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Distribution of capitalized benefits from land conservation

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Land conservation efforts throughout the United States sustain ecological benefits while generating wealth in the housing market through capitalization of amenities. This paper estimates the benefits of conservation that are capitalized into proximate home values and quantifies how those benefits are distributed across demographic groups. Using detailed property and household-level data from Massachusetts, we estimate that new land conservation led to $62 million in new housing wealth equity. However, houses owned by low-income or Black or Hispanic households are less likely to be located near protected areas, and hence, these populations are less likely to benefit financially. Direct study of the distribution of this new wealth from capitalized conservation is highly unequal, with the richest quartile of households receiving 43%, White households receiving 91%, and the richest White households receiving 40%, which is nearly 140% more than would be expected under equal distribution. We extend our analysis using census data for the entire United States and observe parallel patterns. We estimate that recent land conservation generated $9.8 billion in wealth through the housing market and that wealthier and White households benefited disproportionately. These findings suggest regressive and racially disparate incidence of the wealth benefits of land conservation policy.

land conservation | open space | environmental justice | housing | non-market valuation

Accelerating biodiversity loss is increasing global calls to protect more natural land from conversion and degradation (1). Much research informs conservation strategies that are effective, cost effective, and resilient to climate change, such as refs. 2–5. However, little research explores how the benefits of land conservation are distributed among different groups of people in society, even though conflicts over justice are core challenges to sustainable land use (6). Distributional issues are now a federal policy priority in the United States (US) (7), which has long faced problems of income and wealth inequality (8) and environmental injustice (9, 10). Evidence for environmental injustice is well documented by research on how exposure to environmental hazards like poor air quality (11–13), toxic emissions (14), hazardous waste sites (15, 16), and flooding (17) is disproportionately borne by poor and minority communities. However, much less research has focused on equity issues in the incidence of benefits from the provision of public environmental goods like land conservation (18–20).

Concerns about conservation justice have risen to prominence in global conservation efforts (21), and study of conservation easements in the US South (22) shows how White landowners have used easements to protect inherited property from public use. Recent data analysis in New England documents racial inequity in proximity to United States protected open space (23). However, the findings of previous work may be understated due to ecological fallacy (10), and proximity alone is only an important first indicator of the benefits from conservation that accrue to people. This paper advances environmental justice research on conservation by analyzing socioeconomic inequity in the financial benefits that flow to homeowners from capitalization of nearby land conservation in the United States. We use spatially fine-scale, household-level data in a study of Massachusetts to capture patterns that can be missed in aggregate data while also studying patterns in the entire United States to ensure our findings hold beyond a single state.

According to the US Forest Service, 6,000 acres of open space are developed daily (24). However, additions to the network of land protected in the United States are made each year (25), and since 1988, over $80 billion of conservation funding has been approved by municipal referenda across the United States (26–28). Conserving land ensures no future development, enshrines ecological benefits and visual amenities, and sometimes adds recreational opportunities. The benefits of land and open space protection efforts are large (29), and the amenity value of conservation yields positive externalities to nearby properties, which capitalize the amenity value (30, 31) and generate financial wealth for the owners.

However, residential locations in the United States are widely segregated by race (32); there is a racial gap in access to homeownership (33), and land conservation decisions are not random. Thus, the benefits of conservation may not accrue proportionately to people

Significance

Land conservation protects the nature from future development and produces benefits to people; some of those benefits increase the values of homes near newly protected areas, which increase the wealth of the people who own those homes. Concern about environmental justice in the United States is high, but little research documents how the benefits from land conservation are distributed among different groups of people. We estimate how the values of protected areas increase home values in Massachusetts and the entire United States and find that wealth increases generated by newly protected areas accrue disproportionately to households who are wealthy and White. Effort may be needed to account for human inequities while continuing land conservation needed for ecological reasons.

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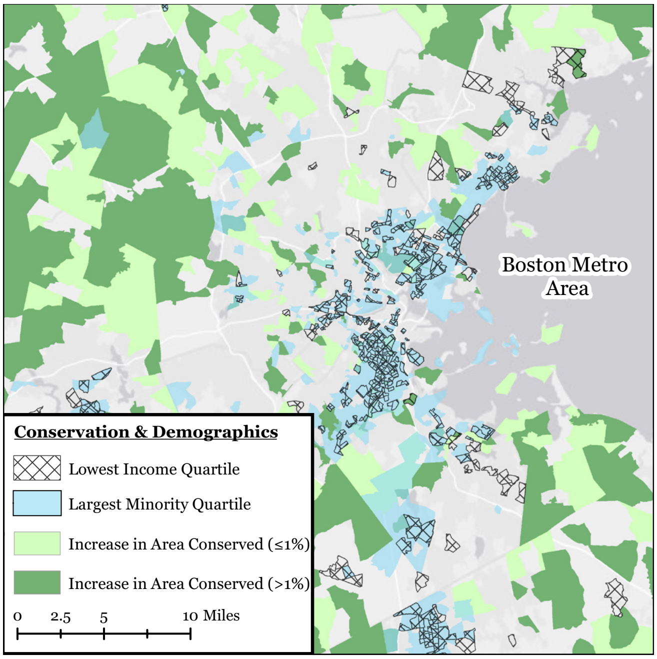

Fig. 1. Spatial distribution of new land conservation and disadvantaged populations. Notes: Area shown is Boston, Massachusetts metropolitan area. Increase in area conserved occurs over years 1998 to 2016. Conservation data come from the USGS Protected Area Database (34). Data on income, race, and ethnicity come from American Community Survey 2016 5-year estimates. Land and population data are plotted at the block group level.

in different demographic groups. This paper quantifies how the financial benefits of conservation are actually distributed among households.

Massachusetts is a data-rich area for this study. It has the second largest number of conserved land parcels among all states (34), much of which was protected recently enough to analyze the impact of new conservation on house values using temporal variation (*SI Appendix,* Figs. S1 and S2). Spatial data exist on where and when parcels were protected. Finally, it is the third most densely populated state in the United States such that a relatively large number of houses are exposed to new conservation. We combine spatial datasets on residential property transactions and conserved lands in Massachusetts from 1998 to 2016. To identify the race, ethnicity, and income of individual homebuyers, we merge mortgage application data with the transaction data. The dynamic nature of this dataset allows us to observe changes in conservation proximate to households over time and individual households' relocations in the state. Fig. 1 shows visually a strong negative correlation between areas in Massachusetts where new land conservation happens and where disadvantaged populations live; our formal analyses of these data are as follows.

Our first analysis is a standard hedonic valuation exercise that estimates the impact of protecting additional land nearby on a house's sales price. This regression uses data on changes in proximate conserved open space at the property level at each year of sale. We mitigate potential bias from correlation between home value trends and the siting of new protected areas (35) by incorporating fine-scale fixed effects to control for trends in time over multiple geographic dimensions.

For the second set of analyses, we use the results of the hedonic regression to estimate how much new equity was capitalized into the values of homes in the study area because of new conservation. We then use observed household characteristics from loan applications to carry out descriptive analyses of how that equity was distributed among homeowners in different socioeconomic groups. First, we quantify relationships between the amount of protected area near with a house being sold and the income and race/ethnicity of the household purchasing the house. Second, we examine how proximate, future conservation (after the household moves in) varies by income and race/ethnicity. Third, we estimate a regression of the household-specific equity gain from new proximate conservation on the socioeconomic features of the household. Finally, we use census population data to calculate proportional benefits and assess which socioeconomic groups are receiving more or less than their fair share.

To establish whether these patterns hold at a larger scale, we present an analogous version of the Massachusetts analysis using aggregate census data for the conterminous United States. We use block group–level panel data on people and property values from the 2000 decennial census and the 2014 5-yr. American Community Survey (2010 to 2014), and we estimate the property value capitalization of changes in the percentage of protected acres at the block group level using the US Geological Survey's (USGS) Protected Area Database (34). We use that estimate to calculate how much new housing value is created by new protected areas for each block group and quantify the distribution of capitalized wealth by race, ethnicity, and income group. The details of those data and analyses are in *SI Appendix,* sections 4–6, but the distribution of equity gain findings is reported in the main text.

Results

Property Capitalization Results in Massachusetts. The property capitalization findings for Massachusetts are in *SI Appendix,* Table S4. The coefficient on Protected Acres is positive and statistically significant across four specifications. Consistent with previous research (30, 36, 37), homeowners value the permanent protection of proximate open space. Column 4 is our preferred model as it includes controls that work best to eliminate bias from the model. These results suggest that on average a one-acre increase in protected acres within a quarter mile of a house increases its value by 0.018%. In context, the average home price in our sample is $366,160, so a 10-acre increase in proximate protected area would result in a capitalization gain of approximately $659. Back-of-the-envelope calculations imply that the total value in the housing market derived from proximate conserved lands in Massachusetts is $317 million, and the value generated from new conservation during our research period of 1998 to 2016 is $62 million.[*]

Distribution of Benefit Results in Massachusetts. Table 1 shows the results for the four regressions exploring how the benefits of land conservation are distributed among different kinds of households in Massachusetts. All regressions in this table are meant to be descriptive and not causal.[†] Column 1 shows the relationship between the amount of open space near a house at the time of purchase and the characteristics of its buyers. The reference group for this table is White households in the lowest income quartile. The indicator variable for Black or Hispanic households is negative and statistically significant; on average, such households purchase properties with 0.84 fewer protected acres nearby than White

[*]The total value calculation multiplies the capitalization coefficient by the average arms-length sales price, the number of properties, and the average number of conserved acres (total or new) within a quarter mile.

[†]Given the myriad of reasons for residential segregation by race, ethnicity, and income, it is difficult to identify exogenous variation for causal inference. An example of causal research related to race and housing is ref. 48, which exploits experimental variation to show realtors are more likely to encourage Black households to live in areas with higher crime and more pollution than White households.

Table 1. Results for buyer patterns and distribution of equity gains analyses

	Massachusetts analysis				US analysis	
Independent variables*	(1) Protected acres†	(2) Future protected acres‡	(3) Homeowner equity gains from conservation§	(4) Homeowner equity gains from conservation (Include tract FE)¶	(5) Homeowner equity gains from conservation#	(6) Homeowner equity gains from conservation (Include tract FE)||
Black/Hispanic	−0.836	−0.196	−15.080	−0.418	−0.681	0.010
	(0.053)***	(0.016)***	(1.097)***	(1.226)	(0.058)***	(0.108)
Asian	0.607	−0.085	−7.806	2.412	−3.787	0.702
	(0.062)***	(0.019)***	(1.292)***	(1.335)*	(0.271)***	(0.622)
Income Quartile 2	0.393	0.053	4.103	1.412	29.769	14.318
	(0.045)***	(0.014)***	(0.939)***	(0.937)	(2.685)***	(3.144)***
Income Quartile 3	1.104	0.146	12.056	7.045	71.309	31.805
	(0.045)***	(0.014)***	(0.945)***	(0.980)***	(3.646)***	(4.149)***
Income Quartile 4	2.666	0.261	31.156	20.772	153.224	68.356
	(0.045)***	(0.014)***	(0.949)***	(1.072)***	(6.015)***	(6.569)***
Observations	540,336	540,336	499,002	499,002	186,144	186,144
R squared	0.011	0.145	0.007	0.059	0.069	0.569

*In Columns 1, 2, 3, and 4, all independent variables are binary indicators measured at the household level. In Columns 5 and 6, the variables Black/Hispanic and Asian are the percentage of the total households of a block group in that category, and Income Quartile variables are binary indicators defined based on block group median income relative to state-level income distributions. Omitted categories are the variables for White and Income Quartile 1. For Columns 1, 2, 3, and 4, subcategories of race "Native American" and "Other" included in Black/Hispanic. For Columns 1, 2, 3, and 4, income quartiles are defined as: Q1 ≤ \$66,314, Q2 ∈(\$66,314, \$95,514], Q3 ∈(\$95,514, \$139,599], and Q4 > \$139,599. For Columns 1, 2, 3, and 4, the models include year fixed effects. In Columns 5 and 6, the models include state fixed effects. In Columns 4 and 6, the models additionally include census tract fixed effects. Standard errors in parentheses. ***$P < 0.01$, **$P < 0.05$, and *$P < 0.1$.

†Observations are all home purchases that match mortgage data records during 1998 to 2016; there is one observation per sale. Dependent variable is Protected Acres, defined as conserved acres within one quarter mile at the time of transaction.

‡Sample is identical to Column 1. Dependent variable is Future Protected Acres, defined as newly conserved acres within one quarter mile during a household's occupancy of the property.

§Observations are all households with home purchases that match mortgage data records during 1998 to 2016; there is one observation per household. Dependent variable is Equity Gain, defined as the estimated home equity the household gained from newly conserved acres within one quarter mile of any of their properties. Dependent variable calculated by multiplying coefficient from Column 4 in *SI Appendix,* Table S4 by purchase price of home and by Future Protected Acres and then summing over homes owned by the household.

¶Sample and analysis are identical to Column 3 except the model includes census tract fixed effects.

#Observations are all census block groups in the conterminous United States. Dependent variable is Equity Gain, defined as the estimated block group mean homeowner equity gain from new conservation, and calculated as the product of the property capitalization coefficient (*SI Appendix,* Table S17 Column 3), the median block group house value, and Protected Area Increase over years 2001 to 2009 (*SI Appendix*, sections 4 and 5). % Asian includes additional category "Pacific Islander". % Black/Hispanic includes additional categories Native American, other, and "two or more races". Observations are weighted by the number of households in each block group. Standard errors clustered at the census tract level.

||Sample and analysis are identical to Column 5 except the model includes census tract fixed effects.

households. The race indicator variable for Asian households is positive and statistically significant indicating that, on average, Asian households purchase properties with 0.61 more protected acres nearby than White households. The coefficients on the income quartile variables are positive, monotonically increasing, and statistically significant for all sequential comparisons; exposure to conserved land rises with income. On average, a household in income quartile 4 purchases a property with 2.67 more acres than a household in income quartile 1.[‡] *SI Appendix,* Table S7 further shows that disparities increase over time.

The regression in Column 2 shows the correlations between types of homeowners and their exposure to new conservation during their occupancy of a home (Future Protected Acres). The race and ethnicity indicator variable coefficients are negative and statistically significant, indicating that on average minorities live in areas where new conservation is less likely to happen. The income quartile coefficients are positive, statistically significant, and monotonically increasing, indicating wealthier households are exposed to more future conservation than poorer households.

Column 3 of Table 1 quantifies how the financial benefits of new land conservation are distributed across different types of households by regressing equity gain on household characteristics. Equity gain is calculated as the product of the property capitalization coefficient from Column 4 in *SI Appendix,* Table S4, the purchase price of the property (adjusted for inflation), and Future Protected Acres. Both race/ethnicity coefficients are negative and statistically significant. On average, Black or Hispanic households receive \$15.08 less than White households from land conservation actions, and Asian households receive \$7.81 less. All income quartile coefficients are positive with monotonic and statistically significant increases in coefficient size. Households in the wealthiest income quartile accrue \$31.16 more in equity gain from land conservation than those in the poorest.

Column 4 of Table 1 is the same as Column 3 but focuses on within-neighborhood (census tract) distribution. This specification explores possible mechanisms leading to inequitable Equity Gain distributions: wealthy towns raising and spending more money on conservation locally, and constraints to conservation opportunities in urban areas. The coefficient on Black/Hispanic is no longer statistically different than zero, and the coefficient for Asian households changes sign. The wealthier income quartile coefficients decrease in magnitude but remain statistically significant. Strong, regressive disparities across income quartiles persist. The findings provide partial support for the proposed mechanisms, but due to household sorting and historical residential legacies, there is less within-tract variation to identify differences, which limits conclusions.[§]

‡Ref. 23 finds that communities in the wealthiest income quartile have almost double the amount of proximate protected open space as those in the poorest quartile; our results are conservative in comparison.

§See *SI Appendix*, Table S8 for this specification with alternative fixed effects.

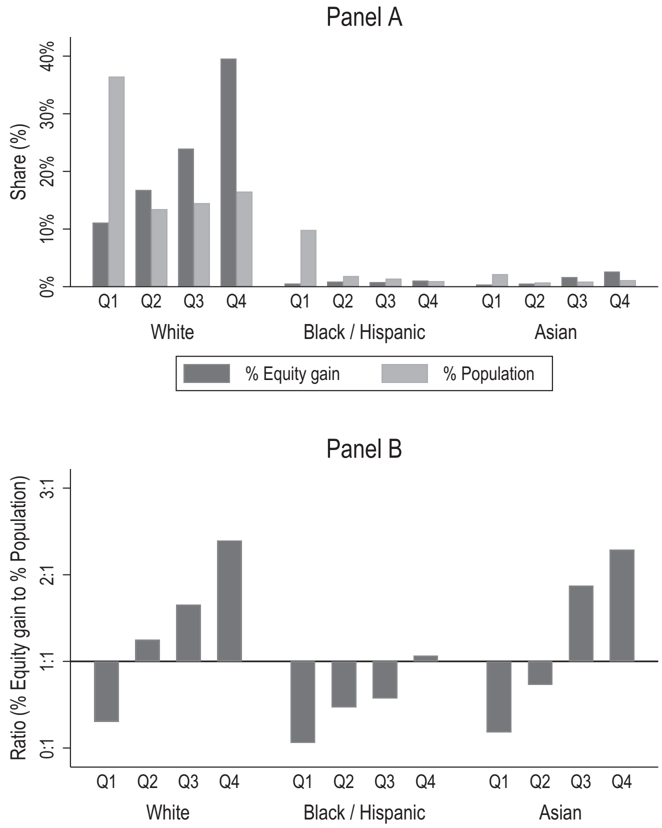

Fig. 2. Distributions of equity gain and population share in massachusetts. Notes: In *A*, the dark gray bars present the total Equity Gain to homeowners from conservation in MA (from 1998 to 2016). Homeowner Equity Gain from Conservation is calculated as the product of the property capitalization coefficient from Column 4 in *SI Appendix*, Table S4, the purchase price of the property (adjusted for inflation), and Future Protected Acres. The light gray bars present the household population shares for income by race/ethnicity groups. These population data come from the 2016 American Community Survey (5 y). In *B*, the bars present the ratio of % Equity gain to % Population for each income by race/ethnicity group; a ratio of one implies proportionate gains. Income quartiles are defined as Q1 ≤ \$66,314, Q2 ∈(\$66,314, \$95,514], Q3 ∈(\$95,514, \$139,599], and Q4 > \$139,599. N = 499,002. See *SI Appendix*, Table S9 for a tabular version of these data.

Finally, we assess how total capitalized gains from conservation are distributed among various groups. Fig. 2*A* shows the percent share of total equity gain for each income quartile by race and ethnicity in Massachusetts. These shares are calculated by summing equity gain for houses owned by people in each group and dividing by the total equity gain across all groups; regression estimates from Table 1 are not used. We find that White households capture 91.4% of total equity gain, whereas Asian households capture only 5.3% and Black/Hispanic households only 3.3%. There are also significant disparities across income groups. The wealthiest households (Q4) receive 43% of equity gain, whereas the lowest income households (Q1) receive only 12%. Intersectionality is important; White Q4 households capture 40% of equity gain compared to 1% for Black/Hispanic Q4 households and 11% for White households in Q1.

Panel *B* presents the ratio of share of equity gained to share of the total population in each group to assess whether the distribution of benefits is proportional. The patterns show the total equity gain generated from conservation flows disproportionately to wealthy and White households. Black and Hispanic households are particularly disadvantaged, with Q1-3 receiving disproportionately less equity gain (ranging from 43 to 94% less than proportionate benefits), and Q4 receiving essentially proportional benefits. In contrast, for Whites, only Q1 households receive less than proportionate benefits, while Q2-4 have disproportionately high benefits with the ratio growing monotonically with income. Q4 Whites gain 140% more than would be with an equal distribution. Asian benefits are highly dependent on income, with Q1-2 receiving disproportionately less and Q3-4 receiving disproportionately more.

Distribution of Benefit Results in the United States. To explore the representativeness of the Massachusetts findings, we report the results of similar analyses using spatially aggregate data from the conterminous United States. Column 5 of Table 1 shows how the mean equity gain per homeowner from conservation actions 2001 to 2009 in a particular block group relates to the income and race/ethnicity composition in that block group. The results of this US equity gain analysis are consistent with our Massachusetts analysis. The coefficients imply that a one–percentage point increase in Black or Hispanic households within a block group is associated with \$0.68 less mean equity gain per household relative to White households. The difference in equity gain is even greater for a percentage point increase in Asian households (\$3.79 less than Whites). In terms of income, our results exhibit the same monotonic relationship seen before, suggesting that homeowners of a block group in the richest quartile benefit \$153.22 more than homeowners of block groups in the poorest quartile.

Column 6 of Table 1 is the same as Column 5 but focuses on within-neighborhood (census tract) distribution. Similar to Column 4, this specification tests mechanisms related to differences in area priorities and capacities. Differences between race and ethnic groups attenuate to zero, and differences between income quartiles also attenuate in magnitude by about half but maintain statistical significance. One interpretation of these results is that the priorities and capacities of different areas are part of the cause of unequal equity gain. However, an important caveat is the limited amount of within-tract variation, which would naturally attenuate differences.[¶]

Fig. 3 shows the distribution of total equity gain from protected areas in the United States. During 2001 to 2009, new land conservation generated \$9.8 billion in home equity across the United States. Panel *A* shows that White households captured 89% of total equity gain, Black and Hispanic households receive only 9%, and Asian households only 2%. Within each race/ethnicity group, equity gain is positively correlated with income. The wealthiest White households capture 44% of the total equity gain from conservation while accounting for only 23.5% of the population. Indeed, Panel *B* shows Q4 households in all racial and ethnic groups of the region see greater than proportional benefits, although Black or Hispanic Q4 households receive only 38% more than proportionate shares of the gains and Q4 Asians 39% more, whereas Q4 Whites receive 89% more. In contrast, only 1.7% of equity gain flows to Q1 Black, Hispanic, and Asian households combined, despite that group comprising 7.5% of the population.[#]

Discussion

We find that land conservation creates wealth for proximate homeowners and that wealth accrues disproportionately to White and

¶There are only 3.19 block groups per tract on average in the year 2000 [49]. See *SI Appendix*, Table S20 for this specification with alternative fixed effects.

#These calculations may underestimate inequities because they implicitly assume equal likelihood of homeownership across race, ethnicity, and income groups and thus likely overestimate the home equity flowing to disadvantaged groups.

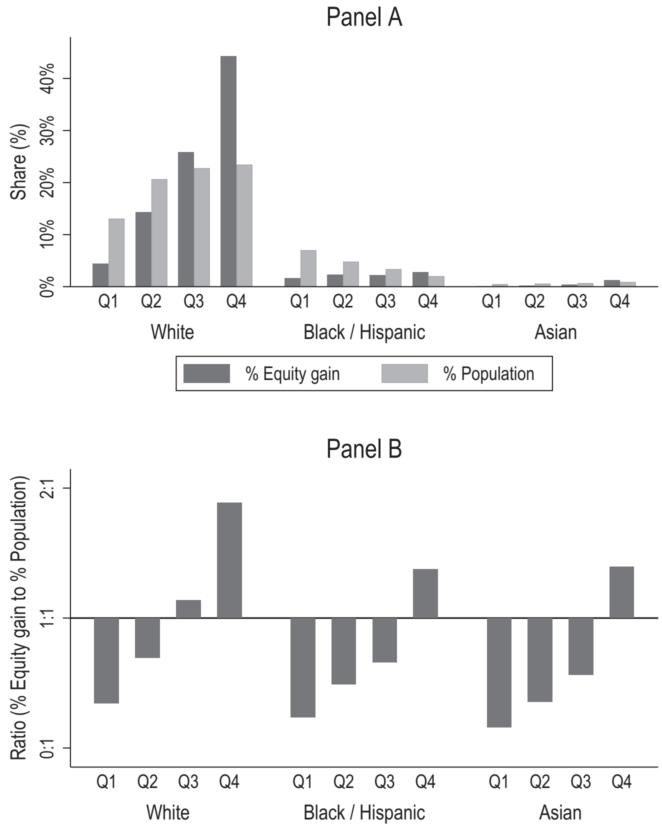

Fig. 3. Distribution of equity gain and population share in the united states. Notes: In *A*, the dark gray bars present the total Equity Gain from new conservation (2001 to 2009) by homeowners for income by race/ethnicity group. Equity Gain is calculated by block group as the product of the property capitalization coefficient from Column 3 in *SI Appendix,* Table S17, the median block group house price, the number of homeowner households in the block group, and the block group's Protected Area Increase. Each block group's Equity Gain is distributed among race/ethnicity and income groups as follows: The block group is classified into an income quartile based on its median income relative to the state income distribution, and within that quartile equity is distributed to race/ethnicity groups proportionately based on the block group's population. The lighter gray bars present the total population share by income and race/ethnicity groups. In *B*, the bars present the ratio of % Equity Gain to % Population for each income by race/ethnicity group; a ratio of one implies proportionate gains. Income quartiles for each block group are assigned based on MSA-level income distributions weighted by the total number of households. Demographic and housing data are from 2000 census. Details are in *SI Appendix,* section 5. N = 186,144. See *SI Appendix,* Table S21 for a tabular version of these data.

wealthier homeowners. There is a persistent and large Black–White wealth gap in the United States (38); our results suggest that land conservation actions are exacerbating that gap.

Our analysis of fine-scale conservation and homeownership data in Massachusetts shows that land conservation increases housing values. On average, a 10-acre increase in protected open space within a quarter mile of a property is associated with a positive increase of $659 in the property value such that land conserved in Massachusetts alone from 1998 to 2016 created about $62 million of increased housing equity. However, we document socioeconomic disparity in who gains that value. Not only are privileged groups more likely to locate near conserved land, they are more likely to be exposed to more future conservation. Overall, White households in the richest income quartile receive 40% of equity gain benefits, which is 140% more than would be expected under an equal distribution. In contrast, Black and Hispanic households in the poorest income quartile receive only 0.56% of total equity gain benefits, which is 94% less than would be expected under an equal distribution.

A more aggregate analysis of the entire United States finds similar patterns, with a majority of financial benefits flowing to predominantly White and wealthier neighborhoods. While minority households account for one fifth of our sample population in the United States, they only receive 11% of the total equity gain from new conservation during this period. Furthermore, the poorest Asian and Black/Hispanic households combined only capture approximately 1.7% of total equity gain despite accounting for 7.5% of the population.

These findings provide strong evidence regarding inequity in some of the benefits of land conservation in the United States. Those findings may not be surprising given pervasive segregation in the United States (32) and well-documented disparities in access to green space and nature (39). However, the magnitude of this monetary inequity is large and important to document for consideration as policymakers consider suites of different environmental management actions that may collectively yield equitable benefits overall. Currently, conservation decisions are typically focused on the ecological value and opportunistically based on what land is available. Land trusts have a growing awareness of diversity, equity, and inclusion issues, but it is a relatively new awareness that is not reflected in mission statements, and land trusts can feel constrained by the area they serve (40).

This research necessarily provides only a limited view of the fairness of benefits that flow from protected areas to people because we measure only impacts on the financial wealth in the form of house value that flows to homeowners. This analysis excludes several other important kinds of effects. First, protected areas provide a range of nonpecuniary benefits from aesthetics, recreation, air quality, water quality, and existence value of biodiversity that people can gain even if they do not own or even rent housing nearby. Valuation research has largely overlooked questions about how those benefits accrue to people in different socioeconomic groups. Second, we study only changes in the values of homes and implicitly assume that protected areas have no financial impacts on renters. However, if conservation drives property values and rents up, that could be financially disadvantageous to renters, who are disproportionately low-income and minority households. The net welfare effects of land conservation on renters have not been studied. Both of these subjects are valuable areas for future research that provides a more comprehensive understanding of how land conservation activity affects overall patterns of environmental and social equity.

Materials and Methods

Massachusetts Data. We use data from three sources in the analysis of the effects of land conservation in Massachusetts and clean the data as described in *SI Appendix,* section 1.

Conserved land data. We gather detailed spatial records from the USGS Protected Area Database (PAD) (34). These data contain comprehensive and historical information on conserved parcels throughout Massachusetts. One limitation is that 52% of conserved parcels in the data do not have recorded dates of conservation. Based on manual inspection, it is relatively safe to assume all of these undated parcels were conserved before 1998, likely many decades prior (see *SI Appendix,* section 1 for more details). We define protected open space as land parcels contained within the PAD that include protected open space, easements, and resource lands owned in fee by agencies and nonprofits that serve natural, recreational, or cultural uses.

House transaction data. Property transaction and assessment data were purchased from The First American Data Tree for the state of Massachusetts from 1998 to 2016. These data include sales price, date of sale, geographic coordinates, housing characteristics, and loan amount.

Buyer characteristics data. The Home Mortgage Disclosure Act (HMDA) requires financial institutions to publicly report individual-level loan data that contain socioeconomic information of applicants. We collect data on all mortgage applications in Massachusetts during our research period from the HMDA dataset. This includes the applicant's race, gender, income, and loan information such as location, amount, year, lender name, and purpose.

Statistical Analyses for Massachusetts.

Property capitalization analysis in massachusetts. To construct a dataset for the property capitalization analysis, property data and open space parcel data are merged using GIS. Property locations are obtained using the geographic coordinates included in the property records. Following previous research (30, 36, 41), we create distance bands of one quarter mile around each property in our transaction dataset and calculate the amount of protected open space that overlaps with these distance bands. This quantifies the amount of open space within a quarter mile of each property each time it is sold from 1998 to 2016. *SI Appendix,* Table S1 Panel *A* provides summary statistics for the 693,085 transactions in the property capitalization data construction.

We use this dataset to estimate a hedonic price model of the determinants of a house's sale price as follows:

$$\ln(p_{ict}) = \beta ProtectedAcres_{ict} + \boldsymbol{X_i}\boldsymbol{\varphi} + \theta_{ct} + \varepsilon_{ict}, \quad [1]$$

where $\ln(p_{ict})$ is the natural log of sales price of property i in location c in year t, $ProtectedAcres_{ict}$ is the number of conserved acres within a quarter mile radius, $\boldsymbol{X}_i$ is a vector of time-invariant structural characteristics of a house such as bedrooms and lot size, and ε_{ict} is the error term. Previous studies (30, 35, 37, 42, 43) observe that the distribution of conserved land is nonrandom due to spatial characteristics that may be correlated with a property's value. We include census tract by year fixed effects, θ_{ct}, that flexibly control for tract-specific price trends to mitigate bias from this type of endogeneity. The parameter β is identified by spatial and temporal variations in proximate open space.[‖]

Distribution of benefit analyses in massachusetts. We merge the HMDA data and property transaction data by loan amount, year of sale/loan, lender name, and census tract. Consistent with previous work (44–46), we matched approximately 64% of the eligible HMDA records. This merge provides socioeconomic information for households purchasing a property. We calculate equity gain at the household level by multiplying Future Protected Acres by the inflation-adjusted purchase price of the house and the estimated coefficient of property capitalization (β from Eq. **1**, Column 4, *SI Appendix,* Table S4). Massachusetts conservation actions over years 1998 to 2016 generated approximately $62 million in total new wealth equity for homeowners. However, because we must observe a home purchase to assign equity to a specific household and the HMDA match rate is only 64%, we can only assign $13 million of this equity gain to households with known race/ethnicity and income.

SI Appendix, Table S1 Panel *B* provides summary statistics of the 540,336 households in the Massachusetts Household Attributes Sample. This sample reflects census estimates of Massachusetts homeowners (*SI Appendix,* Table S2). We use these data in three regressions to quantify the correlations between a household's socioeconomic features and the extent to which they benefit from protected areas.

First, with a version of the data that has one observation for every house sale, we regress the amount of proximate open space associated with a property being bought on the race, ethnicity, and income level of the buying household h:

$$ProtectedAcres_{ht} = \beta_1 Black/Hisp_h + \beta_2 Asian_h + \beta_3 IncomeQuartile2_h + \beta_4 IncomeQuartile3_h + \beta_5 IncomeQuartile4_h + \delta_t + \varepsilon_{ht}, \quad [2]$$

where $ProtectedAcres_{ht}$ is the number of conserved acres within a one quarter mile radius of household h in year t, $Black/Hisp_h$ is an indicator variable for whether the household buying the property is Black and/or Hispanic, $Asian_h$ is an indicator variable for whether the household is Asian, and δ_t is sale year fixed effects. The *IncomeQuartile* variables are indicators for whether the household is in an income quartile of this sample where Q1 ≤ $66,314, Q2 ∈($66,314, $95,514], Q3 ∈($95,514, $139,599], and Q4 > $139,599. These cutoffs are high because low-income households are less likely to be homeowners (*SI Appendix,* Fig. S3).

Second, we examine whether different types of households are exposed to different amounts of new, proximate land conservation after they move in. We define $FutureProtectedAcres_{ht}$ as the number of new conservation acres within a one quarter mile radius that occur during household h's tenure starting in year t, and we regress that variable on the household's race, ethnicity, and income quartile:

$$\begin{aligned} FutureProtectedAcres_{ht} = {} & \beta_1 Black/Hisp_h + \beta_2 Asian_h \\ & + \beta_3 IncomeQuartile2_h + \beta_4 IncomeQuartile3_h \\ & + \beta_5 IncomeQuartile4_h + \delta_t + \varepsilon_{ht} \end{aligned} \quad [3]$$

Third, we return to the full household dataset to quantify which factors are correlated with the equity that household h gains from new protected acres being established near where they own a house at any time during our study period. The data are collapsed to have one observation per household, and the equity gain model is follows:

$$\begin{aligned} EquityGain_{ht} = {} & \beta_1 Black/Hisp_h + \beta_2 Asian_h \\ & + \beta_3 IncomeQuartile2_h + \beta_4 IncomeQuartile3_h \\ & + \beta_5 IncomeQuartile4_h + \delta_t + \varepsilon_{ht} \end{aligned} \quad [4]$$

The variable $EquityGain_{ht}$ is calculated in two steps. First, we multiply Future Protected Acres by the price of the house and the coefficient of property capitalization. Second, we add up all equity gained by a household if they owned multiple consecutive houses, so there is only one observation per household, indexed by the year of their most recent transaction. The other variables are as defined in Eq. **2**.[**]

Property capitalization and distribution of benefit analyses of the united states. We conduct a similar set of analyses for the United States using data at the block group level rather than data on individual households. Details of the data and analyses are in *SI Appendix*, sections 4–6.

Data, Materials, and Software Availability. Replication code and data are available from Dryad at (https://doi.org/10.5061/dryad.w3r2280vr) (47). This includes anonymized Massachusetts data other than property transactions and all US data. Massachusetts housing transactions are proprietary and cannot be shared by the authors, though the data are available from First American Data and Analytics (https://dna.firstam.com/property-research).

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‖Eq. **1** assumes that capitalization does not extend beyond one quarter mile, that prices do not capitalize future conservation, and that all types of land yield equal capitalization rates. All three assumptions are tested and supported. Guided by ref. (50), we find no evidence of capitalization rates correlating with neighborhood demographics, ruling out this channel for unequal benefits. See *SI Appendix*, section 3.

See *SI Appendix*, section 3 for Eqs. **2–**4** estimated with a range of fixed effects. Additionally, we estimate a model similar to Eq. **4** in *SI Appendix*, Table S14 that interacts race/ethnicity variables with income quartiles. The results exhibit similar patterns but also show the importance of intersectionality in understanding disparities.

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