

Luquillo Experimental Forest Biosphere Reserve: Supporting resilient social-ecological systems in Northeastern Puerto Rico

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Key Messages/Lessons Learnt

- The Luquillo Experimental Forest Biosphere Reserve supports a rich and dynamic social-ecological system in the Caribbean.
- The Reserve has benefitted from a long-standing history of protection and research, and more recently, rising public engagement and participation in its management, monitoring, and governance.
- People living and working in adjacent communities, neighboring municipalities, across Puerto Rico, and around the world support and benefit from the goods and services safeguarded by the Reserve and recognize it as a place of profound ecological, economic, social, cultural, and historical importance.

Biosphere Reserve description

Situated in the Luquillo Mountains of Northeastern Puerto Rico, the Luquillo Experimental Forest (LEF) Biosphere Reserve encompasses five subtropical life zones (moist, wet, rain forest; lower montane wet and rain forest), spans nearly 1,000 m in elevation (120 to 1,074 m above sea level), and measures 11,331 ha (Weaver 2012; USDA Forest Service 2016) (fig. 1). It is rich in biodiversity and home to thousands of native species, including 150 fern species and 240 tree species, 23 of which are only found within the reserve (USDA Forest Service 2016). Average temperatures range from about 22° C in the winter to about 30° C in the summer (Scatena 1998). Average annual rainfall is about 3,000 mm, ranging from 2,500 mm at the lower elevations to greater than 5,000 mm at the peaks (Briscoe 1996).

Designated in 1976, the LEF Biosphere Reserve coincides with the El Yunque National Forest (EYNF), which is part of the U.S. National Forest System. It comprises the critical functions of a biosphere reserve as defined by UNESCO and underscored by Batisse (1986), including core areas that are strictly protected and monitored to contribute to genetic, species, and ecosystem

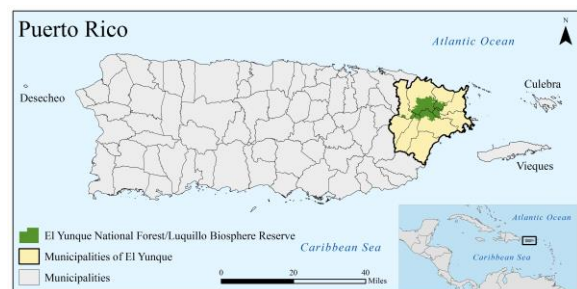


Figure 1. Location of the Luquillo Experimental Forest Biosphere Reserve in Northeastern Puerto Rico (Source: USDA Forest Service).

conservation; buffer areas surrounding these cores that are managed primarily for conservation, education, research, and recreation; and transition zones around the buffers that connect to nearby communities and other land uses and where sustainable development is actively promoted.

The upper reaches of the Reserve predate political association with the U.S., having been established by the Spanish government in 1876 to protect water sources and timber supplies (Domínguez Cristóbal 1997). These and other Spanish Crownland reserves were ceded to the U.S. government after the Spanish–American War in 1898. Soon thereafter, the area protected in the Luquillo Mountains was proclaimed as the Luquillo Forest Reserve

(eventually renamed EYNF and expanded to its current size) and placed under the direction of the USDA Bureau of Forestry (antecedent of today's USDA Forest Service) in 1903 (fig.2).

Research was established as a core component of the Reserve's management early on. By 1956, the National Forest had been officially dually designated in its entirety as an Experimental Forest, with research placed under the direction of the Institute of Tropical Forestry (antecedent of the International Institute of Tropical Forestry) (Weaver 2012). The Experimental Forest designation acknowledged more than half a century of research in the Luquillo Mountains, provided for long-term science and management studies across the range in vegetation types found there, and laid the foundation for the generation of scientific information critical to the Biosphere Reserve designation (Lugo 1989).

Today, the Reserve has several officially designated land uses that contribute to forest conservation and social-ecological sustainability (USDA Forest Service 2016). These include federally designated wild and scenic river segments, research natural area, and wilderness area, as well as a long-term ecological research site established in 1988 and funded by the National Science Foundation, along with the USDA Forest Service and the University of Puerto Rico.



Figure 2. View towards El Yunque Peak in the El Yunque National Forest/Luquillo Experimental Forest Biosphere Reserve (Photo credit : Gary Potts)

The EYNF/LEF Biosphere Reserve is the largest block of protected land in Puerto Rico and is recognized by the Commonwealth Government of Puerto Rico as a priority conservation area, having a scenic byway and a critical wildlife area. In addition, the Commonwealth Government established a special zoning regulation in 1983 to conserve nonurban areas and guide land use in the periphery of the Reserve in an area totaling about 75,000 hectares (750 km²).

This Biosphere Reserve is situated in a region that, like much of the rest of Puerto Rico, has seen significant shifts in population and land use dynamics over the past century and longer. Originally nearly completely forested, the region had been almost entirely cleared for agricultural uses, including coffee, bananas, and subsistence farming by the early 1930s, while the peaks of the Luquillo Mountains were largely left untouched (Wadsworth 1949; Lugo et al. 2004).

As industrialization and economic development expanded across Puerto Rico, by the mid-1900s, a large part of the island's converted lands had been abandoned and later returned to forest through natural regeneration, active planting, or both, including most of the lower elevations of the EYNF/LEF Biosphere Reserve (Birdsey and Weaver 1982; Lugo et al. 2004; Brandeis et al. 2007). Consequently, today, the Reserve is surrounded by a complex matrix of land covers and uses, including dense forest, coastline, agricultural fields, pastures, urban centers, and suburban sprawl (Gould et al. 2012).

Eight municipalities share land and boundaries with the LEF Biosphere Reserve in Northeastern Puerto Rico. Together, they measure about 750 square kilometers (74,867 hectares) and are covered mostly by forest (43 percent), followed by pasture and agricultural lands (36 percent), urban area (10 percent), shrubland (6 percent) and wetland (3 percent) (López Marrero and Hermansen Báez 2011) (fig. 3). The Reserve comprises 15 percent of their combined area and 13 percent of their total forested area.

These eight municipalities are home to about 270,000 people that range from rural to suburban to urban populations and represent a broad spectrum in demographics, business sectors, land use practices and values, and other socioeconomic factors (McGinley 2016). Over time, stakeholders living in adjacent communities, neighboring municipalities, and across the island have taken an increasing interest and role in the Reserve’s decision-making and management. They support and benefit from the goods and services that it provides and recognize it as a place of profound ecological, economic, social, historical, and cultural importance.

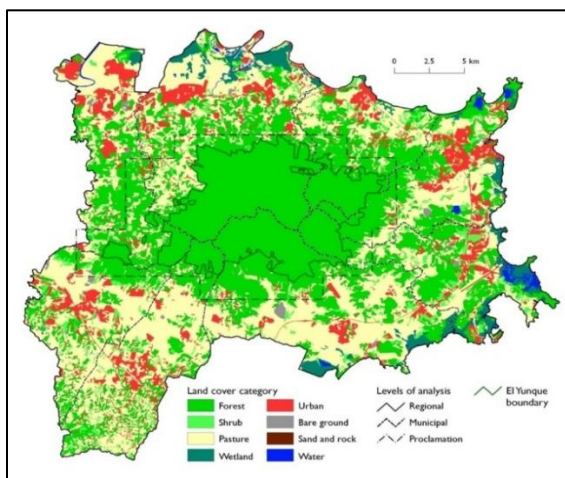


Figure 3. Land Cover in the region surrounding the Luquillo Experimental Forest Biosphere Reserve. Adapted from López Marrero and Hermansen Báez (2011).

BR challenges

The LEF Biosphere Reserve confronts a range of challenges that largely can be categorized as biophysical or anthropogenic processes or disturbances.

The Luquillo Mountains are affected by hurricanes, tropical storms, landslides, treefalls, droughts, and floods – all of which are influenced by climate change. These events are a natural part of life in the Caribbean, but must be understood and accounted for in sustainability planning and management, particularly as they may change in severity and frequency over time. In the Reserve, average temperatures have increased over the past 30 years, and scientists predict warming will continue at an accelerated

pace, yet, climate models vary in the predicted degree of warming (Waide et al. 2013). Records also show decreasing annual rainfall and increasing temperatures in and around the Reserve over the past half century or longer.

Statistical models of Puerto Rico’s future climate vary, but generally predict increasing average annual temperatures (ranging from 4 to 9 Celsius) along with slightly decreasing total rainfall and increasing extreme weather events by the end of the 21st century (Waide et al. 2013; Hayhoe et al. 2013; Henareh Khalyani et al. 2016). These and other documented and predicted changes in climate are expected to affect forest structure and function in the LEF Biosphere Reserve, potentially leading to shifts in species composition and their distribution along the elevational gradient, as well as changes in water supplies and flows (Lasso and Ackerman 2003; Wunderle and Arendt 2011; Schellekens et al. 2004; Jennings et al. 2014).

Hurricane events in the Caribbean also are expected to change with time, likely becoming more severe, with predicted increased wind speeds, rainfall intensity, and storm surge height as the climate changes (Emanuel 1987, 2005). Tropical storms and hurricanes are an integral and constant force that shapes shaping Puerto Rico’s social-ecological systems in general and the LEF Biosphere Reserve in particular, but shifts in their intensity and timing will affect management decisions and uses.

Most recently, Hurricane Maria, a Category 4 storm struck the island on 20 September 2017, just two weeks after the Category 5 Hurricane Irma skirted the island (fig.4). The Reserve sustained significant effects from Hurricane Maria, including widespread defoliation, wind throws, and stem breakage, as well as landslides and infrastructural damages. Communities around the Reserve, like those across the island and throughout the Caribbean, also were severely affected, experiencing impacts to health and human life and major disruptions in access to food, power, transportation, telecommunications, and other basic services for months following the storm.



Figure 4. Hurricane Maria over Puerto Rico and neighboring islands in the Caribbean Sea on 20 September 2017 (Source: National Oceanic and Atmospheric Agency)

By April 2018, the Reserve and surrounding communities were demonstrating measureable signs of recovery and resilience, as barren trees and shrubs sprouted new growth, water supplies were being restored, transportation routes were reopening, and communities were beginning to return to the routines of daily life. Yet, many were still regularly affected by disruptions in power, water, telecommunications, and other services as recovery and restoration ensued.

Anthropogenic or human pressures affecting the LEF Biosphere Reserve also have shifted with time. Historically, the area was shaped by logging, charcoal production, clearing for pasture and crops, and the creation of settlements, among other human processes and practices. While logging and charcoal production have ceased and conversion of forest within the Reserve is prohibited, high density visitation and recreation in parts of the EYNF/LEF, water withdrawals to support municipal water supplies, and land use change and landscape fragmentation in the surrounding region are the most pressing anthropogenic processes affecting the Reserve today.

Puerto Rico is a densely populated and frequently visited place, which directly and indirectly affect the LEF Biosphere Reserve, which receives on average 600,000 visitors per year (USDA Forest Service 2016). Although it

encompasses over 48 km of roads, 58 km of trails, and multiple recreation sites, given the Reserve's popularity, much of these roads, trails, and sites can be congested and overcrowded during frequent high use times, potentially producing negative effects on forest resources and services if unattended or inadequately managed (Fig. 5).

Population pressures are felt beyond the Reserve as well, where inconsistent land use planning and enforcement have resulted in haphazard urban expansion, oftentimes in areas not suitable for urban development (Lugo et al. 2000, 2004). Urban and built-up areas typically lead to landscape fragmentation or removal of forested lands, which in turn affect ecosystem structure and function and the services that forests within and around the Reserve provide. High population density and urban and suburban development also correlate with high demands for public water supplies from the Reserve. Despite recent declines in the population island-wide and around the Reserve in particular—losses which have accelerated recently in response to the ongoing economic crisis and the effects of Hurricane Maria, the EYNF/LEF still provides a high proportion of the island's municipal water supply and managers must be vigilant to ensure those supplies are sustainable.



Figure 5. La Mina Falls, Luquillo Experimental Forest Biosphere Reserve (Photo credit: USDA Forest Service)

Initiatives/Actions on SDG 15

The LEF Biosphere Reserve contributes directly and indirectly to many Sustainable Development Goals (SDG) (e.g., directly: SDG 3: Good health and well-being, SDG 6: Clean water and sanitation, SDG 13: Climate action; e.g., indirectly: SDG 1: No poverty, SDG 2: Zero hunger, SDG 11: sustainable cities and communities). It addresses a wide range of biophysical and anthropogenic challenges through its administration and management. Most explicitly, the LEF Biosphere Reserve contributes to SDG 15: Life on Land, which aims to *protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, halt and reverse land degradation, and halt biodiversity loss.*

Since its inception as a national forest and even earlier as a protected Spanish Crownland, the area encompassed by the LEF Biosphere Reserve has contributed to sustainable development in some form or fashion. Over time, administration and management of the Reserve have incorporated sustainability in a progressively holistic way and with increasingly substantive participation by neighboring community members, residents of nearby cities and towns, local land managers, business owners, and other key stakeholders.

Most recently, the Reserve adopted a landscape-scale approach to land and resource management that takes into account conditions and trends within and beyond its boundaries, cultivates collaboration with local communities and other key stakeholders, and enhances monitoring and assessment of social-ecological conditions and responses to management (USDA Forest Service 2016). This new approach is directed by the Federal Forest Land and Resource Management Planning Rule (USDA Forest Service 2012), which acknowledges the interdependence of ecological, economic, and social factors that shape land and resource conditions and trends, and codifies scientific information, sustainability, collaboration, and adaptiveness in the management of National Forest System lands, complementing the

Experimental Forest designation and practices in place in this Reserve since 1956.

Through this enhanced approach to land and resource management, the Reserve has begun to focus more holistically on the sustainable provision of ecological processes and socioeconomic benefits for a broad range of stakeholders. This management approach differs from those of the past in its integrated view of ecological, economic, and social sustainability, explicit connections to local communities, and adaptive approaches to land and resource management that rely on long-term research and monitoring (McGinley 2017). Specific plan components for the Reserve include the protection of at-risk species; sustainability of water production and quality; opportunities for sustainable recreation and other ecosystem services; protection of wetlands and riparian areas; and mitigation of and adaptation to climate change, all of which contribute directly to 'life on land'.

Practical Outcomes/Achievements

The LEF Biosphere Reserve contributes to the long-term protection of resources and services critical to biodiversity conservation, human health and well-being, and sustainable development across multiple scales, much of which has benefited from a rich and ongoing history of forestry research in the Luquillo Mountains (fig. 6).



Figure 6. Puerto Rican Parrot (*Amazona vittata*) (Photo credit: Jerry Bauer)

The Reserve harbors a vast range and number of plant and animal species, including numerous native and endemic species – some of which are at risk of extinction, like the Puerto Rican parrot (*Amazona vittata*) and the Elfin Woods warbler (*Setophaga angelae*) and whose survival depends in large part on the sound use and protection of the area and its surroundings.

The LEF Biosphere Reserve protects critical water resources, for example, providing an average of 276 cubic hectometers of water per year for municipal uses (USDA Forest Service 2016). It also protects recreational and spiritual values, remaining one of the most visited sites on the island and these visits contribute directly and indirectly to local and island-wide economic development. Many of the goods and services safeguarded by the Reserve also support climate change mitigation and adaptation, and ultimately, contribute to the resilience of neighboring communities and nearby cities and towns.

As the Reserve’s management approach has evolved, social elements critical to long-term sustainability, such as public participation and community involvement, have been integrated with the more traditional environmental aspects, such as at-risk species protection, water and soil conservation, and habitat restoration. Over time, this shift has led to lasting partnerships with landowners, scientists, researchers, practitioners, decision-makers, and others “who learn and work together to support a management system resilient to changes in social, economic, and ecological conditions” (USDA Forest Service 2016).

As these processes have evolved, the concept of co-management has arisen organically from work with collaborators and recently integrated as a key management strategy of the Reserve. Co-management involves the strategic and site-specific engagement of EYNF/LEF staff and active partners, working together in planning, implementation, monitoring, and assessment of the Reserve. It is best exemplified in the Community Interface Resource Management Area that bounds much of the Reserve (fig. 7).

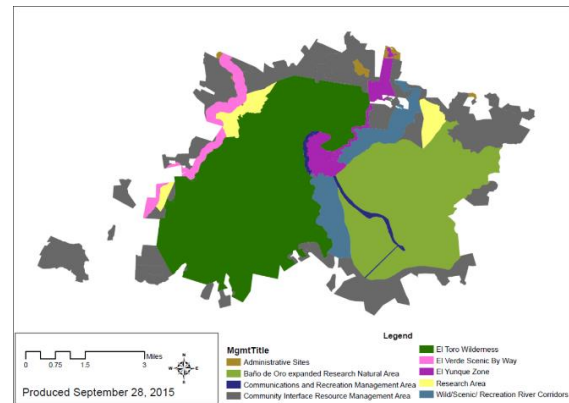


Figure 7. Management Areas of the El Yunque National Forest/Luquillo Experimental Forest Biosphere Reserve (USDA Forest Service 2016).

Co-management represents an intentional shift from top-down agency-driven priorities to a more collaborative approach to decision-making and management, where sustainable forestry practices and educational, recreational, and other opportunities can be developed and put into practice with local community and other key stakeholder participation (USDA Forest Service 2016).

Another outcome of the Reserve’s evolving vision of integrated conservation and sustainable development through an all-lands approach is its proposal to expand the officially designated Biosphere Reserve to go beyond the EYNF/LEF boundaries and include a much larger portion of the surrounding region, totaling more than 77,000 ha. This would include the originally proposed Core Zone of 7,790 ha, which includes the El Toro Wilderness Area, Baño de Oro Research Natural Area, and Wild and Scenic Rivers; a Buffer Zone of 8,411 ha, mostly comprised of the lower elevations of the EYNF/LEF, as well as some adjacent private lands; and an enlarged Transition Zone of more than 61,000 ha comprising a small portion of the EYNF/LEF along with all other lands in the Luquillo Mountain Range (i.e., public and private, urban and non-urban).

In sum, the LEF Biosphere Reserve comprises a resilient social-ecological system, contributing to conservation of biodiversity, provision of goods and services, and support of human health and well-being. It offers unique

opportunities for recreation, relaxation, exercise, solitude, stewardship, spirituality, community, and many other benefits and beneficial experiences. Neighboring community members, nearby city dwellers, scientists, researchers, and other key stakeholders from near and far have become deeply engaged in the Reserve's integrated and adaptive management through an increasingly inclusive and stable structure for meaningful collaboration and co-management – all of which contribute to life on land in particular and sustainable development overall.

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