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Human Dynamics and Forest Management: A Baseline Assessment of the Socioeconomic Characteristics of the Region Surrounding the El Yunque National Forest

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Abstract - In this paper, I examine the socioeconomic dynamics and human–environment interactions in the region surrounding the El Yunque National Forest (EYNF) in northeastern Puerto Rico and their implications for policy development and sustainable resource use. As part of a larger, comprehensive assessment of the conditions and trends of the EYNF and broader region, I collected and analyzed demographic, economic, human health and well being, and other social and cultural data. Herein, I discuss the implications of my findings in terms of the management and conservation of the EYNF. I also present the broader implications for integrating socioeconomic information and analyses in natural-resource planning and management.

Introduction

Located in the Luquillo Mountains of Eastern Puerto Rico, El Yunque National Forest (EYNF), also known as the Luquillo Experimental Forest, includes more than 11,330 ha and ranges in elevation from 120 m to 1704 m above sea level. It encompasses the headwaters of 6 major rivers and a great diversity of plants and animals, including more than 240 tree species and more than 160 vertebrate species (Weaver 2012). Humans have long-standing and complex ties to the forest. However, resource use, human values, and effects of human activity have shifted significantly over time. Understanding these human dynamics and associated social-ecological interactions is critical to developing sound policy to ensure resource sustainability (Harris et al. 2012). This paper examines a broad range of socioeconomic conditions and trends in the region surrounding the EYNF and articulates their associated implications for sustainable forest management.

Historically a place of sacred and supernatural experience revered by the Taínos and other pre-Colombian inhabitants, the forests came to be viewed through a more utilitarian lens as a source of timber and later, charcoal, water, and recreation through the process of European colonization and early association with the US (Domínguez Cristóbal 1997a, b; Robinson 1997). Today, it is a place of profound ecological, social, economic, historical, and cultural importance, and provides numerous benefits and services to local communities and society at large including biodiversity protection, water and soil conservation, recreation, and spiritual inspiration. As noted by Weaver (2012), the EYNF is "a revered place for the Island's

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original occupants and a tranquil refuge to experience nature for current visitors." Maldonado et al. (1999) describe "the journey to El Yunque [as] a type of pilgrimage, almost religious, in which [visitors] experience virgin forest."

The EYNF is under ongoing, and at times conflicting, demands for water, recreation, and other resources and services. Although its natural processes and conditions have been the subject of significant scientific study for more than a century, the related socioeconomic conditions and trends that can act as drivers of resource use and social-ecological interactions have been studied far less, particularly in the context of forest management and sustainability. Until recently, the management of the EYNF was based largely on biophysical information, with comparatively less emphasis on economic and social information, particularly in terms of the socioeconomic forces beyond its boundaries.

Understanding the intricate connections and interactions between humans and the environment is crucial to management for sustainable use of resources and has been incorporated into the recently revised USDA Forest Service Land-Management Planning Rule, which guides land-management planning in US national forests and grasslands (USFS 2012). The National Forest Management Act of 1976 (US Public Law 94-588) requires all national forests and grasslands to develop and maintain a land-management plan. The development, revision, and required content of these plans are outlined in official regulations or planning rules. The 2012 planning rule prescribes an ongoing process of (1) assessment, (2) plan development or revision, (3) implementation, and (4) monitoring, the results of which are analyzed and used to feedback into, and adapt when necessary, the land-management plan. New to this rule (and central to my work) is the emphasis on the interdependence of ecological, social, and economic factors and processes that shape forest conditions and trends (USFS 2012). In February 2012, the EYNF was selected among 8 "early adopter" national forests to revise their land-management plans according to the new planning rule and related regulations and guidelines. Subsequently, the EYNF embarked on a collaborative process of assessing ecological, economic, and social conditions and trends within and around the Forest as a first step in the planning process prescribed under the new planning rule. Building upon work conducted during the forest assessment (EYNF 2014), herein I present and analyze a broad spectrum of socioeconomic information characterizing the EYNF and surrounding region and describe associated implications for future forest planning and management. This paper focuses on the key socioeconomic factors that influence and interact with forest and other land-use decisions in northeastern Puerto Rico, such as trends in demographics, human health and well being, and the economy that should influence management and conservation of the EYNF. I provide an assessment of the related implications for the EYNF and its management and long-term sustainability.

Study Area

The study area is located in northeastern Puerto Rico (Fig. 1). It is delineated by political boundaries at the municipal level and includes the 8 municipalities that

border the EYNF—Canóvanas, Ceiba, Fajardo, Juncos, Las Piedras, Luquillo, Naguabo, and Río Grande. The area is influenced by moisture-laden trade winds that contribute to a mean annual rainfall that increases with elevation from ~889 mm along the coast to nearly 5.08 m on the mountain summits (Briscoe 1966, Gould et al. 2006). Mean annual temperature in the area decreases with elevation from ~27.5 °C to ~19.5 °C (Gould et al. 2006).

The study area extends over 74,867 ha or ~749 square km, which is ~8.3% of Puerto Rico's total area (Table 1). It comprises coastline, plains, hills, and mountains within a complex matrix of land covers and uses (Gould et al. 2012). According to López-Marrero and Hermansen-Báez (2011a), the 3 most-abundant land-cover types in the study area in 2010 were forest (43%), agricultural lands (36%), and urban/built-up (10%) (Table 2, Fig. 2). At the municipal level, forest land-cover ranged from 55% in Luquillo to 26% in Juncos (López-Marrero and Hermansen-Báez 2011a). Agricultural land-cover was most dominant in Las Piedras (54%), and urban/built-up land-cover was most dominant in Fajardo (16%) (López-Marrero and Hermansen-Báez 2011a). Between 1998 and 2010, urban/built-up land-cover increased by more than 1214 ha (21%) in the 8 municipalities surrounding the EYNF (López-Marrero and Hermansen-Báez 2011b). Urban land-cover was defined as having high levels of human activity and structural developments, including those covered by large amounts of impervious surfaces (more than 80 percent cover) such as concrete and cement. These areas included

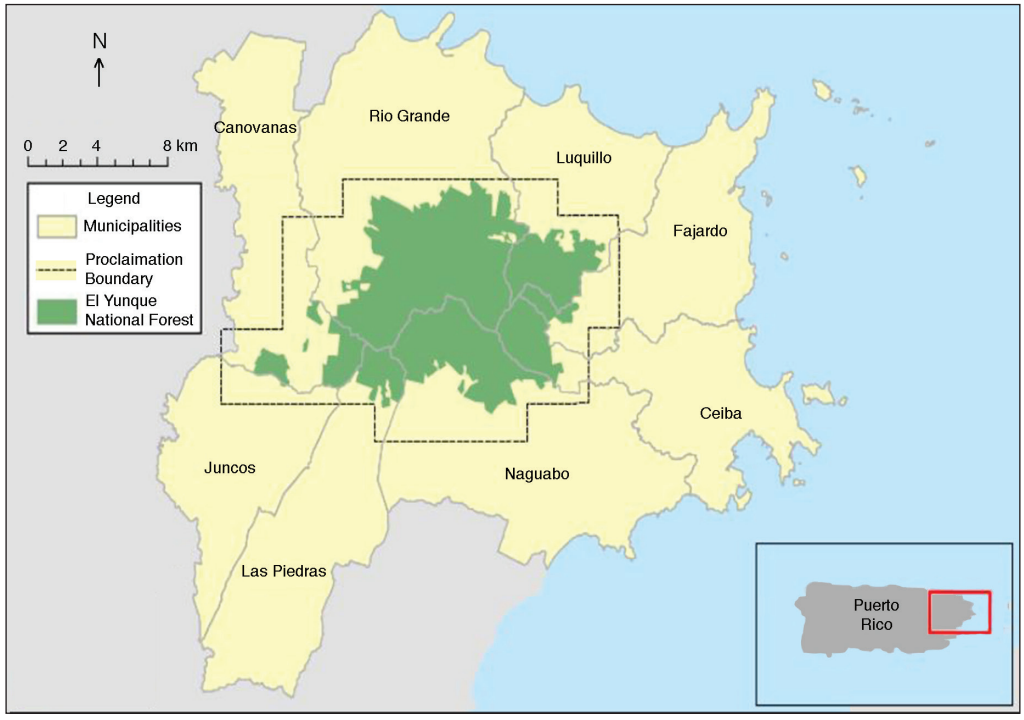

Figure 1. Study area including the El Yunque National Forest and 8 adjacent municipalities in Northeastern Puerto Rico (EYNF 2014).

high-density constructed areas, such as towns, but also low-density constructed areas, such as scattered buildings and subdivisions. During this time, Juncos and Canóvanas showed the greatest increase in the percent of total land-cover classified as urban/built-up, while Ceiba had the least increase in urban/built-up land-cover (López-Marrero and Hermansen-Báez 2011b).

The EYNF is located at the center of the study area and comprises nearly 15% of the combined area of the 8 adjacent municipalities (Table 1). It is the largest block of protected land in Puerto Rico and the only tropical rain forest in the US National Forest System (EYNF 2014). The EYNF occupies a rugged topography with almost a quarter of the land base on ≥60% slopes or steeper, and elevations ranging from 120 m to 1704 m asl (Harris et al. 2012, Weaver 2012). Average temperatures in the EYNF range from ~22 °C in the winter and ~30 °C in the summer (Scatena 1998). The EYNF receives ~381 cm of rainfall a year on average, ranging from ~249 cm in the lower elevations to >450 cm in the peaks (Briscoe 1966). Wet-forest types account for nearly 75% of the total forest area (Weaver 2012).

Table 1. Total area and national forest land-area of Puerto Rico and the region surrounding the El Yunque National Forest (EYNF), 2010. Source: EYNF 2014.

Jurisdiction	Total area (km^2)	EYNF area (km^2)	EYNF % of total area
Canóvanas	85.47	8.26	9.7
Ceiba	75.78	8.65	11.5
Fajardo	78.30	2.46	3.2
Juncos	68.87	0.08	0.1
Las Piedras	87.77	5.13	5.8
Luquillo	66.80	14.56	21.6
Naguabo	134.11	21.70	16.1
Río Grande	157.60	52.47	33.2
Total Region	754.72	113.31	15.1
Puerto Rico	9103.81	113.31	1.2

Table 2. Land cover in the region surrounding the El Yunque National Forest, 2010. Source: López-Marrero and Hermansen-Báez (2011a). Most of the agricultural lands were in pasture.

	Land cover type (ha)							
Jurisdiction	Forest	Shrub	Wetland	Agriculture	Urban	Bare ground	Sand and rock	Water
Canóvanas	3870	282	95	2983	1196	83		52
Ceiba	3289	631	701	1889	684	59	3	179
Fajardo	3068	507	269	2393	1217	97	19	126
Juncos	1764	604		3447	956	103		4
Las Piedras	2478	572		4731	987	20		
Luquillo	3696	465	64	1838	588	10	14	9
Naguabo	6117	603	506	5347	685	106		25
Río Grande	8356	561	789	4395	1433	95	13	96
Region	32,638	4227	2423	27,017	7745	571	49	491

Methods

I worked with an interdisciplinary team of scientists and practitioners participating in a larger, comprehensive assessment of the EYNF and its current conditions and trends to identify the key socioeconomic factors that influence and are influenced by the EYNF and its management and associated them with measurable variables through an iterative process (EYNF 2014; Table 3). Selection of variables was based on the 2012 planning rule and related directives (USFS 2012, 2015), which provide extensive information on key ecological, economic, and social variables to consider in forest assessment, planning, management, and monitoring.

Standard demographic variables, such as population size, age, and gender at multiple scales and points in time were selected as key elements for understanding population dynamics and their direct and indirect effects on the environment. Economic variables, such as per capita and median family income and employment by industry sector were chosen as indicators of the conditions and trends in the local economy and its stability and diversity. We sought to use this information to better understand the economic health of the communities surrounding

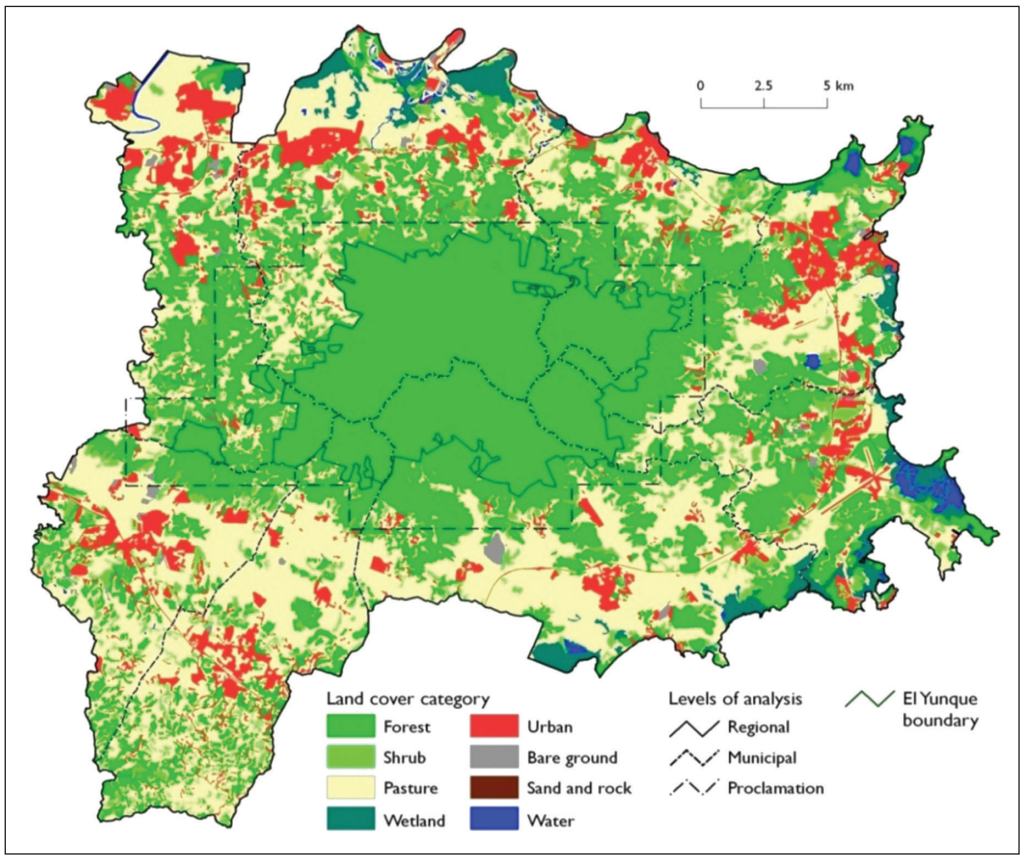

Figure 2. Land cover in the region surrounding the El Yunque National Forest. Adapted from López-Marrero and Hermansen-Báez (2011a).

Table 3. Research variables, scales of measurement, and data sources. M = municipality, R = region, PR = Puerto Rico.

Variable	Year(s)	Geographic scale	Source(s)	Comments
Population size	1970, 1980, 1990, 2000, 2010, 2014	M, R	USCB (2015)	2014 data are USCB 5-year population estimates (2010–2014) and are the most current available for this variable at time of study.
Population structure (by age and gender)	2000, 2014	M, R	USCB (2015)	2014 data are USCB 5-year population estimates (2010–2014) and are the most current available for this variable at time of study.
Population density	1970, 1980, 1990, 2000, 2010, 2014	M, R	USCB (2015)	2014 data are USCB 5-year population estimates (2010–2014) and are the most current available for this variable at time of study.
Urban/rural population	1970, 1980, 1990, 2000, 2010	M, R, PR	USCB (2015)	Data for this variable measured only in decennial census. 2010 is the most recent measurement year from USCB.
Births and deaths	1990, 2000, 2010	M, PR	Departamento de Salud de Puerto Rico, División de Estadística (2015)	Data only readily available since ~1990 for all municipalities.
Age (median, population by age and gender)	1990, 2000, 2010	M, PR	1990: Oficina del Censo, Junta de Planificación de Puerto Rico (2015); 2000, 2010: USCB (2015)	Data for this variable measured only in decennial census. 2010 is the most recent measurement year from USCB.
Education (highest level attained by those aged 25 y and older)	1990, 2000, 2010	M, R	1990: Oficina del Censo, Junta de Planificación de Puerto Rico (2015); 2000, 2010: USCB (2015)	Data for this variable measured only in decennial census. 2010 is most recent measurement year from USCB measurement approach changed between 1980 and 1990 and related comparisons are not recommended.
Income (per capita, median, and in real dollars)	1970, 1980, 1990, 2000, 2010	M, PR	USCB (2015); Oficina del Censo, Junta de Planificación de Puerto Rico (2015)	Data for this variable measured only in decennial census. 2010 is the most recent measurement year from USCB.

Table 3, continued

Variable	Year(s)	Geographic scale	Source(s)	Comments
Poverty (% total pop. and % children)	1970, 1980, 1990, 2000, 2010, 2013	M, R, PR	USCB (2015); Oficina del Censo, Junta de Planificación de Puerto Rico (2015)	In 2010, measurement of this variable shifted from the decennial census to the American Community Survey. Thus, 2010 data are based on USCB 5-year estimates (2006–2010). Subsequent estimates (e.g., 2011, 2013) cannot be compared with 2010 data because the year ranges overlap.
Unemployment	1970, 1980, 1990, 2000, 2010, 2013	M, R, PR	USCB (2015); Oficina del Censo, Junta de Planificación de Puerto Rico (2015)	Data for this variable measured only in decennial census. 2010 is the most recent measurement year from USCB.
Sectorial composition of economy (for civilian employed population)	2010	M, R	USCB (2015)	Data for this variable measured only in decennial census. 2010 is the most recent measurement year from USCB.

EYNF and the capacity of the local economies to adapt to gradual or unexpected changes in the social and natural environments.

We selected measures of human health and well-being to detect limitations to or indicators of a good quality of life. The overall vitality of a community, as a social component of sustainability, can be directly and indirectly linked to the health of the environment upon which it depends. While healthy ecosystems are essential to human health and well-being, human social conditions can have significant positive and/or negative effects on ecosystems and their various components. Therefore, understanding socioeconomic trends is essential to assessing progress towards sustainability.

Human well-being is defined in the Millennium Ecosystem Assessment (MEA) as the "basic material needs for a good life, the experience of freedom, health, personal security and good social relations, which together provide the conditions for physical, social, psychological, and spiritual fulfillment" (MEA 2005). It is a complex concept that is not easy to measure, and is typically assessed through proxies for the quality of human life, such as per capita income, educational attainment, and life expectancy (MEA 2005, UNDP 2013). Many of the less-tangible and value-laden aspects of human well-being are much more difficult to determine and compare across entities or subjects of interest. Therefore, we selected variables related to human health, including life expectancy, death rate, and infant mortality rate, education, personal wealth, and poverty.

We identified data sources and queried them at 3 geographic scales (i.e., municipal, regional, Commonwealth of Puerto Rico) and for multiple time series or timeframes. Published statistics from federal and commonwealth data sources, including the US Census Bureau (USCB), US Bureau of Economic Analysis, US Bureau of Labor Statistics, US Department of Labor, US Department of Commerce, and the Puerto Rico Planning Board were the primary sources of information. Many of these datasets were available through the USCB American Factfinder online database (Table 3; USCB 2015). We used additional sources of information, such as scientific, peer-reviewed research, as well as information generated by the EYNF and other governmental and non-governmental sources to supplement collected data and related findings.

Quantitative data were analyzed through simple and comparative statistics to determine socioeconomic conditions and trends in the region surrounding the EYNF and how they compared and contrasted over time at the intra- and extra-regional levels. Finally, drawing from theory and empirical evidence presented in the scientific literature, we determined implications of the measured socioeconomic conditions and trends for forest planning and management.

Results

Demographics

Population. In 2014, nearly 272,000 people lived in the 8 municipalities surrounding the EYNF (Fig. 3; USCB 2015). The municipalities to the north and west

of the EYNF (Canóvanas, Río Grande, and Luquillo) represented about 44% of the area's total population, followed by those to the south (Naguabo, Las Piedras, and Juncos: 39%), and those to the east (Ceiba, Fajardo; 17%). This area accommodated a growing population and an increasing percent of Puerto Rico's total population through the early 2000s, but there was a population decline between 2010 and 2014 of 2.35% (-0.59% per year; USCB 2015). From 2010 to 2014, Naguabo was the only municipality in the area with an estimated population increase (0.16% per year), Las Piedras showed no measurable change in its population, and the other 6 municipalities saw population declines (USCB 2015). Fajardo and Ceiba saw the highest rates of population loss between 2010 and 2014 (-1.99% and -1.88% per year, respectively).

Puerto Rico as a whole has seen significant changes in the size of its population since the early 2000s (i.e., 2000–2010: -0.22% per year; 2010–2014: -1.19% per year; USCB 2015), representing the greatest exodus of people since the great migration of Puerto Ricans to the mainland US following World War II (Cohn et al. 2014). Population loss across Puerto Rico is projected to persist if not increase with continued outmigration (e.g., 2015–2025 projected at -6.9%; Banco Popular de Puerto Rico 2013) and declining birth rates—e.g., 15.2 and 10.1 live births per 1000 persons in 2000 and 2013, respectively (CDC 2002, 2015).

Population density and urban/rural population. The study area had a population density of 369 persons per km^2 in 2010, which was slightly less than the population density island-wide (420 persons per km^2) (Table 4). Puerto Rico's population density in 2010 was second only to New Jersey (462 persons per km^2) among US states and territories, and placing Puerto Rico among the most densely populated areas in the world (UN 2013). Population densities within the region have increased since 1970, though growth peaked in the early 2000s, following the total population trend. Intra-regionally, population density in 2010 ranged from 181 persons per km^2

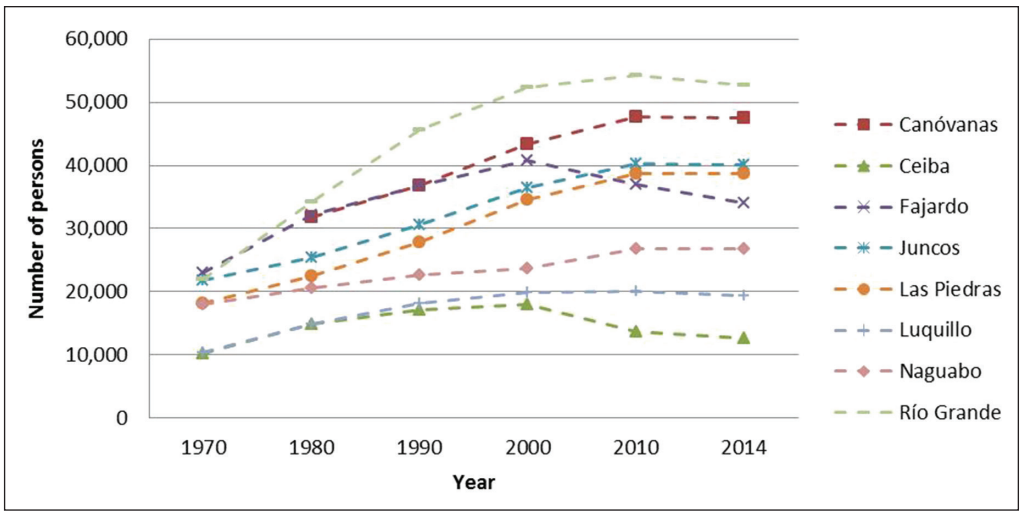

Figure 3. Population of the municipalities surrounding the El Yunque National Forest, 1970–2010 in 10-y increments and in 2014. Data source = USCB (2015).

in Ceiba to 587 persons per km^2 in Juncos. Notably, Ceiba's population density in 2010, while the lowest in the region, ranked higher than most counties in the US (USCB 2015).

In 2010, the USCB classified nearly 95% of the population in the study area as urban, ranging from 77% in Ceiba to 98% in Las Piedras (Table 5). The USCB's urban–rural classification is fundamentally a delineation of geographical areas, whereby urban areas represent densely developed territory, and encompass residential, commercial, and other non-residential urban land uses. The USCB delineates urban areas after each decennial census, applying specific criteria to the data. While the definition has changed slightly over the decades, in 2010, urban area was defined by a densely settled core of census tracts and/or census blocks that met minimum population-density requirements, along with adjacent territory

Table 4. Population density in the region surrounding the El Yunque National Forest and Puerto Rico, in 10-y increments from 1970 to 2010. Data Source: US Census Bureau (2015).

	Persons/km^2				
Jurisdiction	1970	1980	1990	2000	2010
Canóvanas	*	373.0	433.4	510.1	559.8
Ceiba	147.5	213.7	228.3	239.7	181.3
Fajardo	286.9	387.1	476.3	525.7	478.3
Juncos	323.9	363.2	444.3	529.1	587.3
Las Piedras	211.9	254.5	317.7	392.8	440.7
Luquillo	154.3	221.2	271.9	297.7	300.2
Naguabo	133.6	153.1	168.9	177.4	199.7
Río Grande	139.5	213.5	290.3	333.0	345.9
Region	184.8*	260.5	312.4	356.4	368.9
Puerto Rico	305.9	356.9	396.9	429.3	420.2

*Canóvanas was legally designated as a municipality in September 1970, after the decennial census was conducted. Therefore, the regional data point for 1970 does not include Canóvanas.

Table 5. Percent of population classified as urban by the US Census Bureau in the region surrounding the El Yunque National Forest, in 10-y increments from 1970 to 2010. Data source = USCB (2015).

	% urban				
Jurisdiction	1970	1980	1990	2000	2010
Canóvanas	*	61.3	69.1	97.3	97.7
Ceiba	28.6	60.9	78.7	92.7	88.2
Fajardo	79.2	83.9	85.8	97.8	97.9
Juncos	36.6	72.7	81.4	98.5	96.8
Las Piedras	25.6	27.0	58.6	93.1	97.6
Luquillo	0.0	30.4	47.9	93.9	91.6
Naguabo	25.7	20.1	27.6	91.1	90.6
Río Grande	31.8	56.2	55.3	95.6	97.4
Region	36.7*	55.0	64.5	95.6	96.0
Puerto Rico	58.1	66.8	71.2	94.4	93.4

*Canóvanas was legally designated as a municipality in September 1970, after the decennial census was conducted. Therefore, the regional data point does not include Canóvanas in the 1970 data point.

containing non-residential urban land-uses as well as territory with low population-density included to link outlying densely settled territory with the densely settled core. To qualify as an urban area, the territory identified according to criteria must encompass at least 2500 people, at least 1500 of whom reside outside institutional group quarters. As recently as the 1970s, more than 60% of the area's population was classified as rural (USCB 2015). Since then, the area has steadily shifted from a rural to an urban-dominated population as the density of residential, commercial, and other developed areas increased. Only Ceiba has seen a recent decline in the percent of its population classified as urban, which is attributable to the significant decline in its total population since the early 2000s (Table 5, Fig. 3). I expect that a similar trend may be seen in the rest of the study area because people throughout Puerto Rico continue to leave the island from both urban and rural areas and population totals continue to decline.

Gender and age. In the region surrounding the EYNF, females represented slightly more of the population than males (52% versus 48%, respectively; Fig. 4). When I considered age in my analyses, females accounted for 50.5% of the population aged ≤44 y and 54.3% of the population aged >45 y.

The median age of all persons in the study area ranged from 34.3 y (in Naguabo) to 37.7 y (in Ceiba) in 2010 (USCB 2015). Except for Fajardo and Ceiba, the municipalities surrounding the EYNF had slightly younger populations than the US and Puerto Rico as a whole (i.e., 36.8 y and 36.9 y, respectively). The municipalities to the south of the EYNF (Naguabo, Las Piedras, Juncos) had the youngest populations in the area in terms of the median age of their inhabitants, followed by the municipalities to the north (Canóvanas, Río Grande, Luquillo), and those to the east (Fajardo, Ceiba). Overall, the median age of the area's population increased slowly, but steadily over the past several decades (USCB 2015).

The age structure of the population in the study area has changed quite dramatically in recent years (Fig. 4). Through the end of the 20th century, the municipalities surrounding the EYNF had an age structure associated with moderate growth. By 2014, the age structure shifted to a more conical shape, with a smaller proportion of children (≤18 y of age) and a greater proportion of individuals over the age of 40 y. Canóvanas and Fajardo had some of the most pronounced changes in population structure during this time as the older age groups increased and younger age groups contracted (Figs. 5, 6).

Human health and well-being

Life expectancy and mortality. Life expectancy for the average Puerto Rican, and for the average person living in the study area, has steadily increased over the past several decades. In 2010, the life expectancy of a person born in Puerto Rico was 78.91 y, nearly 10 years greater than the life expectancy in 1960 (68.93 y) (The World Bank 2013). Analogously, mortality rates for males and females in Puerto Rico have decreased over the years, falling from 219 per 1000 adult males in 1997 to 132 per 1000 adult males in 2011, and from 79 per 1000 adult females to 51 per 1000 adult females fduring the same time period (World Bank 2013). The death rate (per 1000 persons) in 1990 ranged from 5.88 in Ceiba to 8.80 in Fajardo,

compressing slightly in 2000 to a range of 6.04 in Ceiba to 8.65 in Naguabo, and shifting somewhat in 2010 to a range of 6.71 in Las Piedras to 9.34 in Ceiba in

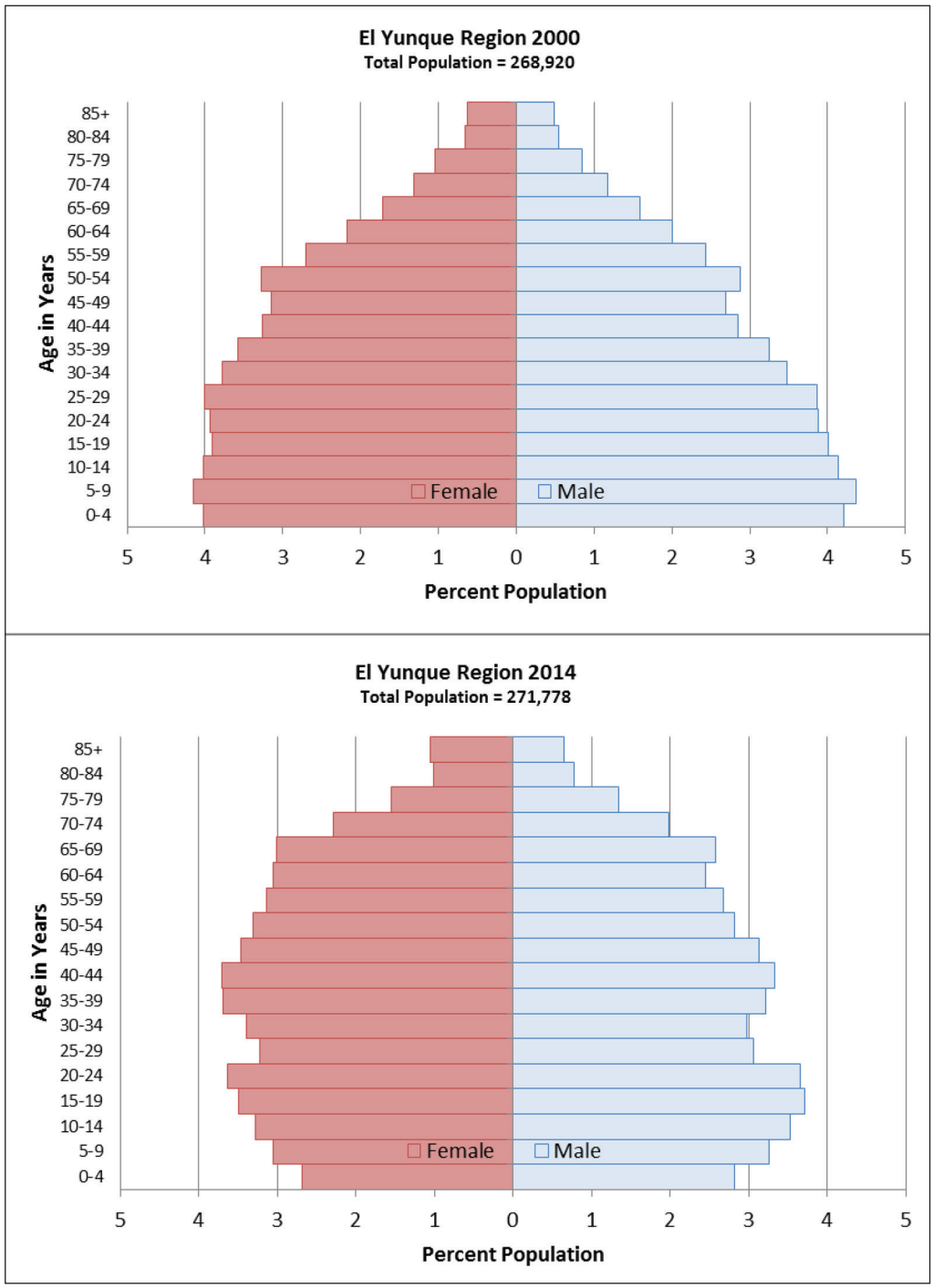

Figure 4. Structure of the total population of the El Yunque Region in 2000 and 2014 by age and gender (USCB 2015).

2010 (Table 6; Departamento de Salud 2015). While increasing death rates, such as those in Ceiba, may be associated with increases in disease or crime, they also are strongly affected by age distribution, whereby rising death rates are correlated with declines in fertility rates and increases in average age (CDC 2015).

Education. In 2010, a large majority of the adult population (25 y or older) in the area had finished high school (69%) and many had completed a Bachelor's degree or higher (19%) (Table 7). Within the region, Fajardo and Ceiba were the most educated in terms of the proportion of adults with a high school and college education, while Naguabo and Las Piedras had the lowest percent of their adult populations having earned a high school diploma and bachelor's degree. Throughout the study area, the percentage of both high school and college graduates increased from 2000 to 2010 (+11.8% and +5.1%, respectively).

Income. Per capita income in the municipalities surrounding the EYNF was $9451 in 2010, which was almost 10% less than that of Puerto Rico as a whole

Table 6. Birth rate (per thousand persons), death rate (per thousand persons), and median age of the population in the region surrounding the El Yunque National Forest and in Puerto Rico, 1990, 2000, and 2010. Data source = USCB (2015).

	1990			2000			2010		
	Birth rate	Death rate	Median age	Birth rate	Death rate	Median age	Birth rate	Death rate	Median age
Canóvanas	23.60	6.80	27.10	17.00	6.90	30.20	14.10	7.42	35.50
Ceiba	21.25	5.88	26.70	16.24	6.04	20.10	11.70	9.34	37.70
Fajardo	20.22	8.80	29.20	16.05	7.94	32.20	12.44	9.16	37.40
Juncos	17.58	7.96	28.50	16.56	6.57	30.50	11.03	6.99	4.40
Las Piedras	19.08	6.51	27.90	16.52	6.57	30.80	11.89	6.71	35.20
Luquillo	19.91	8.00	28.40	14.95	7.05	31.90	12.06	7.23	36.90
Naguabo	19.24	8.69	28.20	15.63	8.65	31.10	11.91	7.24	34.30
Rio Piedras	19.36	6.43	27.50	15.72	6.42	31.30	10.87	7.59	36.70
Puerto Rico	18.87	7.41	28.50	15.58	7.48	32.20	11.34	7.87	36.90

Table 7. Educational level of the population aged 25 y or more in the region surrounding the El Yunque National Forest and Puerto Rico, 1990, 2000, and 2010. Data sources = 1990: Oficina del Censo, Junta de Planificacion de Puerto Rico (2015); 2000, 2010: USCB (2015).

	Total population > 25 years			% high school graduate or higher			% bachelor's degree or higher		
	1990	2000	2010	1990	2000	2010	1990	2000	2010
Canóvanas	19,629	24,911	29,770	44.2	54.9	69.3	8.2	10.9	18.7
Ceiba	9136	10,733	9,158	60.3	66.0	70.7	10.2	16.3	22.0
Fajardo	20,668	25,203	24,231	51.3	63.2	72.6	11.7	16.2	21.5
Juncos	16,855	21,627	25,513	40.7	56.0	70.0	8.3	13.2	19.1
Las Piedras	15,121	20,324	24,916	43.8	57.0	68.2	8.7	13.1	18.2
Luquillo	9933	11,858	13,008	50.6	59.8	70.8	11.4	17.6	17.6
Naguabo	12,326	14,120	16,840	40.5	51.9	65.7	8.4	12.3	17.6
Río Grande	24,522	31,032	35,204	47.9	59.5	70.6	11.9	13.6	19.6
Region	130,180	159,808	178,640	46.1	57.9	69.7	9.8	14.2	19.3
Puerto Rico	1,952,297	2,288,326	2,438,057	49.7	60.0	68.6	14.3	18.3	22.0

($10,355) (Table 8). There were fairly sizable intraregional differences, ranging from a per capita income of $7548 in Naguabo to $10,409 in Río Grande, and a median family income of $18,109 in Naguabo to $24,160 in Río Grande. Overall,

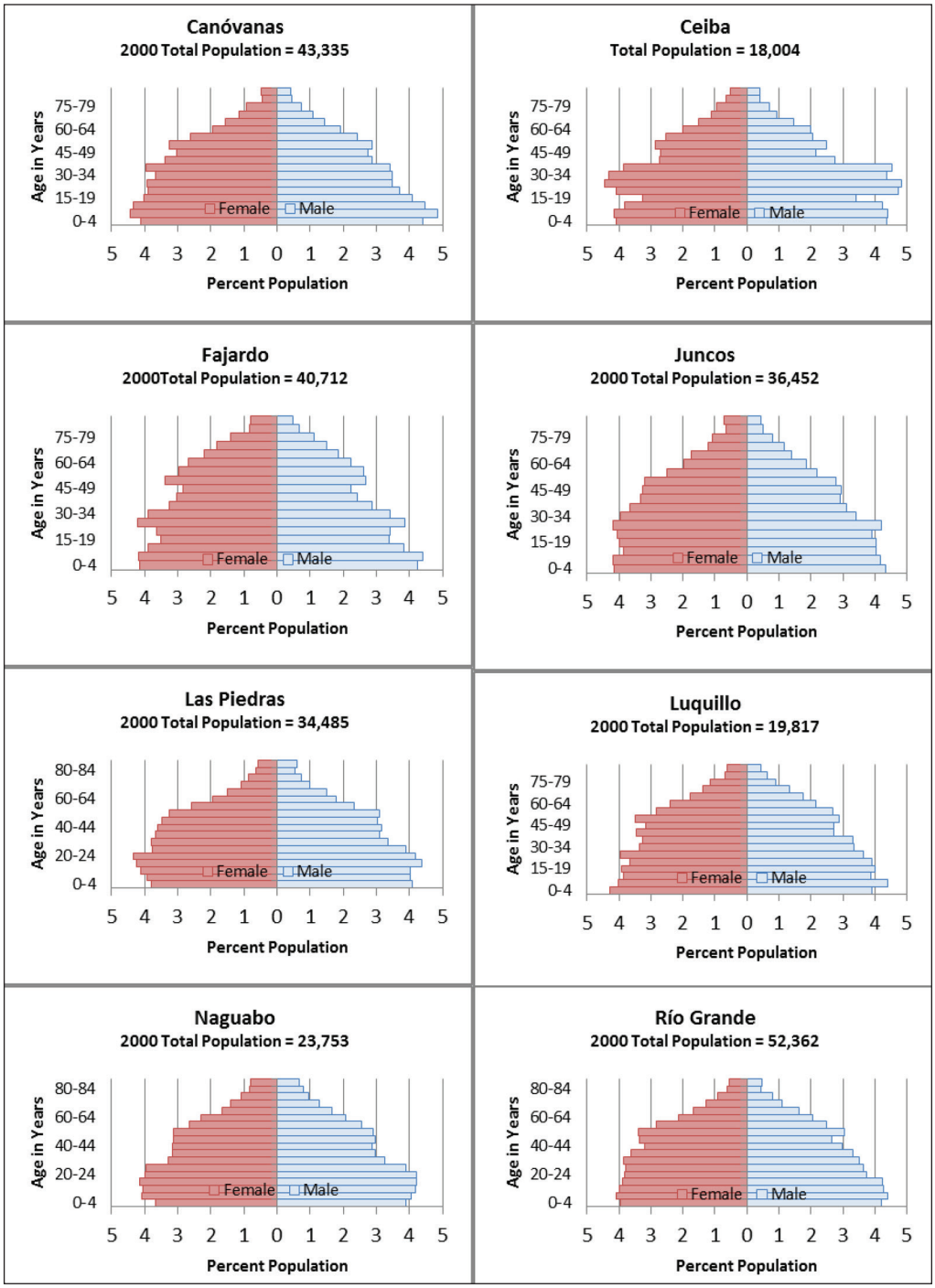

Figure 5. Municipal populations in 2000 by age and gender (USCB 2015).

the municipalities in the northern part of the study area (Río Grande, Canóvanas, and Luquillo) had higher median family and per capita income in 2010, followed by those in the East (Fajardo and Ceiba), while the municipalities in the southern part

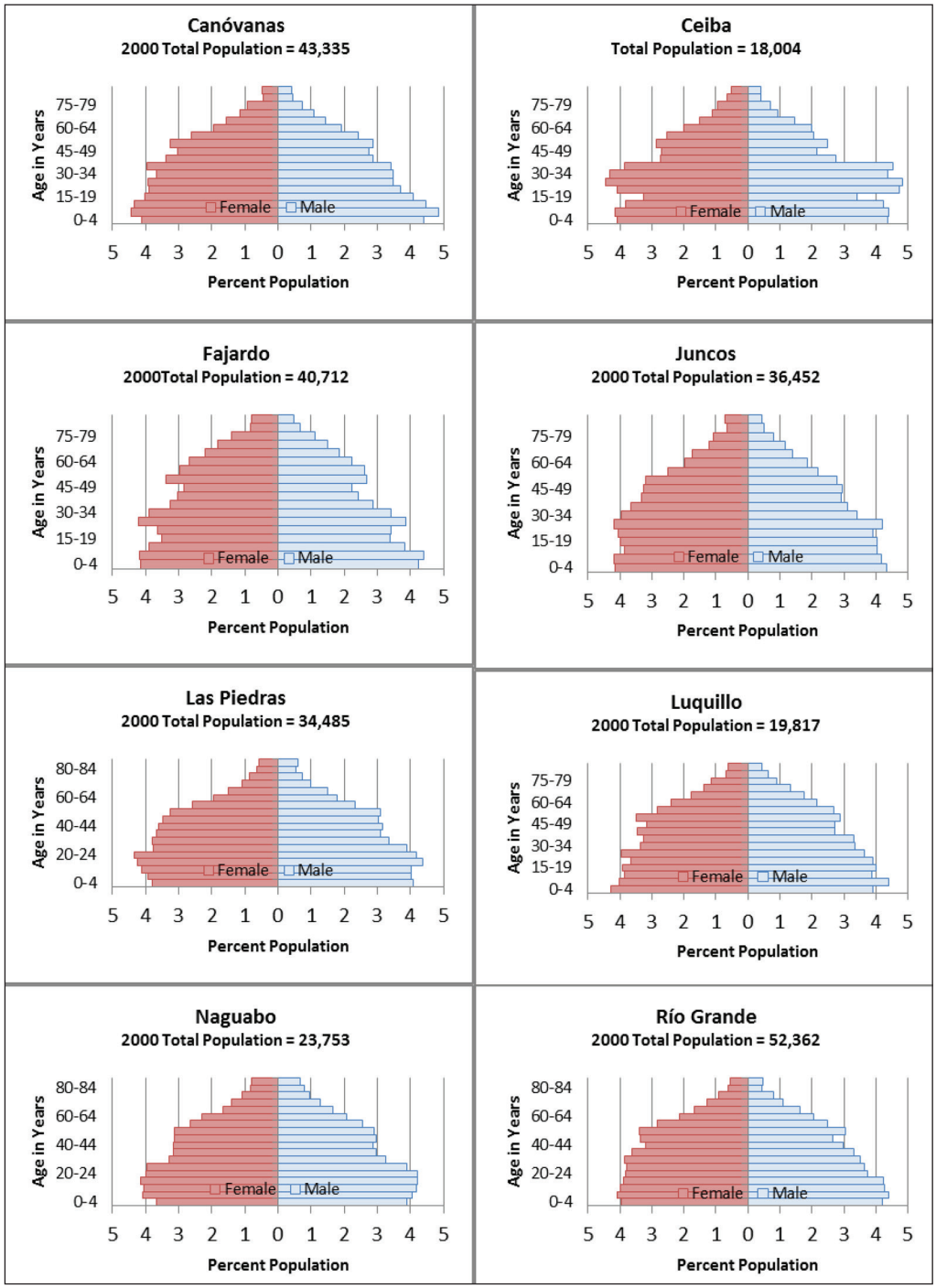

Figure 6. Municipal population in 2014 by age and gender (USCB 2015).

of the study area (Naguabo, Las Piedras, Juncos) exhibited comparatively lower income levels.

Per capita and median family incomes in current dollars (value at the time earned/received) have increased across Puerto Rico and within the study area for several decades (Table 8). However, to accurately compare income over time, summary measures (medians, means, etc.) should be adjusted to account for changes in the cost of living (i.e., inflation) (USCB 2015). When adjusted for inflation, income across Puerto Rico and within the region around the EYNF have only modestly increased since 1970 (0.67% per year and 0.77% per year from 1970 to 2010, respectively; Fig. 7). Within the study area, Río Grande experienced the greatest average annual increase in real median family income between 1970 and 2010 at a rate of 1.35% per year over inflation. Ceiba demonstrated the lowest growth rate in real median family income at 0.07% per year during this 40-y time period. Ultimately, while median family and per capita income have increased in the study area and across Puerto Rico over the past several decades, they have only modestly outpaced the rate of inflation.

Poverty. In 2010, about 44.2% of the population in the study area was living below the poverty level as defined by the USCB (2015). The USCB uses a set of income thresholds that vary by family size and composition to determine who is in

Table 8. Per capita and median family income in current dollars (not adjusted for inflation) of Puerto Rico and the municipalities surrounding the El Yunque National Forest, in 10-y increments from 1970 to 2010. Data sources = 1970–1990: Oficina del Censo, Junta de Planificación de Puerto Rico (2015); 2000, 2010: USCB (2015).

	1970	1980	1990	2000	2010
Per capita income (US $)					
Canóvanas	*	1650	3303	5917	9852
Ceiba	1233	2817	5119	9256	9658
Fajardo	1160	1925	4148	7852	9949
Juncos	801	1623	3388	6369	8968
Las Piedras	714	1627	3965	6427	9078
Luquillo	861	1633	3795	7529	10,506
Naguabo	768	1581	3221	6960	7548
Río Grande	754	1772	3529	7347	10,049
Puerto Rico	981	2126	4177	8185	10,355
Median family income (US $)					
Canóvanas	*	5431	9499	15,033	24,122
Ceiba	3947	7355	13,159	18,851	22,768
Fajardo	3574	5381	10,843	18,387	22,095
Juncos	2842	5073	9144	14,672	20,282
Las Piedras	2691	5339	10,251	16,408	20,931
Luquillo	3039	5296	10,264	15,203	22,866
Naguabo	2350	4725	8795	12,957	18,109
Río Grande	2793	5980	10,795	17,033	24,160
Puerto Rico	3063	5923	9988	16,543	21,764

*Canóvanas was legally designated as a municipality in September 1970, after the decennial census was conducted.

poverty. If a family's total income is less than the family's threshold, then that family and every individual in it is considered in poverty. The official poverty thresholds do not vary geographically, but they are updated for inflation using Consumer Price Index (CPI-U). The official poverty definition uses income before taxes and does not include capital gains or noncash benefits (such as public housing, Medicaid, and food stamps). The 2009 poverty threshold for a single individual was $10,956. (https://www.census.gov/hhes/www/poverty/about/overview/measure.html). Fairly significant intraregional differences existed, with Fajardo and Río Grande having the lowest poverty rates (42.1%), while Naguabo had the highest poverty rate (52.6%). The percentages of people living below the poverty level generally have declined throughout the area since at least 1970, with the exception of Ceiba, which increased to 43.1% in 2010 from 38.6% in 2000 (Oficina del Censo, Junta de Planificación de Puerto Rico 2015) (Table 9, Fig. 8). Despite general improvements, poverty in the region and across Puerto Rico occurs at significantly higher rates than in the US as a whole. For example, the percent of people living in poverty in the region surrounding the EYNF in 2010 was nearly 3 times the national rate (14.3%) and almost double that of Mississippi (21%), which had the highest statewide poverty rate in the US in 2010 (USCB 2015).

As throughout Puerto Rico, children represented a disproportionate share of the poor in my study area. In 2013, children represented less than 25% of the total population in the 8 municipalities surrounding the EYNF, but they represented more than 33% of the population living below the poverty level (Fig. 8). Of the estimated 71,912 children living in the study area in 2013, 56% were considered to be living below the poverty level (USCB 2015). Intraregional differences were also notable for this variable; Luquillo and the municipalities to the south of the EYNF had higher childhood-poverty rates than the other municipalities in the northern and eastern parts of the study area. Naguabo had the highest childhood-poverty

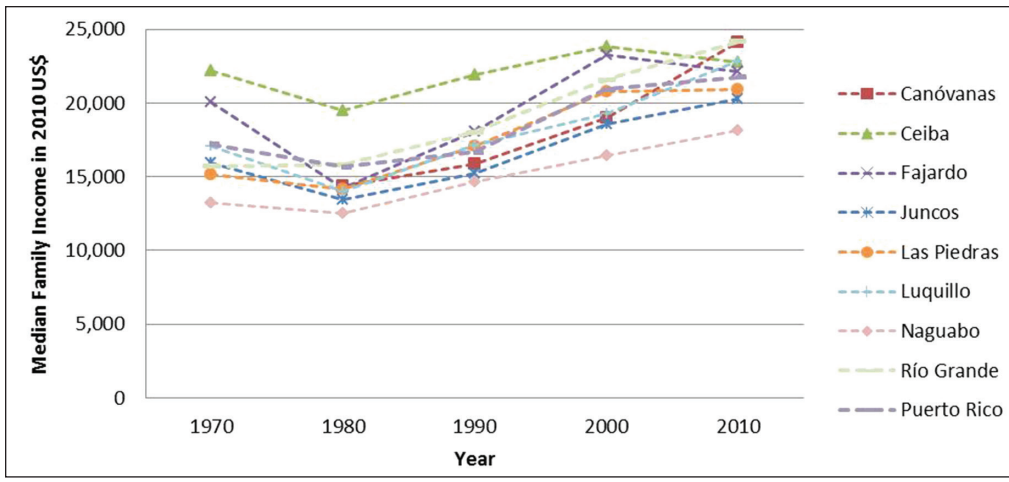

Figure 7. Real median family income (adjusted for inflation to the value of a US dollar in 2010) of Puerto Rico and of the municipalities surrounding the El Yunque National Forest in 10-y increments from 1970 to 2010 (USCB 2015).

rate at 67.5% in 2010. Ceiba had the greatest increase in the childhood-poverty rate (0.93% per year) between 2000 and 2010, despite a decrease in the total number of children living in poverty. Conversely, Canóvanas and Juncos experienced the greatest decreases in childhood-poverty rates between 2000 and 2010 (-0.11% and -0.65% per year, respectively).

Table 9. Number of persons and percent of the population living below the poverty level as defined by the USCB in the municipalities surrounding the El Yunque National Forest and Puerto Rico, in 10-y increments from 1970 to 2010. Data Source = Oficina del Censo, Junta de Planificación de Puerto Rico 2015.

	Persons living below the poverty level									
	1970		1980		1990		2000		2010	
Jurisdiction	Number	%	Number	%	Number	%	Number	%	Number	%
Canóvanas	*	*	21,478	67.5	23,561	64.1	23,447	54.2	19,952	42.5
Ceiba	5330	53.7	7243	52.2	7353	45.2	6479	38.6	6208	43.1
Fajardo	12,903	56.4	20,565	64.3	19,771	53.9	17,045	42.1	15,707	42.1
Juncos	14,668	67.6	17,636	69.5	19,132	62.7	19,677	54.1	18,570	47.3
Las Piedras	13,111	72.6	15,922	71.1	16,170	58.0	16,226	47.3	17,744	47.5
Luquillo	7021	68.0	10,246	68.8	10,692	59.2	10,203	51.7	8922	44.9
Naguabo	12,840	74.1	14,916	72.8	14,833	66.3	13,051	56.0	13,696	52.6
Río Grande	14,565	67.5	21,858	64.3	26,740	59.4	24,130	46.6	22,299	42.1
Puerto Rico	1,749,878	65.2	1,983,201	62.4	2,057,377	58.9	1,818,687	48.2	1,680,370	45.2

*Canóvanas was legally designated as a municipality in September 1970, after the decennial census was conducted.

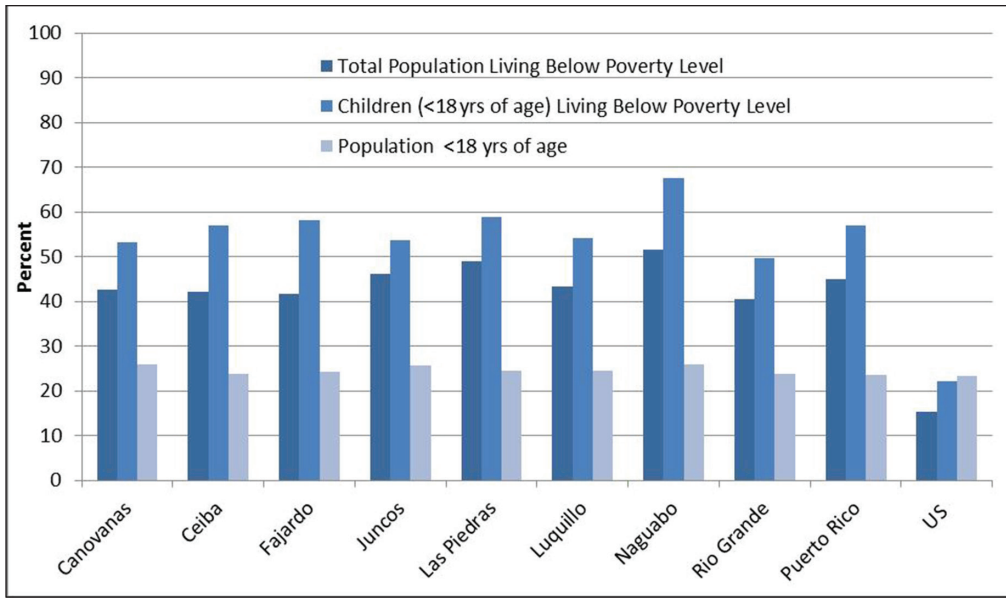

Figure 8. 2013 five-year estimate (2009–2013) of poverty levels for the total population and persons less than 18 y of age and the percent of the total population less than 18 y of age in the region surrounding the El Yunque National Forest, Puerto Rico, and the US (USCB 2015).

Economy

Employment. In the study area, ~48% of the population over 16 y of age was actively seeking employment (i.e., in the labor force) in 2010. This proportion is similar to the island-wide active-labor force rate of 47%, but less than the overall US rate that year of 65% (USCB 2015). About 83% of the active labor force in the area was employed in 2010, resulting in a 16.8% unemployment rate; which was similar to the island-wide rate, but much higher than that of the US as a whole (9.7%) in 2010. Intraregional unemployment rates ranged fairly widely from 11.7% in Ceiba to 21.0% in Luquillo in 2010 (EYNF 2014).

Unemployment rates decreased throughout the area and across Puerto Rico between 2000 and 2010 (USCB 2015). Ceiba had the largest reduction in its unemployment rate in this time period (-0.67% per year), but also saw the only reduction in the number of people actively seeking employment (-0.16% per year) (EYNF 2014). Most municipalities saw considerable increases in their labor forces (greater than 0.5% per year), with the greatest increase occurring in Canóvanas (1.41% per year), which also experienced a significant decrease in unemployment between 2000 and 2010 (-0.58% per year) (EYNF 2014).

Sectorial composition. In 2010, the majority of jobs in the region were in the education, health, and social services sectors (21%), followed by retail trade (13%), manufacturing (12%) and arts, entertainment, recreation, and accommodations (10%) (Table 10), all of which increased over their respective 2000 rates, with the exception of manufacturing (Fig. 9). In 2010, the majority of wage and salary employment in the study area consisted of jobs that produce services (77%) as opposed to tangible objects, and encompass a wide range in wages and skills (e.g., doctors, chemists, software developers, restaurant workers, bus drivers). Goods-producing jobs (i.e., agriculture, forestry, fishing, hunting, mining, construction, and manufacturing) accounted for 23% of the area's jobs. These statistics are similar to those for the rest if the US, where about 79% of jobs were in the services industry and 21% of jobs were in the goods-producing industry in 2010 (USCB 2015).

At the municipal level, education, health, and social services jobs accounted for the greatest proportion of jobs in the area, except in Las Piedras where manufacturing was the biggest provider of jobs in 2010 (Table 10). Although the agricultural industry was once a significant sector in the local economy and in the Puerto Rican economy as a whole, today the sector contributes only about 0.8% to the GDP and provides <1% of jobs island-wide. Similarly, <1% of jobs within the region are attributed to agriculture, ranging from 0.45% in Canóvanas to 2.04% in Las Piedras (Table 10).

Economic recession. Puerto Rico's economy has been somewhat listless, if not stagnant, for the past few decades (Cohn et al. 2014). Longstanding corporate tax breaks fueled economic and industrial growth across the island for many years. Their termination in 2006 combined with the recession in the US, the larger global economic downturn, and other local economic factors to produce an economic crisis from which the Island has yet to recover (Cohn et al. 2014). Moreover, government expenditures and the island's overall debt have increasingly exceeded revenues

Table 10. Percent occupation by industry for civilian employed population 16 y and older of the municipalities surrounding the El Yunque National Forest and Puerto Rico, 2010 (5-year estimate, 2006–2010). Data Source = USCB (2015).

	Canóvanas	Ceiba	Fajardo	Juncos	Las Piedras	Luquillo	Naguabo	Río Grande	Region
Agriculture, forestry, fishing hunting, mining	0.45	1.27	0.73	0.98	2.04	1.50	1.59	0.57	1.00
Construction	9.47	7.04	6.56	9.11	9.03	9.76	15.01	7.32	8.89
Manufacturing	8.52	10.83	7.68	18.46	22.78	12.90	11.17	8.69	12.29
Wholesale trade	3.32	0.22	0.79	3.46	0.93	0.73	1.52	2.78	2.07
Retail trade	13.25	10.72	15.57	10.93	9.07	11.91	14.20	14.29	12.77
Transportation, warehousing, utilities	6.08	3.40	5.25	2.14	2.57	2.65	4.50	5.08	4.24
Information	0.92	0.77	1.54	1.58	0.79	2.44	0.58	1.32	1.24
Finance, insurance, real estate, rental leasing	4.85	6.88	5.53	5.02	4.18	2.57	2.20	4.20	4.47
Professional, scientific, management, administrative, waste management services	6.81	8.07	8.45	6.35	9.46	6.79	5.88	7.05	7.34
Educational, health and social services	22.27	26.09	19.71	19.99	19.52	21.01	20.32	20.83	20.91
Arts, entertainment, recreation, accommodation food services	9.38	10.74	14.95	5.28	8.11	14.17	9.71	11.76	10.35
Other services (except public administration)	4.28	2.67	3.68	2.83	5.13	5.38	4.44	5.71	4.40
Public administration	10.40	11.31	9.56	13.86	6.39	8.17	8.88	10.41	10.01

since the early 1990s, ultimately resulting in the downgrading of its debt to junk status in 2014 (Cohn et al. 2014). These factors and their effects are pronounced across the island, including the area around the EYNF (2014).

Cultural and other non-market ties to forests

Puerto Rico as a whole, and the area surrounding the EYNF in particular, are culturally diverse and dynamic. This cultural diversity is reflected in the human values placed on the EYNF and its resources and services. Today, the EYNF is highly valued for water conservation, soil protection, recreation, research opportunities, and scenic qualities, among many other environmental and social benefits (López-Marrero and Hermansen-Báez 2011c). Specifically, the EYNF is revered as a place of tranquil refuge by local inhabitants, San Juaneros (i.e., capital residents), and visitors from around the world (Weaver 2012). It has long-standing, deep, and significant social and cultural meaning for the people of Puerto Rico and far beyond, providing opportunities to connect with the land, with each other, and with history. The forest contributes to the local and larger economies and to human health and well-being, and offers unique opportunities for recreation, relaxation, exercise,

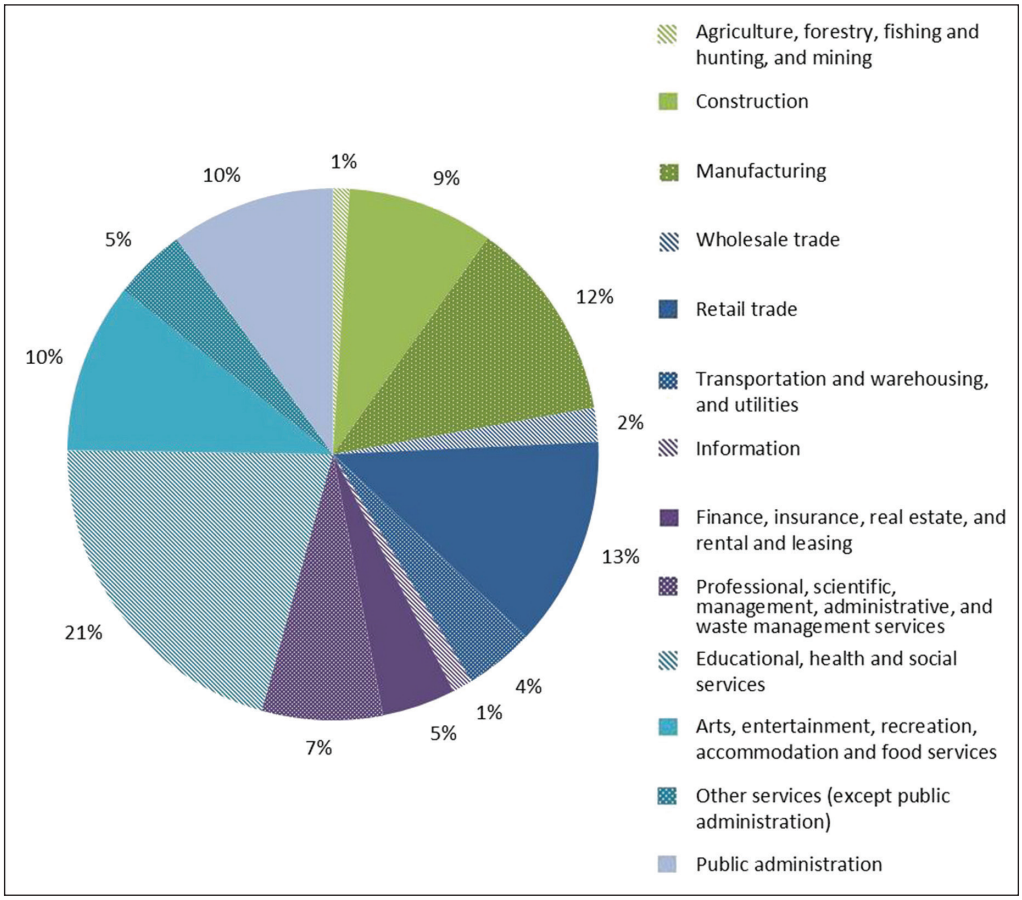

Figure 9. Occupation by industry for civilian employed population 16 y and older of the El Yunque Region, 2010 five-year estimate (2006–2010) (USCB 2015).

solitude, stewardship, spirituality, and community. These cultural ties to the EYNF are well described by Maldonado et al. (1999):

> "El Yunque is a forest of symbol and meanings and is a vital place in which Puerto Ricans, in their exercise of recreation and leisure, away from the mall, the office, and the factories, escape from the urban stress and problems in search of therapy only to find themselves in a natural world that evokes a deep and ill-understood history. … In the popular imagination, El Yunque is the place where the original heroes came from and a space where the national myths and sagas have sprung. Puerto Ricans perceptions of and feeling of attachment to El Yunque are saturated with patriotic and nationalistic meanings. … El Yunque enables Puerto Ricans to create and cement bonds with friends, family, and other important social groups, to transfer across generations their understanding of a unique Puerto Rico experience as can only be had in the forest. Not only does the forest embody their shared past, it also enables the celebrations of rituals and the construction of memories for the future."

Discussion

The population in the region surrounding the EYNF grew throughout much of the 20th century, leading to some of the highest population-density rates in the world, to extensive expansion in housing, infrastructure, other built-up areas, and ultimately, to more than 95% of the population being classified as urban by the USCB (2015). Urbanization can result in increased job opportunities and better health-care options as compared to rural areas, but also often implies increased demands and impacts on natural resources and services (McKinney 2002). Increases in housing, infrastructure, and other built-up areas decrease forest cover and alter forest processes through fragmentation of the landscape, disruption of hydrological systems, introduction of nonnative species, and interruption of nutrient cycles, which collectively result in changes in the benefits and services that a forest provides (Lugo et al. 2004). Indirectly, such increases can lead to reductions in the quality of recreational and other human interactions with nature due to the loss of open spaces, natural scenery, recreational sites, and other resources (Lugo et al. 2004).

Changes in land cover and use generally correlate strongly with population dynamics (see for example Meyer and Turner 1994, Vitousek et al. 1997). However, land use and cover, and changes in them, are determined by a complex array of interacting factors, including original land-cover characteristics, ecological processes, meteorological phenomena, market forces, social norms, public policy, and population dynamics (see for example Angelsen 1999, Gibson et al. 2000, Lambin and Geist 2006, Young et al. 2006). Several studies have shown that over shorter time-scales (<20 y), land-use changes mostly result from individual and social responses to changing economic conditions that are mediated by markets, policies, and larger global processes (Agrawal and Yadama 1997, Angelsen 1999, Lambin and Meyfroidt 2011).

EYNF land-mangers have an opportunity to influence the broader landscape within which the forest is situated and how it is used as they plan for the future, and they should consider changes in population size and density, as well as their relation to land use and cover. In particular, EYNF managers should pursue new opportunities for collaboration in conservation and sustainable resource-use across forest boundaries. This objective can be accomplished in part by working with adjacent and interested public and private land-managers, landowners, and other stakeholders with a landscape approach that protects and connects the remaining open spaces in the area and promotes the (re)establishment of forests and green spaces. For example, pasture and agricultural lands account for >36% of the total study area, and represent an opportunity for growing food; providing habitat for wildlife; increasing employment and income through agroforestry, recreation, and other activities; and connecting natural corridors from the ridgetops to the coastlines and beyond. Likewise, the EYNF should enhance opportunities for conservation education and outreach across all sectors of society.

The recent shift from population growth to decline in the study area, attributed mainly to emigration and a declining birth rate, will trigger needs for change in the EYNF's management and provision of goods and services. Recent studies by Birston and Meléndez (2015), Duany (2015), and others show that emigrants leaving Puerto Rico are younger on average than those who remain in Puerto Rico, but have similar or slightly lower levels of educational attainment as the island-wide population (refuting reports of a perceived "brain drain", i.e., increasing out-migration of the most educated and trained professionals in Puerto Rico). Already perceptible shifts in the study area's age structure, which are likely to be exacerbated by increasing emigration, will bring with them changes in the needs and demands for health care, education, recreation, and other resources and amenities that directly and indirectly influence the EYNF and its planning and management. In response, the EYNF will need to provide new and different opportunities for forest use by and interaction with an aging population (e.g., increased opportunities for less strenuous recreation and other activities).

Regarding the health and well-being of the people in the study area, while the populations surrounding the EYNF are living longer and spending more years in formal educational programs, thereby enhancing the overall knowledge and skills available for responding to demands and changes in the social and natural environment, per capita and family wealth have only modestly outpaced inflation, and poverty rates remain high, particularly among children. Limited growth in individual and family wealth and persistent poverty among a large segment of the population are signs of significant social vulnerabilities and may be indicators that large segments of society are being left behind. If the local economy continues to languish, these conditions are not likely to improve soon. Low income and high poverty-rates often result in greater demands for public services and resources, and this is particularly true where unemployment is high, which is the case in the region surrounding the EYNF.

Through opportunities for recreation, education, spirituality, historical and cultural preservation, wood and non-wood forest-product collection, and other

goods and services, the EYNF can preserve old ways and provide new methods to contribute to healthy lifestyles and a sense of place for neighboring residents, those living in nearby communities, and visitors from near and far. The EYNF also might seek out new ways to directly and indirectly generate employment and stimulate the local and larger economies through the goods and services that it provides. For example, new or expanded areas of low-impact recreation can be facilitated in parts of the Forest where access and/or connections to communities and activities outside the EYNF boundaries can be fostered through co-management initiatives that provide multiple benefits to forest stakeholders. Also, it could pursue other collaborative arrangements that encourage businesses to offer recreation opportunities, goods, and services that increase the sustainability of the EYNF and the landscape in which it is situated. These initiatives would enhance the diversity and resilience of the local economy. And, given the high rates of poverty among children, the EYNF should invest in programs and projects that engage youth, that involve them in management decisions and actions, and that increase their environmental awareness and understanding.

The EYNF has a long and complex history of human–nature interactions based around the environmental, economic, and social values that it represents. It provides unique opportunities for water and soil conservation, biodiversity protection, recreation, relaxation, exercise, solitude, stewardship, spirituality, community, and many other goods and services for local communities and society at large. The socioeconomic dynamics that have long interacted with the EYNF and its natural conditions and processes are changing, in some ways rather dramatically, and will inevitably result in changes in the needs and demands for products and services from the forest. Ultimately, EYNF management should strike a balance between its environmental, economic, and social values. This analysis of a broad range of socioeconomic information for the region surrounding the EYNF brings new and crucial information to the land-management planning process for the EYNF and provides a new baseline against which to monitor future trends in human dimensions in the region. Future assessments should measure and compare these variables over time, and look for measurable correlations between socioeconomic dynamics and forest conditions and trends within the EYNF and the broader landscape. Efforts to examine and integrate socioeconomic information into traditional forest planning enables the system to be much better positioned to address the challenges that a changing world may bring.

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