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## Presentation

### “Sustainable Forestry in Puerto Rico: Managing the Forest for the Trees, Amphibians, Ecological Processes, and Productivity”

Forests provide untold ecosystem services to humans, from carbon storage to air purification to microclimate control. Managing forests in a sustainable fashion integrates the triple-bottom line: environment, economy, and society. One major concern with sustainable forest management is the time frame under which a forest must be managed, in some cases across generations and with short-term economic considerations influencing management decisions. One initiative to overcome economic and environmental constraints in forest conservation is line planting economically valuable timber species within an existing environmentally valuable secondary forest to promote soil conservation and habitat protection while also harboring an economically viable crop.

As an example of a sustainable forestry initiative, Las Casas de la Selva is a 409-ha tabonuco (*Dacryodes excelsa*) forest experimental enrichment project located on steep slopes (ranging from 10-40 degrees) established over 35 years ago in the mountains of southeastern Puerto Rico. Previously logged and used as coffee plantation and grazing land, to enrich the native secondary forest, line planting of a variety of valuable native and introduced broadleaf timber trees, including mahogany (*Swietenia macrophylla*) and blue mahoe (*Talipariti elatum*), was carried out on one-quarter of the forest from 1984-1990. With its steep slopes, average elevation of 600 m, and annual rainfall of over 3,000 mm, even when covered in forest, the site is subject to heavy erosion and landslides.

The rainforest at Las Casas de la Selva has been under study for decades, with a recent project evaluating crop tree response to liberation thinning, which is a method that releases targeted crop trees from competition. In liberation thinning, the marketable crop trees in the treatment area are protected and surrounding trees with crowns that compete for sunlight are removed through extraction, girdling, and vine/liana removal to improve crop tree growth rate with improved light availability to the crown. Nearly a decade ago in early 2009, five 20 m x 30 m plots were selected within the line-planted mahogany areas. Plots were selected where there had been minimal success of the mahogany plantings, but other desirable crop trees at about 10-25 cm diameter at breast height (dbh) were present, and in areas that were accessible by the forest road. Rare or endangered tree species were reserved during this process to protect the native forest richness and diversity. Three plots were selected to have the liberation treatment applied to them and two plots were included as control plots. Each of the five plots has a 10 m isolation strip on each side, and trees within the isolation strip were eligible for felling if they crowded crop trees within the liberation plots. Competitor trees were defined by an algorithm of closeness to crop tree, dbh, height, and crown overtopping or crowding. In each of the three liberation plots, 20 competitor trees were felled or girdled.

Trees were measured five times over a six-year time span (2009, 2010, 2012, 2014, 2015), and as expected, likely owing to the young age of the forest overall, mean area increment (MAI) increased across all five plots, but results specific to each species and plot were confounded by differences in tree species present and size class in study design. It is expected that increases in growth rates will persist for several years; however, previous studies report positive effects on growth rate of liberation thinning decreasing significantly after 10 years. With the recent passage of Hurricane Maria across Puerto Rico in September 2017, a powerful Category 4 storm, it is unclear what damage the stand has sustained or what percent of the crop trees have been damaged beyond salvage. If the liberation experiment is to continue, and should such a slowing in growth rate occur in our experimental plots, the possibility of re-applying the liberation thinning treatment will need to be assessed. Beyond catastrophe planning, another consideration is determining a sustainable cutting cycle for the land once the crop trees have been harvested. It has yet to be determined how much time should pass before liberation thinning is repeated and trees are harvested, which should be determined if the operation is to be truly sustainable, and to ensure future timber crop yields in the long term.

An important consideration in categorizing this experiment as a sustainable forestry exercise is to note findings from previous studies at Las Casas de la Selva showing that line planting within secondary forests can increase the value of secondary forests, providing both sustainable timber production for profit and preservation of biodiversity and other environmental benefits of working forests. For example, a remote sensing analysis of soil slope stability may determine the role of forest enrichment in reduced erosion during catastrophic storm events. Line planting and liberation thinning are part of a long-term strategy to protect the forest ecology, with valuable timber trees such as mahoe taking decades to reach marketable size classes. In support of the ecological condition of these managed forests, the authors have previously reported that line-planting activities supported the expected amphibian community diversity. As well, line-planted areas had a similar diversity, richness, and evenness of tree species than the unplanted forest. Considering these findings, further enrichment and management of secondary forests should be explored as a promising approach to sustainable forestry. Challenges to society such as climate change, fragmentation, globalization and economic development, and population growth, can be addressed through sustainable forestry initiatives, which address the triple bottom line of sustainability.

This abstract presents findings from a manuscript currently in preparation from Thrity Vakil<sup>2,3</sup>, Stephen Loro, Andres Rua<sup>2,3</sup>, Bridget McNassar<sup>2</sup>, Mark Nelson<sup>2,3</sup>, and Frank Wadsworth. Previous papers on Las Casas de la Selva included contributions from Sally Silverstone<sup>4</sup>, Molly Robertson<sup>2,6</sup>, Patricia Burrowes<sup>5</sup>, Rafael Joglar<sup>5</sup>, and Molly Robertson<sup>6</sup>

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