Current Studies in the Caribbean Forest Inventory and Analysis Program

Helmer, E.H., Brandeis, T. and Lugo, A. 2005. **Landscape ecology and remote sensing in the Caribbean Forest Inventory and Analysis Program.** IITF Study Plan #2578, January 31, 2005, Río Piedras, Puerto Rico.

Brandeis, T., Helmer, E., Delaney, M., Parresol, B., Royer, L., Johnson, T. 2005. **Development of allometric equations for predicting Caribbean dry forest biomass and volume from forest inventory data**. USDA Forest Service Southern Research Station, Forest Inventory and Analysis, Study Plan #4801-C4, Knoxville, TN.

Brandeis, T., Oswalt, S., Helmer, E. and Dimick, B. 2004. **Forest Health Monitoring in the Puerto Rico and the US Virgin Islands.** USDA Forest Service Southern Research Station, Forest Inventory and Analysis, Study Plan #4801-C3, Knoxville, TN.

Brandeis, T., Nowak, D. 2002. **San Juan Bay Estuary Urban Forest Inventory**. USDA Forest Service Southern Research Station, Forest Inventory and Analysis, Study Plan #4801-C5, Knoxville, TN.

Helmer, E.H., Brandeis, T. and Lugo, A. 2002. **Tropical forest carbon cycling in response to large-scale clearing, and the spatial structure of forest carbon storage and net fluxes.** IITF Study Plan #2568, March 25, 2002, Río Piedras, Puerto Rico.

Helmer, E.H. 2002. **Detecting land-cover change to urban/built-up lands through an automated approach to image spatial and spectral co-registration**. IITF Study Plan #2572, April 5, 2002, Río Piedras, Puerto Rico.

Helmer, E.H. 1999. **Mapping land cover in Puerto Rico in the U.S. Virgin Islands.** IITF Study Plan #2558, September 7, 1999, Río Piedras, Puerto Rico.

Selected Summaries

Helmer, E.H., Brandeis, T. and Lugo, A. 2005. **Landscape ecology and remote sensing in the Caribbean Forest Inventory and Analysis Program**. IITF Study Plan #2578, January 31, 2005, Río Piedras, Puerto Rico. (Summary updated October 5, 2006).

Caribbean landscapes are centers of biodiversity and endemism (Myers et al., 2000). Rapid land-use and land-cover changes are impacting Caribbean ecosystems, however, and the human societies that depend on them. In the Caribbean, for example, land cover affects near-shore marine resources and hazard levels to human populations from tropical storms and hurricanes, which may increase in strength with global climate change. The broad goal of this research is to characterize how past and current land-use and land-cover changes in Caribbean landscapes are affecting human societies and forest ecosystems and how these changes may interact with global climate changes. In Puerto Rico and the U.S. Virgin Islands, studies will rely on data from the US Forest Service, Caribbean Forest Inventory and Analysis Program (Caribbean FIA). The

Caribbean FIA data will parameterize and validate forest ecosystem and remote sensing models for the broader region. These data will also be used to test hypotheses from the stand to landscape scales about tropical forests recovering from large-scale clearing.

The remote sensing portion of this research will build on and develop new remote sensing datasets, tools, and methods to characterize persistently cloudy tropical landscapes. In the process it will produce maps of forest attributes derived from FIA data. These products will help to quantify and test hypotheses about how current and past land-use and land-cover changes are influencing the spatial structures and distribution of Caribbean forest structure, species diversity and element cycling. Research will 1) develop methods and tools for efficiently monitoring land-use and land-cover changes with fine spatial resolution imagery (1 to 30 m) in persistently cloudy regions, producing algorithms for large-volume image processing, and 2) develop and test approaches for mapping forest attributes, like structure, growth, deciduousness or species composition, through integrating Caribbean FIA data with remotely sensed imagery or lidar data, which will also yield mapped products.

The landscape ecology portion of this research will lead to a greater understanding of the controls on forest ecosystem function and tree species diversity in tropical landscapes recovering from large scale clearing. The research will focus on the influence of current and historical landscape structure (i.e. disturbance history, forest fragmentation, and biophysical attributes) on present forest tree species diversity, composition, structure and function. Specific studies are addressing the relative influence of these variables, from stand-level to landscape-level scales of analysis, on 1) forest carbon storage and other element cycling, 2) the theoretical controls on tree species richness and diversity (succession, competition, productivity, dispersal), and 3) the hierarchical structuring of community composition of trees species after large-scale clearing.

Finally, this research will quantitatively address how the combination of land-cover changes and global climate change may influence the spatial distributions of forest element cycling and species diversity in Caribbean landscapes based on climate mapping and on modeling present and future ecological zones and land cover and in the context of protected areas and watersheds.

Brandeis, T. and Helmer, E. 2002. **Estimating tree volume, biomass and carbon from forest inventory data collected in Puerto Rico and the U.S. Virgin Islands.** USDA Forest Service Southern Research Station, Forest Inventory and Analysis, Study Plan #4801-C1, Knoxville, TN.

The USDA Forest Service's Southern Research Station Forest Inventory and Analysis (SRS-FIA) and International Institute of Tropical Forestry (IITF) will complete field data collection for a forest inventory of the island of the Commonwealth of Puerto Rico and Territory of the U.S. Virgin Islands in 2004. This data set will be supplemented with plots in forest types under-represented in the standard FIA sampling grid. This forest inventory will be the most complete in the island's history.

The goal of this study is to select the best methods for estimating forest wood volume (in cubic meters), AGB (in oven-dry kilograms), and aboveground carbon storage (Mg or tons C /ha) for

Puerto Rican and Virgin Islands' forests using forest inventory data. Accomplishing this goal requires a thorough review of the relevant literature, in particular previous forest surveys on the island, scientific studies of Puerto Rico's forests that estimated tree volume or aboveground biomass (AGB) from individual tree measurements, and publications that give general methodology for estimating these parameters in tropical forests. We will select analytical methods to make estimates of tree volume, AGB and carbon from the current, partial forest inventory data and the previous inventory data. The estimates produced by these methods will be compared to estimates found in detailed forest ecology studies of the island's forests in the published literature. Based on these comparisons, we will make recommendations on how tree volume, AGB and carbon estimates can be made using the latest inventory data.

Forest inventories traditionally include estimates of the volume of merchantable wood fiber. Therefore, an important part of forest inventory data analysis is the use volume tables, geometric equations, or regression equations that convert tree measurements such as diameter at breast height (d.b.h.) and total tree height to some measure of wood volume in the tree's stem, the portion of the tree used for sawn wood and pulp products. These tables and equations are developed in prior studies, and those developed for specific locales, forest types, or species are more accurate than general tables and equations. Merchantable tree volumes (in ft^3 of green wood) are available by forest type and species, and have been presented in prior Puerto Rico forest inventories (Birdsey and Weaver 1982, 1987, Franco et al. 1997). During these previous inventories, detailed measurements were taken of each tree over 12.5 cm d.b.h. to allow the use of a generic tree volume formula, Smalian's equation (Birdsey and Weaver 1982, 1987, Franco et al. 1997). Large branches were also measured and counted to include their volume in estimates of available wood. This approach gave good estimates of merchantable stem volume for forests where local volume tables and equations are still lacking. However, replicating these previous analyses to estimate wood volume in trees measured in the present inventory will not be possible.

The present forest inventory in Puerto Rico follows the new field data collection protocols being implemented by FIA across the continental U.S. and Pacific Islands. Fewer measurements that could be used to estimate volume are taken on each tree, and some of those needed for Smalian's equation are not included. Total height, d.b.h., and live crown ratio are the only measurements being taken presently that would generally be used to make a tree volume estimate. In addition, previous inventories limited their scope to the subtropical moist and wet forest types. The present inventory will be the first to collect data from all forest types found on the island, including mangrove, dry and upper montane forests. Methods for converting tree measurements to volume estimates for these forest types will have to be found. A broader range of questions will be asked of the latest forest inventory. Estimates of Puerto Rican forest productivity and its role in global biogeochemical cycles require the calculation of forest biomass. Individual live tree aboveground biomass (AGB) includes not only stem biomass, but also branch and leaf biomass.

Tree species assemblages will be studied on Puerto Rico and the US Virgin Islands to better understanding of secondary tropical forest community re-assembly after long-term, large-scale anthropomorphic disturbance, widespread introduction of exotic species, and landscape-scale forest fragmentation. Overstory and understory tree species composition at forest inventory plots

will be examined at varying spatial scales and life zones to describe the current forest community composition. Comparison will be made to the species assemblages found at inventory points 10 and 20 years ago to investigate possible shifts in favor of species with life history strategies more adapted to primary forest over those species more adapted to the rapid re-colonization of recently abandoned agricultural land.

The forests of the Caribbean islands of Puerto Rico and the US Virgin Islands have experienced similar land use trends during their history. Extensive deforestation for agriculture began with European colonization and continued through to the mid-20th century. In the case of Puerto Rico, where tropical forest once covered essentially the entire island, deforestation was estimated to be around 96%. Widespread abandonment of agricultural land due to socioeconomic changes allowed reversion to secondary forest over 32% of the island. The forests of Puerto Rico held 547 native tree species were found on Puerto Rico before European colonization (Little et al. 1974), 109 of which are endemic to the island (Francis and Liogier 1991). Since that time, an additional 80 species have become naturalized (Francis and Liogier 1991), and the consequences of these introductions are not well understood. Puerto Rico is a unique natural experiment that will demonstrate the long-term effects that introduced species have on a forested landscape.

The forests of the US Virgin Islands have also been under intense pressure from human activities for long periods. The forests on the island of St. John are the best described.
The moist and dry forests on St. John were described by Woodbury and Weaver (1987) as "in transition", still recovering from agricultural activities which were largely abandoned by the late 19th century. Natural disturbances such as tree mortality due to drought and canopy disruption from hurricanes also occur and interact with the anthropogenic disturbances. Since establishment of the Virgin Islands National Park, which covers 56% of the island, the forests have been free from the development pressure prevalent on the other U.S. Virgin Islands (Ray et al. 1998), and are now considered to be some of the best examples of dry and moist forest remaining in the Lesser Antilles (Weaver and Chinea 1987, Rogers and Reilly 1998). FIA plots installed on St. John will become part of the long-term forest monitoring network of 21 plots already established on St. John as part of the UNESCO biodiversity program (Ray et al. 1998, Rogers and Reilly 1998), and the plots established and followed by the USDA Forest Service (Weaver and Chinea 1987, Weaver 1990, 1994, 1996).

This work will be divided into several separate, yet integrated analyses, each described below.

1. Island-wide estimates of tree species diversity
2. Species capture and sampling adequacy in Caribbean forest inventories
3. Long-term species composition change at inventory points
4. "New " forest types and indicator species
5. Comparison of secondary moist forest fragment in urban and rural matrices
6. Coffee shade trends in Puerto Rico

Brandeis, T., Oswalt, S., Helmer, E. and Dimick, B. 2004. **Forest Health Monitoring in the Puerto Rico and the US Virgin Islands.** USDA Forest Service Southern Research Station, Forest Inventory and Analysis, Study Plan #4801-C3, Knoxville, TN.

This study proposes to establish a forest inventory and monitoring network and take baseline measurements on the Caribbean islands of the Commonwealth of Puerto Rico and the territory of the US Virgin Islands. Data for estimating basal area, stem density, forest condition, merchantable volume, and total aboveground biomass will be collected at permanent forest inventory and monitoring sampling points on these islands. Additionally, tree crown condition, soil productivity, and down woody debris data will be collected at a subset of the sampling points to assess forest health. Forest vegetation structure and diversity will be described in greater detail on St. John, USVI.

The Forestry Research Act (McSweeney-McNary) of 1928, requires the USDA Forest Service to "make and keep current a comprehensive inventory and analysis of the present and prospective conditions and requirements for the renewable resources of the forest and rangelands of the United States and cooperate with the appropriate officials of each State, territory, or possession of the United States" (Resources Planning Act of 1974 (RPA, PL 93-378)). Responsibility for the Forest Inventory and Analysis (FIA) in the Commonwealth of Puerto Rico and the territory of the US Virgin Islands falls to the Southern Research Station (SRS). SRS-FIA has completed periodic forest inventories on mainland Puerto Rico in 1980 and 1990 (see Birdsey and Weaver 1982, Birdsey and Weaver 1987, and Franco et al. 1997 for details), and is now expanding in scope both geographically and in terms of the data collected.

Virtually all of the primary tropical forest in Puerto Rico and the US Virgin Islands was cleared for agricultural purposes, particularly the cultivation of sugarcane, by the early twentieth century (Wadsworth 1950, Little et al. 1974). Changes in global economics and the decline of the Caribbean sugar industry resulted in the abandonment of a large portion of these agricultural lands, allowing their reversion to secondary forest (Thomlinson et al. 1996, Rudel et al. 2000).

These secondary forests now host a large component of tropical species introduced from throughout the world. "New forests" (a term coined in Lugo and Helmer 2002) have become established over much of these islands and are the subject of research regarding their species composition and ability to provide forest ecosystem services to island inhabitants (Brown and Lugo 1990, Chinea and Helmer 2003).

Island forests not only have ecological value, but economic value as well. Direct monetary benefits come from forest products and eco-tourism. Forest ecosystems provide valuable services. A well-forested watershed will retain more freshwater, speeding aquifer recharging. Soils are better stabilized, keeping sediments from damaging coastal coral reefs and regulating freshwater run-off that affects estuarine and coastal marine ecosystems. Through these hydrological mechanisms, forests directly affect many island economic activities such as fishing and tourism that depend on healthy coastal marine ecosystems. Despite their importance to the sustainable development of the islands, secondary forests are currently being cleared for urban development (Lopez et al. 2001, Ramos-Gonzalez 2001, Ramos-Gonzalez et al. 2003). Forest

inventories will provide resource managers and decision-makers the information needed for them to make informed decisions on management of their lands.

The FIA program operates in three phases. Phase 1 (P1) is the use of remotely sensed data (aerial photographs or satellite imagery) to identify forested areas. In Phase 2 (P2) data is collected in the field on forest type, site attributes, tree species, tree size, and forest condition at systematically selected sample sites (one for every 2,400 ha). The collection of additional data to assess the health of the forest, or Phase 3 (P3), is done at a subset of P2 sample plots.

This study plan outlines the implementation of P3 forest health monitoring and its integration with P2 forest inventory on the islands of Puerto Rico, Vieques, Culebra, St. Croix, St. Thomas, and St. John. Forest health monitoring on these islands will focus on forest soils, down woody material, tree crowns, and vegetation structure and diversity (St. John only), and be carried out at 4 geographic scales:

1. Mainland Puerto Rico – studies will include; extensive and detailed studies of forest soils and their changes over time with forest succession; tree crown description and modeling; down woody debris quantification by forest type; integration with forest inventory data from several forest types on the island.
2. US Virgin Islands – studies using combined data set from St. Croix, St. Thomas, and St. John that will include; forest soils descriptions; tree crown description; down woody debris quantification by moist and dry forest types; integration with forest inventory data from moist and dry forest types on the island.
3. Regional – studies of dry and moist forests common to all the Puerto Rican and US Virgin Islands that will include comparisons across the islands along a east (St. John) to west (southwestern Puerto Rico) longitudinal gradient, as well as regional forest health descriptions.
4. St. John – additional forest health monitoring plots, inclusion of a vegetation diversity and structure study, and integration with P2 data will allow for a detailed examination of forest status on this island.

The overall goal of this study is to establish a permanent forest inventory and monitoring network on these islands, take baseline measurements, and monitor these plots for change. Specifically, the monitoring network will collect data that will enable the detection and quantification of the following.