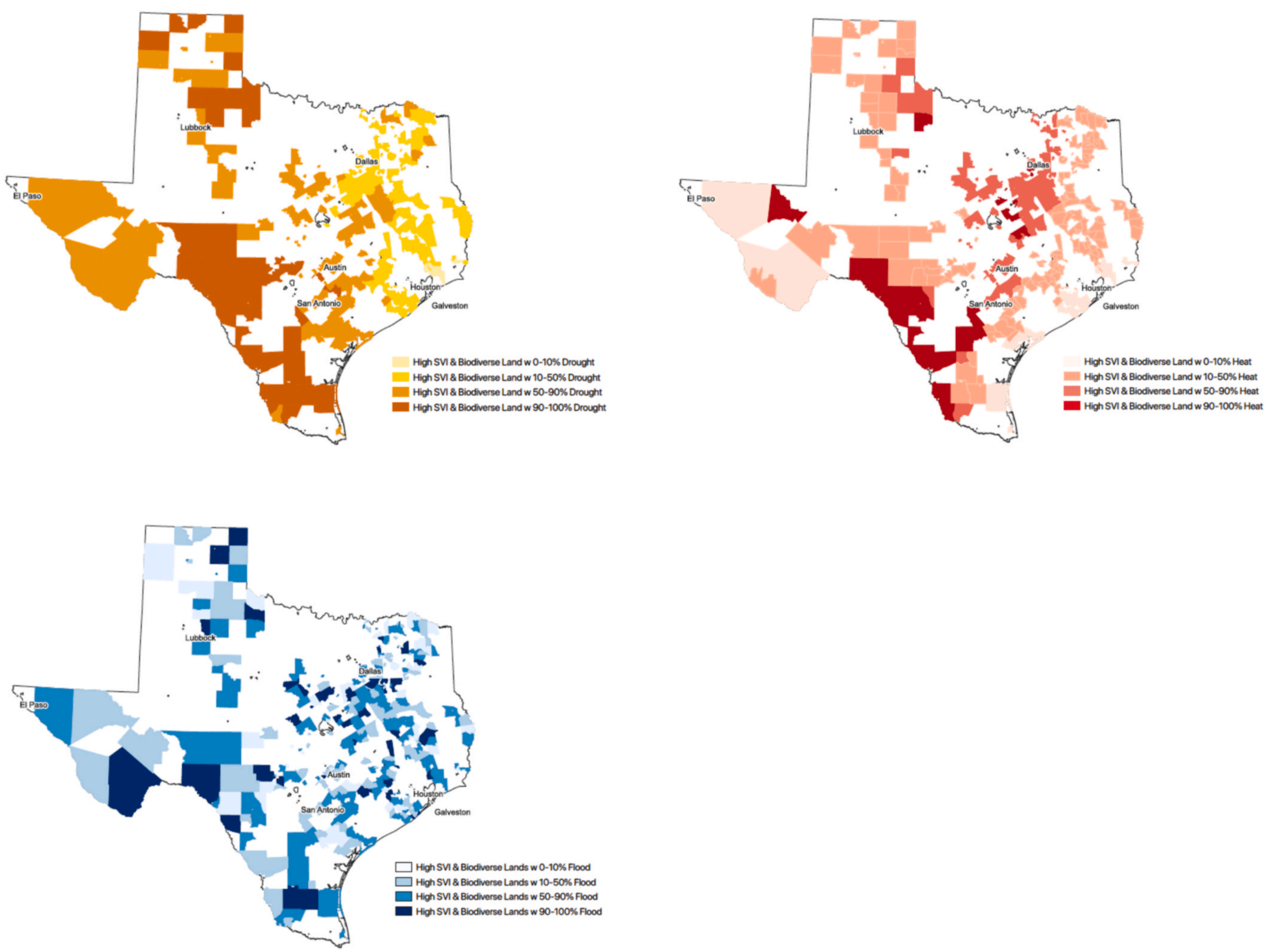

Fig. 2. Significant clusters of high social vulnerability related to high biodiverse landscapes overlaid with drought (yellow), heat (red), and flood (blue) risks (percentile ranks).

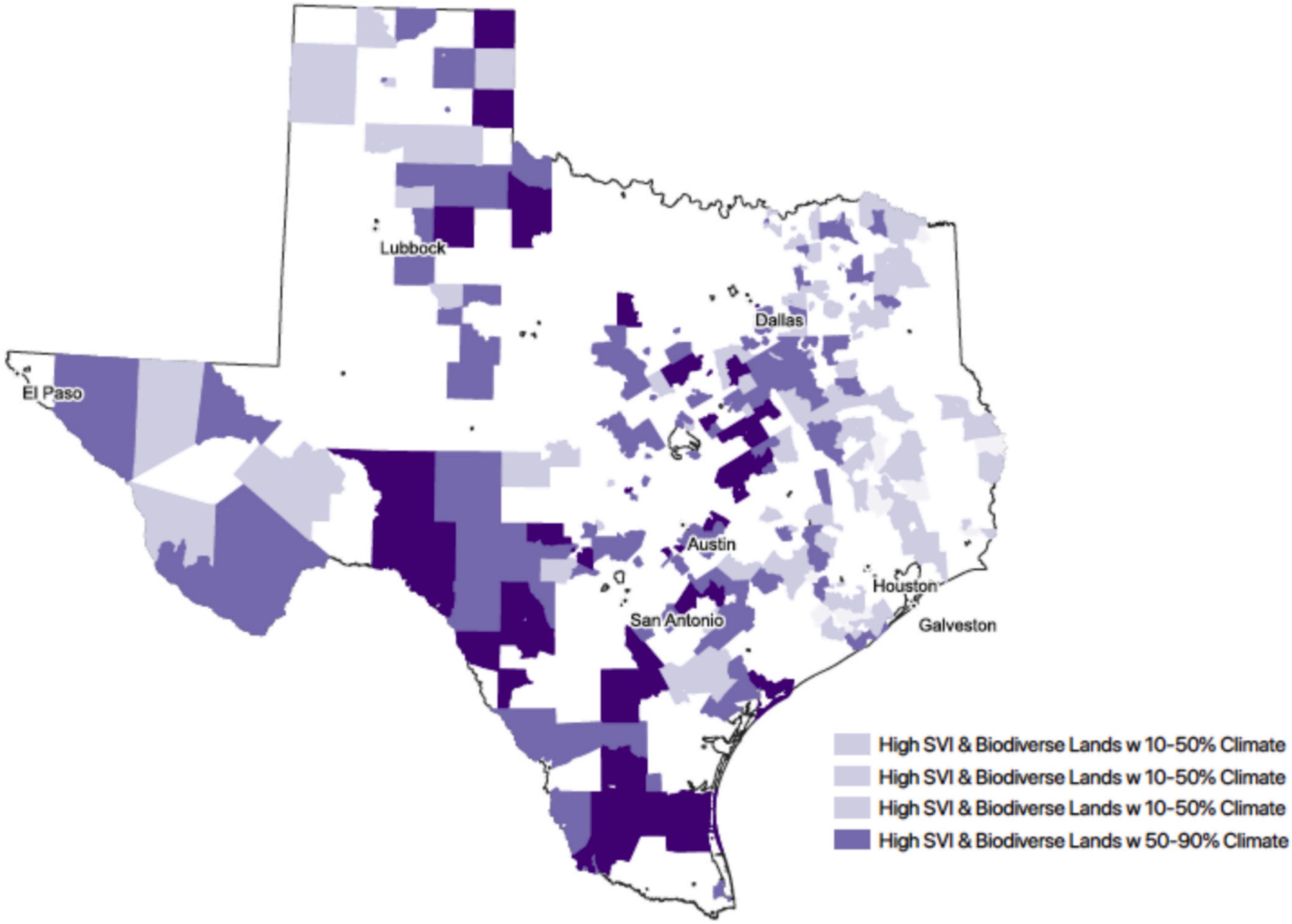

Fig. 3. Significant clusters of high social vulnerability related to high biodiverse landscapes overlaid with climate risk index (purple) (percentile ranks).

injustices if conservation activities do not center equity as a primary goal. We found that tracts with biodiverse landscapes had fewer Black, Latinx, and Asian American residents, along with lower poverty rates and overall social vulnerability scores. A major implication of this finding is that conservation activities focusing solely on biodiversity targets could disproportionately benefit less socially vulnerable populations, white residents, and wealthier communities. This could increase disparities associated with nature-based solutions and their impacts on reducing climate risks and providing other ecosystem services. These results support emerging scholarship documenting environmental injustices associated with inequitable proximity and access to conserved areas in multiple regions in the United States (Sims et al., 2022; Van Sant et al., 2021; Villamagna et al., 2017). Our outcomes also align with studies exploring the potential for nature-based solutions to amplify inequalities for lower-income residents, communities of color, or other groups that have been made vulnerable to climate impacts (Bremer et al., 2021; Shi, 2020; Tozer et al., 2020).

4.2. Tradeoffs and synergies between social vulnerability and biodiverse landscapes

The bivariate LISA analysis identified synergistic locations along the southern border. Outcomes indicating high levels of social vulnerability along the border are consistent with established scholarship characterizing Texas border counties as some of the most socially vulnerable locations in the United States, where residents face high levels of persistent poverty, inadequate infrastructure, and extensive environmental injustices (Durst and Ward, 2014; Grineski et al., 2013; Rowles et al., 2020; Cutter and Finch, 2008; Summers et al., 2018; USDA ERS, 2015). Similarly, the high concentration of biodiverse landscapes aligns with ecological studies documenting the region's significant diversity, endemism, and endangered species (Fowler et al., 2018; Leslie, 2016; Titley et al., 2021). Drawing attention to where synergistic locations occur provides additional insights into where land management programs and conservation activities may offer opportunities to improve both human and ecological well-being.

Results showing that major urban areas have varying levels of social vulnerability but limited biodiverse landscapes suggest that cities are important locations for addressing socio-ecological inequalities but may offer fewer opportunities for large-scale conservation efforts. We expected cities to have divergent measures of social vulnerability given long-standing research on urban segregation along with disaster and environmental justice scholarship on the urban socio-spatial inequalities of environmental harms and benefits (Bailey et al., 2017; Bullard, 1994; Hoffman et al., 2020; Jacobs, 2019). The limited amount of biodiverse landscapes in and around cities seemingly contradicts extensive scholarship showing that cities are critical for biodiversity and ecosystem services (Gómez-Baggethun et al., 2013; Nowak, 2010; Shaffer, 2018). This contradiction is likely related to our use of The Nature Conservancy's Resilient & Connected Network (RCN) to measure biodiverse landscapes. The RCN was designed to focus on large habitat landscapes, which tends to exclude major urban areas. Future research could utilize local-level biodiversity datasets that highlight conservation opportunities at the city-scale. This could be especially critical for environmental justice efforts given the high population density in cities and the increasing attention to urban applications of nature-based solutions for

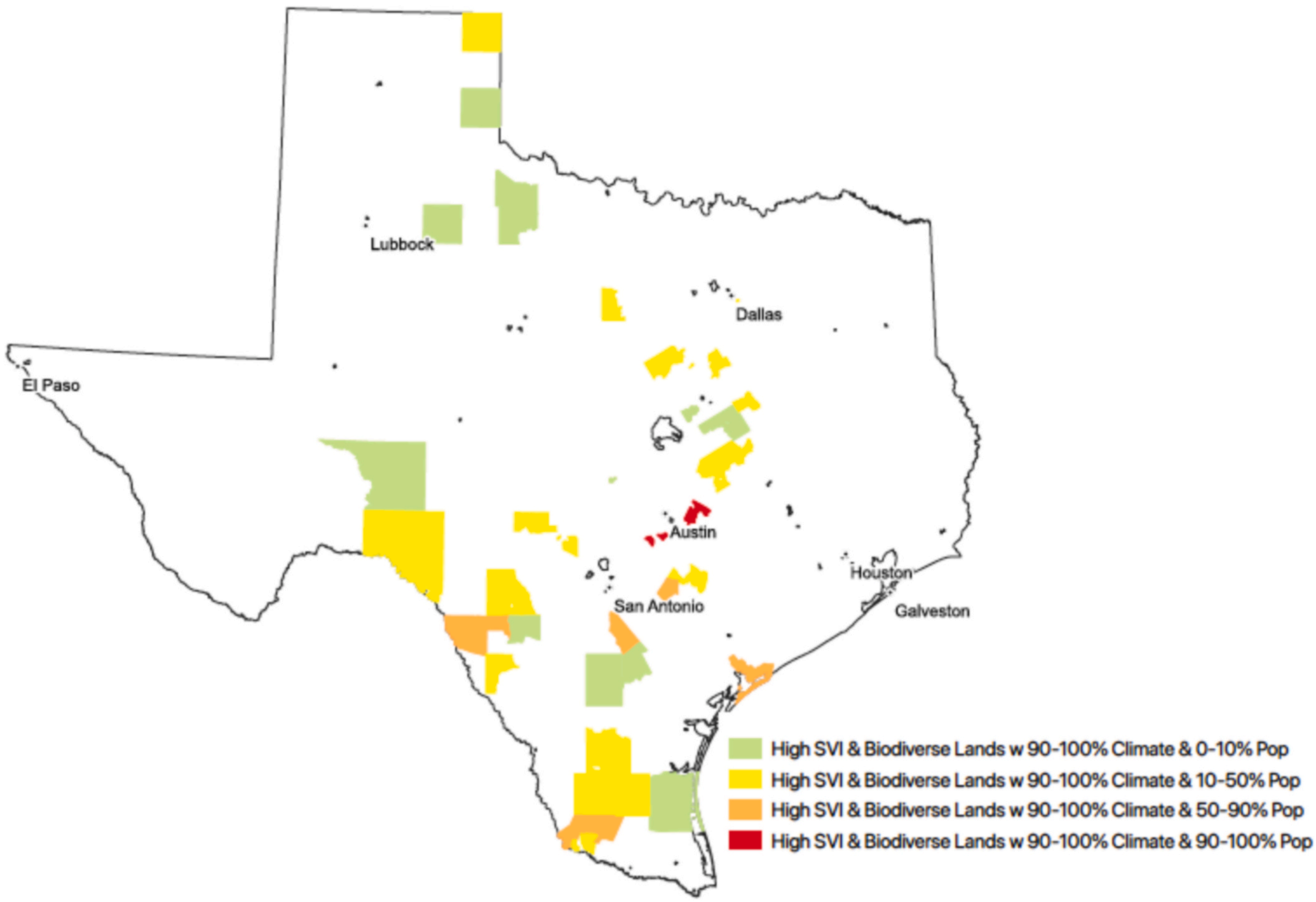

Fig. 4. Significant clusters of high social vulnerability related to high biodiverse landscapes overlaid with climate risk index (>90th percentile) and differentiated by population growth projections (percentile ranks).

climate mitigation and adaptation (Bremer et al., 2021; Kato-Huerta and Geneletti, 2022; Shi, 2020; Tozer et al., 2020).

The third major implication from our bivariate LISA analysis stems from the proximity between areas of tradeoffs (low levels of social vulnerability surrounded by high levels of biodiversity) and synergies (high levels of social vulnerability surrounded by high levels of biodiversity) in central and northwest Texas. We found comparable amounts of biodiverse landscapes in those clusters; however, measures of Black, Latinx, and Asian American residents, poverty levels, and overall social vulnerability were almost two times higher in synergy clusters compared to tradeoff clusters. These outcomes extend our earlier analysis demonstrating economic, racial, and vulnerability inequalities between tracts with and without biodiverse landscapes to emphasize the potential for equity impacts within areas with similarly high levels of biodiversity. Our results contribute to broader scholarship stressing the need to understand the distributional impacts of conservation actions in areas with comparable biodiversity opportunities and to incorporate social equity into conservation planning and decision-making (Cousins, 2021; Lieberknecht, 2009; Merenlender et al., 2004; Palfrey et al., 2021; Villamagna et al., 2017).

4.3. Focusing conservation activities in areas of high social vulnerability, biodiverse landscapes, climate risks, and population growth

Our overlay analysis highlights regions in Texas with concurrent threats and opportunities. Understanding which climate risk poses the greatest threats to communities and ecosystems is an essential component of spatially targeting nature-based solutions to facilitate both human and ecological adaptation capacity (Arneth et al., 2020; Reaney, 2022; Seddon et al., 2020). In our analysis, the semi-arid Great Plains ecoregion that extends from Texas to Canada emerged as a drought-prone location (Fig. 2A). Like many other parts of the Great Plains, much of the land is under livestock and agricultural use and has severely depleted local and regional aquifers (Steward and Allen, 2016). Given those socio-ecological conditions, conservation activities for drought resilience could focus on working with landowners to conserve and restore wetlands and alter irrigation practices. These types of programs have been shown to support local aquifer recharge, provide habitat for local and migrating species, and sustain water sources for human, agriculture, and livestock needs (Texas Playa Conservation, 2022-a; Texas Playa Conservation, 2022-b).

By combining climate risks into an index, we found that again the southern border region emerged as an area with significant social and ecological precarity, which is amplified by climate-driven extreme dry-wet-dry conditions that characterize many parts of the US-Mexico borderlands (Archer and Predick, 2008; Mazdiyasni and AghaKouchak, 2015; Stewart et al., 2015; USGCRP, 2018). Our results suggest the southern border area offers important large-scale conservation opportunities, like establishing networks of land trusts, parkland, and wildlife refuges, which may become increasingly important as governments, NGOs, and communities prepare for amplified flows of people and species due to climate change and other drivers (Barros et al., 2014; Nadin et al., 2017; Titley et al., 2021).

Lastly, by incorporating population growth, we further refined areas that may offer time-sensitive opportunities for conservation actions or land use regulations. We identified high population growth areas in rapidly growing exurban communities which may require more urgent attention to land use policies or habitat protection efforts given expected development pressures and their associated impacts on habitat conversion, impervious cover, increasing climate risks, and rising costs of land acquisition. There are debates regarding the economic and ecological effectiveness of conserving habitat in highly urbanizing areas compared to less fragmented locations; however, the growing consensus is that both approaches are necessary (Brooks et al., 2006; Mokany et al., 2020; Wintle et al., 2019). Understanding where population growth may drive land use change takes these debates into account and could inform prioritization efforts, especially across the Sun Belt region where social inequality, biodiversity loss, climate change, and rapid population growth challenges converge (McKee et al., 2015; U.S. Census Bureau, 2021; USGCRP, 2018).

5. Conclusion

Three major contributions emerged from our analysis. First, our multidimensional approach extends current conservation prioritization scholarship that primarily focuses on one or two major drivers of biodiversity loss. In the past, researchers have characterized priorities based on their potential to address the misalignment between U.S. protected areas and species habitat needs (Jenkins et al., 2015). Others like the Nature Conservancy's Resilient & Connected Network, used in this study, have selected areas that could best support existing biodiversity and climate-driven shifts in species ranges (Anderson et al., 2016). More recently, studies have incorporated future land use pressures (Simkin et al., 2022) or begun to focus on issues of social inequality (Gourevitch et al., 2021; Sims et al., 2022). This study documents how addressing concurrent threats and opportunities may influence spatial priorities beyond what would emerge if the analysis was limited to one or two factors.

Our second contribution offers conservation organizations, land managers, and policy-makers a methodology to identify high-impact conservation areas with the potential to simultaneously meet biodiversity, social vulnerability, and climate adaptation objectives while being responsive to population growth pressures. Importantly, our prioritization approach holds addressing social vulnerability and biodiversity as equally weighted conservation goals. Environmental justice advocates and community groups have long proposed this type of prioritization, and it is a growing area of practice for conservation organizations and government funding allocation schemes (Bowan, 2020; Brune, 2020; Bruno and Jepson, 2018; Exec. Order No. 8, 14008, 2021; Harris County Flood Control District, 2018; Jacobs, 2019; Kohl, 2021; Méndez et al., 2020; Pellow, 2001; Thomas et al., 2019).

The process we have outlined here identified key geographies that target multiple social and ecological objectives at once. Importantly, as part of this analysis we did not assume which conservation activities should be prioritized, what ecosystem services those would yield, and how those services would be distributed, which are critical questions that would guide next steps in conservation strategy and action. We would recommend that after identifying potential high-impact "win-win-win" areas, the next steps would require further engagement with local communities and conservation organizations to refine appropriate locations, safeguards, and types of conservation activities for different geographies. Inclusive of that approach is describing which benefits might result from various conservation activities and how those benefits would be distributed. Community engagement and qualitative methods can help ensure that prioritization efforts reflect local needs and desires and consider ecological gentrification pressures (Battaglia et al., 2016; Carmichael and McDonough, 2018; Dooling, 2009; Faber and Kimelberg, 2014; Kehler and Birchall, 2021; Wolch et al., 2014). The Nature Conservancy's "Scaling Up Nature-based Solutions" (SUNS) is an example of this type of approach. SUNS program staff work directly with local stakeholders to identify their priorities and create a customized portfolio of solutions that address both climate risks and habitat benefits (The Nature Conservancy. (n.d.-b), 2022). As a starting point, this study provides conservation NGOs and land managers operating with limited resources and multiple competing priorities with a replicable and scalable way to map initial synergistic areas.

Our last contribution highlights the wide range of settings that emerged as high-impact conservation priorities, and we suggest these offer potential implications outside of Texas and directions for future research. Our analysis found "win-win-win" opportunities in rapidly developing exurban locations, the drought-prone Great Plains, and the highly vulnerable borderlands. Future research could evaluate if similar opportunities arise in analogous areas. For example, testing if synergies also emerge in other exurban locations like near Atlanta, which shares similar climate threats, population growth projections, and conservation challenges as the areas we identified in central Texas (Barten and Ernst, 2004; Benez-Secanho and Dwivedi, 2020; Immergluck and Balan, 2018; Lichter and Ziliak, 2017; Miller, 2012; Muse et al., 2022; Sun et al., 2018), could provide important results for larger-scale conservation planning. This may be especially insightful as the U.S. moves closer towards 90% of the population living in urban centers (United Nations, 2019). For areas with dominant climate risks, like the drought-prone Great Plains, future research might evaluate how to adequately scale conservation efforts given the high percentage of private landowners and the national importance of regional aquifers and agricultural production (Augustine et al., 2021; Barnes et al., 2020; Brown et al., 2017; Cameron et al., 2014). Lastly, our research suggests that the Texas-Mexico border region offers critical large-scale conservation opportunities to increase human and ecological resilience to escalating extreme dry-wet-dry conditions. Understanding where to expand ongoing research and programs working to jointly address socio-ecological challenges across the broader US-Mexico borderlands may be critical as human and non-human species migrate toward climate refugia (Chester, 2005; Liverman et al., 1997; Petersen et al., 2018; Pezzoli et al., 2014; Schlyer, 2021; Varady et al., 2013). Ultimately, our work suggests that it is possible and important to prioritize habitats that offer multiple co-benefits as we work towards meeting national commitments to conserve 30% of U.S. lands and waters by 2030.

Funding

This work was supported by the MFI Foundation, United States of America and Planet Texas 2050, a research grand challenge at The University of Texas at Austin, United States of America.

CRediT authorship contribution statement

Deidre Zoll: Conceptualization, Methodology, Data curation, analysis, Visualization, Writing – original draft, Writing – review & editing. **Katherine Lieberknecht:** Conceptualization, Writing – original draft, Writing – review & editing, Funding acquisition, Supervision. **R. Patrick Bixler:** Conceptualization, Writing – review & editing, Funding acquisition, Supervision. **J. Amy Belaire:** Conceptualization, Writing – original draft, Writing – review & editing, Funding acquisition, Supervision. **Shalene Jha:** Conceptualization, Writing – original draft, Writing – review & editing, Funding acquisition, Supervision, Project administration.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: J. Amy Belaire reports financial support was provided by MFI Foundation.

Data Availability

Data will be made available on request.

Acknowledgements

We would like to thank Nina Safavi and Dr. Charles Nicholson for conversations that refined concepts and analysis developed in this article. We would also like to thank the two reviewers and Editor Laura Tozer for their insightful comments and feedback which strengthened this article.

References

Albert, C., Schröter, B., Haase, D., Brillinger, M., Henze, J., Herrmann, S., Gottwald, S., Guerrero, P., Nicolas, C., Matzdorf, B., 2019. Addressing societal challenges through nature-based solutions: how can landscape planning and governance research contribute. Landsc. Urban Plan. 182, 12–21. https://doi.org/10.1016/j.landurbplan.2018.10.003.

America the Beautiful Interagency Working Group. (2021). America the Beautiful Interagency Working Group 2021 Year one report: America the beautiful. www.whitehouse.gov/wp-content/uploads/2021/12/AtB-Year-One-Report_.pdf.

Anderson, M.G., Barnett, A., Clark, M., Prince, J., Sheldon, A., Vickery, B., 2016. Resilient and connected landscapes for terrestrial conservation (p. 161). the nature conservancy, eastern conservation science. East. Reg. Off. http://easterndivision.s3.amazonaws.com/Resilient_and_Connected_Landscapes_For_Terrestial_Conservation.pdf.

Anderson, M.G., Clark, M., Olivero, A.P., Barnett, A.R., Hall, K.R., Cornett, M.W., Ahlering, M., Schindel, M., Unnasch, B., Schloss, C., Cameron, D.R., 2023. A resilient and connected network of sites to sustain biodiversity under a changing climate. e2204434119 Proc. Natl. Acad. Sci. 120 (7). https://doi.org/10.1073/pnas.2204434119.

Anguelovski, I., Shi, L., Chu, E., Gallagher, D., Goh, K., Lamb, Z., Reeve, K., Teicher, H., 2016. Equity impacts of urban land use planning for climate adaptation: critical perspectives from the Global North and South. J. Plan. Educ. Res. 36 (3), 333–348. https://doi.org/10.1177/0739456X16645166.

Anselin, L., 1995. Local indicators of spatial association. Geogr. Anal. 27 (2), 93–115.

Archer, S.R., Predick, K.I., 2008. Climate change and ecosystems of the southwestern United States. Rangelands 30 (3), 23–28. https://doi.org/10.2111/1551-501X(2008)30[23:CCAEOT]2.0.CO;2.

Arkema, K.K., Griffin, R., Maldonado, S., Silver, J., Suckale, J., Guerry, A.D., 2017. Linking social, ecological, and physical science to advance natural and nature-based protection for coastal communities. Ann. N. Y. Acad. Sci. 1399 (1), 5–26. https://doi.org/10.1111/nyas.13322.

Arneth, A., Shin, Y.-J., Leadley, P., Rondinini, C., Bukvareva, E., Kolb, M., Midgley, G.F., Oberdorff, T., Palomo, I., Saito, O., 2020. Post-2020 biodiversity targets need to embrace climate change. Proc. Natl. Acad. Sci. 117 (49), 30882–30891. https://doi.org/10.1073/pnas.2009584117.

Augustine, D., Davidson, A., Dickinson, K., Van Pelt, B., 2021. Thinking like a grassland: challenges and opportunities for biodiversity conservation in the great plains of North America. Rangel. Ecol. Manag. 78, 281–295. https://doi.org/10.1016/j.rama.2019.09.001.

Bailey, Z.D., Krieger, N., Agénor, M., Graves, J., Linos, N., Bassett, M.T., 2017. Structural racism and health inequities in the USA: evidence and interventions. Lancet 389 (10077), 1453–1463. https://doi.org/10.1016/S0140-6736(17)30569-X.

Barnes, J.C., Sketch, M., Gramza, A.R., Sorice, M.G., Iovanna, R., Dayer, A.A., 2020. Land use decisions after the conservation reserve program: re-enrollment, reversion, and persistence in the southern great plains. Conserv. Sci. Pract. 2 (9) https://doi.org/10.1111/csp2.254.

Barros, V., Field, C., Dokke, D., Mastrandrea, M., Mach, K., Bilir, T.E., Chatterjee, M., Ebi, K., Estrada, Y., & Genova, R. (2014). Climate change 2014: Impacts, adaptation, and vulnerability. Part B: Regional Aspects-Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Barten, P.K., Ernst, C.E., 2004. Land conservation and watershed management for source protection. J. AWWA 96 (4), 121–135. https://doi.org/10.1002/j.1551-8833.2004.tb10603.x.

Battaglia, M., Buckley, G.L., Galvin, M., Grove, J.M., 2016. It's not easy going green: obstacles to tree-planting programs in East Baltimore. Cities Environ. 7 (2), 125–152. https://doi.org/10.1201/b21179.

Belote, T., Aplet, G., Carlson, A., Dietz, M., May, A., McKinley, P., Schnure, M., Garncarz, J., 2021. Beyond priority pixels: Delineating and evaluating landscapes for conservation in the contiguous United States. Landsc. Urban Plan. 209, 104059 https://doi.org/10.1016/j.landurbplan.2021.104059.

Benez-Secanho, F.J., Dwivedi, P., 2020. Analyzing the provision of ecosystem services by conservation easements and other protected and non-protected areas in the Upper Chattahoochee Watershed. Sci. Total Environ. 717, 137218 https://doi.org/10.1016/j.scitotenv.2020.137218.

Bixler, R.P., Yang, E., Richter, S.M., Coudert, M., 2021. Boundary crossing for urban community resilience: a social vulnerability and multi-hazard approach in Austin, Texas, USA. Int. J. Disaster Risk Reduct. 66, 102613 https://doi.org/10.1016/j.ijdrr.2021.102613.

Bowan, A. (2020). A necessary reckoning. https://www.landtrustalliance.org/blog/necessary-reckoning.

Bremer, L.L., Keeler, B., Pascua, P., Walker, R., Sterling, E., 2021. Chapter 5—nature-based solutions, sustainable development, and equity. In: Cassin, J., Matthews, J.H., Gunn, E.L. (Eds.), Nature-based Solutions and Water Security. Elsevier, pp. 81–105. https://doi.org/10.1016/B978-0-12-819871-1.00016-6.

Brooks, T.M., Mittermeier, R.A., da Fonseca, G. a B., Gerlach, Hoffmann, J., Lamoreux, M., Mittermeier, J.F., Pilgrim, C.G., D, J., Rodrigues, A.S.L., 2006. Global biodiversity conservation priorities. Science 313 (5783), 58–61. https://doi.org/10.1126/science.1127609.

Brown, J., Alvarez, P., Byrd, K., Deswood, H., Elias, E., Spiegal, S., 2017. Coping with historic drought in california rangelands: developing a more effective institutional response. Rangelands 39 (2), 73–78. https://doi.org/10.1016/j.rala.2017.01.002.

Brune, M., 2020. Pulling our Monum.

Bruno, T., Jepson, W., 2018. Marketisation of environmental justice: U.S. EPA environmental justice showcase communities project in Port Arthur, Texas. Local Environ. 23 (3), 276–292. https://doi.org/10.1080/13549839.2017.1415873.

Bullard, R.D., 1994. Overcoming racism in environmental decisionmaking. Environ.: Sci. Policy Sustain. Dev. 36 (4), 10–44. https://doi.org/10.1080/00139157.1994.9929997.

California Senate Bill 535,no. SB-535 (2012). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201120120SB535.

Cameron, D.R., Marty, J., Holland, R.F., 2014. Whither the rangeland?: Protection and conversion in California's rangeland ecosystems. PLoS One 9 (8), e103468. https://doi.org/10.1371/journal.pone.0103468.

Carmichael, C.E., McDonough, M.H., 2018. The trouble with trees? Social and political dynamics of street tree-planting efforts in Detroit, Michigan, USA. Urban For. Urban Green. 31, 221–229. https://doi.org/10.1016/j.ufug.2018.03.009.

Census Bureau, U.S., 2021. New vintage 2021 population estimates available for the nation. *S. Puerto Rico*. Census Gov. ⟨https://www.census.gov/newsroom/press-releases/2021/2021-population-estimates.html⟩.

Centers for Disease Control and Prevention. (n.d.). National Environmental Public Health Tracking Network. Retrieved November 7, 2022, from https://ephtracking.cdc.gov/.

Centers for Disease Control and Prevention. (2016). SVI 2014 Documentation. 1–31.

Chester, C.C., 2005. From conservation diplomacy to transborder landscapes: the protection of biodiversity across North America's Borders. Georg. Wright Forum 22 (1), 27–34.

Chi, G., Zhu, J., 2008. Spatial regression models for demographic analysis. Popul. Res. Policy Rev. 27, 17–42. https://doi.org/10.1007/s11113-007-9051-8.

Ciurean, R., Gill, J., Reeves, H.J., O'Grady, S., Aldridge, T., 2018. Review of multi-hazards research and risk assessments. Br. Geol. Surv. ⟨https://nora.nerc.ac.uk/id/eprint/524399/⟩.

R. Core Team. (2021). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing.

Cousins, J.J., 2021. Justice in nature-based solutions: research and pathways. Ecol. Econ. 180, 106874 https://doi.org/10.1016/j.ecolecon.2020.106874.

Cutter, S.L., & Finch, C. (2008). Temporal and spatial changes in social vulnerability to natural hazards. Proceedings of the National Academy of Sciences, *105*(7), 2301–2306. https://doi.org/10.1073/pnas.0710375105.

Cutter, S.L., Boruff, B.J., Shirley, W.L., 2003. Social vulnerability to environmental hazards. Soc. Sci. Q. 84, 242–261. https://doi.org/10.1111/1540-6237.8402002.

Cutter, S.L., Emrich, C. t, Morath, D. p, Dunning, C. m, 2013. Integrating social vulnerability into federal flood risk management planning. J. Flood Risk Manag. 6 (4), 332–344. https://doi.org/10.1111/jfr3.12018.

Dooling, S., 2009. Ecological gentrification: a research agenda exploring justice in the city. Int. J. Urban Reg. Res. 33 (3), 621–639. https://doi.org/10.1111/j.1468-2427.2009.00860.x.

Drakes, O., Tate, E., 2022. Social vulnerability in a multi-hazard context: a systematic review. Environ. Res. Lett. 17 (3), 033001 https://doi.org/10.1088/1748-9326/ac5140.

Drakes, O., Tate, E., Rainey, J., Brody, S., 2021. Social vulnerability and short-term disaster assistance in the United States. Int. J. Disaster Risk Reduct. 53, 102010 https://doi.org/10.1016/j.ijdrr.2020.102010.

Durst, N.J., Ward, P.M., 2014. Measuring self-help home improvements in Texas colonias: a ten year "snapshot" study. Urban Stud. 51 (10), 2143–2159.

Economic Policy Institute. (2016). Income inequality in the U.S. by state, metropolitan area, and county. https://www.epi.org/publication/income-inequality-in-the-us/.

Emrich, C.T., Cutter, S.L., 2011. Social vulnerability to climate-sensitive hazards in the Southern United States. Weather, Clim., Soc. 3 (3), 193–208. https://doi.org/10.1175/2011WCAS1092.1.

Exec Order No. 14008, 86 FR 7619 7619 (2021).

Faber, D., Kimelberg, S., 2014. Sustainable urban development and environmental gentrification: the paradox confronting the U.S. environmental justice movement. In: Hall, H., Robinson, C., Kohli, A. (Eds.), Uprooting Urban America: Multidisciplinary Perspectives on Race, Class & Gentrification. Peter Lang, pp. 77–92.

Fargione, J.E., Bassett, S., Boucher, T., Bridgham, S.D., Conant, R.T., Cook-Patton, S.C., Ellis, P.W., Falcucci, A., Fourqurean, J.W., Gopalakrishna, T., Gu, H., Henderson, B., Hurteau, M.D., Kroeger, K.D., Kroeger, T., Lark, T.J., Leavitt, S.M., Lomax, G., McDonald, R.I., Griscom, B.W., 2018. Natural climate solutions for the United States. Sci. Adv. 4 (11), eaat1869. https://doi.org/10.1126/sciadv.aat1869.

Fatemi, F., Ardalan, A., Aguirre, B., Mansouri, N., Mohammadfam, I., 2017. Social vulnerability indicators in disasters: findings from a systematic review. Int. J. Disaster Risk Reduct. 22, 219–227. https://doi.org/10.1016/j.ijdrr.2016.09.006.

Fazel-Zarandi, M.M., Feinstein, J.S., Kaplan, E.H., 2018. The number of undocumented immigrants in the United States: estimates based on demographic modeling with data from 1990 to 2016. PLOS ONE 13 (9), e0201193. https://doi.org/10.1371/journal.pone.0201193.

FEMA. (2022). National Risk Index. https://hazards.fema.gov/nri/.

Fischer, J., Lindenmayer, D.B., 2007. Landscape modification and habitat fragmentation: a synthesis. Glob. Ecol. Biogeogr. 16 (3), 265–280. https://doi.org/10.1111/j.1466-8238.2007.00287.x.

Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K., 2005. Global consequences of land use. Science 309 (5734), 570–574. https://doi.org/10.1126/science.1111772.
Fowler, N., Keitt, T., Schmidt, O., Terry, M., Trout, K., 2018. Border wall: bad for biodiversity. Front. Ecol. Environ. 16 (3), 137–138. https://doi.org/10.1002/fee.1785.
Frantzeskaki, N., McPhearson, T., Collier, M.J., Kendal, D., Bulkeley, H., Dumitru, A., Walsh, C., Noble, K., van Wyk, E., Ordóñez, C., Oke, C., Pintér, L., 2019. Nature-based solutions for urban climate change adaptation: linking science, policy, and practice communities for evidence-based decision-making. BioScience 69 (6), 455–466. https://doi.org/10.1093/biosci/biz042.
Frey, W.H. (2021). Census 2020: First results show near historically low population growth and a first-ever congressional seat loss for California. Brookings Metropolitan Policy Program. https://www.brookings.edu/research/census-2020-data-release/.
Fulton, W., Hazle, S.G., Choudary, W., Sherman, S., 2020. The urban sun belt: an overview. rice university kinder institute for urban. Research. https://doi.org/10.25611/08BZ-KJ50.
Girardin, C.A.J., Jenkins, S., Seddon, N., Allen, M., Lewis, S.L., Wheeler, C.E., Griscom, B. W., Malhi, Y., 2021. Nature-based solutions can help cool the planet—If we act now. Nature 593 (7858), 191–194. https://doi.org/10.1038/d41586-021-01241-2.
Gómez-Baggethun, E., Gren, Å., Barton, D.N., Langemeyer, J., McPhearson, T., O'farrell, P., Andersson, E., Hamstead, Z., Kremer, P., 2013. Urban ecosystem services. In *Urbanization, biodiversity and ecosystem services: Challenges and opportunities*. Springer, Dordrecht, pp. 175–251.
Gourevitch, J.D., Alonso-Rodríguez, A.M., Aristizábal, N., de Wit, L.A., Kinnebrew, E., Littlefield, C.E., Moore, M., Nicholson, C.C., Schwartz, A.J., Ricketts, T.H., 2021. Projected losses of ecosystem services in the US disproportionately affect non-white and lower-income populations. Article 1 Nat. Commun. 12 (1). https://doi.org/10.1038/s41467-021-23905-3.
Grineski, S.E., Collins, T.W., Chakraborty, J., McDonald, Y.J., 2013. Environmental health injustice: exposure to air toxics and children's respiratory hospital admissions in El Paso, Texas. Prof. Geogr. 65 (1), 31–46. https://doi.org/10.1080/00330124.2011.639625.
Hamilton, H., Smyth, R.L., Young, B.E., Howard, T.G., Tracey, C., Breyer, S., Cameron, D. R., Chazal, A., Conley, A.K., Frye, C., Schloss, C., 2022. Increasing taxonomic diversity and spatial resolution clarifies opportunities for protecting US imperiled species. Ecol. Appl. 32 (3) https://doi.org/10.1002/eap.2534.
Harris County Flood Control District. (2018). Prioritization Framework for the Implementation of the Harris County Flood Control District 2018 Bond Projects. https://www.hcfcd.org/Portals/62/Resilience/Bond-Program/Prioritization-Framework/final_prioritization-framework-report_20190827.pdf?ver=2019–09-19–092535-743.
Hino, M., Field, C.B., Mach, K.J., 2017. Managed retreat as a response to natural hazard risk. Nat. Clim. Change 7 (5), 364–370. https://doi.org/10.1038/nclimate3252.
Hoffman, J.S., Shandas, V., Pendleton, N., 2020. The effects of historical housing policies on resident exposure to intra-urban heat: a study of 108 US Urban Areas. Climate 8 (1), 12. https://doi.org/10.3390/cli8010012.
Howell, J., Elliott, J.R., 2019. Damages done: the longitudinal impacts of natural hazards on wealth inequality in the United States. Soc. Probl. 66 (3), 448–467. https://doi.org/10.1093/socpro/spy016.
Hsiang, S., Kopp, R., Jina, A., Rising, J., Delgado, M., Mohan, S., Rasmussen, D.J., Muir-Wood, R., Wilson, P., Oppenheimer, M., Larsen, K., Houser, T., 2017. Estimating economic damage from climate change in the United States. Science 356 (6345), 1362–1369. https://doi.org/10.1126/science.aal4369.
Hsu, A., Sheriff, G., Chakraborty, T., Manya, D., 2021. Disproportionate exposure to urban heat island intensity across major US cities. Article 1 Nat. Commun. 12 (1). https://doi.org/10.1038/s41467-021-22799-5.
Immergluck, D., Balan, T., 2018. Sustainable for whom? Green urban development, environmental gentrification, and the Atlanta Beltline. Urban Geogr. 39 (4), 546–562. https://doi.org/10.1080/02723638.2017.1360041.
Jacobs, F., 2019. Black feminism and radical planning: new directions for disaster planning research. Plan. Theory 18 (1), 24–39. https://doi.org/10.1177/1473095218763221.
Jenkins, C.N., Van Houtan, K.S., Pimm, S.L., & Sexton, J.O. (2015). US protected lands mismatch biodiversity priorities. Proceedings of the National Academy of Sciences, *112*(16), 5081–5086. https://doi.org/10.1073/pnas.1418034112.
Jones, B., O'Neill, B.C., McDaniel, L., McGinnis, S., Mearns, L.O., Tebaldi, C., 2015. Future population exposure to US heat extremes. *Nat. Clim. Change*, *5*(7), Artic., 7 https://doi.org/10.1038/nclimate2631.
Kato-Huerta, J., Geneletti, D., 2022. Environmental justice implications of nature-based solutions in urban areas: a systematic review of approaches, indicators, and outcomes. Environ. Sci. Policy 138, 122–133. https://doi.org/10.1016/j.envsci.2022.07.034.
Keenan, J.M., Hill, T., Gumber, A., 2018. Climate gentrification: from theory to empiricism in Miami-Dade County, Florida. Environ. Res. Lett. 13 (5), 1–11.
Kehler, S., Birchall, S.J., 2021. Social vulnerability and climate change adaptation: the critical importance of moving beyond technocratic policy approaches. Environ. Sci. Policy 124, 471–477. https://doi.org/10.1016/j.envsci.2021.07.025.
Kohl, E., 2021. 'Some we's weren't part of we': Intersectional politics of belonging in U.S. environmental justice activism. *Gender*. Place Cult. 28 (11), 1606–1626. https://doi.org/10.1080/0966369X.2020.1832968.
Koks, E.E., Jongman, B., Husby, T.G., Botzen, W.J.W., 2015. Combining hazard, exposure and social vulnerability to provide lessons for flood risk management. Environ. Sci. Policy 47, 42–52. https://doi.org/10.1016/j.envsci.2014.10.013.
Lempert, R.J., Arnold, J.R., Pulwarty, R.S., Gordon, K., Greig, K., Hawkins-Hoffman, C., Sands, D., Werrell, C., 2018. Chapter 28: Adaptation Response. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II. U.S. Global Change Research Program. https://doi.org/10.7930/NCA4.2018.CH28.
Leslie, D.M. Jr. (2016). *An international borderland of concern: Conservation of biodiversity in the Lower Rio Grande Valley* (Scientific Investigations Report) [Scientific Investigations Report]. USGS. ⟨https://pubs.usgs.gov/sir/2016/5078/sir20165078.pdf⟩.
Lichter, D.T., Ziliak, J.P., 2017. The rural-urban interface: new patterns of spatial interdependence and inequality in America. Ann. Am. Acad. Political Soc. Sci. 672 (1), 6–25. https://doi.org/10.1177/0002716217714180.
Lieberknecht, K., 2009. Public access to U.S. conservation land trust properties: results from a national survey. J. Am. Plan. Assoc. 75 (4), 479–491. https://doi.org/10.1080/01944360903212087.
Liverman, D., Merideth, R., & Holdsworth, A. (1997). *Climate Variability and Social Vulnerability in the U.S.-Mexico Border Region*. USGS. ⟨https://geochange.er.usgs.gov/sw/impacts/society/border/⟩.
Mawdsley, J.R., O'malley, R., Ojima, D.S., 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conserv. Biol. 23 (5), 1080–1089. https://doi.org/10.1111/j.1523-1739.2009.01264.x.
Mazdiyasni, O., AghaKouchak, A., 2015. Substantial increase in concurrent droughts and heatwaves in the United States. Proc. Natl. Acad. Sci. 112 (37), 11484–11489. https://doi.org/10.1073/pnas.1422945112.
McGuire, J.L., Lawler, J.J., McRae, B.H., Nuñez, T.A., Theobald, D.M., 2016. Achieving climate connectivity in a fragmented landscape. Proc. Natl. Acad. Sci. 113 (26), 7195–7200. https://doi.org/10.1073/pnas.1602817113.
McKee, J.J., Rose, A.N., Bright, E.A., Huynh, T., Bhaduri, B.L., 2015. Locally adaptive, spatially explicit projection of US population for 2030 and 2050. Proc. Natl. Acad. Sci. 112 (5), 1344–1349. https://doi.org/10.1073/pnas.1405713112.
Méndez, M., Flores-Haro, G., Zucker, L., 2020. The (in)visible victims of disaster: understanding the vulnerability of undocumented Latino/a and indigenous immigrants. Geoforum 116, 50–62. https://doi.org/10.1016/j.geoforum.2020.07.007.
Mennis, J.L., Jordan, L., 2005. The distribution of environmental equity: exploring spatial nonstationarity in multivariate models of air toxic releases. Ann. Assoc. Am. Geogr. 95 (2), 249–268.
Merenlender, A.M., Huntsinger, L., Guthey, G., Fairfax, S.K., 2004. Land trusts and conservation easements: who is conserving what for whom. Conserv. Biol. 18 (1), 65–76. https://doi.org/10.1111/j.1523-1739.2004.00401.x.
Miller, M.D., 2012. The impacts of Atlanta's urban sprawl on forest cover and fragmentation. Appl. Geogr. 34, 171–179. https://doi.org/10.1016/j.apgeog.2011.11.010.
Mokany, K., Ferrier, S., Harwood, T.D., Ware, C., Di Marco, M., Grantham, H.S., Venter, O., Hoskins, A.J., & Watson, J.E.M. (2020). Reconciling global priorities for conserving biodiversity habitat. Proceedings of the National Academy of Sciences, *117*(18), 9906–9911. https://doi.org/10.1073/pnas.1918373117.
Muse, N., Iwaniec, D.M., Wyczalkowski, C., Mach, K.J., 2022. Heat exposure and resilience planning in Atlanta, Georgia. Environ. Res.: Clim. 1 (1), 015004 https://doi.org/10.1088/2752-5295/ac78f9.
Nadin, R., Watson, C., & Opitz-Stapleton, S. (2017). *Climate change, migration and displacement: The need for a risk-informed and coherent approach.* ODI. ⟨https://odi.org/en/publications/climate-change-migration-and-displacement-the-need-for-a-risk-informed-and-coherent-approach/⟩.
Nielsen-Gammon, J., Holman, S., Buley, A., Jorgensen, S., Escobedo, J., Ott, C., Dedrick, J., 2021. Assessment of Historic and Future Trends of Extreme Weather In Texas, 1900–2036. Office of the Texas State Climatologist, p. 44.
Nowak, D.J., 2010. Urban biodiversity and climate change. Urban Biodivers. Des. 101.
Otto, I.M., Reckien, D., Reyer, C.P.O., Marcus, R., Le Masson, V., Jones, L., Norton, A., Serdeczny, O., 2017. Social vulnerability to climate change: a review of concepts and evidence. Reg. Environ. Change 17, 1–12. https://doi.org/10.1007/s10113-017-1105-9.
Palfrey, R., Oldekop, J., Holmes, G., 2021. Conservation and social outcomes of private protected areas. Conserv. Biol. 35 (4), 1098–1110. https://doi.org/10.1111/cobi.13668.
Pellow, D.N., 2001. Environmental justice and the political process: movements, corporations, and the state. Sociol. Q. 42 (1), 47–67.
Petersen, B., Aslan, C., Stuart, D., Beier, P., 2018. Incorporating social and ecological adaptive capacity into vulnerability assessments and management decisions for biodiversity conservation. BioScience 68 (5), 371–380. https://doi.org/10.1093/biosci/biy020.
Pezzoli, K., Kozo, J., Ferran, K., Wooten, W., Gomez, G.R., Al-Delaimy, W.K., 2014. One bioregion/one health: an integrative narrative for transboundary planning along the US–mexico border. Glob. Soc.: J. Interdiscip. Int. Relat. 28 (4), 419–440. https://doi.org/10.1080/13600826.2014.951316.
Pickard, B.R., Daniel, J., Mehaffey, M., Jackson, L.E., Neale, A., 2015. EnviroAtlas: a new geospatial tool to foster ecosystem services science and resource management. Ecosyst. Serv. 14, 45–55.
Pineda-Pinto, M., Frantzeskaki, N., Nygaard, C.A., 2022. The potential of nature-based solutions to deliver ecologically just cities: lessons for research and urban planning from a systematic literature review. Ambio 51 (1), 167–182. https://doi.org/10.1007/s13280-021-01553-7.
Piontek, F., Müller, C., Pugh, T.A.M., Clark, D.B., Deryng, D., Elliott, J., Colón González, F., de, J., Flörke, M., Folberth, C., Franssen, W., Frieler, K., Friend, A.D., Gosling, S.N., Hemming, D., Khabarov, N., Kim, H., Lomas, M.R., Masaki, Y., Mengel, M., Schellnhuber, H.J., 2014. Multisectoral climate impact hotspots in a

warming world. Proc. Natl. Acad. Sci. 111 (9), 3233–3238. https://doi.org/10.1073/pnas.1222471110.
QGIS Development Team. (2020). *QGIS Geographic Information System* (3.28). QGIS Association. ⟨https://qgis.org/⟩.
Reaney, S.M., 2022. Spatial targeting of nature-based solutions for flood risk management within river catchments. J. Flood Risk Manag. 15 (3), e12803 https://doi.org/10.1111/jfr3.12803.
Ribot, J., 2014. Cause and response: vulnerability and climate in the anthropocene. J. Peasant Stud. 41 (5), 667–705.
Rowles III, L.S., Hossain, A.I., Ramirez, I., Durst, N.J., Ward, P.M., Kirisits, M.J., Araiza, I., Lawler, D.F., Saleh, N.B., 2020. Seasonal contamination of well-water in flood-prone colonias and other unincorporated U.S. communities. Sci. Total Environ. 740, 140111 https://doi.org/10.1016/j.scitotenv.2020.140111.
RStudio Team. (2020). RStudio: Integrated Development for R RStudio. http://www.rstudio.com/.
Rudd, L.F., Allred, S., Bright Ross, J.G., Hare, D., Nkomo, M.N., Shanker, K., Allen, T., Biggs, D., Dickman, A., Dunaway, M., Ghosh, R., González, N.T., Kepe, T., Mbizah, M.M., Middleton, S.L., Oommen, M.A., Paudel, K., Sillero-Zubiri, C., Dávalos, A., 2021. Overcoming racism in the twin spheres of conservation science and practice. Proc. R. Soc. B: Biol. Sci. 288 (1962), 20211871 https://doi.org/10.1098/rspb.2021.1871.
Rufat, S., Tate, E., Burton, C.G., Sayeed, A., 2015. Social vulnerability to floods: review of case studies and implications for measurement. Int. J. Disaster Risk Reduct. 14, 470–486. https://doi.org/10.1016/j.ijdrr.2015.09.013.
Rufat, S., Tate, E., Emrich, C.T., Antolini, F., 2019. How valid are social vulnerability models. Ann. Am. Assoc. Geogr. 109 (4), 1131–1153. https://doi.org/10.1080/24694452.2018.1535887.
Schlyer, K. (2021). Embattled Borderlands. https://www.biologicaldiversity.org/programs/international/borderlands_and_boundary_waters/story-map/index.html.
Schmeltz, M.T., Petkova, E.P., Gamble, J.L., 2016. Economic Burden of Hospitalizations for Heat-Related Illnesses in the United States, 2001–2010. Int. J. Environ. Res. Public Health 13 (9). https://doi.org/10.3390/ijerph13090894.
Seddon, N., Chausson, A., Berry, P., Girardin, C.A.J., Smith, A., Turner, B., 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philos. Trans. R. Soc. B: Biol. Sci. 375 (1794), 20190120 https://doi.org/10.1098/rstb.2019.0120.
Shaffer, H.B., 2018. Urban biodiversity arks. Nat. Sustain. 1 (12), 725–727. https://doi.org/10.1038/s41893-018-0193-y.
Shi, L., 2020. Beyond flood risk reduction: how can green infrastructure advance both social justice and regional impact. Socio-Ecol. Pract. Res. 2 (4), 311–320. https://doi.org/10.1007/s42532-020-00065-0.
Shokry, G., Connolly, J.J., Anguelovski, I., 2020. Understanding climate gentrification and shifting landscapes of protection and vulnerability in green resilient Philadelphia. Urban Clim. 31, 100539 https://doi.org/10.1016/j.uclim.2019.100539.
Simkin, R.D., Seto, K.C., McDonald, R.I., Jetz, W., 2022. Biodiversity impacts and conservation implications of urban land expansion projected to 2050. Proc. Natl. Acad. Sci. 119 (12), e2117297119 https://doi.org/10.1073/pnas.2117297119.
Sims, K.R.E., Lee, L.G., Estrella-Luna, N., Lurie, M.R., Thompson, J.R., 2022. Environmental justice criteria for new land protection can inform efforts to address disparities in access to nearby open space. Environ. Res. Lett. 17 (6), 064014 https://doi.org/10.1088/1748-9326/ac6313.
Smith, A.B., 2020a. U.S. billion-dollar weather and climate disaster [Data set]. NOAA Natl. Cent. Environ. Inf. https://doi.org/10.25921/STKW-7W73.
Smith, A.B. (2020b). U.S. Billion-dollar Weather and Climate Disasters, 1980—Present (NCEI Accession 0209268) [Data set]. NOAA National Centers for Environmental Information. https://doi.org/10.25921/STKW-7W73.
Sohl, T.L., Wimberly, M.C., Radeloff, V.C., Theobald, D.M., Sleeter, B.M., 2016. Divergent projections of future land use in the United States arising from different models and scenarios. Ecol. Model. 337, 281–297. https://doi.org/10.1016/j.ecolmodel.2016.07.016.
SoVI®—College of Arts and Sciences | University of South Carolina.(n.d.). Retrieved April 18, 2023, from https://sc.edu/study/colleges_schools/artsandsciences/centers_and_institutes/hvri/data_and_resources/sovi/index.php.
Spielman, S.E., Tuccillo, J., Folch, D.C., Schweikert, A., Davies, R., Wood, N., Tate, E., 2020. Evaluating social vulnerability indicators: criteria and their application to the Social Vulnerability Index. Nat. Hazards 100 (1), 417–436. https://doi.org/10.1007/s11069-019-03820-z.
Stein, B.A., 2002. States of the Union: Ranking America's Biodiversity | NatureServe. NatureServe. ⟨https://www.natureserve.org/publications/states-union-ranking-americas-biodiversity⟩.
Stein, B.A., Kutner, L.S., Adams, J.S. (Eds.), 2000. Precious Heritage: The Status of Biodiversity in the United States. Oxford University Press. ⟨https://www.natureserve.org/publications/precious-heritage-status-biodiversity-united-states⟩.
Steward, D.R., Allen, A.J., 2016. Peak groundwater depletion in the High Plains Aquifer, projections from 1930 to 2110. Agric. Water Manag. 170, 36–48. https://doi.org/10.1016/j.agwat.2015.10.003.
Stewart, I.T., Ficklin, D.L., Carrillo, C.A., McIntosh, R., 2015. 21st century increases in the likelihood of extreme hydrologic conditions for the mountainous basins of the Southwestern United States. J. Hydrol. 529, 340–353. https://doi.org/10.1016/j.jhydrol.2015.07.043.
Summers, J.K., Harwell, L.C., Smith, L.M., Buck, K.D., 2018. Measuring community resilience to natural hazards: the natural hazard resilience screening index (NaHRSI)—development and application to the United States. GeoHealth 2 (12), 372–394. https://doi.org/10.1029/2018GH000160.
Sun, X., Crittenden, J.C., Li, F., Lu, Z., Dou, X., 2018. Urban expansion simulation and the spatio-temporal changes of ecosystem services, a case study in Atlanta Metropolitan area, USA. Sci. Total Environ. 622–623, 974–987. https://doi.org/10.1016/j.scitotenv.2017.12.062.
Tate, E., Rahman, M.A., Emrich, C.T., Sampson, C.C., 2021. Flood exposure and social vulnerability in the United States. Nat. Hazards 106 (1), 435–457. https://doi.org/10.1007/s11069-020-04470-2.
Taylor, P., & Fry, R. (2012). The Rise of Residential Segregation by Income (p. 26). Pew Research Center.
Texas Playa Conservation Initiative. (2022-a). Playas Help Texans Live Within Water Means – Playas Work For Texans. Retrieved November 6, 2022, from https://playasworkfortexans.com/2019/04/26/playas-help-texans-live-within-water-means/.
Texas Playa Conservation Initiative. (2022-b). Texas Playa Conservation Initiative. Texan By Nature. Retrieved November 6, 2022, from https://texanbynature.org/projects/texas-playa-conservation-initiative/.
Texas Water Development Board. (2021). *2022 State Plan Population Projections Data |*. https://www.twdb.texas.gov/waterplanning/data/projections/2022/popproj.asp.
The Nature Conservancy. (n.d.-a). Resilient Land Mapping Tool. Retrieved November 7, 2022, from https://maps.tnc.org/resilientland/coreConcepts_resConnSimp.html.
The Nature Conservancy. (n.d.-b), 2022. Scaling up nature based solutions (SUNS) in Bay, Gulf, and Franklin Counties. Nat. Conserv. (from https://www.nature.org/en-us/about-us/where-we-work/priority-landscapes/gulf-of-mexico/stories-in-the-gulf-of-mexico/suns-climate-solutions/).
Thomas, K., Hardy, R.D., Lazrus, H., Mendez, M., Orlove, B., Rivera-Collazo, I., Roberts, J.T., Rockman, M., Warner, B.P., Winthrop, R., 2019. Explaining differential vulnerability to climate change: a social science review. WIREs Clim. Change 10 (2), e565. https://doi.org/10.1002/wcc.565.
Titley, M.A., Butchart, S.H.M., Jones, V.R., Whittingham, M.J., Willis, S.G., 2021. Global inequities and political borders challenge nature conservation under climate change. Proc. Natl. Acad. Sci. 118 (7), e2011204118 https://doi.org/10.1073/pnas.2011204118.
Tozer, L., Hörschelmann, K., Anguelovski, I., Bulkeley, H., Lazova, Y., 2020. Whose city? Whose nature? Towards inclusive nature-based solution governance. Cities 107, 102892. https://doi.org/10.1016/j.cities.2020.102892.
U.S.D.A. ERS. (2015). Persistant Poverty. https://www.ers.usda.gov/data-products/county-typology-codes/descriptions-and-maps/#ppov.
United Nations, 2019. World urbanization prospects: the 2018 revision. U. Nations, Dep. Econ. Soc. Aff. 126. ⟨https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf⟩.
University of Virginia Weldon Cooper Center. (2018). National Population Projections. https://demographics.coopercenter.org/national-population-projections.
USGCRP. (2018). *Fourth National Climate Assessment.* ⟨https://nca2018.globalchange.govhttps://nca2018.globalchange.gov/chapter/1⟩.
USGS, 2018. Protected areas database of the United States (PAD-US) 2.0 [Map]. U. S. Geol. Surv. https://doi.org/10.5066/P955KPLE.
Van Sant, L., Hardy, D., Nuse, B., 2021. Conserving what? Conservation easements and environmental justice in the coastal US South. Hum. Geogr. 14 (1), 31–44. https://doi.org/10.1177/1942778620962023.
Varady, R.G., Scott, C.A., Wilder, M., Morehouse, B., Pablos, N.P., Garfin, G.M., 2013. Transboundary adaptive management to reduce climate-change vulnerability in the western U.S.–Mexico border region. Environ. Sci. Policy 26, 102–112. https://doi.org/10.1016/j.envsci.2012.07.006.
Villamagna, A., Scott, L., Gillespie, J., 2015. Collateral benefits from public and private conservation lands: a comparison of ecosystem service capacities. Environ. Conserv. 42 (3), 204–215. https://doi.org/10.1017/S0376892914000393.
Villamagna, A., Mogollón, B., Angermeier, P.L., 2017. Inequity in ecosystem service delivery: socioeconomic gaps in the public-private conservation network. Ecol. Soc. 22 (1). ⟨http://www.jstor.org/stable/26270082⟩.
Wilson, S.M., Richard, R., Joseph, L., Williams, E., 2010. Climate change, environmental justice, and vulnerability: an exploratory spatial analysis. Environ. Justice 3 (1), 13–19. https://doi.org/10.1089/env.2009.0035.
Wintle, B.A., Kujala, H., Whitehead, A., Cameron, A., Veloz, S., Kukkala, A., Moilanen, A., Gordon, A., Lentini, P.E., Cadenhead, N.C.R., Bekessy, S.A., 2019. Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. Proc. Natl. Acad. Sci. 116 (3), 909–914. https://doi.org/10.1073/pnas.1813051115.
Wolch, J.R., Byrne, J., Newell, J.P., 2014. Urban green space, public health, and environmental justice: the challenge of making cWolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: the challenge of making cities "just green enough." Landsca. Landsc. Urban Plan. 125, 234–244. https://doi.org/10.1016/j.landurbplan.2014.01.017.
Woznicki, S.A., Baynes, J., Panlasigui, S., Mehaffey, M., Neale, A., 2019. Development of a spatially complete floodplain map of the conterminous United States using random forest. Sci. Total Environ. 647, 942–953. https://doi.org/10.1016/j.scitotenv.2018.07.353.
Zuzak, C., Goodenough, E., Stanton, C., Mowrer, M., Ranalli, N., Kealey, D., Rozelle, J., 2021. National risk index technical documentation. FEMA.