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Review

Sprawling and diverse: The changing U.S. population and implications for public lands in the 21st Century

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ABSTRACT

Public lands are typically established in recognition of their unique ecological value, yet both ecological and social values of public lands change over time, along with human distribution and land use. These transformations are evident even in developed countries with long histories of public land management, such as the United States. The 20th Century saw dramatic changes in the American population, in distribution and in racial and ethnic diversity, leading to new challenges and new roles for public lands. Our goal with this paper is to review changing demographics and implications for terrestrial protected areas in the U.S. We overview the fundamentals of population change and data, review past trends in population change and housing growth and their impacts on public lands, and then analyze the most recent decade of demographic change (2000–2010) relative to public lands. Discussions of demographic change and public lands commonly focus on the rural West, but we show that the South is also experiencing substantial change in rural areas with public lands, including Hispanic population growth. We identify those places, rural and urban, where demographic change (2000–2010), including diversification and housing growth, coincide with public lands. Understanding the current trends and long-term demographic context for recent changes in populations can help land managers and conservation scientists mitigate the effects of residential development near public lands, serve a more diverse population, and anticipate future population changes.

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1. Introduction

Public lands are important ecological and social resources, protecting biodiversity, ecosystem processes, and cultural heritage, while providing invaluable social, economic, and health benefits. Although protected in perpetuity, and considered the bulwark of biodiversity conservation, the ecological and social value of these lands is not fixed. Human presence and land-use intensification in the vicinity of public lands have profound consequences on ecological functioning within these lands (Pringle, 2000; Hansen et al., 2005). These populations adjacent to public lands also benefit from the ecosystem services (recreational, cultural, and economic) provided by public lands. Understanding human population composition and change in the vicinity of public lands is therefore important not only to anticipate environmental impacts of population change on public lands, but also to understand the ecosystem services used and desired by local populations. Working with populations around public lands to balance ecological functioning of public lands and sustained provisioning of ecosystem services is increasingly emphasized in public land management (Mace, 2014).

Dynamics about public lands and population change are often studied in developing countries, particularly where protected areas have recently been established (Naughton-Treves et al., 2005). Here, research frequently focuses on land cover change (i.e., deforestation) as a result of population change (DeFries et al., 2005), and the impacts of land protection on human livelihoods (Wilkie et al., 2006). However, understanding population change over time remains important in developed countries, such as the United States, where protected areas have a long history of establishment: the world's first National Park, Yellowstone, was created in 1872 and the first National Forest in 1891. Since public lands were first established in the U.S., the population has transformed in size, distribution, and composition, with widespread ramifications for the use and value of these lands.

Over the past century, the U.S. population grew from 92 million people in 1910 to 309 million people in 2010 (325 million as of 2017), shifted in distribution towards the West and South, expanded in residential footprint, and became far more diverse (Hobbs and Stoops, 2002; Brown et al., 2005; US Census Bureau, 2017; U.S. Census Bureau, 2011). As rates of population increase have slowed in recent decades, the environmental impacts of population redistribution and migration are often most directly expressed through residential development, particularly exurban growth or sprawl (Brown et al., 2005). Changes in distribution and composition have also had profound impacts for public lands' value to society (Teel and Manfredo, 2010; Weber and Sultana, 2013). The increasing racial and ethnic diversity of the American population has particularly important implications for public land management, as managers work to understand how diversification affects social values and desires for public lands, to provide equitable access to public lands as a matter of environmental justice, and to maintain political support for public lands among a diversifying public (Roberts et al., 2009; Vander Naald and Cameron, 2017).

However, understanding population change and its implications for public lands can be challenging: the spatial scales at which demographic data are collected are often inconsistent with the data used by land managers and ecologists (Syphard et al., 2009; Ruther et al., 2015), and the impacts of demographic change may unfold over long time scales. Furthermore, effects of demographic change on public lands are typically studied by different disciplines: conservation biologists and ecologists examine the effects of population change and housing growth on biodiversity and ecological processes in public lands (e.g., Hansen et al. (2005)), while social scientists examine attitudes about and use of public lands (e.g., Byrne and Wolch (2009)). Social science research has typically focused on either rural change resulting from in-migration to rural areas, also called amenity development (McGranahan, 1999; Winkler et al., 2007; Gosnell and Abrams, 2011), or on urban change occurring through increasing racial and ethnic diversity and its effects on public land use (Struglia and Winter 2002; Byrne and Wolch, 2009; Fernandez et al., 2015). Changing racial and ethnic population composition is rarely considered along with amenity development, even though diversification coincides with amenity migration in some places (Nelson et al., 2009).

Our goal with this paper is to review changing demographics and implications for public land management in the U.S. We focus on the U.S. as it has a long history of public land establishment, and the population trends found here—diversifying population and expanding residential footprint, particularly around public lands—are relevant to many other developed countries (McGuirk and Argent, 2011; Bradbury et al., 2014; Castro-Prieto et al., 2017). We first provide background on past patterns of demographic change and implications for public land management. We then examine recent demographic change and housing growth (2000–2010) in relation to public lands and identify those counties where public lands, housing growth, and racial and ethnic diversity coincide. We include those federally, state, or locally owned public lands identified in the Protected Areas Database (The Conservation Biology Institute, 2012) in the conterminous U.S., using the term “public lands” because levels of protection and use vary with ownership (although residential and commercial development are excluded from all after establishment). By including all publicly owned lands in the conterminous U.S. we can provide a complete picture of population change (including racial and ethnic diversification) and management implications, in urban and rural areas.

2. Overview of past population and housing change and impacts for public lands

2.1. Past population growth and redistribution

The U.S. population has more than tripled in size over the past 100 years, yet population growth rates in the U.S. are generally declining, similar to other developed countries (Hobbs and Stoops, 2002; Allendorf and Allendorf, 2012). Between the last two decadal censuses (2000–2010) the U.S. population grew only 9.7 percent, the lowest growth rate since the 1930s (Mackun et al., 2011). The environmental impacts of recent population change stem, therefore, not from runaway population growth, but rather population redistribution and the expansion of residential development, particularly at low densities (exurban growth or sprawl) (Brown et al., 2005).

As the rate of natural increase (births minus deaths) diminished after the baby boom, migration emerged as the most powerful force in population change (Johnson et al., 2005b). Today, about 12

percent of the U.S. population changes place of residence each year, fewer than on average during the 20th Century, but still a higher rate than in most developed countries (Molloy et al., 2011). Many of these are short-distance moves, often within the same county (Molloy et al., 2011). However, the cumulative effect of longer-distance migration has been a substantial redistribution of the U.S. population over the past century, with strong population gains in recent decades in the West and the South (Fig. 1). Migration to the South and West was fostered by shifts in industrial relocation, growth of the service economy, improved communication and transportation infrastructure, air-conditioning, reduced racial discrimination, and increased appeal of areas with natural amenities, such as public lands, forests, mountains, coasts, and temperate climates (McGranahan, 1999; Johnson, 2013).

Migration and residential development has also changed the distribution of population between rural and urban areas. One of the most commonly used definitions divides counties into metropolitan (metro) or urban, and nonmetropolitan (nonmetro) or rural (75 Federal Register 123 2010) (different from the Census Bureau's sub-county definitions of urban and rural places (76 Federal Register 164 2011)). Both the number of metropolitan counties and the proportion of the population residing in them have increased substantially over time. After the 2010 Census, metro counties contained 84% of the total population and covered 26% of the land area of the country (Wilson et al., 2012). Although the U.S. as a whole has become more urban, actual population and housing gains have consistently been greater on the outer periphery of urban areas (suburban and exurban places) (Johnson et al., 2005a). This "population deconcentration" was fueled by economic prosperity, changing cultural tastes, and transportation innovations (Johnson and Cromartie, 2006). In addition, some nonmetropolitan, or rural, areas have experienced substantial in-migration and residential development since the 1970s, fueled by demand for natural amenities as well as desires for small-town lifestyles (McGranahan, 1999; Gosnell and Abrams, 2011). In the 1970s, nonmetro counties actually grew faster than metro counties, reversing decades-long trends of out-migration and population decline. Amenity migration to nonmetropolitan areas continued at lower levels in the 1990s and 2000s, although rural areas lacking in natural amenities—i.e., Great Plains and Midwest—experienced protracted out-migration and population decline (Johnson, 2013). Concerns about the environmental impacts of expanding and deconcentrating population led to a proliferation of studies of the ecological effects of expanding residential land use (Hansen et al., 2005; Radeloff et al., 2010; Wood et al., 2014).

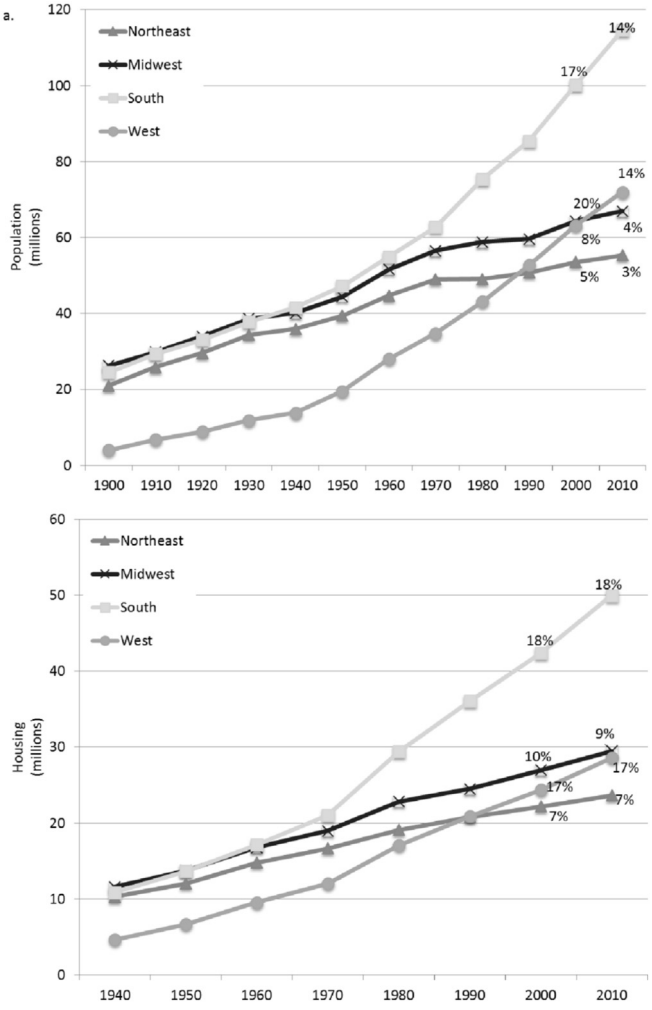

Fig. 1. Population (a) and housing (b) change (in millions) for each census region, over the past Century, including percent growth rates for 1990s and 2000s. Housing was only included in the decennial census from 1940 onward.

2.2. Changing residential development, environmental impacts, and implications for public lands

As population redistributed, ecologists realized the environmental impacts of this change is primarily expressed through residential development, including the number, location, and characteristics of households (Liu et al., 2003; Allendorf and Allendorf, 2012). Declining average household size and increasing prevalence of second homes means that the number of households and housing units is rising faster in the U.S. than population (Bradbury et al., 2014). Between 1940 and 2010, the number of houses increased by 352 percent compared to a population gain of 234 percent (Fig. 1). In each Census Region, housing growth rates exceeded population growth rates for the past two decades (Fig. 1) (Throughout this review we use the four Census Bureau Regions: Northeast, Midwest, South, and West, labeled on all maps).

The expansion of residential land use has profound impacts on ecosystem health and functioning (Pringle, 2000; Hansen et al., 2005; Bar-Massada et al., 2014; Wood et al., 2014). Construction of housing and associated infrastructure removes and fragments vegetation, increases impervious surface, spreads pollutants, and changes nutrient and biogeochemical cycles (Hansen et al., 2005; Kaushal et al., 2006; McKinney, 2006). Residential development adjacent to and among wildland vegetation alters the frequency and intensity of wildfires, increasing the cost and difficulty of wildfire management (Bar-Massada et al., 2014). Homeowners may exacerbate these effects through landscaping and supporting predatory domestic pets (Lepczyk et al., 2004; Gavier-Pizarro et al., 2010). As the area occupied by housing and impervious surface increases, biodiversity declines, native species decrease in abundance and richness, and synanthropic species increase (Hansen et al., 2005; McKinney, 2006).

The form and extent of residential development has also changed over time: both on the edges of urban areas and in rural areas, housing development is now commonly dispersed at low densities, sometimes referred to as sprawl or exurban development (Brown et al., 2005; Hammer et al., 2009a). Nationally, low-density development expanded from 5% of the conterminous U.S.in 1950 to 25% by 2000 (Brown et al., 2005). Dispersed development is of particular concern for ecologists and natural resource managers as it extends the impacts of each house over a larger area, increasing the cumulative footprint of development (Hansen et al., 2005,

Leinwand et al., 2010). The impacts of residential development also spread beyond individual homes to alter natural resources and ecosystem functioning in adjacent wildlands and public lands (Hansen and DeFries, 2007). For example, housing development at the boundary of public lands degrades the avian communities within, favoring synanthropic species and decreasing species of conservation concern (Wood et al., 2014). Similarly, in the western U.S., extirpation rates of large mammals within National Parks increased with human population density outside park boundaries (Parks and Harcourt, 2002). In urban areas as well, expanding residential land use and encroachment can negatively impact vegetation and biodiversity within protected areas (Hostetler and McIntyre, 2001; McWilliam et al., 2014; Beninde et al., 2015).

Effects of housing development on public lands have been most commonly studied outside larger public lands, such as U.S. National Parks, or other federal land holdings, often located in rural areas. These public lands have been particularly affected by the rise of amenity migration and population redistribution to the West (where many large federal public lands are located, Supplemental Figure) (Radeloff et al., 2010; Wade and Theobald, 2010; Davis and Hansen, 2011; Piekielek and Hansen, 2012). For example, around the largest National Parks ($n = 57$), housing density increased at rates well in excess of national averages from 1940 to 2000 (329% versus 210%) (Davis and Hansen, 2011). By 2000, a full 24% of the private land around these parks was at exurban or rural housing densities (Davis and Hansen, 2011). Housing growth around public lands (wilderness areas, National Parks, and National Forests) was especially pronounced during the 1990s, when housing within 1 km of these areas increased by 20%, in contrast to 13% growth nationally (Radeloff et al., 2010).

As populations and housing increase near public lands, managers must contend with the complexity of managing natural resources in a rapidly changing social context. An influx of amenity-seeking migrants typically coincides with broader economic restructuring, including the decline of extractive industries and the growth of service-based and recreation-focused economies (Gosnell and Abrams, 2011). A substantial proportion of migrants are retirees who are older and wealthier than typical residents (Gosnell and Abrams, 2011). Many of the existing studies of natural resource management under such changing conditions have focused on the differences between long-term residents and newly arrived migrants (Smith and Krannich, 2000). Migrants to rural, high-amenity areas, often differ from longer-term residents in their socioeconomic characteristics and perspectives on natural resource management, on both public and private land (Gosnell and Abrams, 2011; Qin, 2016). These differences may be highlighted by the challenges of ongoing development, which is expected to continue as baby-boomers relocate with retirement (Hammer et al., 2009b). Assuming a moderate projection scenario, demographers anticipate the rural and small-town population of 55–75 year olds will reach 14.2 million by 2020, a two-thirds increase from 2000 (Cromartie and Nelson, 2009). Less research has examined how amenity migration and racial and ethnic diversity interact. In some cases, migration may lead to conflicts between amenity migrants (typically older and white non-Hispanic) and established land management or resource use traditions of minority groups (e.g., Native Americans (McAvoy, 2002), Hispanic residents in New Mexico (Macias, 2008), African-Americans in South Carolina (Hurley and Halfacre, 2011)). Some locations also see diversification with amenity migration, as changing labor markets and expanding service industries draw Hispanic populations (Nelson et al., 2009), yet little research has examined the implications of such linked amenity migration and diversification for public land management.

2.3. Increasing diversity and implications for public lands

There have been broad changes in the racial and ethnic diversity of the American public over the last century. At the start of the 20th Century, when Theodore Roosevelt became President of the U.S., and domestic natural resource management became a policy priority, 87.5% of the U.S. population was majority, or white non-Hispanic (Hobbs and Stoops, 2002). By 2010, just 63.7% of the population was white non-Hispanic. We recognize that race and ethnicity are socially constructed, and their definitions have changed over time. Current racial categories include (1) white, (2) black or African American, (3) Asian, (4) American Indian and Alaska Native, and (5) Native Hawaiian and other Pacific Islander (Office of Management and Budget, 1997). Individuals can also choose 'other' race, and starting in 2000, could select more than one race. The two ethnic groups are Hispanic (or Latino) and non-Hispanic, first included on the 1980 decennial census. Here we classify an individual as minority if they are Hispanic or not white. As of 2010, minorities were broadly represented in the U.S. population, including Hispanics (16.3%), African-Americans (12.6%), and Asians (4.8%) (Humes et al., 2011). By 2020, nearly half of the under 18 population is expected to be minority, with the country as a whole achieving "majority-minority" status by 2044 (U.S. Census Bureau, 2014).

Much of this diversification began after 1970, fueled by immigration from Latin America and Asia (Gibson and Jung, 2006). Hispanic populations more than doubled from 1980 to 2000, due to immigration, high fertility, and low mortality (Saenz, 2010). Over the past century, minority populations also redistributed, with populations shifting away from traditional enclaves (for example, black populations in the South, Asian populations on the West Coast, and Hispanics in urban cores and gateway cities in the Southwest). As a result, urban areas are no longer the only areas with diverse populations; minority and immigrant redistribution to new destinations fueled growing rural diversity (Lee and Sharp, 2017). Hispanic population redistribution has been particularly noticeable in rural areas: Hispanics accounted for 54% of the nonmetro gain in population between 2000 and 2010, although they were only 5.4% of the nonmetro population in 2000 (Johnson, 2013).

Growing and redistributing minority populations alter opportunities for public land use, and pose new challenges and opportunities for public land managers tasked with maintaining access and relevance for an increasingly diverse potential user base (e.g., for Federal lands, Exec. Order No. 12898 1994). However, minorities are less likely to recreate on public lands (Cordell, 2012; Vander Naald and Cameron, 2017), due to a variety of cultural and social factors, and as a result visitors to federal public lands remain primarily white. For example, among 51 sites managed by the National Park Service (including National Parks but also cultural sites such as National Battlefields), an average of 93% of visitors from 1999-2010 identified as white, 3.3% as Asian, 2.3% as Native American, 2.1% as black, and 3.8% as Hispanic (all categories could overlap) (Weber and Sultana, 2013). National Forest visitation data collected from 2010-2016 estimated that 95% of all visits were made by those who identified as white, 2.6% as Asian, 3.0% as Native American, 1.3% as black, and 6.0% as Hispanic (all categories could overlap) (National Visitor Use and Monitoring Program, 2018).

Minority population distribution relative to public lands is a key factor in determining rates of public land use by minorities (Fernandez et al., 2015). This underscores the importance of understanding the distribution, migration, and growth of racial and ethnic minorities, between and among groups. Beyond population distribution, reasons for lower rates of public land visitation by minorities include: (1) other challenges with access/economic-

related barriers; (2) cultural factors or preferences for recreation; and (3) discrimination, both current practices and legacies of discrimination and exclusion (Krymkowski et al., 2014). We note that racial and ethnic groups are not homogenous in their attitudes toward and use of public lands; use of public lands is also affected by other socio-demographic factors (age, gender, education, income, acculturation), and characteristics of the public lands themselves (location, facilities, landscapes, safety) (Struglia and Winter 2002; Byrne and Wolch, 2009; Fernandez et al., 2015).

In the past, efforts to increase public land use by diverse groups focused on urban areas where minorities were concentrated. For example, the "parks-to-people" initiative undertaken by the National Park Service established national recreation areas (NRA) in urban settings in the 1970s (Weber and Sultana, 2013). However, these efforts have been only partially successful—for example visitors to the Santa Monica Mountains NRA remain primarily white non-Hispanic (Byrne et al., 2009). However, populations in rural areas are increasingly diverse, with notable growth in Hispanic populations. This potentially has broad implications for recreation as Hispanic immigrants are often more avid recreationists than other minorities (Cordell, 2012; Gaither et al., 2015). For example, some rural Hispanic population increases are tied to amenity migration, which creates jobs in construction and service industries (Nelson et al., 2009). However, research suggests that Hispanic populations in such amenity areas remain geographically isolated from other migrants, with Hispanics clustered in urban centers or in proximity to highways, rather than in the low-density, dispersed development typically associated with amenity migrants (Nelson et al., 2009). Therefore, Hispanic arrivals and amenity migrants would potentially have different environmental impacts through residential development. Nor is it clear whether increasing Hispanic populations in rural amenity destinations alter public land use, or what implications linked minority-amenity migration will have for broader minority access to public lands.

3. Demographic change from 2000-2010 and public lands

3.1. Methods to examine demographic change, 2000–2010, in relation to public lands

To study population change and housing growth in the first decade of the 21st Century, we compared county-level demographic change and proportion of area in public lands, using each Census Region's metro and nonmetro counties (for example, percent population change relative to proportion of public lands for nonmetro counties in the South). We used counties as our unit of analysis because they govern land use and management for much of the U.S. (counties have jurisdiction over unincorporated lands); their boundaries remain stable over time; they are standard reporting units for demographic data; and they are classified as metropolitan or nonmetropolitan by OMB. We conducted analyses for the conterminous U.S. only (2023 nonmetro counties and 1085 metro counties), using federal, state, and local public lands data from the Protected Areas Database U.S. v 2 (The Conservation Biology Institute, 2012). We examined each Census Region separately because public land distribution in the U.S. is uneven, and because past and expected future demographic trends differ by regions. Most public lands are located in the West, are owned mainly by the U.S. Forest Service or the Bureau of Land Management, and are often concentrated in nonmetro counties (Supplemental Figure). The other regions have less public land, more often in state or local ownership, but private land development is extensive, making it important to understand changing population and housing growth in relation to public lands outside of the West.

The data on population and housing came from the 2000 and 2010 decennial censuses. We derived estimates of net migration using the residual method, whereby net migration is the remainder of total population change minus natural increase, i.e., births minus deaths (Johnson et al., 2005a). We used general least squared regression analysis to compare demographic and housing change to the proportion of public lands in each county. We acknowledge that public land base is one of many factors that could influence change in population and housing. Here, we focus on public lands and surrounding population and housing at the county level so that we can conduct nationally consistent analyses, and identify those places where demographic change and public lands intersect.

Our generalized least squares models accounted for spatial autocorrelation among counties by estimating spherical, exponential, or ratio spatial covariance structures of residuals based on the distances between county centroids (see supplementary material for the spatial covariance structure of each model). All statistical analyses were performed using R version 3.2.3 (R Core Team, 2015). Regression models were constructed using the "gls" function in the R package "nlme" (Pinheiro et al., 2015), which uses the restricted log-likelihood method to estimate parameter coefficients and exponential spatial error terms. We compared AIC values to select the variogram shape (exponential, spherical, ratio, Gaussian, or linear) that best fit each model. We assessed model fit by comparing AIC values between the null model (spatial structure and no covariates) and the full model (spatial structure and public land as a covariate), and we calculated pseudo-R2 estimates for our models with the R package "MuMIn" (Bartoń, 2016), which calculates a coefficient of determination based on the likelihood-ratio between full and null models. Spatial autocorrelation of normalized residuals were assessed visually and with Moran's I, computed using the R package "ape" (Paradis et al., 2004). Incorporating range and nugget estimates into the models substantially reduced spatial autocorrelation of residuals, but spatial autocorrelation of residuals remained for several demographic variables (Moran's I values were significant).

In order to visualize trends in the data, we graphed demographic change from 2000 to 2010, grouping counties by their proportion of public land, per region: low (0-20th percentile), moderate (20th-60th percentiles), and high (≥60th percentile). We then created additional figures and tables to identify those places with regionally high amounts of public lands (60-100th percentiles) and changing populations. Regardless of the statistical relationship between rates of change and public lands, those counties with substantial land in public lands and changing population and/or housing from 2000-2010 are the locations where environmental impacts of growth are being felt on public lands, and land management perceptions and attitudes may be changing with new users. We examined the distribution of counties with higher housing growth rates (≥10% housing growth 2000–2010; found in 40% of all counties, nationwide). We also examined relative housing growth, subtracting population growth rates from housing growth rates to map the relative balance of housing growth and population growth. Because Hispanic population change has been one of the most notable trends in diversification over the past 30 years, particularly in nonmetro areas, we then mapped Hispanic population growth for both metro and nonmetropolitan counties with high proportion of public lands (≥60th percentile). Lastly we present data on the overlap between high housing growth and notable minority populations and/or growth, in counties with high proportion of public lands (≥60th percentile).

3.2. Trends in population, housing growth, and public lands, 2000–2010

Changes in population and housing varied with metro status and across regions (Fig. 2). Continuing the trends of past decades, the Northeast and Midwest Regions had lower housing and population change than the South and West (Fig. 2). There were no statistically significant correlations between proportion public land and population and housing change in metro counties (Supplementary Information). In nonmetropolitan areas, the Midwest, West, and South all showed trends of increasing population, housing, and net migration with higher proportion of public lands (Fig. 2), although these relationships were statistically significantly for only some regions: increases in housing growth in the Midwest, in-migration in the West, and population growth, housing growth, and in-migration in the South were all statistically positively related to the proportion of public land (Table 1). For the Midwest, West, and South, therefore, models all showed some evidence of growth correlated with public lands, or potential amenity growth (Table 1, Fig. 2). The decline in natural increase with percent public land in the Northeast was also statistically significant, meaning births were more likely to be outpaced by deaths in a given county

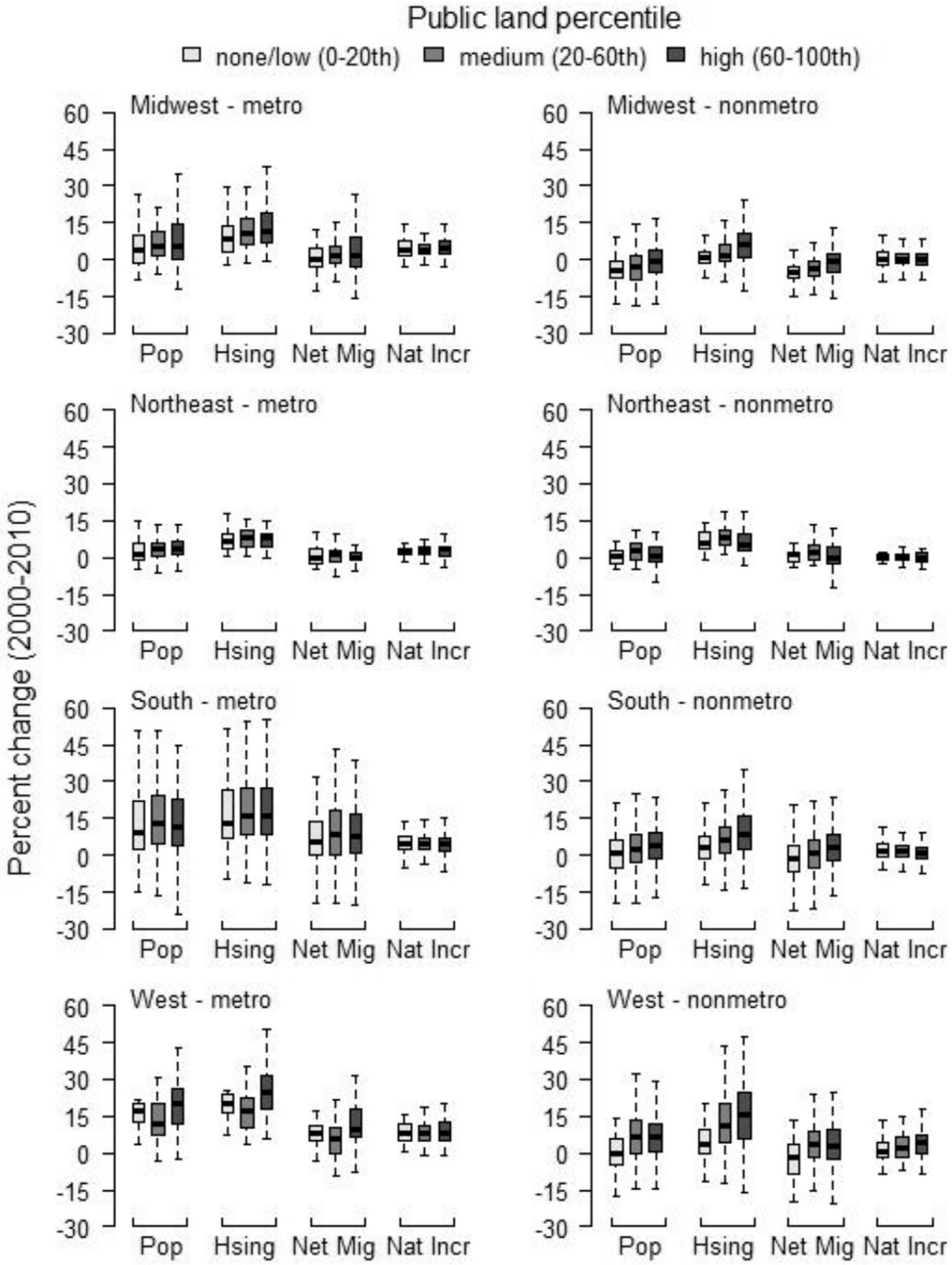

Fig. 2. Boxplots of population growth, housing growth, net migration, and natural increase from 2000-2010 by proportion of public lands for metropolitan (left) and nonmetropolitan counties (right) in each census region.

Table 1
Relationships between percent public land in a county and demographic change from 2000-2010 for nonmetropolitan counties by Census Region (*p-value < 0.05,** p-value <0.01).[a]

Census Region Demographic variable (% change)	Public land (%) - slope coefficient	AIC (null)	AIC (full)	ΔAIC	Pseudo-R^2
Northeast					
Natural increase	−0.08**	432	425	−7	0.150
Black population	2.18*	1173	1168	−5	0.059
Midwest					
Housing	0.07**	4725	4726	1	0.009
Hispanic population	−1.10**	9509	9503	−6	0.010
South					
Population	0.11**	6624	6617	−7	0.016
Net in-migration	0.27**	6552	6488	−64	0.078
Housing	0.34**	6728	6650	−78	0.092
White, non-Hisp. pop.	0.23**	6827	6788	−39	0.051
Hispanic population	1.12**	10535	10521	−14	0.018
West					
Net in-migration	0.06*	2168	2171	3	0.015

[a] Results only shown for models with significant slopes; see Supplementary Materials for additional model results.

as the concentration of public land increased. These models all had weak explanatory power (low pseudo-R^2), which was expected, given the diversity of other social, economic, and environmental factors that influence population change and housing growth.

Housing growth rates of 10% or more in U.S. counties from 2000-2010 were found in just over 40% of all U.S. counties, but distributed unevenly across regions and with public land proportions (Table 2). The Northeast had few counties with such high housing growth rates, regardless of public lands. In other regions, sizeable percentages of metro counties with high proportion of public lands (≥60th percentile) also had high housing growth rates (from 63%-94% of metro counties with high proportion of public lands also had 10% or greater housing growth rates) (Table 2). In the West more than half of all nonmetro counties with high proportion of public lands (≥60th percentile) also had housing growth rates 10% or higher; while such high housing growth rates were less common in nonmetro counties with high proportion of public lands in the South and Midwest (Table 2).

In all regions the vast majority of high proportion of public lands (≥60th percentile) also had housing growth rates that exceeded population growth rates (nonmetro counties in each region had 78%–86% of counties with higher housing growth than population growth; for metro counties 81%–97%) (Fig. 3). For all regions, nonmetro counties had greater divergence between housing and population growth rates; for example, 15% of all nonmetro counties in the West had housing growth rates 16% or greater than population growth rates vs 6.3% of metro counties in the West (Fig. 3). Many of these counties with the highest differences between housing and population growth rates were in well-known amenity areas: mountain and coastal amenity regions in the Northeast and South, forest and lake areas in the Upper Midwest, and the interior West (Fig. 3). Housing loss for all regions was also more common in nonmetro counties (from 5%-19% of all nonmetro counties in each region had housing loss in comparison to 0%–4% of metro counties).

3.3. Changes in racial and ethnicity diversity and public lands, 2000–2010

Across the U.S., minority populations remained unevenly distributed in 2010, with different access to and proximity to public lands (Fig. 4). Diverse counties (≥10% of population in one or more racial/ethnic minority group) were concentrated in the South and West, with less diversity in the Northeast and Midwest, although the Plains States and Upper Midwest have areas with high concentrations of Native Americans (Fig. 4). We use 10% minority population as a reasonable threshold that allows us to highlight diverse places, including those with multiple racial/ethnic minority groups. In each region, some counties had both high racial and ethnic diversity (≥10 percent of population in one or more racial/ethnic minority group) and high proportion public lands (≥60th percentile) (Table 2, Fig. 4). These counties included nonmetro and

Table 2
Counties with notable racial and ethnic diversity (2010), Hispanic population growth (2000–2010), high proportion of public lands (HPL; ≥ 60th percentile), and notable housing growth (2000–2010), by metro and nonmetropolitan status.

Regions	Metro status	All counties					High public land counties (≥60th percentile)			
		n	counties with ≥10% minority	counties with Hispanic growth ≥ 50%	counties with housing growth ≥ 10%	counties ≥ 60th percentile public lands (HPL)	HPL counties with ≥10% minority (% of HPL)	HPL counties with Hispanic growth ≥ 50% (% HPL)	HPL counties with housing growth ≥ 10% (% HPL)	HPL counties with housing growth ≥ 10% and diversity[a] (% HPL)
Northeast	Nonmetro	94	4	68	25	38	2 (5.3%)	25 (65.8%)	9 (23.7%)	6 (15.8%)
	Metro	123	44	87	34	49	19 (38.8%)	36 (73.5%)	11 (22.4%)	10 (20.4%)
Midwest	Nonmetro	770	104	467	131	312	48 (15.4%)	179 (57.4%)	94 (30.1%)	67 (21.5%)
	Metro	285	64	220	156	110	28 (25.5%)	81 (73.6%)	69 (62.7%)	64 (58.2%)
South	Nonmetro	872	591	511	283	321	168 (52.3%)	222 (69.2%)	142 (44.2%)	135 (42.1%)
	Metro	551	372	447	370	248	169 (68.1%)	214 (86.3%)	171 (69%)	169 (68.1%)
West	Nonmetro	288	142	124	147	133	70 (52.6%)	57 (42.9%)	80 (60.2%)	67 (50.4%)
	Metro	126	86	68	106	32	20 (62.5%)	18 (56.3%)	30 (93.8%)	26 (81.3%)
	Total	3109	1407	1992	1252	1243	524 (42.2%)	832 (66.9%)	606 (48.8%)	544 (43.8%)

[a] Either 10% minority in 2010 or Hispanic growth (2000–2010) ≥ 50%.

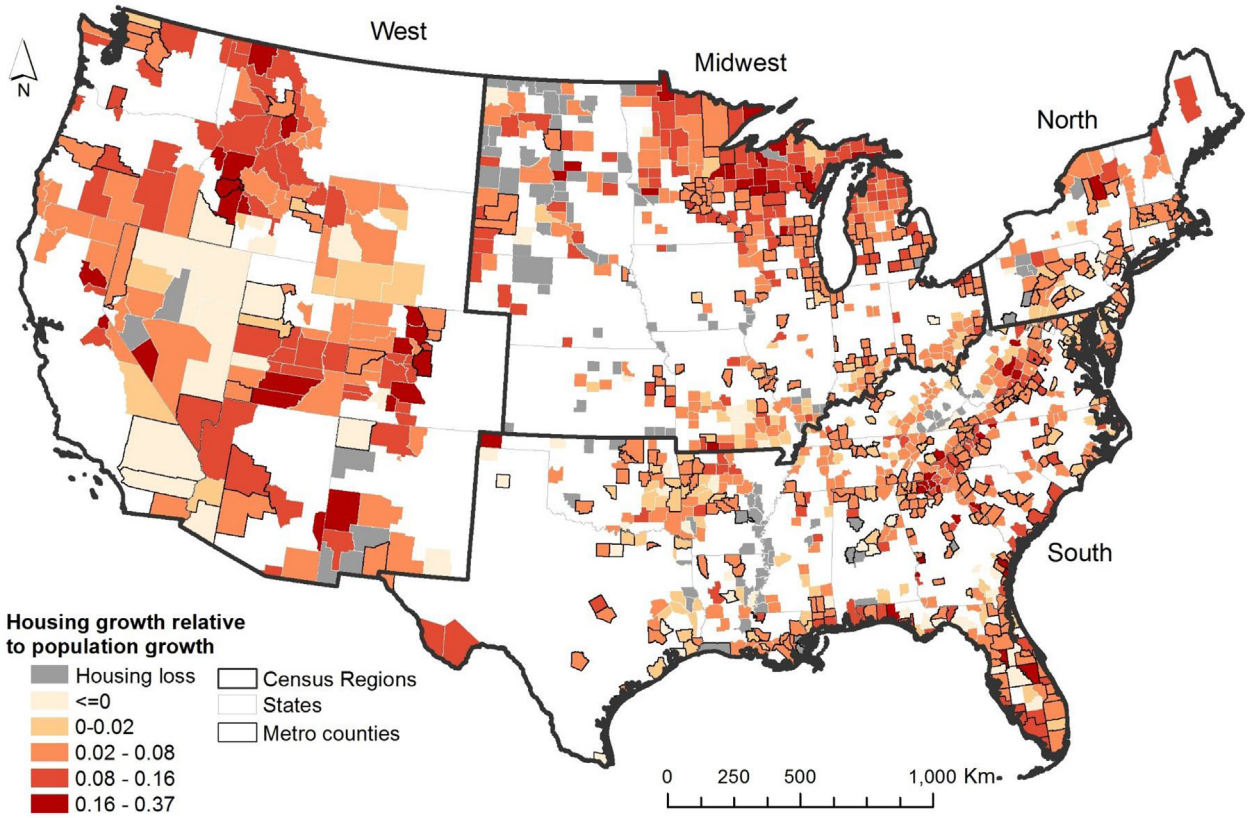

Fig. 3. Housing growth rate relative to population growth for counties with high proportion public lands (≥60th percentile, calculated for each census region).

metro areas—some urban cores that retained minority populations and had relatively high amounts of public lands, as well as rapidly growing cities proximate to public lands. In both the South and the West, more than half of metro and nonmetro counties with higher proportions of public lands also had 10% or more minority populations (Table 2). However, in the West, the vast majority of diverse counties with higher proportions of public lands were nonmetros while in the South equal numbers of metro and nonmetro counties had sizeable minority populations and higher proportions of public lands (Table 2). In the Midwest and Northeast there were fewer counties where public land and minority populations coincided (Table 2).

The growth of racial and ethnic minority populations from 2000-2010 was statistically significantly related to the proportion of land in public ownership in nonmetro counties only (Table 1, Supplemental Tables). Hispanic population growth increased with proportion of public lands in nonmetropolitan counties in the South (Table 1) (n = 872, mean percent change = 79, st. dev. = 103, min = −70, max = 1741), but decreased with proportion of public lands in nonmetropolitan counties in the Midwest (Table 1) (n = 770, mean percent change = 88, standard deviation = 118, min = −100, max = 1550). Black populations increased with proportion of public lands in nonmetropolitan counties in the Northeast (Table 1), driven by a few counties with high percent increase and low starting populations (n = 94, mean percent change = 61, st. dev. = 126, min = −46, max = 1149). White non-Hispanic populations increased in the nonmetropolitan South with increasing proportion of public lands (n = 872, mean percent change = −1, st. dev. = 12, min = −0.51, max = 126). No changes in minority populations were significantly related to public land amount in the West.

Counties with high Hispanic population increase (≥50 percent) and a high proportion of public lands (≥60th percentile) were common in each region, and in both metropolitan and nonmetropolitan counties (Table 2, Fig. 5). In the Northeast, Midwest, and South, 60% or more of all counties with higher proportion of public land (≥60th percentile) also had high Hispanic growth (≥50% increase) (Table 2). Looking at metro counties only, the vast majority with a higher proportion of public lands also had 50% or more growth in Hispanic populations (Table 2). The West started with a larger Hispanic population, and thus had fewer counties with both high proportion of public lands and 50% or more Hispanic growth (Fig. 5). In both the West and Midwest, there were more nonmetro counties than metro counties with high proportion public lands and Hispanic population increase (nonmetro counties outnumber metros by approximately 2:1 in the Midwest and 3:1 in the West) (Table 2). The South, in contrast, had equal numbers of metro and nonmetro counties with a high proportion of public land and high Hispanic increases (Table 2). Locations with high Hispanic growth and high proportion of public lands in the West and South included well-known amenity areas including mountainous counties in the interior West, and mountain and coastal areas in the South (Fig. 5). Counties with high Hispanic growth and public lands in the Midwest and Northeast occurred in a diversity of settings, across metro and nonmetro counties (Fig. 5).

Counties with high proportions of public lands and rapid housing growth typically also had sizable minority populations or rapidly increasing Hispanic populations. Of the 606 counties nationally with a high proportion of public lands (≥60th percentile) and 10% or more housing growth from 2000-2010, only 62 counties did not have either substantial minority populations (≥10%) in 2010 or rapidly growing Hispanic populations (≥50% increase) from

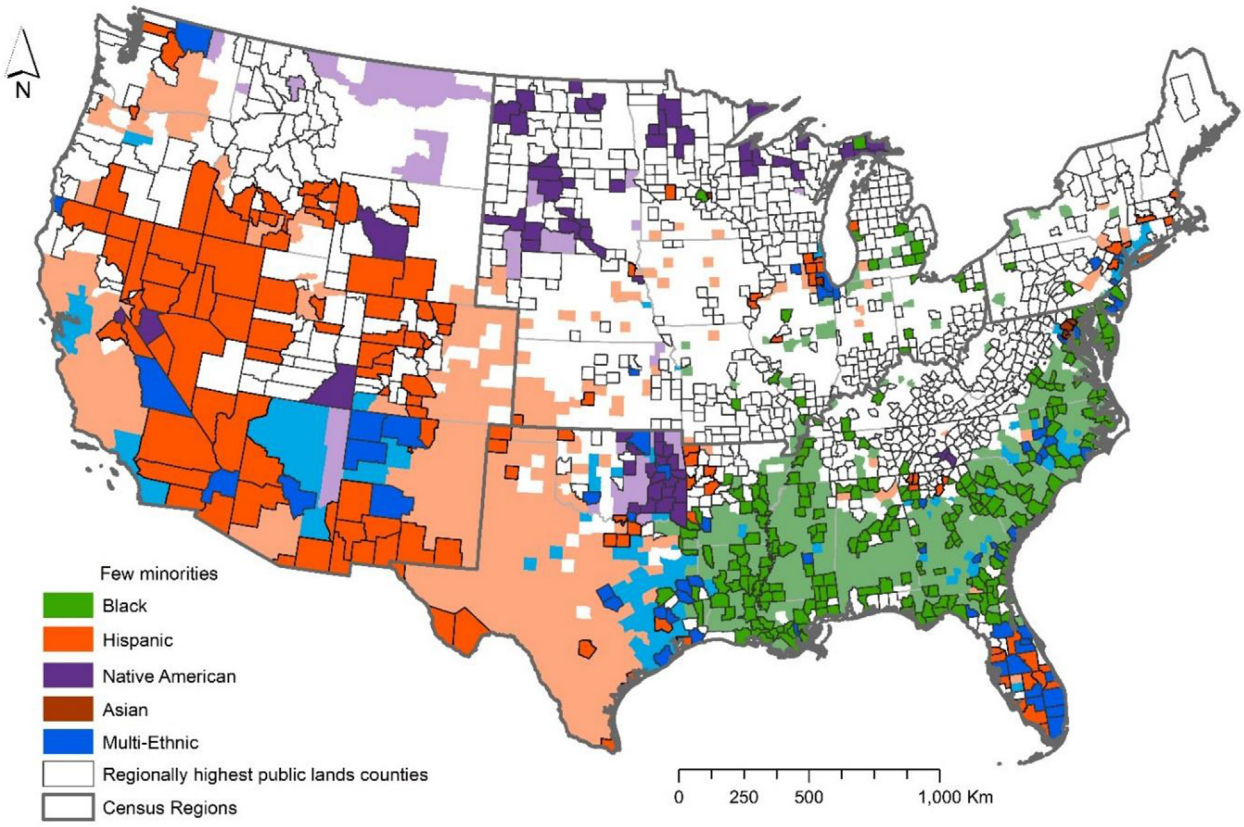

Fig. 4. Counties with significant (≥10 percent) minority populations in 2010, highlighting counties in the 60-100th public land percentiles for each region. Counties with 10 percent or more of population in multiple racial/ethnic groups are labeled "Multi-Ethnic."

2000-2010 (Table 2). The prevalence of counties with notable minority populations/growth and housing growth coupled with high proportions of public lands (≥60th percentile) varied between regions, but at least 40% of the counties with high proportions of public lands also experienced high housing growth and had notable minority populations in metro counties for the Midwest, South, and West, and in nonmetro counties for the South and West (Table 2).

4. Discussion

As populations continue to change and grow, the burdens on and desires for publically-protected lands also continue to evolve, even in developed countries such as the U.S., requiring considered public and private land management. The challenges of rising residential development per capita (Allendorf and Allendorf, 2012; Bradbury et al., 2014), and amenity fueled development around public lands are common in other countries as well (Dearden and Dempsey, 2004; Castro-Prieto et al., 2017). In the U.S., nonmetropolitan areas in the West have been a particular focus of both popular and academic attention on the topic of growth around public lands, and indeed, we found that in-migration from 2000-2010 was positively correlated with public land base in Western nonmetro counties. However, our analyses also highlighted the South as an area where population change and housing growth are correlated with public lands in nonmetro counties. Maps revealed large areas of the Upper Midwest where housing growth exceeds that of population, in counties with substantial public land bases. Driven by diminishing household size and preferences for rural settings and natural amenities, the impacts of housing growth in nonmetro areas is likely to remain a substantial environmental challenge.

Where housing is rapidly growing, it is important to design, construct, and maintain built landscapes so that environmental effects are minimized (Hostetler, 2012; Pejchar et al., 2015). Land use planners who regulate development can use a variety of policy tools to manage growth, including zoning controls on density, mixed use zoning to encourage higher density urban centers, growth limitations tied to infrastructure provisioning such as water and septic pipes, urban growth boundaries or greenbelts, and purchaser or transfer of development rights (Bengston et al., 2004). Public land managers have valuable expertise and knowledge to contribute to these local planning and land protection efforts, although these local processes are outside the lands they manage (Carr and Stein, 2014). As populations change, public land managers can build relationships with neighboring populations, and identify the best pathways to engage with nearby residents. For example, a social network analysis in a fire-prone area of Oregon identified opportunities for cooperative planning between organizations focused on fire and those focused on forest restoration (Fischer et al., 2016). Such efforts will require ongoing evaluation and study as populations continue to change. For example, managers can assess how newcomers and long-term residents differ in their environmental views and preferences (e.g., as assessed by the New Environmental Paradigm (Wolters and Hubbard, 2014)), being mindful of heterogeneity within these groups and how residents' values will continue to evolve and change with time since migration (Qin, 2016). Similarly, minority populations have diverse perspectives and backgrounds, and perspectives on and use of public lands will continue to change over time, for example, with acculturation (Fernandez et al., 2015). Furthermore, understanding residential management and environmental practices is important even areas that have seen slow growth recently, such as the

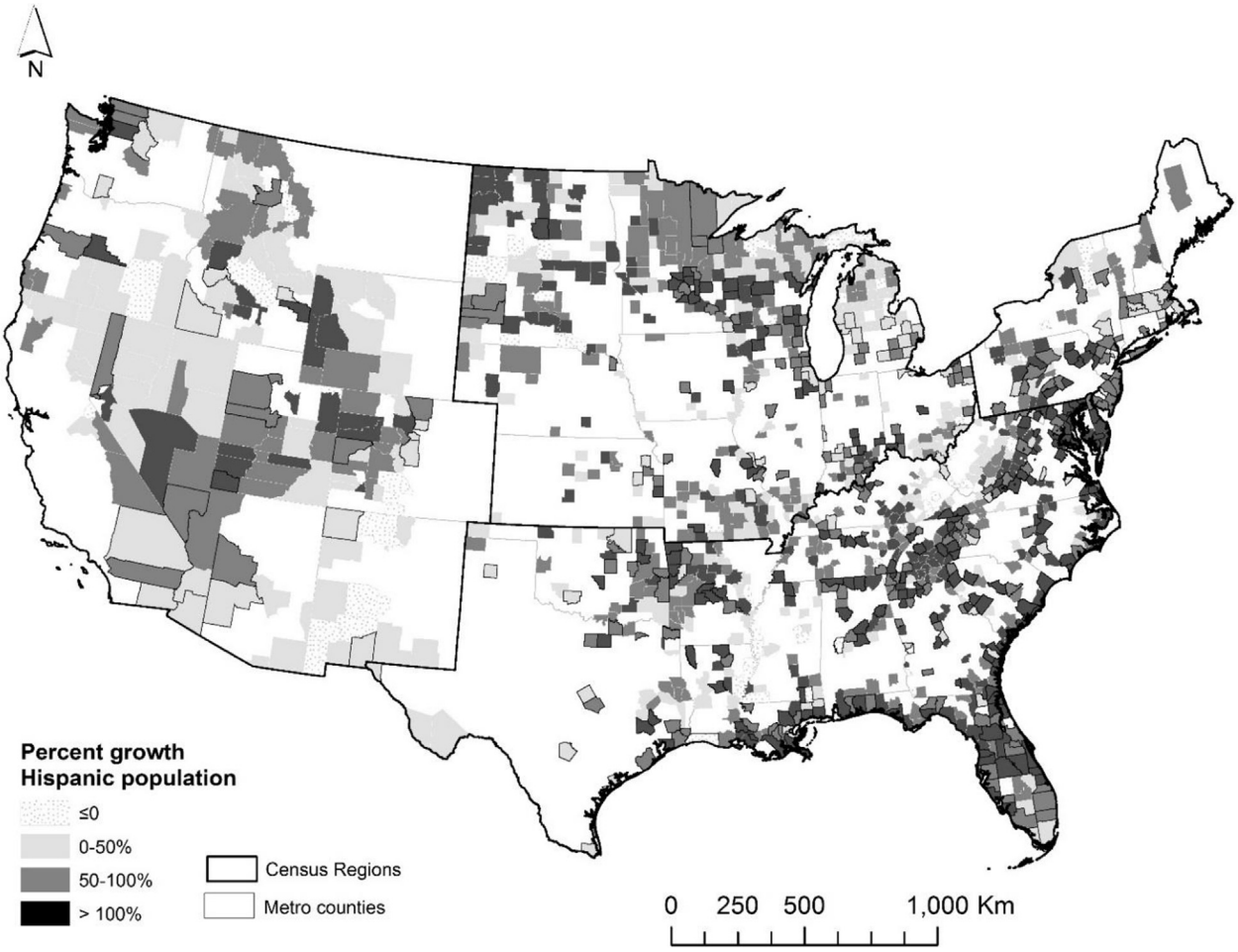

Fig. 5. Hispanic population growth rate for counties with high proportion public lands (≥60th percentile, calculated for each census region).

Northeast—housing development has long ecological legacies and homeowner management remains important to maintenance of ecological processes and biodiversity.

More heavily developed metro areas are also important locations where relatively high proportion of public lands and housing growth can combine; although these relationships were not statistically significantly correlated, metro counties in the Midwest, South, and West with high proportion public lands more commonly had high rates of housing growth (≥10%) than nonmetro areas. For example, nearly all metro counties in the West with high proportions of public lands also had housing growth rates of 10% or more (30 out of 32). The broader ecology literature increasingly recognizes the ecological value of urban areas, and the need to maintain ecosystem services for urban residents, through considered design of urban development (Childers et al., 2015). Although the scope and scale of such development is different from nonmetro areas confronting an influx of amenity migrants, insights from this literature on urban sustainability may offer insights for housing growth and residential footprint expansion in exurban or rural settings.

While housing development has become a serious environmental concern, the natural resource management and ecology communities less commonly consider other changes in population, such as increasing racial and ethnic diversity. However, increasing diversity has been one of the most substantial shifts in the U.S. population over the past Century. Indeed, our analyses showed that the vast majority of counties with high proportions of public lands and rapid increase in housing (≥10%), both metro and nonmetro, typically also had sizable minority populations or rapidly increasing Hispanic populations. Our findings confirm that metro counties, with a long history of being America's diverse places, do still represent important opportunities to engage a large and diverse segment of the American public (Byrne and Wolch, 2009; Weber and Sultana, 2013). Similarly, encouraging public land use by diverse populations in urban areas has also emerged as a priority in Europe and Canada (Laing et al., 2008; Gentin, 2011). In the past rural areas in the U.S. were less diverse than urban areas, but minority growth rates and population distribution in nonmetro areas are rapidly changing (Lee and Sharp, 2017). In nonmetro counties, the South was the only region to have a statistically significant relationship between Hispanic population growth and public lands, suggesting it may a particularly important place where amenity migration and diversification coincide. Over 50% of all nonmetro high public lands counties in the West and nearly all nonmetro high public lands counties in the South had both notable housing growth (≥10%) and diversity, either sizeable minority populations or rapid Hispanic population growth. However, the natural resource management implications of recent diversification in such rural areas have not been well-studied (Winkler and Johnson, 2016). Minorities may have different residential footprints than typical amenity migrants (Nelson et al., 2009) and the implications of such linked migration for use of and access to public lands are unclear.

Across settings, additional study will be needed to link changes in demographics to any changes in use of public lands. In some cases, rising minority use of public lands gain broader attention because of conflicts or intensification of use {an influx of Latinos in western North Carolina led to increased gathering of floral greens on public lands (Emery et al., 2006); arrival of Hmong refugees led to conflicts around hunting', fishing', and gathering on public lands (Bengston et al., 2008). However, broader relationships between demographic change and visitation often go unexplored, in part because visitation data are more limited than demographic data (Weber and Sultana, 2013). Visitation data may not be sufficient to allow change analysis; data are typically restricted to one type of public lands (e.g., National Forests); and variation in survey implementation (e.g., are people surveyed upon entry or exit, at developed sites, at non-developed sites) will influence the race and ethnicity of the visitors surveyed. Researchers have identified a number of strategies to increase minority visitation such as: facilitating transportation, developing and marketing recreation programs to minority groups, incorporating cultural considerations when designing facilities, programing, and public land and park establishment, and working to undo discriminatory legacies and present-day bias in treatment and staffing practices(Struglia and Winter 2002; Krymkowski et al., 2014).

Our analyses were conducted at the county level because county-level governance largely determines land use and planning, particularly in rural areas. In contrast, ecological processes function at the landscape-level far beyond the range of any one unit of public land. Finer-scale analyses proximate to individual public lands can further enhance our identification of locations that are currently experiencing rapid change, or have experienced extensive change over time (e.g., Piekielek and Hansen, 2012). Detailed analyses of economic, cultural, and geographic factors that influence migration and housing growth can further delineate the role of public lands relative to other factors. Population trends clearly vary with larger economic and social forces, as demonstrated in uneven patterns of amenity migration and diversification across and within regions. For example, in the nonmetro Midwest, Hispanic population growth from 2000-2010 was negatively correlated with the proportion of public lands, while white non-Hispanic growth during the same time period was positively related. In addition, we recognize that our analyses considered only the populations and public lands within the same county when discussing minority access. While this is appropriate given research establishing that closer proximity to public lands is associated with more minority use, we recognize that being within the same county does not mean public lands are proximate or otherwise easily accessible for resident populations (Weber and Sultana, 2013), particularly in the West where counties are large.

Refining our ability to respond to population change will require leveraging multiple areas of inquiry. Social science research on minority recreation, economic and demographic analyses of amenity migration, and ecological studies of the impacts of housing development have historically been pursued in isolation. As our preliminary efforts demonstrate, integrating such analyses is invaluable to better understanding the complex effects of population and housing change on public land functioning and use. Both our analyses of the past decade and our review of past literature mean we can expect the continuation of meaningful long-term trends, such as population diversification and aging. However, we also recognize that demographic change can be rapid and that we only analyzed the first decade of demographic change in the 21st Century. Migration patterns can change especially quickly, and many cultural changes that dramatically altered our population distribution, including the baby boom, migration to the South and West, and diversification of rural areas, were completely unanticipated by demographers. Interdisciplinary research teams tracking demographic change and anticipating its ecological consequences will best help managers meet the challenges of public land conservation in the 21st Century.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jenvman.2018.03.053.

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