The Forest Ecosystems Observatory in Guadeloupe (FWI)

Guy Van Laere[1], Yolande Gall[2], and Alain Rousteau[3,*]

Abstract - Between 2010 and 2012, Parc National de la Guadeloupe, Office National des Forêts, and Université des Antilles et de la Guyane established 9 permanent 1-ha plots in tropical rain forest of Basse-Terre Island (Guadeloupe). These plots comprise the Guadeloupian Forest Observatory, and are specifically designed for long-term tree-growth measurements and forest-dynamics surveys. We marked more than 8000 trees with a diameter at breast height >10 cm and equipped them with tape dendrometers for measurement at 5-y intervals. We describe our field protocols for plot establishment and tree-growth data collection, and present preliminary results from analyses of the first data recorded in these plots.

Introduction. Parc National de la Guadeloupe (PNG) was founded in 1989. The core of the park includes both a marine and terrestrial component exceeding 17,000 ha. Tropical rain forest covers most of the park's terrestrial area. Although research in tropical rain forests is ongoing in many parts of the world, most of the sites are concentrated in mainland areas, and few permanent field surveys are located in insular forests (http://www.forestplots.net/). However, island tree communities seem to exhibit different features from their mainland counterparts.

Caribbean island forest-dynamics may differ from those observed in continental regions. Hurricanes and volcanic activity frequently disturb insular Caribbean forests and influence forest structure and composition in the long term (Burslem et al. 2000; Heartsill Scalley 2010; Imbert et al. 1996, 1998). In addition, the sharp mountain ranges on these small land-masses magnify the effects of climatic and edaphic changes along elevation gradients. The so-called Massenerhebung effect (Grubb 1971) compresses the distinct forest types and sharpens structural and dynamical contrasts between them. Due to these particular environmental conditions, Caribbean islands offer situations relevant to examine general questions about forest ecology, climate gradients, and disturbance. In this way, islands are ideal laboratories for ecosystem studies. Therefore, in order to obtain suitable data on insular forest-structure and long-term forest dynamics, the national park took the initiative to establish permanent forest plots and create the Guadeloupian Forest Observatory.

Field-site description. Belonging to the Guadeloupe archipelago, Basse-Terre (16°N, 61°43W) is a volcanic island less than 3 million years old (Samper et al. 2007), about 840 km^2 in area. It is a continuous mountain range dominated by an

[1]Parc National de Guadeloupe, Montéran, 97120 Saint Claude, Guadeloupe, France. [2]Office National des Forêts, Jardin Botanique, 97100 Basse-Terre, Guadeloupe, France. [3]Faculté des Sciences, Université des Antilles et de la Guyane, 97159 Pointe à Pitre, Guadeloupe, France. [*]Corresponding author - aroustea@univ-ag.fr.

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active volcano (la Soufrière) at an elevation of 1467 m asl. Climatic conditions drastically change from the windward to the leeward side of the mountain range. Climate is also linked to elevation on both sides of the range. On the windward side, mean annual rainfall increases from 2200 mm at 250 m asl (Choisy plot) to 6500 mm at 850 m asl (Bains-jaunes plot). Rainfall exceeds evapotranspiration in all months (data from Cabaussel 1982, Météo-France 1996). Near sea level, the leeward coast receives 1500 mm/yr. However, Pointe-noire at 360 m asl, the only forest plot on the leeward side, receives more than 2500 mm/yr.

The core of PNG (170 km²) harbors mainly rain forest ecosystems; montane thickets and shrubs develop on the highest ridges. Except along the roads and in some locations, the land has never been cleared. If we define trees as any ligneous plant exceeding 10 cm in diameter at breast height (stem diameter 1.3 m above the ground; dbh), then Basse-Terre island hosts 329 tree species, of which more than 250 occur in rain forests (Rollet 2010). In addition to the tree community, rain forests of Guadeloupe also harbor 302 fern species (Bernard 2010), 571 bryophytes (Lavocat-Bernard and Schäfer-Verwimp 2011) and 104 orchid species (Feldmann and Barré 2001). As a proportion of the Lesser Antilles flora, endemism in Guadeloupe reaches ~12% in ferns and fern allies (Bernard 2010) and 15% in flowering plants (Fournet 2002) and 20–30% for tree communities (Rollet 2010).

Occurrence of the three main forest types in Guadeloupe varies with increasing elevation (Rousteau 1996b). These types are very similar to those that Beard (1949) recognized in the island of Dominica. The lower montane rain forest (above 250–300 m asl) is mainly dominated by *Amanoa caribaea* Krug & Urb. (Phyllanthaceae), *Tapura latifolia* Benth. (Dichapetalaceae), and *Dacryodes excelsa* Vahl (Burseraceae). The montane rain forest is dominated by *Richeria grandis* Vahl (Bois Bandé; Phyllanthaceae), and the submontane rain forest seems to be a transitional community (Rousteau 1996b).

Plot protocol and methods. The protocol we adopted to establish the plots was the same that the CIRAD used in French Guyana (Gourlet-Fleury et al. 2006). We delineated nine 1 ha-plots during the years 2010–2012 in different locations of Basse-Terre island (Fig. 1). Six of these plots are within the core of PNG. In these plots, we labeled all stems >10 cm dbh and equipped them with tape dendrometers. We made the dendrometers on-site with steel tapes and coil springs. The stem labels were attached to the dendrometers, so we didn't need to use nails or paint on the trees (Fig. 2). The XY coordinates of each labeled stem were measured with both measuring tape and laser telemeter. To facilitate fieldwork and monitoring, we divided each 1 ha-plot into twenty-five 400-m^2 square subplots marked out with twine and PVC stakes (Fig. 3). We plan to monitor 2–3 plots annually in order to visit each of the 9 plots every 5 years. Establishing one plot requires 4 days of work for 3–4 persons. It will take 3–4 people 2 days to complete subsequent tree-diameter measurement and monitoring. We have also surveyed and described the topography for each plot, and we will monitor the local climatic conditions with mobile weather stations.

Preliminary results. We are monitoring a total of 8447 trees in the 9 permanent plots and have computed structural descriptors for each 1-ha plot (Table 1).

We have not yet completed tree identification to the species level, but that work is in progress. Results of our provisional analysis of species composition for all the plots show that 5 species are dominant: *Tapura latifolia* (13% of total stems), *Amanoa caribaea* (11%), *Dacryodes excelsa* (9.5%), *Richeria grandis* (9%) and

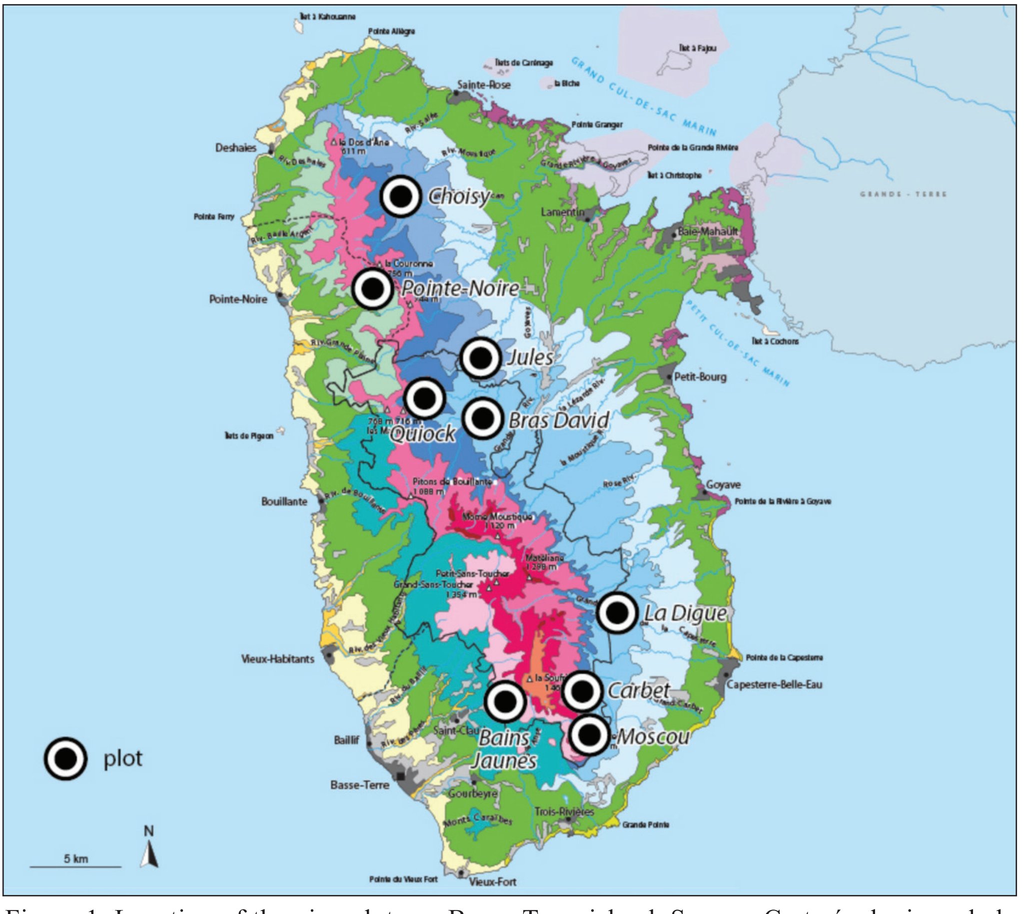

Figure 1. Location of the nine plots on Basse-Terre island. Source: Carte écologique de la Guadeloupe, A. Rousteau, 1996.

Table 1. Forest structure of the nine forest plots.

Plot name	Elevation (m)	Stem number (dbh > 10 cm)	Basal area (m²/ha)
Carbet	606	1207	42.4
Quiock	420	1044	53.6
Bras-David	270	1065	45.9
La Digue	450	795	67.6
Choisy	250	855	59.4
Moscou	650	904	40.2
Bains jaunes	850	1127	50.9
Pointe-Noire	360	593	43.9
Jules	260	857	45.7
Mean/plot		938	50.0

Figure 2. Tape dendrometer and label attached to the tape.

Figure 3. PVC stake materializing the corner of a plot. Stakes with yellow-painted head limit the 400-m² subplots.

Rudgea citrifolia (9%). These 5 species amount to 52% of the permanently monitored stems.

In 2013, fifteen months after plot establishment, we began to assess tree growth by remeasuring tree diameters in two plots (Carbet and Bras-David). We adjusted our measurements to reflect a 12-month growth period (Fig. 4). The annual increments were significantly greater in the Bras-David plot than in the Carbet plot (unilateral Wilcoxon test, *P*-value <0.001). The mean annual increment in the Bras-David plot (2.86 mm/yr, $n = 974$) exceeded that in the Carbet plot (1.71 mm/yr, $n = 1152$). However, we observed null or negative increments in both plots, so the between-plot difference is essentially due to the frequency of high growth rates.

Discussion. From the Bras-David plot (270 m asl) to the Carbet plot (606 m asl), stem density increased by 13% and basal area decreased by 8%. Though this difference was based on preliminary analyses of data from only 2 plots, these structural differences conform to the standard elevation-effect on old-growth forest stands (Moser et al. 2008, Weaver and Murphy 1990). Comparison of the same 2 plots showed that mean annual growth was 62% lower in the Carbet plot than the Bras-David plot. This preliminary finding verifies that altitude-driven structural changes co-occur with a reduction in growth rate (Bräuning et al. 2008).

Despite the preliminary status of the data, the Guadeloupe plots seem different from the lowland rain forest plots (Figs. 5, 6). The stem density we measured exceeded that of lowland stands (Fig. 5). Such high stem density characterizes high-elevation tree communities so that, even at low elevation, the structure of Guadeloupe rain forests looks like that of montane rain forest (Moser et al. 2008, Rousteau 1996a, Weaver and Murphy 1990). The fact that these trends in forest

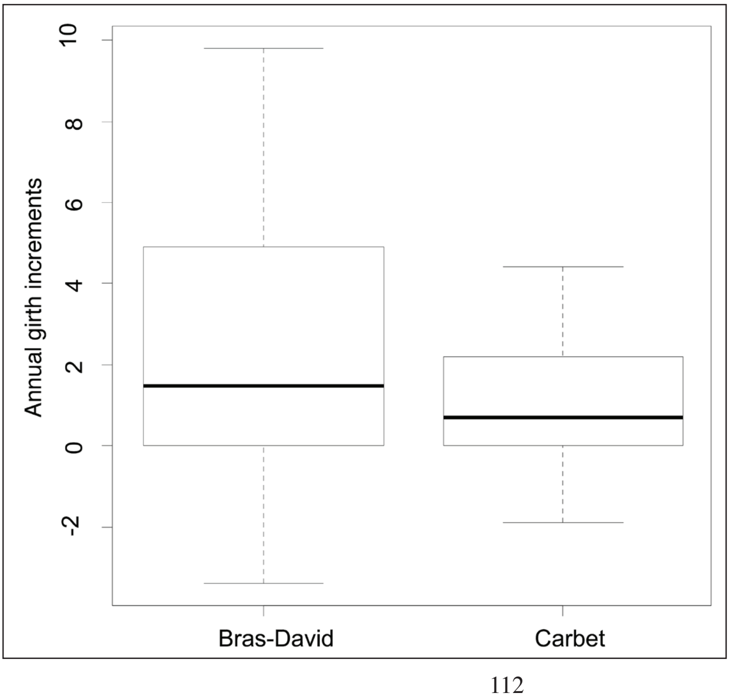

Figure 4. Box plot of the annual girth increment in Bras-David plot and Carbet plot. Annual increments were computed for a 365-day period from the measured increments, during 2012. Area of boxes represents 50% of the individual measures. The horizontal thick lines reveal median levels. Whiskers extend 1 times the interquartile range from the box. Negative or null increments are frequent events in both plots.

structure are apparent at lower elevations is probably an indication of the Massenerhebung effect combined with island size. However, although basal area in our montane stands may be limited by the low growth rates like those we observed in the Carbet plot (Fig. 4), the basal areas we measured in the 9 permanent Guadeloupe plots always exceeded those of lowland stands (Fig. 6). The combination of high density and high basal area is not unique to mountain forests or to lowland forests, rather it could be a characteristic of island forests, but further study is needed to explain this situation.

Although the use of dendrometers on all the stems is expensive and their installation is time-intensive, this method gives much more accurate data than

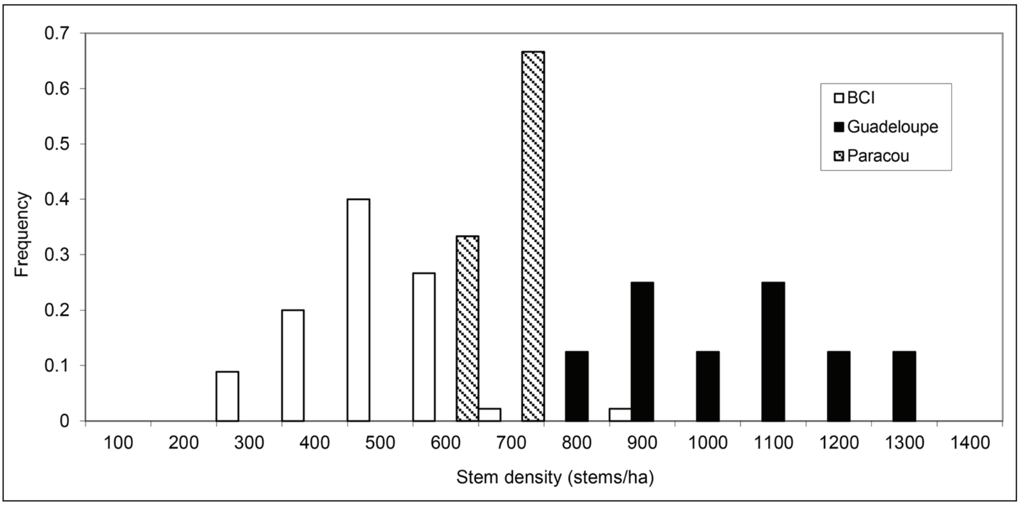

Figure 5. Comparison of stem density (dbh > 10cm) with 2 other study sites, Barro Colorado Island, (BCI) Panama (Chave et al. 2004) and Paracou, French Guyana (Gourlet-Fleury et al. 2004).

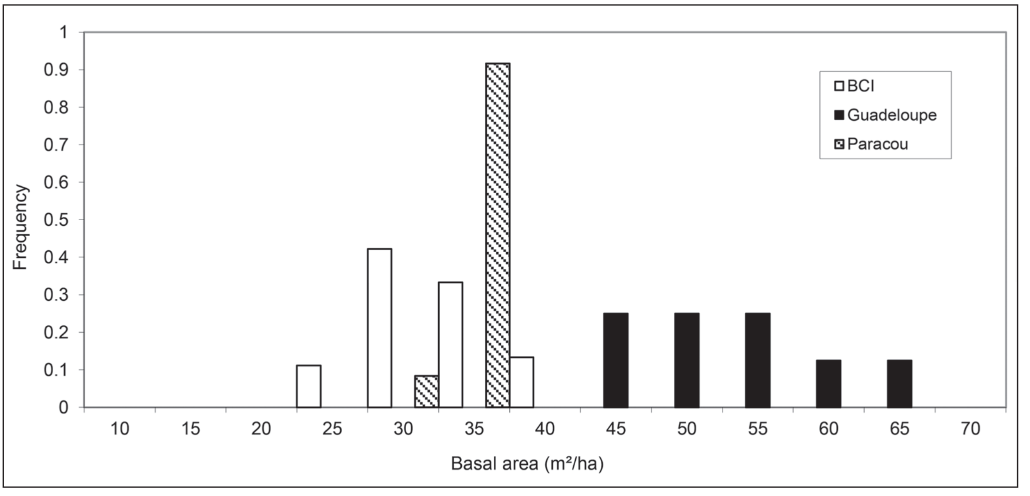

Figure 6. Comparison of basal area with 2 other study sites, Barro Colorado Island, (BCI) Panama (Chave et al. 2004) and Paracou, French Guyana (Gourlet-Fleury et al. 2004).

standard methods. Reading the dendrometer with a micrometer enables us to measure girth increments as small as 0.1 mm. Consequently, it is possible to detect significant differences in growth rates quickly. As we show in this paper, we were able to detect significant growth-rate differences within a 12-month period.

The first goal of the Guadeloupian Forest Observatory is to compare the structure and dynamics of Caribbean rain forests to those in other tropical regions. In a few years, we will be able to understand the environmental constraints acting on tree growth and stand dynamics. Due to the Massenerhebung effect, the very strong altitudinal gradient could help us to understand the impact of climatic changes on forest dynamics. Lastly, we believe that the Guadeloupe Forest Observatory system of permanent forest plots will be useful for a broad range of research projects on plant and animal ecology, and we hope that those in the scientific community will initiate research in these plots.

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