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# THE RESTORATION DIAGNOSTIC

*Case Example: Puerto Rico*

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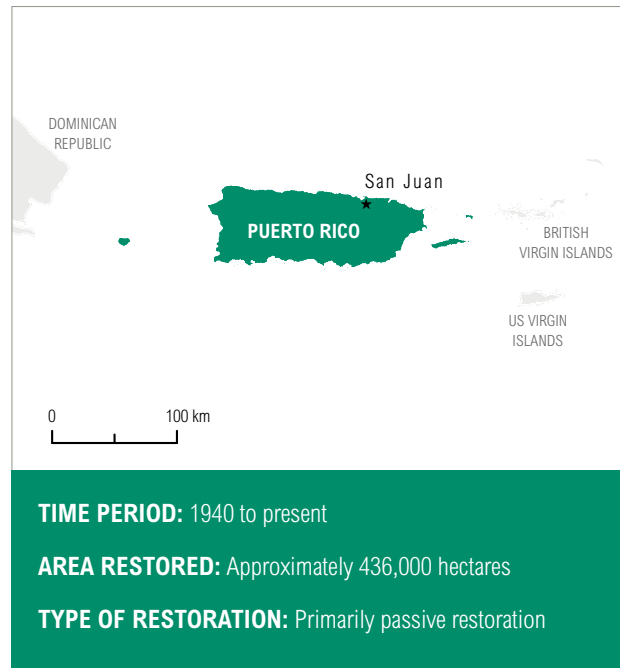
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# CASE EXAMPLE: PUERTO RICO

## SUMMARY

At the time of initial European contact in 1493, most of the island of Puerto Rico was forested. Deforestation occurred slowly over the following three centuries before accelerating during the 19th century with the emergence of coffee and sugarcane plantations<sup>1</sup> (Rudel et al. 2010) and a ten-fold increase in human population (Grau et al. 2003). By 1828, timber and agricultural development had reduced the island's forest cover to 587,000 hectares (Wadsworth 1950), or 66 percent of the land area. Additional forest clearing began after 1916. By 1931, forests covered only 9 percent of the country and fell to a low of 6 percent in the 1940s (Birdsey and Weaver 1987). Farmers were producing coffee in the mountainous interior for the European market, while American corporations were producing sugar for the North American market in the coastal region (Rudel et al. 2010).

Between 1950 and 1990 forest area surged back, climbing to 37 percent of the island's land area (Rudel et al. 2010). Economic shifts triggered the majority of this recovery. Starting in the 1940s, Puerto Rico shifted to light industry as a backbone of the economy, which led to the abandonment of sugarcane plantations (Aide 1996). The decline in coffee prices in the 1950s resulted in workers moving off the land and seeking alternative livelihoods in urbanized areas (Rudel et al. 2010). In addition, agriculture was made less competitive due to an increase in the federal minimum wage within the industry and inefficiencies in the sugarcane industry, which had been taken over by the government (Lugo, A. 2014. pers.comm., 18 August). By 1980, agriculture represented less than 5 percent of Gross National Product (GNP), while manufacturing had grown to account for almost 50 percent (Grau et al. 2003). Recovery of forestland was mostly through natural regeneration, although this natural regeneration was complemented (at a smaller scale) by some assisted restoration (Lugo and Helmer 2004). By 2009, forests covered 55 percent of Puerto Rico (Brandeis and Turner 2013).



## WHICH FEATURES AND KEY SUCCESS FACTORS WERE EXHIBITED?

The recovery of forests in Puerto Rico exhibited several of the features and key success factors of forest landscape restoration. Those with the most impact are described as key success factors under the theme of enabling conditions.

### Motivate

Factors inadvertently motivating restoration included:

- **CRISIS EVENTS.** Developments in export agriculture and finance markets led to the collapse of the commercial agricultural industry. The sugarcane sector was unable to modernize to industrial scale and keep pace with European competition, and limited access to credit meant that the decline of coffee prices crashed the industry. These developments led to a fundamental shift in the utilization of land in Puerto Rico (Bergad 1978).<sup>2</sup>

### Enable

Several enabling conditions were in place that facilitated restoration in Puerto Rico, namely:

- **MARKET CONDITIONS.** Since the 1940s, several market factors converged that relieved demand for cleared forest lands. First, Puerto Rico started to industrialize its economy through “Operation Bootstrap” (see below) and related measures. In 1930, sugar accounted for nearly 54 percent of total exports and dominated the agrarian and employment structure of the island. But the shift to light industry in the 1940s led to the abandonment of sugarcane plantations (Grau et al. 2003). Second, market prices for coffee declined during the 1950s. This made production on marginal lands uneconomic and catalyzed increased yields per hectare on the already more productive lands. This combination of declining coffee markets and industrialization both pushed smallholders out of agriculture and pulled them to the growing non-farm labor market in urban areas (Helmer 2004). As a result, demand for alternative uses of deforested lands started to decline, making possible the recovery of forests in some of these areas. The decline in agricultural demand was particularly rapid between 1959 and 1974, a period when sugarcane experienced its sharpest decline in acreage (Rudel et al. 2010).<sup>3</sup>
- **ECOLOGICAL CONDITIONS.** As agricultural pressure on the land declined, several ecological conditions were favorable for the recovery of forests, allowing for most of the recovery to be via natural or natural regeneration (passive restoration)<sup>4</sup> (Rudel et al. 2010). For instance, soil, water, and climate conditions in most areas remained conducive for tree regrowth. An exception was in areas where natural conditions were conducive to the growth of dry forests. In these areas, lack of moisture, compacted and eroded soils, nutrient limitations, and exposure to high temperatures have led to slower succession and lower biomass growth (Molina Colon et al. 2011). Plants and animals that might impede the regrowth of trees were either absent or controlled; for example, fences were used to control livestock. Remnant tracts of forest remained to provide seeds for forest recovery.<sup>5</sup> Even small

tracts of less than one hectare have proven important for connecting larger forest tracts and serving as seed sources (Lugo and Helmer 2004).

The ability of an area to recover (and species diversity within that recovery) is a function of the previous land use. For example, abandoned coffee sites have achieved more compositional stability than abandoned pastures due to the prevalence of shade tolerant species in the former (Rivera and Aide 1998). Moreover, introduced species have played an important role in reversing forest fragmentation and deforestation without causing the extinction of island biota (Lugo and Helmer 2004).

- **POLICY CONDITIONS.** The government initiated “Operation Bootstrap” in 1940 to catalyze the development of light industry in Puerto Rico. It provided exemptions from federal and state taxes to companies that established industrial facilities in the commonwealth. During the first two decades of the program, more than 1,400 U.S. companies established manufacturing enterprises on the island. Although the effects of the program are debatable, Puerto Rico registered one of the most rapid rates of economic growth in the world during the post-war period (Rudel et al. 2010). This industrialization contributed to an economic shift away from agriculture toward industry, and a migration of people away from rural areas.<sup>6</sup> Since the 1940s, migration and population growth mainly occurred in urban areas and along the northeast coast. Between 1940 and 1990, the rural population did not change significantly, but the rural working population (between 15 and 64 years old) decreased, reflecting the decrease in agricultural activities (Grau et al. 2003).

Some older policies have proven important, too. Public forests designated for conservation between 1910 and 1940 served as an anchor for some of the restored areas and provided source populations for regeneration. In 1952, the Constitution of the Commonwealth of Puerto Rico established a public policy for “the most efficient conservation of natural resources, as well as the best development and use of these for the benefit of the community.” In 1972, Commonwealth Law No. 23 established further programs for the conservation of natural resources, including forests. By 1975, Commonwealth Law No. 133 was amended to become more explicit about forests. Known as the Puerto Rico Forests Act, it aimed to protect, expand, and conserve the forest resources of Puerto Rico. This law also authorized the creation of the Commonwealth Forest Service (DNER 2010).<sup>7</sup> More recently, the U.S. Forest Service—which has jurisdiction in Puerto Rico—has been encouraging reforestation on abandoned agricultural lands. By the 1980s, the Forest Service had started to focus forest management toward recreation, scientific research, and educational goals (Foster et al. 1999), all of which are conducive for restoration.

Although policies played a role in forest landscape restoration in Puerto Rico, they were a secondary factor in relation to the market and ecological conditions. Most of the recovered areas were either abandoned shade coffee plantations in the interior (which had partial forest cover already) or abandoned sugarcane and pasture fields near the coasts (many of which are now dominated by exotic species). Therefore, they regenerated naturally due to the land not being valued for other purposes (Chinea, J.D. 2014. pers. comm., 7 August).

Finally, it is important to note that policy efforts to conserve and restore Puerto Rico's forests date back to the 1800s. For example, regulations regarding stream buffer zoning date to 1824, and a law requiring restoration was introduced in 1876. But there is little evidence that these regulations had any effect (Wadsworth 1950). These laws on paper were not enforced.

## Implement

Some capacity and resources were in place that helped with implementation, including:

- **LEADERSHIP.** Local and U.S. leadership facilitated the maintenance of restoration activities. For instance, Puerto Rico created a Department of Natural and Environmental Resources in 1972. The first head of the Department, Cruz Matos, led the charge to ensure sustainable forest management across the commonwealth. Complementing this, the U.S. Forest Service changed its philosophy regarding forest management in the 1980s and 1990s, placing increased emphasis on forest conservation and restoration, and not just forest timber production (DNER 2010).
- **TECHNICAL DESIGN.** The technical designs of restoration sites are climate resilient and efforts at both active and passive restoration embraced practices that facilitated large-scale recovery. These included restoring small tracts of marginal lands to increase wider forest connectivity, recognizing the utility of using some non-native species as pioneers, and accepting the emergence of “novel ecosystems” that are adapted to modern conditions, instead of only seeking to achieve “pre-European” ecosystems (Lugo and Helmer 2004).

## LOOKING FORWARD

The gains in forest landscape restoration in Puerto Rico are by no means secure. Recent studies suggest that since the change of government in 2009, planning processes have become weaker, enabling the fast-tracking of industry development and threatening many recovered forest areas (Borak 2011). Planning and economic policies will need to respect the contributions that restored landscapes can provide to Puerto Rico's development and well-being.

An even bigger challenge is food. Puerto Rico imports a significant proportion of its food (~80 percent), creating the threat of food insecurity for its citizens. Puerto Rico will have to make some difficult decisions at some point about the amount of land dedicated to growing food and how to decide which lands should be (re) converted to agricultural use (Chinea, J.D. 2014. pers. comm., 7 August). Realistically, the issue is not how to maintain forest cover, but rather how to limit forest cover reduction to just 50 percent in light of food demands (Lugo, A. 2014. pers. comm., 18 August).

## REFERENCES

- Aide, T.M. 1996. "Forest Recovery in Abandoned Cattle Pastures Along an Elevational Gradient in Northeastern Puerto Rico." *Biotropica* 28 (4a): 537–548.
- Bergad, L.W. 1978. "Agrarian History of Puerto Rico, 1870–1930." *Latin American Research Review* (13) 3: 63–94.
- Birdsey, R.A., and P.L. Weaver. 1987. "Forest Area Trends in Puerto Rico; Research Note." Asheville, NC: United States Department of Agriculture SO-331, Forest Service, Southern Experiment Station.
- Borak, M. 2011. "Weak Planning Process Frustrates Protection of Puerto Rico's Threatened Coastline." *Sustainable Law and Policy* 12 (1): 23, 51, 58.
- Brandeis, T.J., E.H. Helmer, H. Marcano-Vega, and A.E. Lugo. 2009. "Climate shapes the novel plant communities that form after deforestation in Puerto Rico and the U.S. Virgin Islands." *Forest Ecology and Management* 258: 1704–1718.
- Brandeis, T.J., and J.A. Turner. 2013. "Puerto Rico's forests, 2009." *Resour. Bull.* SRS-RB-191. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station.
- Chinea, J.D. 2002. "Tropical forest succession on abandoned farms in the Humacao Municipality of eastern Puerto Rico." *Forest Ecology and Management* 167: 195–207.
- Chinea, J.D., and E.H. Helmer. 2003. "Diversity and composition of tropical secondary forests recovering from large-scale clearing: results from the 1990 inventory in Puerto Rico." *Forest Ecology and Management* 180: 227–240.
- DNER (Department of Natural and Environmental Resources). 2010. "Puerto Rico Statewide Assessment and Strategies for Forest Resources." Department of Natural and Environmental Resources, Government of Puerto Rico.
- Foster, D.R., M. Fluet, and E.R. Boose. 1999. "Human or Natural Disturbance: Landscape-Scale Dynamics of the Tropical Forests of Puerto Rico." *Ecological Applications* 9 (2): 555–572.
- Grau, H.R., T.M. Aide, J.K. Zimmerman, J.R. Thomlinson, E. Helmer, and X. Zou. 2003. "The Ecological Consequences of Socioeconomic and Land-Use Changes in Post-agriculture Puerto Rico." *BioScience* 53 (12): 1159–1168.
- Helmer, E.H. 2004. "Forest conservation and land development in Puerto Rico." *Landscape Ecology* 19: 29–40.
- Lugo, A.E. 2004. "The outcome of alien tree invasions in Puerto Rico." *Frontiers in Ecology* 2 (5): 265–273.
- Lugo, A.E., and E. Helmer. 2004. Emerging forests on abandoned land: Puerto Rico's new forests. *Forest Ecology and Management* 190: 145–161.
- Molina Colon, S., A.E. Lugo, and O.M.R. Gonzalez. 2011. "Novel dry forests in southwestern Puerto Rico." *Forest Ecology and Management* 262: 170–177.
- Office of Legislative Services of the Legislature of PR 1998. "Puerto Rico Forest Act." Accessible at: <<http://www.oslpr.org/download/en/1998/0190.pdf>>.
- Rivera, L.W., and T.M. Aide. 1998. "Forest recovery in the karst region of Puerto Rico." *Forest Ecology and Management* 108: 63–75.
- Rudel, T.K., M. Perez-Lugo, and H. Zichal. 2010. "When Fields Revert to Forest: Development and Spontaneous Reforestation in Post-War Puerto Rico." *The Professional Geographer* 52 (3): 386–397.
- Thomlinson, J.R., M.I. Serrano, T. del M. Lopez, T.M. Aide, and J.K. Zimmerman. 1996. "Land-Use Dynamics in a Post-Agricultural Puerto Rican Landscape (1936–1988)." *Biotropica* 28 (4): 525–536.
- Wadsworth, F. H. 1950. "Notes on the climax forests of Puerto Rico and their destruction and conservation prior to 1900." *Caribbean Forester* 11(1):38–47. Published in Spanish in the same issue, 11(1):298–306.

## ENDNOTES

1. Sugarcane eventually became the dominant crop. Coffee declined due to U.S. customers preferring cheaper coffee. Also, the U.S. Cabotage laws drastically limited exportation to former coffee clients (China, J.D. 2014. pers. comm., 7 August).
2. During the 1940s and 1950s, new political changes led to a preference for industrial development and the abandonment of agricultural governmental support, forced in part by political decisions in the United States. Puerto Rico had much more diversified agriculture prior to the advent of becoming a U.S. territory in 1898 (China, J.D. 2014. pers. comm., 7 August).
3. The increase in wages made agriculture less competitive and contributed to its decline as a share of Gross Domestic Product (GDP). Unfortunately, the minimum federal wage came as a blow to the industry (Lugo, A. 2014. pers. comm., 18 August).
4. Because of the large proportion of tree stands dominated by exotic species, “non-assisted regeneration” may be a preferred description to “natural regeneration” (China, J.D. 2014. pers. comm., 7 August).
5. Though not yet well-documented, reforested areas dominated by the exotic African tulip tree (the most abundant tree in Puerto Rico, according to the 1990 U.S. Forest Service survey) were likely seeded by roadside planted trees. A similar situation is exemplified by another exotic tree of more recent arrival, *Albizia procera* (China, J.D. 2014. pers. comm., 7 August).
6. To some extent, such migration out of Puerto Rico was actively promoted by the government, apparently to reduce the unemployment rate and social assistance programs (China, J.D. 2014. pers. comm., 7 August).
7. The “Puerto Rico Forest Act” authorized the creation of Commonwealth Urban Forests to be developed in municipal urban zones, and for other purposes (Office of Legislative Services of the Legislature of PR 1998).

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