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LETTER

Environmental justice criteria for new land protection can inform efforts to address disparities in access to nearby open space

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Abstract

Substantial funding is being allocated to new land protection and access to protected open space for marginalized communities is a crucial concern. Using New England as a study area, we show striking disparities in the distribution of protected open space across multiple dimensions of social marginalization. Using a quartile-based approach within states, we find that communities in the lowest income quartile have just 52% as much nearby protected land as those in the most affluent quartile. Similarly, communities with the highest proportions of people of color have just 47% as much protected land as those in the lowest quartile. These disparities persist across both public and private protected land, within urban, exurban and rural communities, for different sized buffers around communities, and across time. To help address these disparities in future conservation plans, we develop a screening tool to identify and map communities with high social marginalization and low nearby protected open space within each state. We then show that areas prioritized according to these environmental justice (EJ) criteria are substantially different from areas prioritized according to conventional conservation criteria. This demonstrates how incorporating EJ criteria in conservation prioritization processes could shift patterns of future land protection. Our work provides methods that can be used broadly across regions to inform conservation efforts.

1. Introduction

The protection and restoration of land for recreation, sustainable food and resource production, cultural heritage, human health, and biodiversity is a core societal goal (UN General Assembly 2015). Globally, conservation actors are calling for 30% of the globe to be protected by 2030 and up to half protected in the long term (Dinerstein *et al* 2019, Díaz *et al* 2020). In the U.S., the recent bipartisan 'Great American Outdoors Act' will support up to $900 million annually to fund investments in land and water conservation through the National Park Service (NPS 2020). The U.S. Department of Agriculture will spend $6.7 billion per year on conservation programs (Congressional Research Service 2020) and voters have approved more than $3.7 billion in local ballot initiatives for parks, public lands, and climate resiliency (Trust for Public Land 2020a). The Biden Administration has pledged to meet the 30-by-30 goals (Gibbens 2021), with an emphasis on increasing access to open space for marginalized communities and others historically excluded from the benefits of conservation (America the Beautiful Interagency Working Group 2021).

The allocation of funding and organizational focus for these efforts will be informed by prioritization systems for land protection and restoration (Newbold and Siikamäki 2015, Rosa and Malcolm 2020). Yet despite growing awareness of structural inequality in access to environmental benefits (Schell *et al* 2020, Trust for Public Land 2020b) and the past inequities of conservation (Spence 1999, Taylor 2016), current land-protection prioritization rubrics do not systematically incorporate environmental justice (EJ) criteria. We address this knowledge gap in the EJ and conservation literatures by assessing disparities in access to protected open space, developing new screening methods to identify conservation focus areas based on EJ criteria, and testing the extent to which conventional conservation rankings support EJ goals. In the absence of such methods to systematically identify underserved communities, the benefits of ambitious conservation efforts are likely to remain inequitably distributed across communities.

EJ requires equitable treatment in policy processes, decision-making, and outcomes for people regardless of their race, ethnicity, income, educational attainment, or other markers of marginalization (Taylor 2000a, Bonorris 2004, Agyeman 2008). Injustices have been well-documented across dimensions of race and income for environmental harms including air pollution, water pollution, toxic waste, and climate resiliency (Banzhaf *et al* 2019). EJ also has a positive component, affirming that all communities have a right to enjoy environmental benefits. Indeed, greater access to protected open space for recreation, social activities, mental and physical health, food production, and resilience to heat waves has been a goal of many local EJ organizations for decades (Taylor 2000a, Lanfer and Taylor 2005, Agyeman 2008).

Prior research documents disparities in equitable access to nearby open space within urban areas. Lower income neighborhoods often have less tree cover and plant diversity (Schell *et al* 2020), fewer, smaller, and lower quality parks (Jennings *et al* 2012, Trust for Public Land 2020b, Chapman *et al* 2021), and more summer heat (Rigolon *et al* 2018, Trust for Public Land 2020a). There is also case-based evidence of racial inequity in participation in outdoor recreation (Flores *et al* 2018, Winter *et al* 2020) and exclusion from local park spaces or public land for reasons including institutional discrimination and structural inequality in leisure time and access to transportation (Taylor 2000b, Roberts and Rodriguez 2008, Erickson *et al* 2009), as well as exclusion due to personal experiences of racism, limited access points, or congestion of park spaces (e.g. García and Baltodano 2005, Sister *et al* 2010, Finney 2014). Questions of access are also important for Native American and Indigenous communities and are further complicated by issues of tribal sovereignty, customary use, and land rights (e.g. Krakoff 2018, Deur and James 2020).

Prior work also documents the substantial benefits of access to open space (e.g. Hartig *et al* 2014), including material benefits for historically excluded and currently marginalized communities. However, even if those benefits were limited, disparities in access to environmental benefits that are patterned on race or other characteristics of marginalization are unacceptable (e.g. under Title IV of the Civil Rights Act 1964, EPA Executive Order 12898). Racial, class, or other caste disparities should be viewed as automatically requiring redress (Lado 2019).

Contributing to this prior literature, our work provides three substantial advances. First, we comprehensively analyze disparities in nearby open space within states at a regional scale for both public and private land protection, and do so in a way that could be scaled to other states or regions. Regional-scale analysis is crucial because marginalized groups live across the landscape and much of the new land that will be protected in the next decade is likely to occur in peri-urban communities and at landscape scales involving multiple states. Private land protection is important to study because it has grown rapidly in recent decades (Land Trust Alliance 2015), yet there is little understanding of how it may contribute to or mitigate potential disparities in available protected land.

Second, we move beyond documenting inequities by developing a potential prioritization system that identifies and assesses gaps in access to open space based on EJ criteria. While the majority of EJ scholarship has focused on establishing drivers of disproportionate harms, we contribute to work understanding access to environmental benefits and the specific social structures that can support thriving, healthy communities (e.g. Benner and Pastor 2015, Lado 2019, Beery 2020, Gulyas and Edmondson 2021). Our approach is informed by established EJ screening methods (Sadd *et al* 2011, U.S. Environmental Protection Agency 2019, Solomon *et al* 2016). Screening provides systematic information on demographic and socioeconomic characteristics that have historically been associated with disproportionate environmental harm, as well as direct information on indicators of exposure to environmental harm or risks such as air pollution and toxic waste (MA Department of Environmental Protection 2012, U.S. Environmental Protection Agency 2019, Connecticut Department of Energy and Environmental Protection 2020, August *et al* 2021). We follow EJ screening methods by first identifying communities with a high degree of social marginalization due to income and race, as well as English language isolation and low educational attainment (MA Department of Environmental Protection 2012, Luna 2019, U.S. Environmental Protection Agency 2019). We then combine this with spatial data on protected open space to identify communities that also currently have low access to nearby protected land. We map and characterize these EJ focus areas.

Finally, we examine whether and how an EJ focus would shift priorities for new land protection. To date, most conservation prioritization systems have centered on ecological or ecosystem service goals such as wildlife habitat, recreation opportunities, drinking water or carbon sequestration (Wilson *et al* 2006, Anderson *et al* 2016, Dinerstein *et al* 2019, Mandle *et al* 2020). Economists have also developed prioritization systems that seek to maximize social welfare by considering both the benefits of conservation (including the threat of loss) and the costs (e.g. Ando *et al* 1998, Costello and Polasky 2004, Newbold and Siikamäki 2015, Nolte 2020). However, we are not aware of prior studies that have assessed whether conventional conservation prioritization would support or contradict EJ goals. We provide a novel test of differences in prioritization according to conventional conservation rankings versus EJ criteria.

2. Methods

2.1. Assessing disparities in access to protected lands

We use the New England region as a study case to understand how EJ criteria could matter for new land protection. We first assess access to nearby protected lands across dimensions of social marginalization including race and income, as well as educational attainment and language isolation. Our approach defines communities based on census tracts. Data on protected open space is from the Harvard Forest/Highstead Protected Open Space (POS) Dataset (see SI, figure S1 available online at stacks.iop.org/ERL/17/064014/mmedia). It includes data on public land as well as private land protected by legal easements or ownership by land trusts and conservation NGOs. Data on social characteristics is from the American Community Survey (SI table 1 and figure S2).

New England provides an important study case because conservation actors have succeeded in permanently protecting more than 24% of land overall, with approximately half of this protected in the decades since 1990 by a range of public and private actors (Harvard Forest/Highstead POS database). The rapid expansion of land protection observed in New England is likely to preview trends in many other regions where conservation by private actors and in densely settled areas is increasing (Land Trust Alliance 2015).

We define access to open space as the percentage of land area protected within each census tract or within distance-based buffer areas around that tract. Our main measure is the percentage of protected land inside or within a 1 km buffer of each tract. We prefer this measure because it adjusts with census tract area, is consistently available across the region, and encompasses protected land that is within community boundaries or close enough to reach without a car (see figure S1, SI). We also analyze different buffer sizes following case-based analyses that use different catchment sizes to define access (e.g. Nicholls 2001, Kim and Nicholls 2016a). More detailed information on specific access points or rules of use is not available at a regional scale as this information is not provided consistently across the underlying sources compiled to build the protected open space database (see SI for additional discussion).

To assess disparities in access to open space, we group census tracts into quartiles based on demographic data within each state. We use a state-based approach to account for overall differences in factors such as the cost of living or overall racial diversity across states. We then compare the distributions of percent of land protected across quartile groups for income and percent people of color (figure 1). We also characterize the continuous relationships using both bivariate and multivariate regression (SI). We analyze disparities according to multiple social characteristics for public vs. private protection, for urban, exurban and rural communities, and for historical vs. recent land protection (figure 1, SI).

2.2. Identifying focus areas based on environmental justice criteria

To identify potential EJ focus areas within New England, we calculate the within-state percentile rank of each census tract for median household income, percent people of color, percent people English-language isolated, and percent of nearby land protected. For each state, we identify the tracts that are in the lowest quartile of income and protection, and the highest quartile of percent people of color. While each of these criteria are separately important for social justice, we focus on tracts that fall within *all* of these criteria in order to emphasize the most marginalized communities within each state. This provides a method for screening that is based on widely-available census data and can be scaled-up across states. Statistics by state and examples of more detailed map areas are given in the SI (table S2, figures S6 and S7). We also identify a second set of alternative focus areas as communities with the least land protection, lowest income, highest percent people of color, and additionally in the highest quartile for degree of language isolation (see SI).

2.3. Comparing prioritization based on environmental justice versus ecosystem-based criteria

To evaluate whether conventional prioritization systems reduce or reinforce existing inequities in access to protected open space, we calculate the average conservation ranking scores of available land in each tract for three commonly used ecosystem-based priority systems. These are: the Nature Conservancy's index of resilient terrestrial sites for biodiversity conservation (Anderson *et al* 2016) which is designed to prioritize areas that can support the persistence of a high number of species under changing climate conditions; the USDA's Forests to Faucets assessment (U.S. Department of Agriculture 2018) which prioritizes areas that supply surface drinking water and face development threats; and a national assessment of terrestrial carbon stocks in above-ground vegetation (Kellndorfer *et al* 2013) which indicates opportunities for climate mitigation and can also proxy

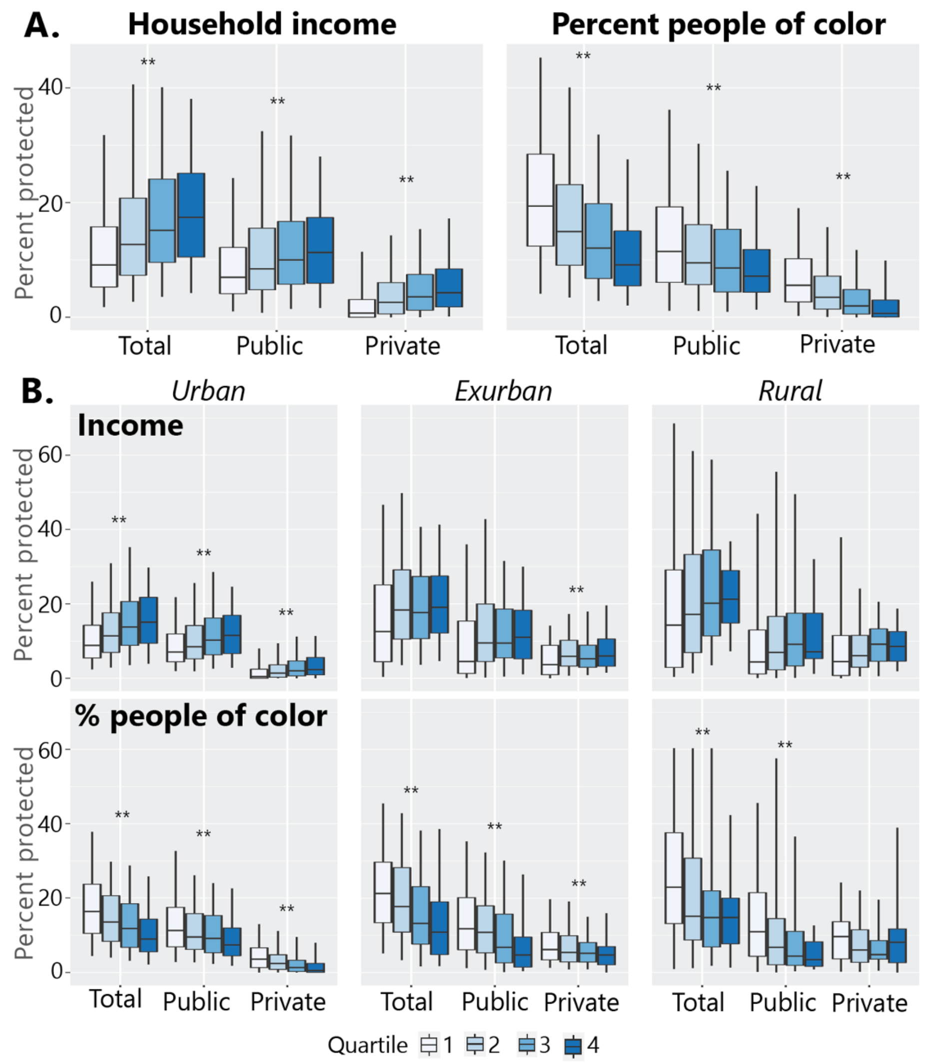

Figure 1. Disparities in protected open space by income and race. Distribution of the percent of land protected inside and within a 1 km buffer of census tracts by state-based quartiles of income and percent people of color. For each quartile group, boxplots show the median (line), 25th and 75th percentiles (box), and 5th and 95th percentiles (whiskers) of the percent protected. Stars indicate a statistically significant (* $p < 0.05$, ** $p < 0.01$) correlation between percent protected and the percentile rank of income or percent people of color. For each set of quartiles, access to protected open space is analyzed for all protected lands, then by public and private ownership. (A) All tracts ($N = 3344$). (B) Subsets of each quartile that are: urban ($N = 2131$), exurban ($N = 918$) and rural tracts ($N = 295$) (also see table S9).

for local benefits of trees, such as cooling, biodiversity, and health benefits. Each of these scoring systems is currently in use by major conservation organizations and plays a role in funding decisions from local to regional levels. We define available land as land that is undeveloped according to the land-cover data and unprotected according to the POS data. Tracts receive a score if they have at least 10 acres of available land according to each layer (see SI for additional details). To test how census tracts would rank according to conventional conservation priorities vs. EJ criteria, we plot each tract according to its scores for resilience, carbon, or drinking water vs. the median income or percent people of color in that tract (figure 3). Finally, we additionally examine possibilities for re-development by overlaying EJ focus areas with identified brownfields sites (see SI).

3. Results

3.1. Disparities in access to protected land

We find substantial disparities in access to nearby protected land for more vs. less socially marginalized communities. These are illustrated by differences in the distributions of the percent of land protected across the state-based quartiles of demographic characteristics (figures 1(A) and S2). Households in census tracts in the lowest income quartile for each state (figure 1(A)) tend to have 52% as much protected open space inside or within a 1 km distance of that tract (total land protected: median = 9.1%, SE = 0.32%) as those in the highest quartile of income (total land protected: median = 17.4%, SE = 0.47%). The percentile rank of income and the percent of land protected are statistically significantly correlated for protected land as a whole ($\rho = 0.22$, $p < 0.0001$) as well as for both public ($\rho = 0.13$, $p < 0.0001$) and private land ($\rho = 0.22$, $p < 0.0001$).

There are also substantial disparities in nearby protected land for communities with a higher proportion of people of color (figure 1(A), see SI). For census tracts in the highest quartile for percent people of color, only 9.1% (SE = 0.31%) of nearby land is protected, compared to 19.4% (SE = 0.55%) for tracts in the lowest quartile. This means that communities with a high proportion of people of color have just 47% as much protected land. There is also a significant negative correlation between the percentiles of people of color and percent land protected for all protected land ($\rho = -0.33$, $p < 0.0001$), as well as for both public protection ($\rho = -0.20$, $p < 0.0001$) and private protection ($\rho = -0.34$, $p < 0.0001$).

Prior work on environmental injustices has found that relationships between socioeconomic factors and outcomes can vary considerably across spatial context (e.g. Mennis and Jordan 2005, Grineski *et al* 2015, Kim and Nicholls 2016b, Chakraborty *et al* 2017). We further examine spatial variation in potential disparities by analyzing the subsets of tracts that are urban, exurban and rural, by using multiple regression, and by using geographically weighted regression (see figures 1–2–S5, tables S3–S7). We find that disparities by income and race persist strongly within urban tracts (figure 1(B)), with correlations of $\rho = 0.25$ ($p < 0.0001$) and $\rho = -0.28$ ($p < 0.0001$). Statistically significant disparities by income also persist for private protection within exurban tracts, and by race for protection as a whole within both exurban and rural tracts (figure 1(B)). We also find that disparities exist within all states in the region (table S8 and figure S8). In addition, we find substantial and statistically significant disparities by educational attainment and English language isolation (figures S2 and S5).

To evaluate access across a range of distances from highly walkable to requiring a car or public transit, we assess the percent of protected land within each tract and a 1 km buffer (our primary measure), as well as within each tract with no buffer, and each tract plus a 2, 10 or 25 km buffer (table S5 and figure S9). Disparities in nearby protected land are greatest when we consider land only within each census tract, and least when considering larger buffer areas. This indicates that disparities are often localized and that more access to open space exists for those with access to transportation. Unfortunately, disparities in access to transportation itself (Luna and Estrella-Luna 2021) currently limit access to sites that are not walkable, highlighting the importance of local protected open space.

To understand whether land protection in more recent decades has effectively contributed to the reversal of historic inequalities, we analyze the patterns of lands protected since 1990 and how they correspond to current demographic characteristics (figure S4, tables S6 and S7). We do not find that more recent public or private land protection is correlated with characteristics of marginalization in ways that suggest it has contributed to reducing disparities (figure S4, tables S6 and S7).

Finally, since characteristics of marginalization are often related to each other, we supplement our main analysis by using multiple regression to relate protected land to several tract characteristics simultaneously. The results indicate that for the region as a whole, structural inequality in access to education and high-paying jobs, as well as low land availability, are related to income-based and racial disparities in nearby protected land (SI text, tables S3 and S4).

Together, our analyses show that the distribution of nearby protected land is strongly negatively associated with characteristics of social marginalization, indicating environmental injustice in current patterns of land conservation. In addition to more comprehensive social reform to reduce marginalization itself and desegregate the landscape, moving towards greater EJ will depend on processes and patterns of future land protection that reduce these disparities in access to open space.

3.2. Focus areas based on environmental justice criteria

Priorities for land use must ultimately be determined by fair, locally-oriented and community-led processes, which can be assisted by appropriate screening tools. Figure 2 indicates the census tracts identified as EJ focus areas for each state given the criteria of having low availability of nearby protected open space and high degree of marginalization by income and race. While we highlight EJ focus areas on the map that meet all three criteria—low income, high percent people of color, and low protection—each of the criteria may also separately identify possible areas of need. The information shown in figure 2 is available at finer detail in a publicly available web map (viewable at: http://bit.ly/EJ-OS-NE, also see SI for examples). Table S2 provides the land area and number of focus areas in each state.

Many of the tracts we identify as potential focus areas from an EJ-based land protection standpoint also overlap with areas identified as experiencing an undue burden of air or water pollution or proximity to toxics sites according to the EPA's EJSCREEN (U.S. Envionmental Protection Agency 2019) or individual state EJ criteria (e.g. MA Department of Environmental Protection 2012, Connecticut Department of Energy and Environmental Protection 2020). In our analysis, 96% of tracts identified as EJ focus areas also had at least one brownfield site listed by the EPA. This highlights the potential importance of redevelopment as a means to improve access to greenspace as well as the intersectionality of EJ concerns. In addition, we examined the distribution of the population in New England that identifies as Native American and found that some of the census tracts identified

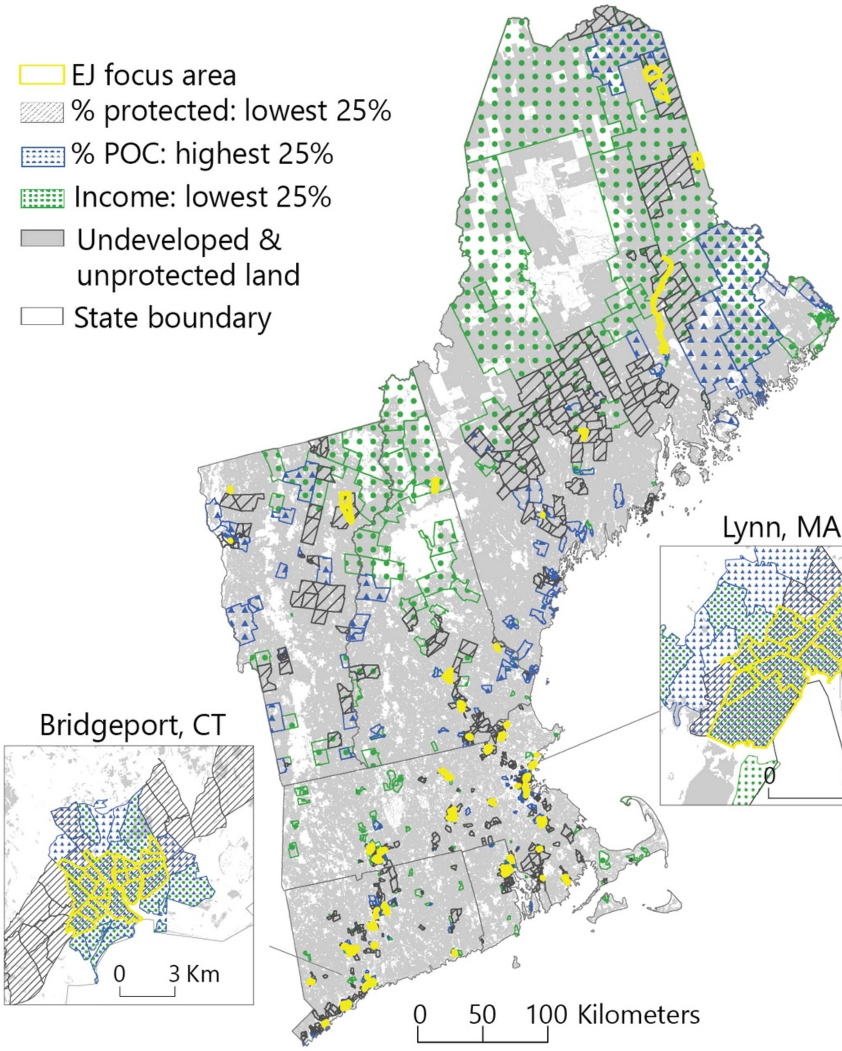

Figure 2. Areas of potential focus for new land protection according to EJ criteria. EJ focus areas are census tracts within each state that are in the lowest quartile for nearby protected land, the lowest income quartile, and the highest quartile for percent people of color (Harvard Forest/Highstead Foundation database of protected open space; 2014–2018 American Community Survey estimates). Web map available at: http://bit.ly/EJ-OS-NE.

as potential EJ focus areas have high proportions of people identifying as Native American (see SI). Processes that maximize local autonomy when considering new land protection may be particularly important for these communities given the specific histories of dispossession.

3.3. Environmental justice criteria vs. conventional conservation priorities

We find evidence of substantial tradeoffs between EJ priorities and conventional conservation rankings, as well as some opportunities that rank highly according to both criteria. We present these relationships graphically in figure 3 by plotting each community according to its scores for resilience, carbon or drinking water vs. that community's median income or percent people of color (figure 3). The communities with low current availability of nearby open space are indicated by black dots, with all other communities represented by grey dots.

First, considering the relationship between income and ecological resilience, we find a statistically significant positive correlation ($\rho = 0.10$, $p < 0.0001$, $N = 2987$). In addition, very few low-income communities that currently have low protection are also among those with the highest resilience scores (figure 3(A); less than 3% or 20 out of 748 high resilience tracts are also in the lowest income quartile). These results suggest tradeoffs between prioritizing resilience and serving the lowest-income communities. However, among tracts that might be targeted for high resilience scores, we find that those with current low protection do have lower median incomes on average than those with high protection (figure 3(A)). Low protection tracts within the highest resilience quartile were on average \$15 800 less well-off according to median annual income, suggesting some scope to reach middle-income communities through targeting for ecological resilience.

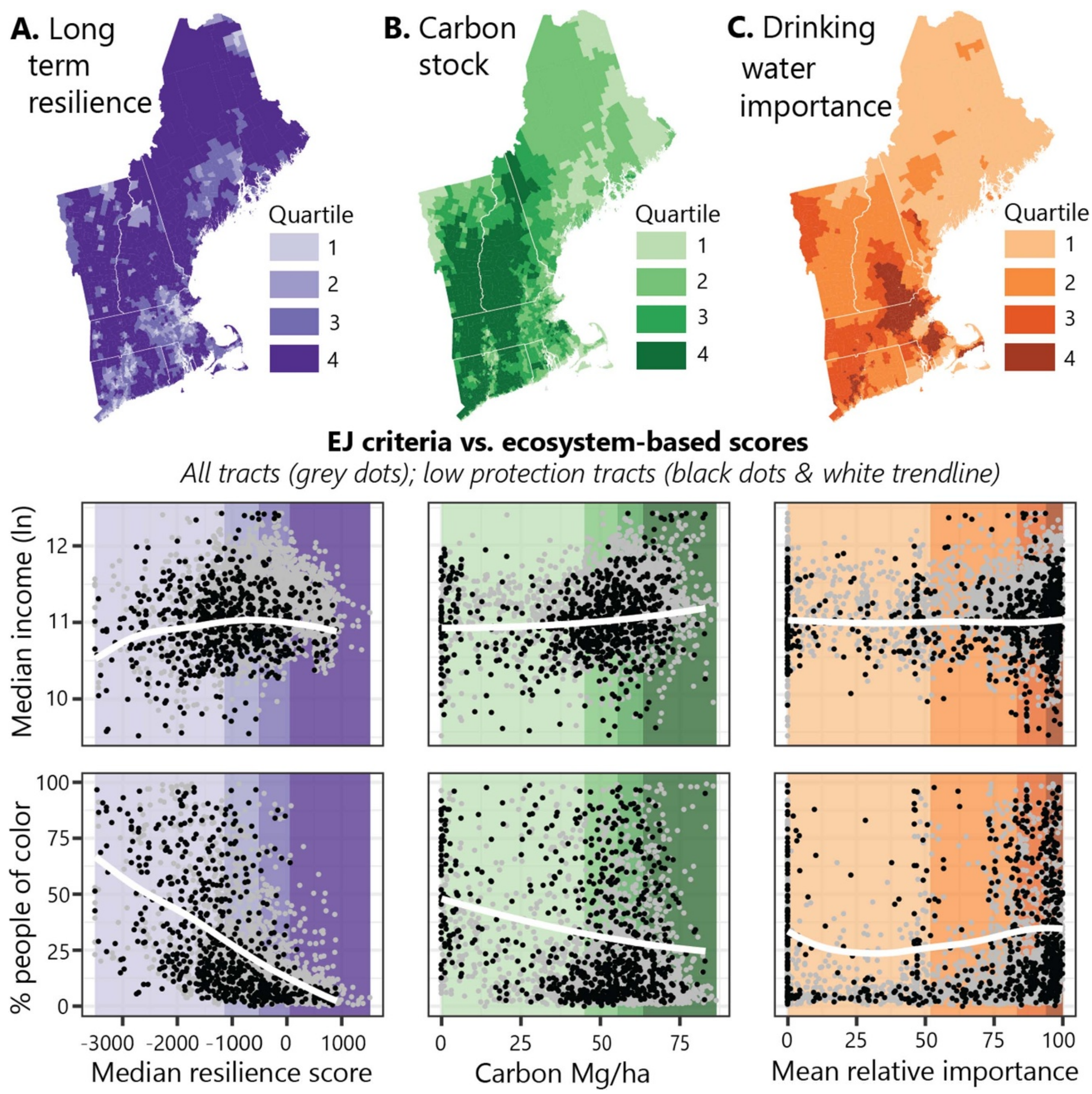

Figure 3. Comparison of conservation rankings based on EJ criteria versus conventional conservation criteria. Maps indicate ecosystem-based prioritization scores for unprotected and undeveloped land by tract; darker shading indicates higher quartile of regional prioritization. Plots show EJ criteria versus the ecosystem-based ranking scores for all tracts and for those in the lowest quartile of protected land in each state. Lines show a kernel-weighted local polynomial regression (bandwidth = 500, 50, 15) for the low protection tracts ($N = 654, 757, 757$).

We also find a steep tradeoff between prioritizations based on ecological resilience versus additional access to open space for communities of color. Among low-protection tracts, there is a very strong negative correlation between percent people of color and resilience prioritization scores (figure 3(A), $\rho = -0.51$, $p < 0.0001$, $N = 654$). Even using the state-based quartiles for percent people of color, less than 0.5% of communities in the highest quartile for resilience scores were also in the highest quartile for percent people of color and in the lowest quartile for protection. This indicates that conservation prioritizations that heavily weight resilience could actually exacerbate inequalities in access for racially diverse communities in our region.

Second, prioritization based on carbon scores also suggests likely tradeoffs with respect to both income and race. Among tracts with low current levels of protection, carbon scores were positively correlated with income (figure 3(B), middle panel, $\rho = 0.13$, $p < 0.0005$, $N = 757$). Carbon scores for tracts with low current protection were negatively correlated with percent people of color (figure 3(B), bottom panel, $\rho = -0.22$, $p < 0.0001$, $N = 757$). Although these relationships are weaker than those for ecological resilience, they continue to indicate that protecting land based on conventional ecological priorities will not tend to reduce current disparities in access.

Finally, in contrast, we found that prioritization scores based on clean drinking water had somewhat greater potential to decrease racial or income disparities in land protection. Among tracts with high drinking water priority, those with current low protection tended to have lower incomes (difference of ~\$26 000). High drinking water prioritization scores were also positively correlated with percent people of color among the low protection tracts (figure 3(C), bottom panel, $\rho = 0.09$, $p < 0.018$, $N = 757$). These correlations indicate more possibility for this conservation priority to contribute to reduced disparities in access.

4. Discussion

Achieving EJ requires reframing priorities to focus attention on the connections between human and ecological systems, as well as addressing the underlying causes of marginalization (Taylor 2000a, Agyeman 2008, Mandle *et al* 2020, Schell *et al* 2020). Globally, efforts to rapidly expand land protection could directly affect the livelihoods of more than a billion people, creating risks for community harms as well as potential opportunities (Alix-Garcia *et al* 2018, Naidoo *et al* 2019, Schleicher *et al* 2019, Zafra-Calvo *et al* 2019). Past conservation efforts have often actively and passively dispossessed marginalized people through displacement, loss of traditional user rights, environmental gentrification, exclusionary zoning and redevelopment that does not meet community priorities (Spence 1999, Heckert and Mennis 2012, Lang and Rothenberg 2017, Rigolon and Németh 2018, Anguelovski *et al* 2019, Carmichael and McDonough 2019).

Although the change needed is complex and multifaceted (e.g. Rigolon *et al* 2020), our work illustrates how the analysis of disparities in access to protected land and the explicit incorporation of EJ criteria in land conservation prioritization systems could play a role in future efforts to avoid and redress these injustices. Using New England as an example study region, we find that communities in the lowest income quartile or with the highest proportions of people of color have just half as much nearby protected land as those in the opposite quartiles. These disparities persist across alternate markers of marginalization, public and private land, within the urban to rural gradient, and within recent decades.

To inform efforts to redress these disparities, we identify and map potential EJ focus areas according to high social marginalization and low nearby protected open space. Our screening approach is state-based and uses data that would be broadly available for the U.S., thus providing a potential model for other regional or national analyses of EJ focus areas. Methods to systematically screen for disparities in access to open space can empower underserved communities and their allies with the necessary data to advocate for access and protections based on their own needs, goals, and aspirations. Additionally, our work offers conservation organizations insight into the full composition of the communities they seek to benefit. It provides guidance on who needs to be at the table and involved in conservation planning decisions, and can be if the door is opened.

Finally, to evaluate whether conventional conservation prioritization systems will likely reduce or reinforce existing inequities in access to protected open space, we assess conservation rankings for each community based on three commonly used prioritization layers. We find substantial differences in which areas rank highly according to EJ criteria versus conventional conservation criteria. These results illustrate that continuing to follow conventional conservation prioritization systems for new land protection may exacerbate existing inequalities. Crucially, our results indicate the need for future work to understand these relationships in other regions and for other conservation prioritization layers.

Our analysis of conservation prioritization focuses primarily on remaining undeveloped land, but future work should also consider the role that ecological restoration can play in providing access to nature's benefits. This will be particularly important in urban areas where most land is already developed (e.g. Ingram 2008, Gobster 2010, Tarrant *et al* 2013, Highstead Foundation 2020). Enhancements to urban greenspace can include permanently protecting spaces for urban food production (e.g. White 2011, Cahn and Segal 2016), improving forest canopy in marginalized communities (McDonald *et al* 2021), adding greenways along waterways or former rail lines, and promoting plantings that increase biodiversity. In addition to new greenspace, conservation organizations can also focus on institutional reform including changes in mission and programming or partnerships that can increase community access to existing spaces (e.g. García and Baltodano 2005, Sister *et al* 2010, Flores and Kuhn 2018, Rigolon 2019). Each of these avenues for change provides opportunities to better ensure future equity in access to the crucial benefits of protected land. As this previous work has highlighted, there is substantial heterogeneity in the purpose of land protection and access to that land according to legal provisions, services provided, transportation access, and institutional structures. Better information systems and screening tools that include specific access points and allowable land uses will be crucial to future efforts to improve EJ in conservation.

Access to nearby open space and the benefits of nature are fundamental aspects of a just society. Our work humbly offers an approach to support the deeper shift that several conservation organizations have called for: meaningful reform incorporating anti-racist and social justice goals and practices in their organizational structures and decisions (Land Trust Alliance 2020). The approach we present here will not by itself redress historic and ongoing environmental injustices. It aims to support people who work in and lead conservation organizations who are making the choice to respectfully engage and be led by historically excluded and currently marginalized communities in conservation decision-making.

Ultimately, EJ in future land protection will depend on improved processes of public engagement and decision-making in siting and management that meaningfully include and advance the priorities, concerns, and goals of historically marginalized communities (Estrella-Luna 2010, González 2018). In the U.S. context in particular, true equity will depend on much deeper structural shifts including institutional change, desegregation of the landscape, land restoration, and greater equality of income and wealth, all of which can promote more permanent equitable access to the benefits of open space.

Data availability statement

All data is available in the supplementary information or online.

The data that support the findings of this study are openly available at the following URL/DOI: https://harvardforest.fas.harvard.edu/harvard-forest-data-archive.

Author contributions

All authors contributed to conception, analytical design, and writing. L G L and K R E S conducted analysis. K R E S, N E L and J R T led analysis.

Conflict of interest

Authors declare no competing interests.

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SUPPLEMENTAL INFORMATION FOR:

Environmental justice criteria for new land protection can inform efforts to address disparities in access to nearby open space

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Using #EJ criteria in #conservation planning may address disparities in access to nearby #openspace: EJ focus areas viewable at: http://bit.ly/EJ-OS-NE

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SUPPLEMENTAL INFORMATION:

1. Detailed description of methods

We analyze protected land, characteristics of marginalization, and conservation scores for communities in the New England region. Our unit of analysis is the census tract. We collect and analyze four pieces of information for each tract: demographics from the U.S. Census, percent of land area protected, average "score" for several conservation prioritization layers, and the number of brownfields (remediation sites). All data sources are summarized in Table S1.

1.1 Protected open space data and measures of access

Data on protected open space in New England comes from Version 1.1.0 of the Harvard Forest/ Highstead POS Dataset (2021; Fig. S1). The POS dataset includes public land as well as conservation easements and private acquisitions of land by conservation NGOs and small local land trusts. It records a year of protection for a majority of sites (which allows us to investigate historical vs. recent protection). The data was compiled from over a dozen sources including direct data from local land trusts and other institutions supporting conservation in the region. In addition to regional, state, and local sources, this version of the POS layer contains data from the Protected Areas Database of the United States (PAD-US) 2.1, which substantially improved the representation of urban open space due to PAD-US 2.1's inclusion of the Trust for Public Land's ParkServe data (U.S. Geological Survey Gap Analysis Project 2020).

Data on specific entry points to protected lands or allowable public uses of each parcel is not comprehensively available at a regional scale. Although this information is collected by some of the underlying data sources that are included in the POS data, it is not comprehensively collected by all sources.

Our primary measure of access to open space is the percent of land protected inside or within a 1 km buffer of each census tract (Fig. S1). This is intended to represent protected open space within a community or within a feasible walking distance of that census tract. We use the percent of land protected rather than an absolute amount because census tracts (and buffers) vary considerably in size. Buffers are important to capture access for people near the boundaries of the census tracts, particularly for communities immediately adjacent to park areas. Some parks receive their own census tracts (code range 9800's; Boston's Emerald Necklace area is an example) and would not be counted as part of any community if we did not use the buffering approach.

We also analyze the data with no buffer and apply a series of additional buffers (2km, 10km, 25km) to census tracts to understand the distribution of protected open spaces at varying scales, which may proxy for access to open space on foot versus by car or public transportation. Further analysis of specific travel times is not possible due to a lack of availability of data on entry points to protected open spaces. While such data exists for many urban areas, it is not available comprehensively at a regional scale.

Nearby protected open space is assessed overall as well as by different categories according to ownership (public or private) and year of protection (before or after 1990) (Fig. S1). Public open spaces in the dataset (~13% of the region's land area) include state parks, national parks and national forests, as well as municipal parks and conservation land. Nearly all public open spaces in our region allow public access (limited exceptions include military lands / restricted drinking water supply areas). For this reason, we also analyze publicly protected lands separately as they are particularly important for recreation access. Private open spaces (~12% of the region's land area) are conservation lands owned by individuals, mission-oriented organizations, and more than 300 local and regional land trusts. This includes land with permanent legal restrictions on development ("conservation easements"). Given traditions in the region of allowing public access to protected open space, the majority of private lands in our region also allow public access (Daigle et al. 2012). Protected lands that do not allow public access still provide many locally important ecosystem services including flood protection, pollination services, biodiversity protection, cooling during extreme weather events, and amenity value (Foster et al. 2017, Sims et al. 2019, Mandle et al. 2020). This motivates our use of proximity to all types of protected lands in the main analysis.

Our focus on permanently protected open space may underestimate current access to nature in rural communities. However, we feel that the focus on permanently protected land is appropriate because of ongoing and increasing loss of rural open space which threatens future access. A recent report highlights that the loss of natural land cover due to development has also been borne disproportionately by low income and high minority communities (Rowland-Shea et al.

2020). Indeed, the COVID-19 pandemic has led to dramatic pressures on home prices and development in many exurban and rural areas that highlight these threats (Kolko et al. 2021).

The POS layers were rasterized at 10m resolution prior to analysis, a resolution that is small enough to represent smaller or more narrow protected open spaces (e.g., riparian corridors or pedestrian walkways) and large enough to feasibly run analyses at a regional scale. Although census tract boundary data comes with land and water area estimates for each tract, when calculating percent of land protected, we define land area using the 2016 NLCD for consistency with land area estimates for buffered census tracts.

1.1.1 Characteristics of social marginalization

We use the five-year 2014-2018 American Community Survey (ACS) estimates for census tracts including total housing units, total population, median household income, race, educational attainment, and English proficiency (Manson et al. 2020b, 2020c). These data are the basis for the four demographic variables critical to our analysis: median household income, percent people of color, percent of people 25 or older without at least a 4-year degree, and percent of people 5 or older who do not speak English at home and speak English less than 'very well'. They are also used to categorize communities as urban, exurban, or rural, according to housing density. In our analysis, the percent people of color variable is measured by including all people who identify with categories other than White, non-Hispanic. This includes people who self-identify as Black, Asian, Native American, Native Hawaiian or Pacific Islander, multiracial, and White Hispanic or Latino.

Figure S2 shows the distribution of demographics relevant to social justice within the region. These variables are joined to the 2018 TIGER/Line census tract boundaries (Manson et al. 2020a).

Access to land is a particularly important issue for Native and Indigenous people, who lived throughout this region prior to the arrival of colonial settlers and subsequent dispossession of nearly all land in the area. According to the ACS data, 0.15% of the population of New England currently identifies as Native American. We also calculated that 0.28% of New England's land area is currently controlled by federally recognized tribes, which are sovereign nations with powers of self-government (U.S. Bureau of Indian Affairs 2018). Additional land is owned by communities that lack federal or any official recognition, but we are not aware of systematic data on this beyond population estimates derived from the self-identified data in the census.

Publicly and privately owned protected open spaces may have a role to play in supporting land access or land back for Native and Indigenous communities, if deemed appropriate by those communities. Native and Indigenous people may have distinct motivations for pursuing land protections, including but not limited to the protection of sacred sites or ensuring access to traditional foods and medicines (Krakoff 2018, Deur and James 2020). While full analysis of the ways protected open spaces may be accessible or inaccessible to Native and Indigenous people in the region is beyond the scope of the paper, the analysis and maps do identify some census tracts with a high proportion of people who self-identified as Native American as potential environmental justice focus areas. This includes three federally recognized tribes with sovereign governments (Aroostook Band of Micmacs, Houlton Band of Maliseet Indians, and Penobscot Nation). Ensuring processes that maximize local autonomy regarding land protection may be additionally important for these communities given the specific histories of dispossession.

1.1.2 Definitions of urban, exurban and rural

Total housing units are divided by the census-provided land-area estimate to determine each tract's housing density. Tracts are classified as urban, exurban, or rural according to housing density following the cutoffs in Radeloff et al. 2005 (Urban: >128 housing units/km^2, exurban: 16–128 housing units/km^2; rural: <16 units/km^2). We visually inspected these classifications and reclassified one tract from rural to exurban because it was surrounded by neighboring tracts that were majority urban and was far away from any other rural tracts. We excluded tracts from statistical analysis if they had no housing units, fewer than 100 people, or were missing income data (n = 26). The final dataset comprises N= 3344 tracts*:* Urban N=2131, exurban N=918 and rural tracts N=295. The distribution of urban, exurban and rural tracts, as well as the excluded tracts, are shown in Figure S3. Housing density variables are tied to overall cutoffs that were derived from national data and could be used at a national scale. These values therefore are not adjusted within state.

1.1.3 Ecosystem-based prioritization layers

To analyze conventional conservation priorities, we calculated average scores from three datasets used to aid in conservation prioritization (Table S1) for land that is still available for conservation. We define available land as land that is undeveloped according to the land cover data and unprotected according to the POS data. Tracts receive a score if they have at least 10 acres of available land according to each layer.

Resilience: The Nature Conservancy's terrestrial resilience layer is a national dataset that ranks the long-term resilience of the land with a relativized, unitless index at 30m resolution (Anderson et al. 2016). We use the median index score within 1km buffered census tracts. Since the layer does not include scores for areas that are classified as developed, we exclude those areas from the median score calculation. The total number of tracts scored is 2,987 out of the 3,344 total.

Clean drinking water: USDA's Forests to Faucets 2.0 Assessment is a national layer that ranks sub-watershed importance for cleaning drinking water using a unitless index (U.S. Department of Agriculture Forest Service 2018). We use the relative importance which reflects the percentile rank of each watershed at the national level and allows for comparison across watersheds. We rasterize this layer at 30m resolution for analysis with ArcGIS and use the mean relative importance score within 1km buffered census tracts. The total number of tracts scored is 3,212 out of the 3,344 total.

Carbon: The National Biomass and Carbon Dataset for the Year 2000 is a collection of national maps including aboveground biomass estimates circa 2000 at 30m resolution (Kellndorfer et al. 2013). We mosaic the maps for zones 65 and 66, which together cover all of New England, and use the mean of each map's pixels in areas of overlap. We estimate metric tons of carbon per hectare (C Mg/ha) using the map's original units of kg/m^2 x 10. To do so, we first estimate biomass within each 1km buffered census tract by multiplying the sum of pixels within each tract by 0.09 (which accounts for the proportion of a hectare in each 30m pixel) as described in the dataset user guide (Kellndorfer et al. 2013). We divide this estimate by each tract's available land area to determine biomass Mg/ha. Finally, we divide by two to convert biomass Mg/ha to C Mg/ha (Schlesinger 1991). The total number of tracts scored is 3,211 out of the 3,344 total.

Undeveloped land: To estimate undeveloped land in 1990 and 2016, we use Landsat-derived land cover classifications. For 1990, land cover information is derived from two sources: the Continuous Change Detection and Classification (CCDC) algorithm (Olofsson et al. 2016) and the National Land Cover Database (NLCD) (Homer et al 2015). CCDC is an annual product covering the majority of New England but excluding northwest Vermont and northeast Maine. Because it was developed specifically for New England, we considered it to be the more accurate data source for 1990 and used it first where available. Where CCDC data was not available, we filled the remainder of the study area with the 1992 NLCD. For 2016, we used the 2016 NLCD, which has more detail on developed land uses compared to CCDC.

1.1.4 Brownfields data

To assess redevelopment potential, we analyzed overlap between the EPA's data on the locations of brownfields and the census tracts (U.S. Environmental Protection Agency 2020). We provide a count because the EPA data is in points.

1.2 Analysis methods: additional details

1.2.1 Assessing disparities in access

To assess disparities in access to protected open space by demographic characteristics, we group census tracts into within-state quartiles based on their demographics. We use relative ranking within each state to identify marginalized communities and potential focus areas, with the goal of developing a method that is easily scalable across regions. Specifically, we use the percentile rankings for each of these characteristics within each state. This adjusts for the fact that some states have overall higher or lower incomes or higher or overall levels of racial and ethnic diversity, education, or language isolation.

We compare the distributions of percent of land protected across each of these quartile groups as shown in the boxplots (Fig. 1). Specifically, for each quartile group, Figure 1 shows the median percent protected (horizontal line), the 25^{th} and 75^{th} percentiles (ends of each box), and the 5^{th} and 95^{th} percentiles of this variable. The stars on each boxplot indicate the statistical significance of the pairwise correlation coefficient between the percent of land protected and the percentile rank of household income or percentile rank of % people of color (* $p<.05$, ** $p<.01$). These correlation coefficients characterize the continuous relationships between protected open space and characteristics of marginalization. In addition, we report in the text the median percent protected in low and high quartiles for some quartiles. For those, we calculate the standard errors of the median using bootstrapping with 1000 replications.

In addition to Figure 1 as described in the main text, we provide analysis of disparities across time and by alternate characteristics. Figure S4 indicates the percent of land protected before and after 1990, by quartiles of income and percent people of color based on current demographics. Figure S5 analyzes patterns of disparities using educational attainment and language isolation rather than income and race as characteristics of marginalization.

1.2.2 Identifying EJ focus areas

To identify potential EJ focus areas within New England, we calculate the within-state percentile rank of each census tract for median household income, percent people of color, percent people English-language isolated, and percent of land protected within 1km of the tract. We use a state-based approach because of the role that states play in allocating funding for conservation and to adjust for overall differences between states in terms of income, availability of open space, and racial or ethnic diversity. We identify the tracts that are in the lowest quartile (percentile rank less than or equal to 0.25) of income and protection, and the highest quartile (percentile rank greater than 0.75) of percent people of color and percent language isolated within each state. While each of these groups can be considered social justice communities, we consider tracts that fall within *all* of these groups as our core environmental justice focus areas. This narrows the environmental justice focus to the most marginalized communities. Statistics by state and examples of more detailed map areas are given in Table S2 and Figs. S6 and S7.

1.2.3 Multivariate analysis of disparities and land protection patterns

The main focus of our analysis is on current patterns of disparity in nearby open space. These are potentially driven by a complex set of intersecting historical factors, including development pressure, land availability, patterns of settlement across the region, and discrimination in siting of conservation. Fully disentangling the potential causal influence of these multiple factors is outside of the scope of our analysis. However, we report the results of a limited set of multiple regression models to analyze how current access to nearby protected land is jointly related to demographic characteristics, urbanicity and land availability (Tables S3-S8, Fig. S8).

2. Supplementary results and discussion

2.1 Assessing disparities in access: additional figures and multiple regression analysis

2.1.1 Educational attainment and language isolation

Figure S5 analyzes patterns of disparities using educational attainment and language isolation. This confirms that very similar patterns of disparities to Figure 1 result when we consider educational attainment or language isolation as markers of marginalization. Communities where fewer people have a four-year degree or where there is more language isolation also have substantially less nearby protected land.

In Table S3, part a, we relate the percentage of land protected inside or within a 1 km buffer of each census tract to race, income, settlement density (urban/rural/exurban) and educational attainment (percent with a college degree). We find a strong and statistically significant negative relationship between the percent of people of color in a tract and the percent of land protected (Column 1; coefficient = -0.123, SE = 0.007). We also find a strong and statistically significant positive relationship between income and the percent of land protected nearby (Column 2; coefficient = 0.729, SE = 0.059). These coefficients remain statistically significant when both are in the model together (Column 3) and when we control for whether a census tract is urban, exurban or rural (Column 4). The coefficient on percent people of color becomes smaller in magnitude as we add median household income, whether or not a tract is urban or exurban, and the percent of individuals 25 years or older who do not have a college education (Column 5; coefficient = -0.018, SE = 0.008). This change indicates that income, location in more densely settled areas, and educational opportunity are correlated with both the percent of people of color and the percent of available protected land. This is consistent with the idea that historical structural inequality—differential access to educational opportunities, jobs, and residential areas on the basis of race—likely plays a crucial role in present day access to protected land. Results are similar when we include state fixed effects (indicator variables for each state), which uses variation in relationships from within each state (Table S3, part b). As before, the percent people of color is significantly negatively correlated with nearby protected land and income is significantly positively correlated (Columns 1-4). With state fixed effects and the percent of people without a college education included, the relationship between income and percent protected becomes negative, likely because of the high correlation between income and educational attainment (Column 5).

2.1.2 Public vs. private

We also examine these partial relationships by estimating the same models for public and private protected land separately (Table S4). At a regional level, we find that the percent of people of color has a less negative relationship with public versus private protected land (Part a, Columns 4-6 vs. 1-3). Indeed, when we include structural factors of income, urban/exurban/rural and educational attainment in the model, race does not significantly predict access to public land and the coefficient is zero or slightly positive (Part a, Columns 2 and 3). For privately protected land, however, the relationship remains negative and statistically significant (Part a, Column 6). When we include state fixed effects (Table S4, part b), we find that the relationship between public land protected and percent people of color is consistently significantly negative despite adding additional controls (Table S4, part b), and the same holds for private protected land.

2.1.3 Varying buffer sizes

In Table S5, we show the relationship between land protected, percent people of color and income for different size buffer areas around each tract and the tract with no buffer. Prior literature of specific cases has used a wide variety of catchment areas in defining access (Flores et al 2018, Castaneda 2017, Kim and Nicholls 2016, Nicholls 2001). Here we include state fixed effects so that estimates are derived from within-state variation, following our main approach in the paper. For percent people of color, we find that the gradient of disparity is generally reduced as the buffer size increases. For income, we find that up to the 10 km buffer there is a significant and positive relationship between income and nearby protected land. This relationship reverses for the largest buffer (25 km), reflecting the overall greater availability of protected land in more rural and lower income communities in the region.

In Figure S9, we provide an alternative version of Figure 1 using unbuffered census tracts. We find that the trends and relationships between the percent of land protected and income or percent people of color do not meaningfully change with or without a 1km buffer. The only difference in significance between versions is that with no buffer there is a statistically significant correlation between income and percent of total land protected in exurban tracts, which was not significant in the main figure.

2.1.4 Pre 1990 and post 1990

Since 1990, more than 5 million acres of open space were protected in the region (approximately half of all protected land). Dates of protection in our dataset allow us to examine how current (ACS 2018) characteristics of marginalization relate to land protected before versus after 1990 (Figure S4, Table S6). If more recent land protection was positively correlated with percent people of color or negatively correlated with income, it could indicate that newer protection had contributed to reductions in current disparities even if historical protection did not. Since we do not observe how the composition of communities may also have changed over time, the conclusions we can draw are limited. For example, new protection could have been targeted to help underserved communities and then resulted in the displacement of marginalized communities to areas with less protection.

Keeping these limitations in mind, we do not see evidence that more recent protection has reversed trends of disparities in access to protected land. As shown in Fig. S4, there are disparities in the patterns of land protected both pre-1990 and post-1990. Considering the relationship between current (ACS 2018) tract characteristics and protection since 1990, we find strong negative correlations between new land protected and the percent people of color and positive correlations with median household income (Table S6, Columns 1 and 2). One reason for this is that the amount of land that was actually available for protection by 1990 is a significant predictor of what was protected. As shown in column 3 of Table S6, the percent of land available in 1990 is a strong predictor of the percent protected between 1990 and the present, with an R^2 of 32.6% of the variation in new land protected. Adding other variables measuring race, income, urban/exurban/rural status, and educational attainment explains relatively little additional variation in new land protected (column 5, $R^2 = 35.9\%$). This indicates strong co-occurrence of marginalized communities and areas with little land left to be protected by 1990. The same holds true in the current data, with strong correlation between the percent people of color in the 2018 ACS estimates and the percent of land currently available (rho=-0.605, $p < 0.0001$). This suggests that future land protection that proceeds along similar lines to protection since 1990 will very likely result in further increasing disparities in access to protected land.

Table S7 indicates that these patterns hold for new protection of both public and private land since 1990. New land protected inside or within 1 km of census tracts is negatively correlated with the percent people of color and positively correlated with income for both public and private land. All coefficients are statistically significantly different from zero.

2.1.5 State by state analysis

Table S8 investigates disparities for each state in the region using bivariate regressions. Part A shows regressions with the variables in standard values (percent and dollars). Part b shows regressions of the percentile rank of variables within each state. In part A, the coefficients indicate a strong positive gradient between median household income and land protection in all states except New Hampshire. The coefficients also indicate that all states had a negative relationship between the percent protected and percent people of color. This relationship is weakest in Maine, which also has the least racial diversity within the dataset. Vermont's coefficients are consistent with our overall findings but have limited precision due to the smaller number of census tracts. In part B, we see confirmation of positive relationships between the state-based percentile rank of land protected and income and of negative relationships with percent people of color. All relationships are statistically significant except for percent people of color in Maine and income in Vermont. Overall, these results indicate that there is substantial disparity either by income or race within each state in the region.

2.1.6 Geographically weighted regression

Nevertheless, local variation is important and should be a crucial part of ultimate decisions about funding allocation or focus areas. In Figure S8 we show the results from geographically weighted regressions of the main bivariate relationships described in Figure 1 and Table S3, part A between the percent protected and income or race. These figures are helpful in indicating some areas of the region where relationships may be different, for example close to the federally protected White Mountains area in New Hampshire. This further highlights the importance of robust community-centered processes that consider the actual amount of land currently protected and local information on access to that land in decisions about focus areas for new protection or restoration. It also reinforces the utility of a state-based approach to identifying environmental justice focus areas.

2.2 Additional figures and results on environmental justice focus areas

Table S2 provides summary statistics on the environmental justice focus areas by state. While states differ in their relative abundance and characteristics of each EJ group, due to different state sizes and demographics, using a state-based approach ensures that all states have environmental justice focus areas. The focus area tracts with high conservation value from an environmental justice perspective collectively include 6.3% of the population and 0.38% of the land area in New England.

We further identify focus areas with and without the inclusion of language isolation as a criterion (shown in the web map) and find that 87% of focus areas identified using our three core criteria (income, race, protection) are also in the highest quartile of English-language isolation. This highlights the ways in which many communities are cumulatively marginalized and demonstrates the importance of translation and interpretive services for community engagement.

Figure S6 shows EJ focus areas in four different parts of New England using three criteria. The figure shows in more detail how the tracts presented in Figure 2 overlay in different parts of the region. Figure S6 also highlights that we identify EJ focus areas in a range of communities, from a large, heavily urbanized city like Boston to smaller cities with more exurban environments like Concord and Manchester, New Hampshire.

Figure S7 shows a screenshot of the web map, which includes census tracts in the highest quartile of language isolation and the focus areas identified with four criteria, in addition to those shown in Figure 2 and Figure S6. Protected open space and brownfields data add conservation context to the map. The user can click on protected areas or census tracts to see the underlying data. For census tracts, we provide the unique tract ID, tract type, demographic information, and land protection information. For protected open space, we provide the owner type (public or private), year protected, and area name.

SUPPLEMENTAL FIGURES

Figure S1: Study area and nearby protected open space by census tracts. *Left panel provides a map of all protected lands in New England, broken down by public and private ownership. Right panel shows a map of the census tracts in the region. Tracts are color coded according to the percent of land area that is in protected open space inside or within 1 km of each census tract.*

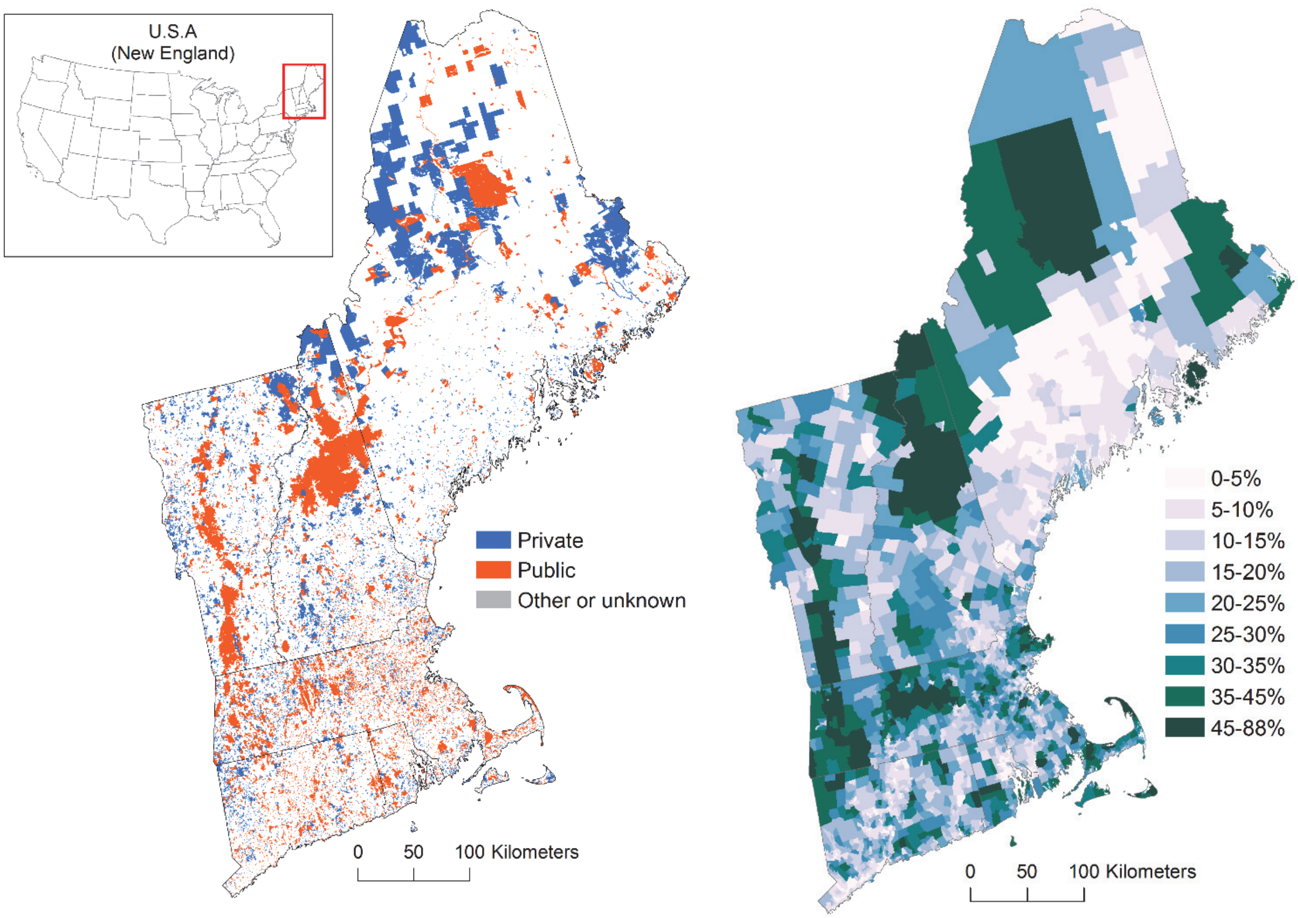


Figure S2: Distribution of income, race, education, and language isolation by within-state quartiles

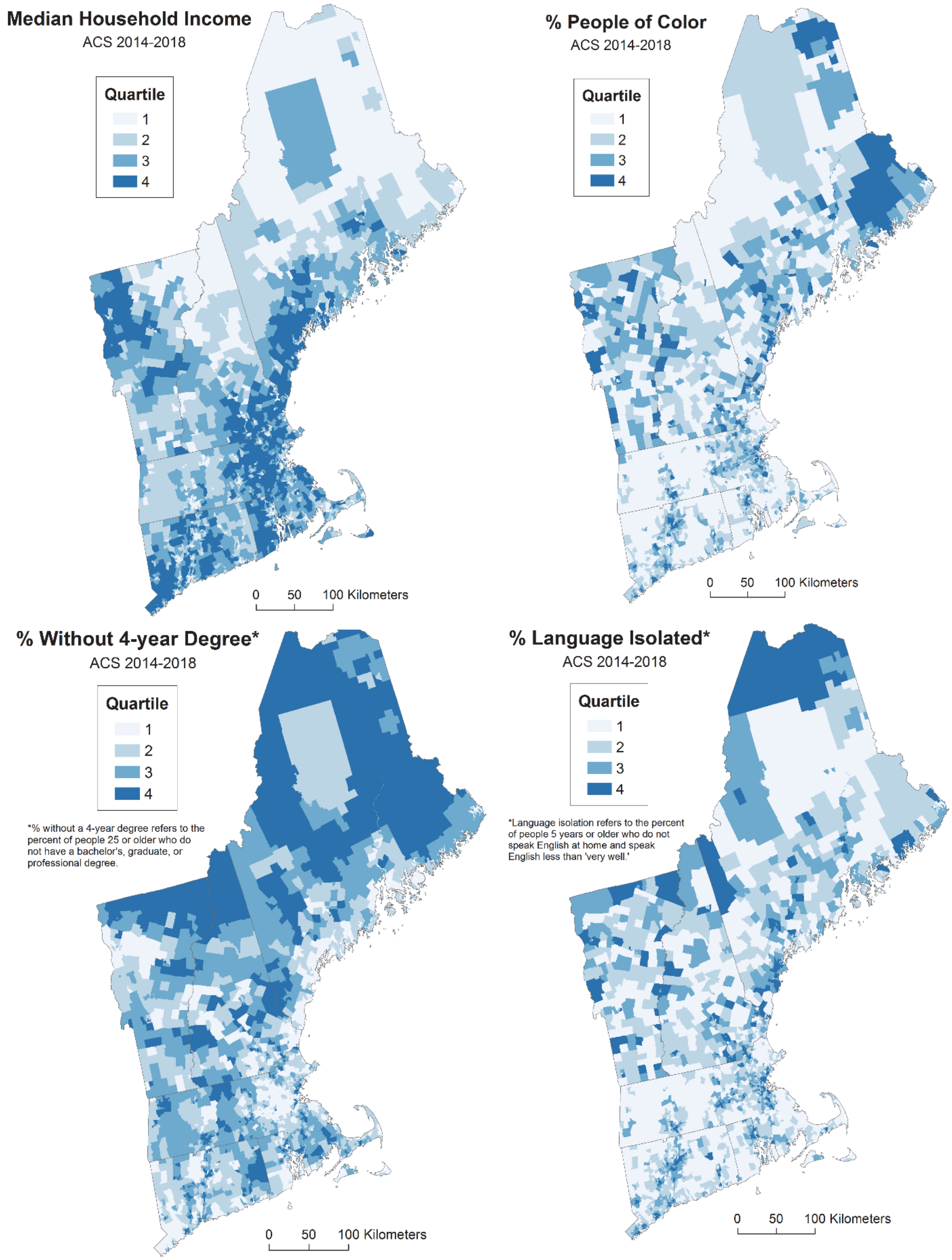


Figure S3: Distribution of tract types and tracts not used in statistical analysis. *Map shows the census tracts classified as rural, exurban and urban according to housing density. (Urban: >128 housing units/km^2, exurban: 16–128 housing units/km^2; rural: <16 units/km^2).*

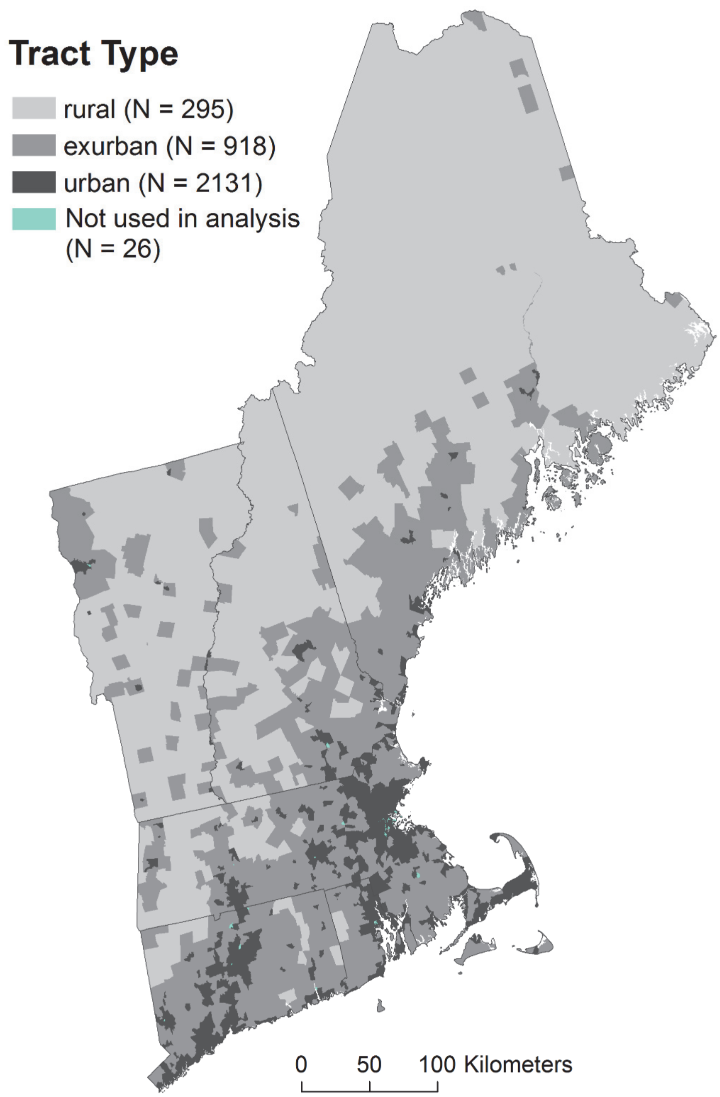


Figure S4: Disparities in land protected since 1990. *Percent protected before and after 1990 within a 1 km buffer of current census tracts by within-state quartiles of income and percent people of color. For each quartile group, boxplots show the median (line), 25th and 75th percentiles (box), and 5th and 95th percentiles (whiskers). Stars indicate a statistically significant (* p<.05, ** p<.01) correlation between percent protected and the percentile rank of income or percent people of color. For each set of quartiles, access to protected open space is analyzed before 1990 and 1990 or later. A) All tracts (N=3344). B) Subsets of each quartile that are: urban (N=2131), exurban (N=918) and rural tracts (N=295).*

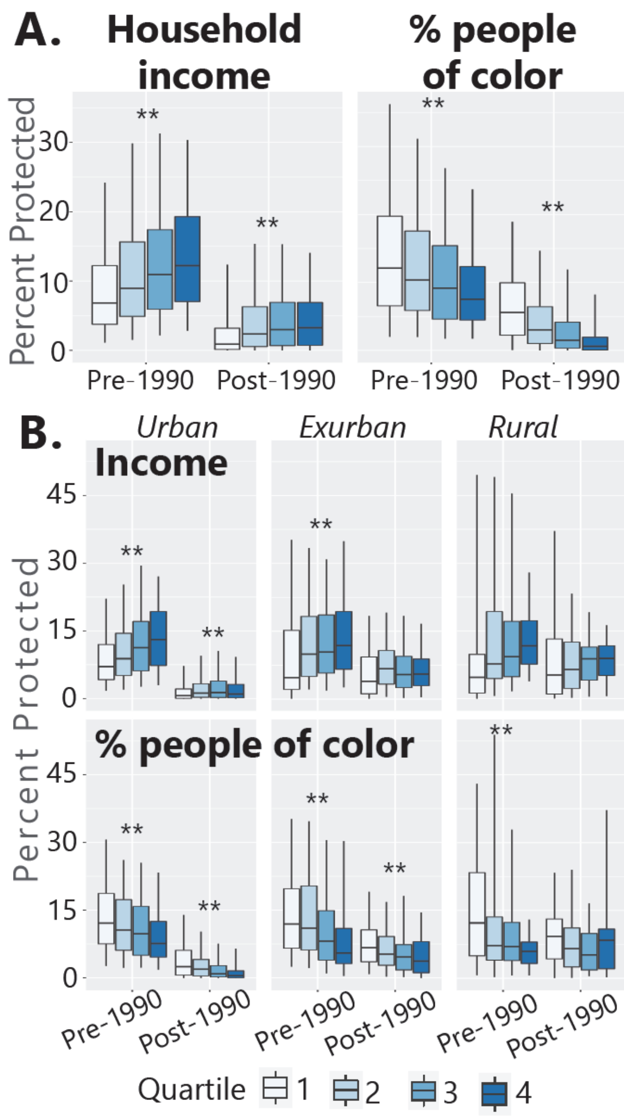


Figure S5: Disparities in land protected by degree of language isolation and educational attainment. *Distribution of the percent of land protected within a 1 km buffer of census tracts by within-state quartiles of percent without a four-year degree and percent language isolated households. For each quartile group, boxplots show the median (line), 25th and 75th percentiles (box), and 5th and 95th percentiles (whiskers). Stars indicate a statistically significant (* p<.05, ** p<.01) correlation between percent protected and the percentile rank of educational attainment or English-language isolation. For each set of quartiles, access to protected open space is analyzed for all protected lands, then by public and private ownership. A) All tracts (N=3344). B) Subsets of each quartile that are: urban (N=2131), exurban (N=918) and rural tracts (N=295).*

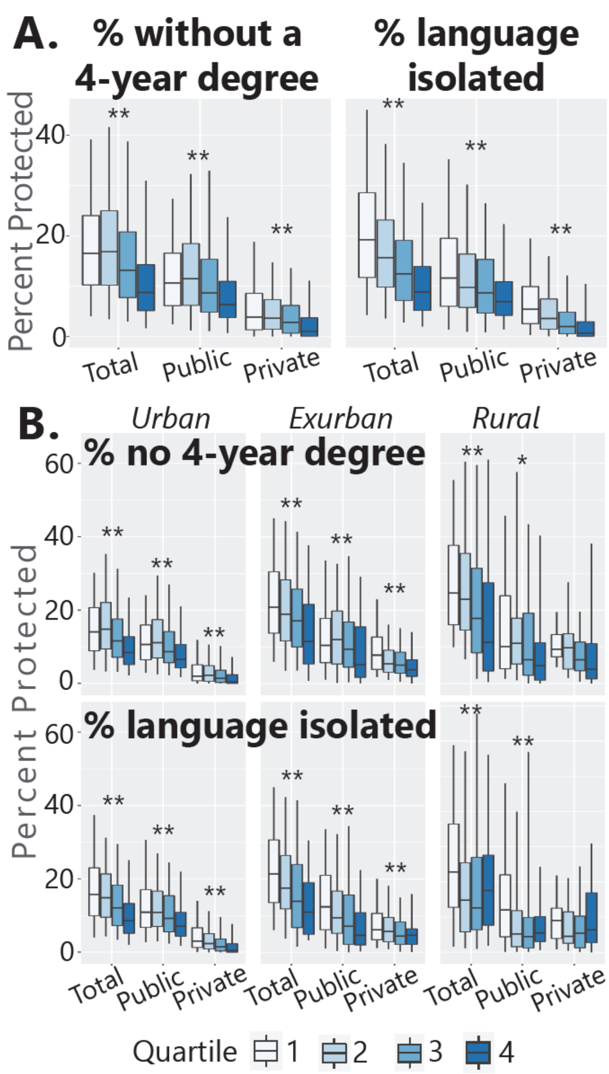


Figure S6: Areas of potential focus for new land protection according to environmental justice criteria: examples of detail for four metro-areas.

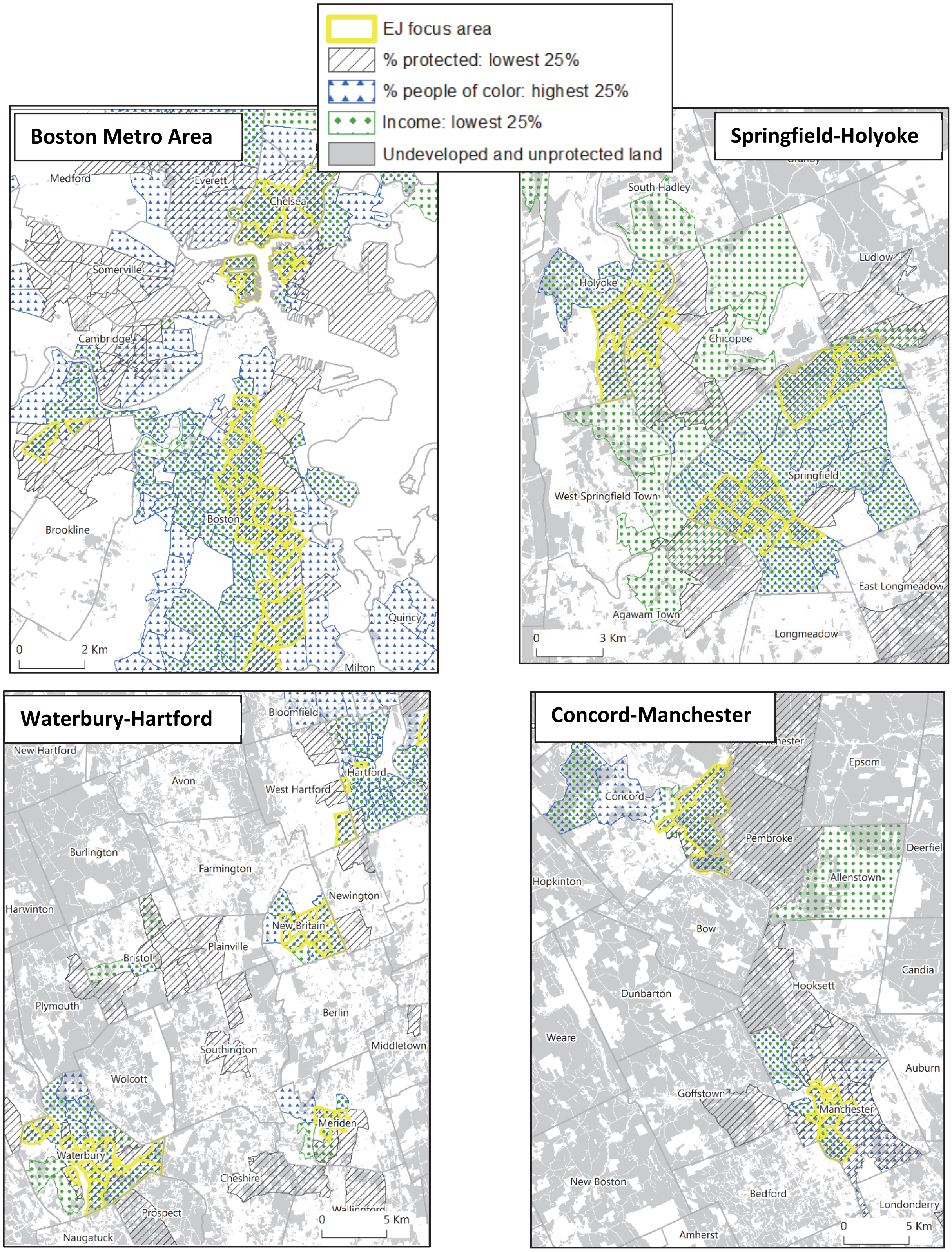


Figure S7: Example of web-based map showing focus areas for environmental justice *in Boston, Massachusetts, the largest city in New England. The web map shows the same data as shown in Figure 2, plus data on language-isolated census tracts. Additional layers including protected open space (shown below), brownfields (not shown), and tract scores for the three conservation prioritization layers in Figure 2 (not shown) add conservation context. The user can click on map features to see data in pop-up windows. View map online:* http://bit.ly/EJ-OS-NE.

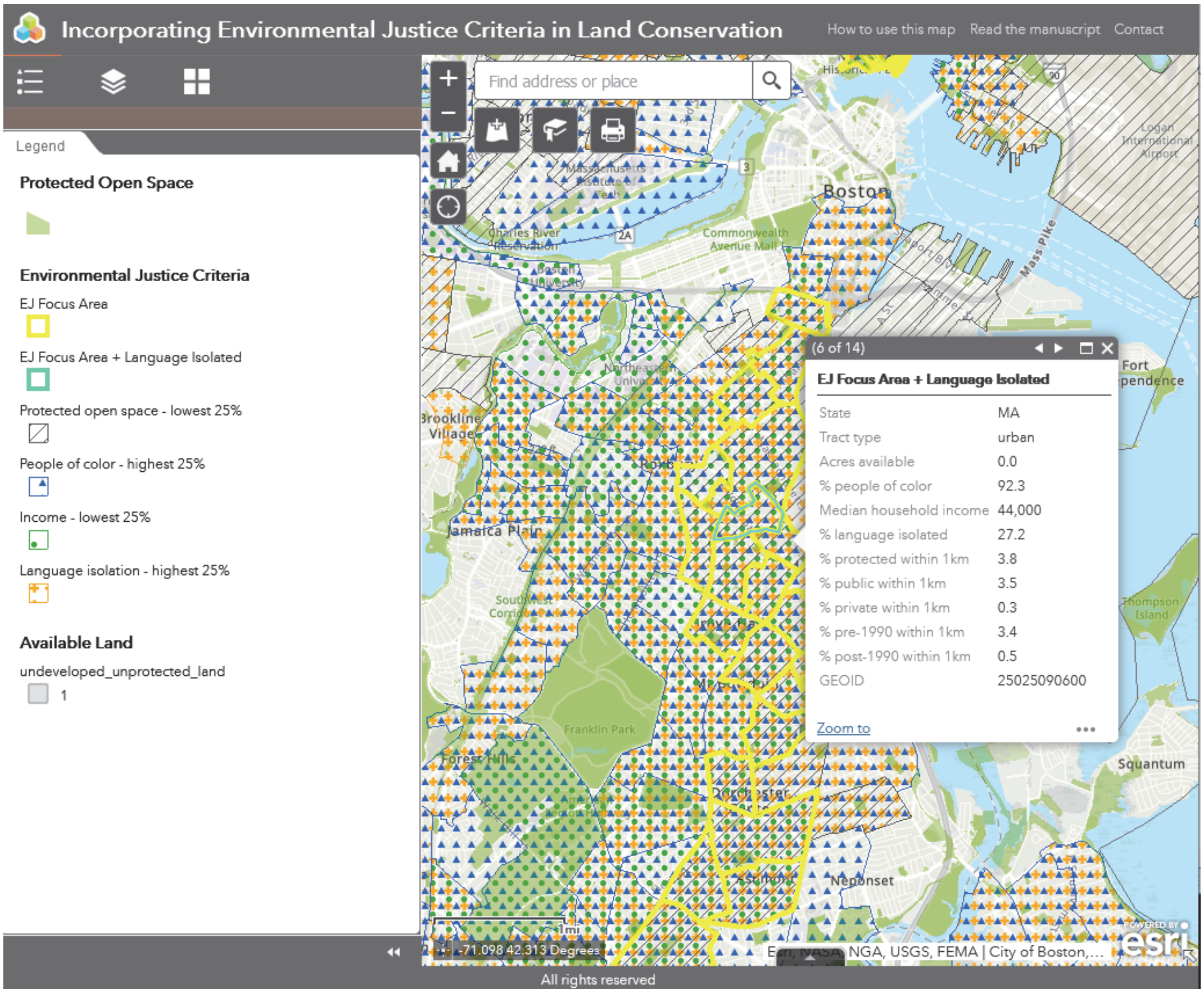


Figure S8: Coefficients for income and percent people of color in bivariate geographically weighted regression. *The maps show an overall positive relationship between income and percent protected and an overall negative relationship between percent people of color and percent protected across the region. Histograms show that the OLS coefficients (columns 1 and 2 of Table S3, part a) are approximately in the center of the distribution of GWR coefficients and represent the regional average. Local regressions in GWR are calculated using an adaptive kernel of 100 neighbors, which results in a smaller kernel in more densely populated areas and larger kernel in more sparsely populated areas.*

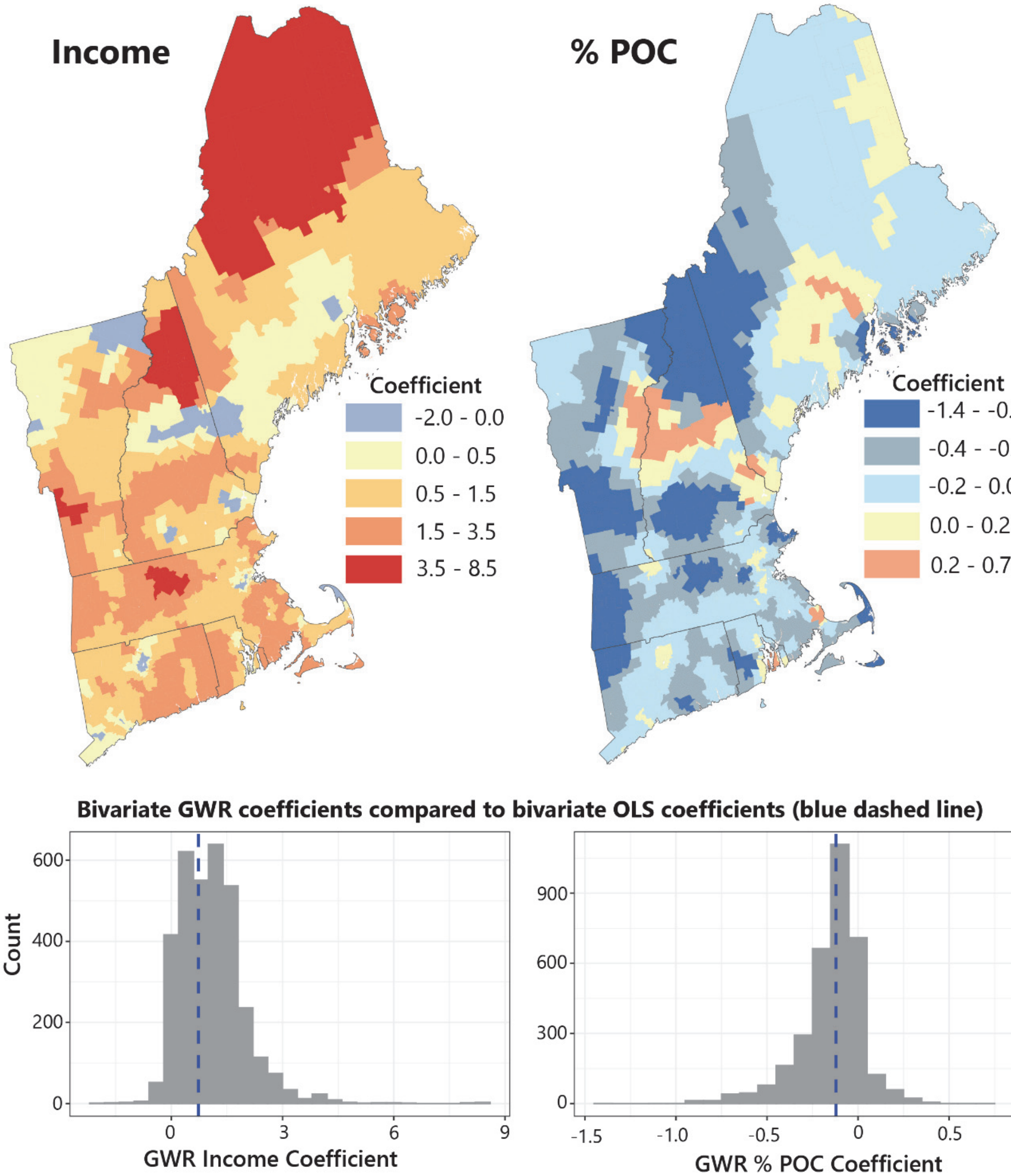
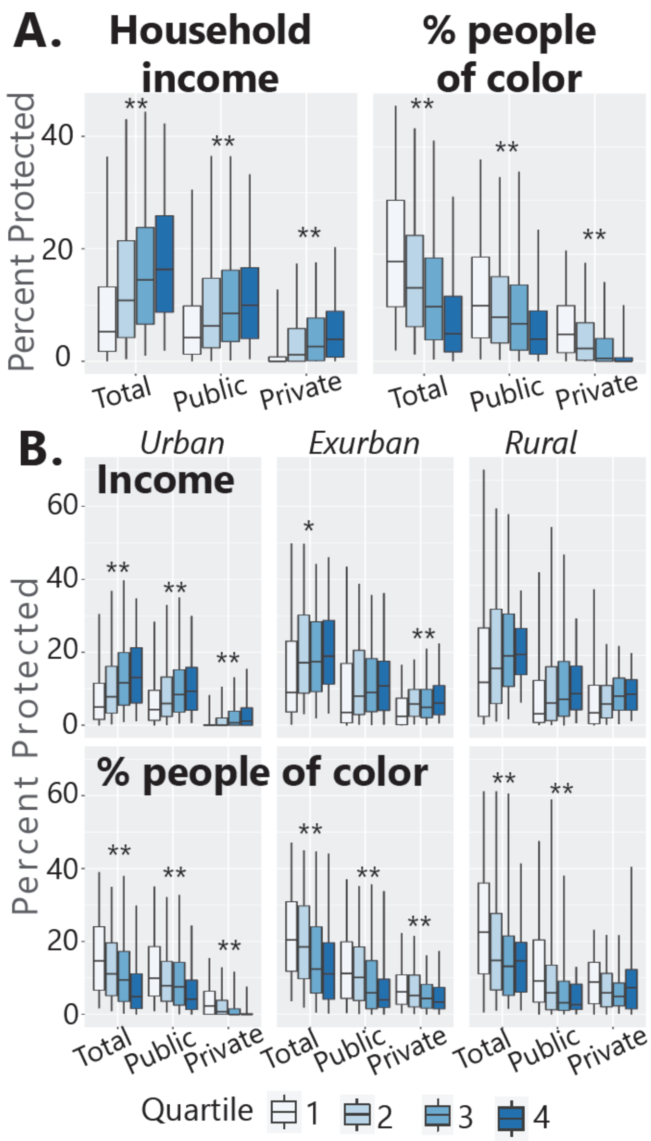


Figure S9: Alternate version of Figure 1 using unbuffered census tracts. *Distribution of percent of land protected within census tracts by state-based quartiles of income and percent people of color. For each quartile group, boxplots show the median (line) 25th and 75th percentiles (box) and 5th and 95th percentiles (whiskers) of the percent protected. Stars indicate a statistically significant (* p<.05, ** p<.01) correlation between percent protected and the percentile rank of income or percent people of color. For each set of quartiles, access to protected open space is analyzed for all protected lands, then by public and private ownership. A) All tracts (N=3344). B) Subsets of each quartile that are: urban (N=2131), exurban (N=918) and rural tracts (N=295).*



SUPPLEMENTAL TABLES

Table S1: Data sources

Layer or variable	Source	Year	Resolution
Census tract boundaries	Manson et al. 2020a	2018	Tract
Total housing units	Manson et al. 2020b	2014-2018	Tract
Median household income	Manson et al. 2020c	2014-2018	Tract
Percent people of color, total population	Manson et al. 2020c	2014-2018	Tract
Percent language isolated	Manson et al. 2020c	2014-2018	Tract
Percent with less than a 4-year degree	Manson et al. 2020c	2014-2018	Tract
Protected open space	Harvard Forest and Highstead Foundation 2021	2021	10m
Land area, undeveloped land area	National Land Cover Database 2016	2016	30m
Undeveloped land area	Olofsson et al. 2016 + National Land Cover Database	1990	30m
Terrestrial resilience	Anderson et al. 2016	2016	30m
Forests to Faucets 2.0	U.S. Department of Agriculture Forest Service 2018	2018	30m
National Biomass and Carbon Dataset 2.0	Kellndorfer et al. 2013	2000	30m
Brownfields	U.S. Environmental Protection Agency	2020	points

Table S2: Area and number of tracts with high environmental justice value characteristics

State (code)	All total area (acres) # of tracts	Lowest quartile Income % area # of tracts	Highest quartile % people of color % area # of tracts	Lowest quartile nearby PAs % area # of tracts	Lowest income + highest % POC + lowest nearby PAs % area # of tracts
CT (9)	3,090,870	3.5%	3.1%	6.7%	0.76%
	823	205	206	205	70
ME (23)	19,730,036	47.3%	12.9%	14.7%	0.26%
	351	87	88	87	7
MA (25)	4,990,524	5.2%	2.5%	6.1%	0.63%
	1455	363	364	363	126
NH (33)	5,735,184	30.6%	4.7%	5.0%	0.25%
	292	73	73	73	19
RI (44)	664,631	3.6%	3.0%	5.8%	0.82%
	240	60	60	60	20
VT (50)	5,912,137	19.8%	10.4%	12.1%	0.46%
	183	45	46	45	4
All states	40,123,382	31.5%	9.1%	11.1%	0.38%
	3344	833	837	833	246

Table S3: Percent protected within census tract and 1 km buffer as a function of tract characteristics

a. Regional model

Dep var: % protected in 1 km buffer	(1)	(2)	(3)_	(4)	(5)
% people of color (2014-2018 ACS)	-0.123***		-0.097***	-0.034***	-0.018**
	(0.007)		(0.008)	(0.008)	(0.008)
Median HH income 2018 ($10,000s)		0.729***	0.476***	0.596***	0.042
		(0.059)	(0.066)	(0.066)	(0.090)
Urban (1/0)				-8.644***	-9.692***
				(1.085)	(1.072)
Exurban (1/0)				-3.943***	-4.118***
				(1.126)	(1.110)
% without college education					-14.088***
					(1.450)
N	3344	3344	3344	3344	3344
R^2	0.070	0.051	0.088	0.135	0.159

Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10

b. State fixed effects

Dep var: % protected in 1 km buffer	(1)	(2)	(3)_	(4)	(5)
% people of color (2014-2018 ACS)	-0.155***		-0.143***	-0.083***	-0.071***
	(0.007)		(0.009)	(0.008)	(0.008)
Median HH income 2018 ($10,000s)		0.651***	0.152**	0.121**	-0.424***
		(0.054)	(0.064)	(0.059)	(0.084)
Urban (1/0)				-14.107***	-15.400***
				(1.034)	(1.022)
Exurban (1/0)				-6.683***	-7.118***
				(1.018)	(1.000)
% without college education					-13.291***
					(1.415)
State fixed effects	yes	yes	yes	yes	yes
N	3344	3344	3344	3344	3344
R^2	0.193	0.138	0.195	0.295	0.316

Model includes state fixed effects (a dummy variable for each state). Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10

Table S4: Public and private land protected as a function of tract characteristics

a. Regional model

Dependent variable:	**Percent public land protected in 1 km buffer**			**Percent private land protected in 1 km buffer**		
	(1)	(2)	(3)	(4)	(5)	(6)
% people of color	-0.040***	0.000	0.011	-0.080***	-0.033***	-0.028***
(2014-2018 ACS)	(0.006)	(0.007)	(0.007)	(0.003)	(0.003)	(0.003)
Median HH income 2018		0.467***	0.102		0.136***	-0.049
($10,000s)		(0.054)	(0.077)		(0.027)	(0.037)
Urban (1/0)		-2.760***	-3.450***		-5.599***	-5.949***
		(0.970)	(0.970)		(0.529)	(0.523)
Exurban (1/0)		-1.615	-1.730*		-2.200***	-2.258***
		(1.007)	(1.000)		(0.545)	(0.541)
% without college education			-9.271***			-4.700***
			(1.239)			(0.648)
N	3344	3344	3344	3344	3344	3344
R^2	0.011	0.038	0.053	0.128	0.223	0.235

Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10

b. State fixed effects

Dependent variable:	**Percent public land protected in 1 km buffer**			**Percent private land protected in 1 km buffer**		
	(1)	(2)	(3)	(4)	(5)	(6)
% people of color	-0.081***	-0.047***	-0.039***	-0.074***	-0.036***	-0.032***
(2014-2018 ACS)	(0.006)	(0.007)	(0.007)	(0.003)	(0.004)	(0.003)
Median HH income 2018		0.039	-0.325***		0.080***	-0.099**
($10,000s)		(0.051)	(0.074)		(0.028)	(0.041)
Urban (1/0)		-7.665***	-8.528***		-6.326***	-6.751***
		(0.961)	(0.967)		(0.558)	(0.556)
Exurban (1/0)		-4.147***	-4.437***		-2.519***	-2.662***
		(0.952)	(0.946)		(0.552)	(0.546)
% without college education			-8.879***			-4.368***
			(1.206)			(0.667)
State fixed effects	yes	yes	yes	yes	yes	Yes
N	3344	3344	3344	3344	3344	3344
R^2	0.152	0.191	0.204	0.155	0.257	0.266

Model includes state fixed effects. Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10

Table S5: Percent protected by race and income within buffers of different sizes

Dep var: % protected in tract and buffer	(1)	(2)	(3)	(4)	(5)
	No buffer	1 km buffer	2 km buffer	10 km buffer	25 km buffer
% people of color (2014-2018 ACS)	-0.185***	-0.155***	-0.139***	-0.088***	-0.048***
	(0.009)	(0.007)	(0.006)	(0.004)	(0.003)
State fixed effects	Yes	yes	yes	yes	Yes
N	3344	3344	3344	3344	3344
R^2	0.138	0.193	0.220	0.347	0.464
	(1)	(2)	(3)	(4)	(5)
Median HH income 2018 ($10,000s)	0.794***	0.651***	0.559***	0.085***	-0.122***
	(0.067)	(0.054)	(0.048)	(0.029)	(0.021)
State fixed effects	Yes	yes	yes	yes	Yes
N	3344	3344	3344	3344	3344
R^2	0.087	0.138	0.166	0.297	0.445

Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10. Each model includes a dummy variable for each state (state fixed effects).

Table S6: Protection since 1990 related to present-day tract characteristics and land availability in 1990.

Dep var: % protected in 1 km buffer Since 1990	(1)	(2)	(3)	(4)	(5)
% people of color (2014-2018 ACS)	-0.071***			-0.014***	-0.006*
	(0.00)			(0.00)	(0.00)
Median HH income 2018 ($10,000s)		0.137***		-0.138***	-0.287***
		(0.02)		(0.02)	(0.03)
Percent land available in 1990			11.755***	8.573***	9.623***
			(0.36)	(0.52)	(0.55)
Urban (1/0)				-4.110***	-4.065***
				(0.54)	(0.54)
Exurban (1/0)				-2.310***	-2.363***
				(0.53)	(0.53)
% without college education					-3.777***
					(0.55)
State fixed effects	yes	Yes	yes	yes	yes
N	3344	3344	3344	3344	3344
R^2	0.151	0.070	0.326	0.353	0.359

Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10. Regressions include state-level fixed effects.

Table S7: Public and private protection since 1990 related to present-day race and income

Dependent variable:	**Percent public land protected in 1 km buffer**		**Percent private land protected in 1 km buffer**	
	(1)	(2)	(3)	(4)
% people of color (2014-2018 ACS)	-0.031***		-0.040***	
	(0.00)		(0.00)	
Median HH income 2018		0.029**		0.106***
($10,000s)		(0.01)		(0.01)
State fixed effects	yes	yes	yes	yes
N	3344	3344	3344	3344
R^2	0.072	0.027	0.170	0.122

Model includes state fixed effects. Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10

Table S8: Percent protected within census tract and 1 km buffer as a function of tract characteristics by individual states

a. Values: regional model

	CT	MA	RI	NH	ME	VT
Dep var: % protected in 1 km buffer	(1)	(2)	(3)	(4)	(5)	(6)
% people of color (2014-2018 ACS)	-0.117***	-0.178***	-0.143***	-0.484***	-0.047	-0.236
	(0.010)	(0.011)	(0.017)	(0.058)	(0.060)	(0.212)
N	823	1455	240	292	351	183
R^2	0.127	0.147	0.147	0.098	0.001	0.008
Dep var: % protected in 1 km buffer	(1)	(2)	(3)	(4)	(5)	(6)
Median HH income 2018 ($10,000s)	0.336***	0.900***	1.556***	-0.115	0.628***	0.301
	(0.076)	(0.071)	(0.277)	(0.316)	(0.233)	(0.518)
N	823	1455	240	292	351	183
R^2	0.025	0.084	0.176	0.000	0.012	0.001

Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10

b. Percentiles: state-based model

	CT	MA	RI	NH	ME	VT
Dep var: Percentile rank: % protected in 1 km buffer	(1)	(2)	(3)	(4)	(5)	(6)
Percentile rank: % people of color (2014-2018 ACS)	-0.416***	-0.439***	-0.516***	-0.381***	-0.016	-0.157**
	(0.032)	(0.023)	(0.051)	(0.053)	(0.054)	(0.072)
N	823	1455	240	292	351	183
R^2	0.173	0.193	0.266	0.145	0.000	0.025
Dep var: Percentile rank: % protected in 1 km buffer	(1)	(2)	(3)	(4)	(5)	(6)
Percentile rank: median HH income 2018 ($10,000s)	0.294***	0.364***	0.475***	0.166***	0.206***	0.105
	(0.033)	(0.023)	(0.052)	(0.059)	(0.051)	(0.074)
N	823	1455	240	292	351	183
R^2	0.087	0.133	0.226	0.027	0.042	0.011

Variables are the within-state percentile rank of the percent protected within each tract or a 1km buffer, the within-state percentile rank of the percent people of color and the within-state percentile rank of median household income. Ordinary least squares regression with robust standard errors; *** p < .01; ** p < .05; * p < .10

Table S9: Tract counts per boxplot shown in Figure 1, parts (A) and (B)

	All tracts (A)		Urban tracts (B)		Exurban tracts (B)		Rural tracts (B)	
Quartile	**Income**	**% POC**	**Income**	**% POC**	**Income**	**% POC**	**Income**	**% POC**
1	833	833	696	271	76	431	61	131
2	837	837	555	489	166	261	116	87
3	837	837	477	614	277	166	83	57
4	837	837	403	757	399	60	35	20
Total	3,344	3,344	2,131	2,131	918	918	295	295

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