A NEW LOOK AT THE FORESTS OF PUERTO RICO[1] /

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Resumen

Un inventario reciente de los bosques secundarios en terrenos potenciales para la producción de madera en Puerto Rico, indica que casi la mitad de ellos (52 000 ha) ya contienen, sin sembrarlos, una nueva cosecha potencial de árboles de 21 especies maderables De estas especies estos bosques contienen por lo menos 100 árboles/ha de 12.5 hasta 27.5 cm dap ó 250/ha de 2.5 hasta 12.5 cm dap. De hecho contienen un promedio mucho más alto, de 176/ha de la clase mayor a 725/ha de la clase menor. Este acontecimiento reduce a la mitad del área a sembrarse Lo que plantea nuevas interrogantes para investigarse. ¿Cómo se regeneró este número tan alto de árboles? ¿Siguen este proceso los otros bosques secundarios? ¿Cuán rápido crecen estos árboles? ¿Responderían al tratamiento silvicultural? ¿Podría ser su producción económicamente viable?

Introduction

It is time for a new look at the potential for productive forests in Puerto Rico. Consumption of wood and wood products on the island continues to rise, yet with few exceptions they are bought from elsewhere, already produced, processed, and packaged. The Puerto Rican consumer thus provides employment for possibly 20 000 workers elsewhere and in addition pays for long-haul transportation of commodities that are bulky and heavy. Each year their cost is nearly half a billion dollars

While traditional outside sources of wood are facing future shortages (U S Forest Service 5), large areas no longer farmed in Puerto Rico have reverted naturally to forest. Although the harvesting of wood from Puerto Rico's forests is negligible and by some is considered environmentally undesirable it is time for a rational assessment of the potential of local forests to meet prospective wood requirements

About 90 percent of Puerto Rico's wood consumption is in construction materials and pulp and paper products that utilize primarily the high strength/weight ratio of wood. These products require trees with straight trunks, 20-40 cm in diameter, which produce strong wood or long, light-colored fibers.

Other wood products, including furniture and cabinetwork, panels, turnery, art work, and musical instruments, are more demanding but worth the difference. They require trees large enough to produce wide boards, high proportions of heartwood, and, above all, woods that are workable and attractive.

Wood energy might also come from forests in Puerto Rico. However, fuelwood is expected to remain much less remunerative than sawtimber or pulpwood, and so might appear only as a by-product. As such, its sustainable production would contribute insignificantly toward meeting island-wide energy requirements at the level foreseen for present crop maturity (Wadsworth, 7). Wood residues from the forest and from processing could, nevertheless, contribute substantially toward energy-sufficiency of at least forest industries.

Land for Timber Production

Puerto Rico's most productive soils clearly are needed for food and forage, including coffee and

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tree fruits. The next decade's prospective markets for food and forage could be met with appropriate modern production technology on 350 000 ha within Puerto Rico (Vicente, 6) Foreseeable residential, industrial, commercial, and transportation infrastructure will occupy another 120 000 ha. These uses account for half of the island.

Of the other half, most has been cropped repeatedly and abandoned as submarginal for agriculture. About half of it, some 220 000 ha, is too rainy, dry, steep, rocky, or swampy for commercial wood production. This area, about one quarter of the island and including all remaining virgin forests, would be most beneficial if left natural indefinitely. Native forests already cover and protect most of this area The remaining lands, about 200 000 ha in the northern foothills and slopes of the Cordillera, are appropriate for wood crops and so comprise Puerto Rico's potential timberlands.

Timber Plantations

Construction sawtimber and pulpwood are required in quantities that necessarily involve high energy costs for transportation from stump to consumer. Local production, to be cost effective, would have to be concentrated in rapid-growing plantations with processing facilities nearby. About 100 000 ha, half of the potential timberland, would be required to supply Puerto Rico's predicted product demand at the earliest probable harvest date. Where practical, timber plantations should be established on lands now unforested.

Native Secondary Forests

Puerto Rico's potentially commercial forests are of two classes. More than half are volunteer stands that regenerated on abandoned cultivated or pastured areas. The remainder is abandoned coffee plantations. These, depending on the period of abandonment, contain coffee and shade trees more or less invaded by secondary forest species (Weaver and Birdsey, 8).

These forests are the only remaining potential source of wood from those native tree species that once provided innumerable useful products. Because of the continuing need for such products, these forests could have multiple potentials.

The Forest Survey

Puerto Rico's potentially productive timberlands were surveyed by the Forest Service in 1980 (Birdsey and Weaver, 1). The island was stratified to focus on regions with commercial forest potential. Excluded were the prime agricultural lands of the northern coast and interior valleys and the dry southern coast. The highest mountain regions were also excluded due to extreme rainfall or slopes above 60 percent. These watershed forests are too susceptible to deterioration for intensive timber production. The survey covered a gross area of 436 600 hectares, enclosing the 200 000 ha of potential timberlands.

An initial estimate of current forest area was made from a dot-count on 1:20 000 aerial photographs. Field sample locations at the intersection of a grid of lines spaced 3 kilometers apart were selected on U. S. Geological Survey topographic maps and transferred to the photos. The estimates of forest area obtained from the dot-count were adjusted according to a ground check of land use at each sample location. Data on species composition and timber volume were obtained from permanent sample plots established at all forested sample locations. A detailed site description was made for each forested location.

Forest Cover

Nearly half of the potential timberland is forested (Table 1). More than 45 percent of the potential timberland is used agriculturally, and another 6 percent has been recently abandoned. These unforested areas should be the easiest to plant with timber trees. However, the compelling economics of concentrated siting near transportation and processing facilities means that plantations might be destined for well

Table 1. Potential timberland by current cover.

Cover	Area	95 percent confidence limits
	1 000 ha	
Forest:		
Volunteer forest	59.2	± 2.6
Abandoned coffee shade	38.2	± 2.1
	97.4	± 3.2
Nonforest:		
Abandoned farmland[1]	11.7	± 1.4
Cropland and pasture[2]	90.9	± 3.1
	102.6	± 3.3
Total	200.0	

1 Nonstocked forest land.

2 Includes some active coffee plantations

located areas that are already forested. To avoid needless sacrifice of any of these forests that may already be adequately stocked with timber species, careful assessment of each is required

Sites

The classification of the timberlands by broad elevation and slope appears in Table 2. Elevation is critical to forest composition, many of the tree species being unequally distributed through the elevation range. Slope is significant to watershed values and the need for precautions in tree harvesting. More than half of the timberland is between 45 and 60 percent.

The rainfall and physical soil properties of forested timberlands are summarized in Table 3. The 2 m annual isohyet separates the Subtropical Moist Forest and Wet Forest Life Zones (Holdridge, 3). Three of the four general soil types are derived from volcanic products. The deep clays are ultisols derived generally from basaltic extrusives. The shallow clay soils are inceptisols, tuffaceous in origin. The sandy loams are also inceptisols but derived from granitic intrusives. The limestone soils are mollisols of variable depth derived from tertiary sediments. Deep clays are the most widespread soils, particularly in the Subtropical Wet Forest Life Zone. In contrast, most of the shallow clay and limestone soils are in the Subtropical Moist Forest Life Zone. The data show 54 percent of areas as Wet Forest.

Stocking

Prospective timber yields depend on the quality, size, and number of the trees that compose the forest. Quality potential is defined fundamentally by species. Among Puerto Rico's common trees at least 21 species are capable of yielding products that will be required in addition to the lumber, poles, and cellulose from plantations. These species and their uses (Longwood, 4) are listed in Table 4

Table 2. Elevation and slope of forested timberland.

Elevation (m)	Slope (%)			Total
	0-25	26-45	45+	
	Percent			
0–200	11	11	14	36
201–400	4	3	16	23
401–600	2	3	11	16
600+	3	4	18	25
TOTAL	20	21	59	100

Table 3. Soils and rainfall on forested timberland.

Soil group	Annual rainfall		Total
	Less than 2 m	More than 2 m	
	Percent		
Volcanic soils			
Deep clays	7	39	46
Shallow clays	16	7	23
Sandy loams	7	7	14
Sedimentary soils			
Limestone	16	1	17
Total	46	54	100

Trees of these species must attain 30 to 60 cm diameter at breast height (dbh) to yield their most useful products. They must also form a crop that can all be harvested at the same time, because partial fellings damage residual trees.

At full stocking a mature crop of timber has a continuous canopy of tree crowns large enough to produce rapid stem growth. For most Puerto Rican trees this crown diameter must be about 20 times the stem diameter at breast height. If at maturity the trees average 40 cm dbh, a fully stocked stand would contain 200 trees per hectare with a basal area of 25 m^2

The common impression that Puerto Rico's forests are not generally ready for harvesting was confirmed by the survey. The basal area of timber species averages only 4.3 m^2 per hectare, or less than 20 percent of full stocking at maturity. In expectation of this finding the survey assessed immature trees suitable for future crops.

The larger trees in an immature crop are more valuable and worthy of culture because they are nearly ready to harvest. The survey data suggested that the largest diameter range likely to contain adequate crops of immature timber trees would be from 12.5 to 27.5 cm, or pole-sized trees.

For full stocking, a pole-sized crop requires more trees than a mature crop to compensate for anticipated mortality. The survival record of protected and tended crop trees elsewhere suggests that an allowance for 20 percent tree loss should suffice (Dawkins, 2) So at least 250 pole-sized trees of timber species per hectare are required for full stocking.

Table 4. **Common timber species in natural timberland forests.**

Scientific name	Common name	Highest use[1]
Andira inermis (W. Wright) H. B. K.	Moca	Turnery
Buchenavia capitata (Vahl) Eichl	Granadillo	Turnery
Bucida buceras L.	Ucar	Turnery
Byrsonima coriacea (SW.) DC	Maricao	Cabinetwork
Calophyllum calaba L.	Maria	Cabinetwork
Cedrela odorata L.	Cedro	Cabinetwork
Cordia alliodora (Ruiz & Pav.) Oken	Capa prieto	Cabinetwork
Dacryodes excelsa Vahl.	Tabónuco	Cabinetwork
Didymopanax morototoni (Aubl.) D. + P.	Yagrumo macho	Plywood, matches
Guarea guidonia (L.) Sleumer	Guaraguao	Cabinetwork
Hymenaea courbaril L.	Algarrobo	Turnery
Inga fagifolia (L.) Willd.	Guama	Cabinetwork
Meliosma herbertii Rolfe	Aguacatillo	Millwork
Micropholis chrysophylloides Pierre	Caimitillo	Cabinetwork
M. garciniefolia Pierre	Caimitillo verde	Turnery
Nectandra spp.	Laurel	Millwork, novelties
Ormosia krugii Urban	Palo de matos	Millwork
Petitia domingensis Jacq.	Capa blanco	Turnery
Pouteria multiflora (A. DC) Eyma	Jacana	Turnery
Spondias mombin L.	Jobo	Plywood, matches
Tabebuia heterophylla (DC.) Britton	Roble blanco	Cabinetwork

1 From Longwood (4).

Crops of pole-sized trees need not be fully stocked to be worthy of protection and management rather than conversion to plantations. Poles are nearly half grown sawtimber. The conversion of pole stands to plantations would mean their sacrifice in addition to the costly process of land clearing. This cost would not be required on the currently large area of cleared and idle land. For these reasons, pole crops only 40 percent stocked, that is, with at least 100 pole-sized timber trees per hectare, were assumed to be "adequately" stocked. The survey showed that 23 600 hectares of the forests in Puerto Rico's timberlands meet this standard (Table 5).

Forests less than adequately stocked with pole-sized timber trees may still be worthy of protection and culture if adequately stocked with saplings of good species between 2.5 and 12.5 cm dbh. These smaller trees face a greater risk of damage or mortality before they can be harvested. An allowance of 60 percent for such losses means that full stocking requires 500 saplings of timber species per hectare. Then, assuming that 50 percent sapling stocking is sufficient to eliminate the need for plantation establishment, 250 saplings of timber species per hectare were considered "adequate". The survey showed that, in addition to the adequately stocked pole stands, Puerto Rico's timberlands also bear 28 000 hectares with adequate sapling stocking (Table 5).

Table 5. **Area of adequately stocked[1] forests by timber stand size and forest class.**

Timber stand size	Volunteer forests	Abandoned coffee shade	Total	95 percent confidence limits
	1 000 ha			
Poletimber[2]	11.2	12.4	23.6	± 1.7
Sapling[3]	21.1	6.9	28.0	± 1.8
Total	32.3	19.3	51.6	± 2.5

1 Adequate timber stocking for poletimber stand is 100 trees/ha, and for sapling stands, 250 trees/ha

2 Poletimber trees range from 12.5 to 27.5 cm dbh.

3 Saplings range from 2.5 to 12.5 cm dbh.

Adequately stocked stands surveyed average well above these minimum standards (Table 6). Pole crops average 176 trees per hectare instead of 100, or 70 percent of full stocking. The average tree in the pole crop has a diameter of 18.3 cm, well above the minimum of 12.5 cm. The sapling crops average 725 trees per hectare instead of the 250 for adequate stocking, nearly 50 percent above full stocking. The 250 largest saplings per hectare average 7.7 cm dbh, whereas the minimum requirement is only 2.5 cm.

Table 6. Actual stocking of adequately stocked forests.

Timber stand size	Timber species stocking			
	Minimum	Average	Minimum	Average
	Trees/ha		Mean dbh (cm)	
Poletimber	100	176	12.5	18.3
Saplings	250	725	2.5	5.2[a]

a Increases to 7.7 for 250 largest timber saplings per hectare

All 21 timber species are represented in these adequately stocked forests, the most common being guaraguao*, roble blanco, and moca (Table 7). In addition to these timber species, the survey recorded 168 other tree species.

Table 7. Composition of adequately stocked forests.

Species	Proportion of all timber trees[1]	
	Poletimber stands	Sapling stands
	Percent	
Capa prieto	3	3
Guama	11	4
Guaraguao	25	21
Maria	3	6
Moca	16	18
Roble blanco	10	37
Yagrumo macho	11	1
Other timber	21	27
Total	100	100

1 Timber species only of pole-size in poletimber stands and only of sapling-size in sapling stands

Management Implications

The major conclusion is that more than a quarter of Puerto Rico's potential timberland area and more than half of the existing forests within it (51 600 ha) are already adequately stocked with timber species.

A second conclusion is that if adequate stocking occurred naturally in half of the existing forests without any special cultural treatment, it may soon take place also in other understocked forests. All that appears required is continued protection and exposure to the action of birds, bats, and the wind. In fact, the understocked stands already contained, on the average, 77 saplings of timber species per hectare, nearly one-third of adequate stocking.

A third conclusion is that natural regeneration has greatly reduced the land area needing tree planting. These forests already adequately stocked need only liberation, a practice much less costly than planting. Then if planting is concentrated first on unforested areas, the understocked forests may naturally attain adequate stocking in the meantime and thus not require planting either. The aggregate saving in planting might eventually total 100 000 hectares.

A fourth conclusion is that the adequately stocked forests contain more trees than is desirable, including many non-timber species. On the average, about 85 percent of the trees in these forests are in excess of full stocking, occupying space needed by the maturing timber crop. For accelerated growth the crop trees must be liberated from such competition, and the sooner this process begins, the sooner crop maturity will be reached.

A fifth conclusion concerns the diversity of these forests. Most of the species recorded in the survey (168 out of 189) are apparently of little or no direct economic interest, even potentially. Yet each species, including animals as well as plants, is a component of an ecological web that may be critical to the health of the forest and the sustainable productivity of the site. Some minimum level of forest diversity must be preserved. All trees, regardless of species, not interfering with the crop trees should be retained. As the crop trees grow and require more space, however, these other species will have to be thinned; their total disappearance can thus be delayed a maximum period during which alternatives, if needed, may be found through research. Selecting crop trees solely for apparent value potential should also be resisted. Rather, the mix of crop trees should include several timber species of less value as well as those thought most promising. Too little is known about the ecology of these forests and future markets for their products to warrant selection of only a few species.

Research implications

Notwithstanding the evidence supporting intensified culture of Puerto Rico's forests, a continuing

* Common and scientific names are listed in Table 4.

need exists to strengthen the scientific basis for management, reduce costs, and fully assess all consequences. Appropriate inquiries for research include the following:

1 **How valid are the premises of this analysis?** The prediction of future forest products requirements, the consequent selection of tree species and sizes at maturity, and the standards selected for full and adequate stocking are all based on incomplete information and estimates. This provisional basis for forest management needs scientific scrutiny.

2. **Where, precisely, are the adequately stocked forests?** On the map (Figure 1) they appear to be widely distributed throughout the potential timber producing area. Before they can be studied or treated, however, their extent and boundaries must be mapped more precisely.

3. **Can we accelerate the process of natural restocking?** Adjacent forests that contrast sharply in stocking of timber species suggest that studies of sites and histories of treatment might suggest practices that could accelerate the regeneration of potential crop trees.

4. **How productive are untended adequately stocked forests?** Repeat-measurement tree and crop growth-rate benchmarks are needed for comparisons of treatments.

5. **What responses can be expected from silvicultural treatment?** Reduction in competition for light, moisture, and nutrients can be expected to stimulate crop increment. Research must determine the best type and intensity of treatment, and monitor secondary effects on the ecosystem as a whole, including the preservation of the productive quality of the site.

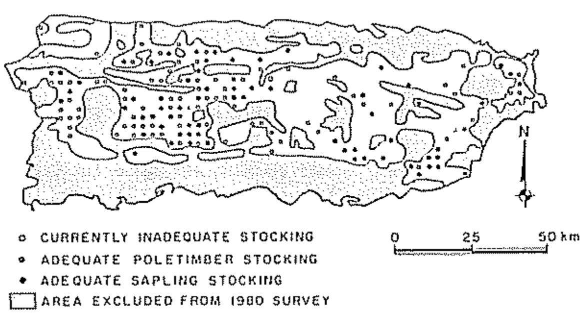

Fig 1 Location and characteristics of 1980 forest survey plots

6. **How well can secondary forests redeem investments in their production?** Before widespread support for investments in largely privately-owned secondary forests is likely there must be more evidence of the returns from alternative land uses, including timber plantations. Small-scale, efficient wood processing systems need testing or developing. Assessment of their relative social benefits should clarify the management roles of the government and private landowners.

Native secondary forests, an unrecognized opportunity

All local evidence indicates that naturally regenerated forests of native tree species will prove incapable of producing usable wood yields at a rate comparable to intensively managed plantations of pine, eucalyptus, and other rapid-growing tree species. However, there can be important compensations. Productive native forests once grew and are reappearing throughout the potential timberlands, some of which are too steep and inaccessible for plantations. Native woods are distinct and today worth more per unit than are woods of locally proven rapid-growing plantation species; in the marketplace, they could also be supplemental rather than competitive.

The private landowner may prefer native forests because of low stand establishment and maintenance costs which result in less initial investment than conversion to plantation.

These conclusions and previous knowledge about silviculture in Puerto Rico suggest that we stimulate timber species growth in these adequately stocked forests. Their silvicultural treatment as a part of rural development should be environmentally acceptable, and economically preferable to continued importation of all timber products.

Summary

A 1980 inventory of the secondary forests on lands of timber production potential in Puerto Rico has shown that about half of them (52 000 ha) are adequately stocked with poletimber or saplings of timber species to produce a second crop whithout artificial regeneration. Twenty-one timber species were identified. Adequate stocking called for 100 trees/ha of poletimber size (12.5 to 27.5 cm dbh) or 250 trees/ha of sapling size (2.5 to 12.5 cm dbh). The means for the adequately stocked areas were much higher than these minima, 176 poletimber tree/ha or 725 saplings/ha. This finding reduces drastically the land area in need of tree planting.

It raises new questions for research. How did this stocking develop? Is it developing on additional areas? How rapidly are these trees growing? How well will they respond to silvicultural treatment? Will this treatment prove economic?

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Reseña de libros

Metodología para obtener semilla de alta calidad: Arroz, frijol, maíz, sorgo. CIAT, Cali, Colombia. 1984.

El problema de la escasez de semilla de alta calidad para el cultivo comercial de arroz, frijoles, maíz y sorgo en la región centroamericana y caribeña es, de acuerdo al criterio de políticos y expertos en la materia, resultado de la falta de información detallada sobre: 1) las características varietales de los cultivos, 2) las normas y requisitos que deben observarse durante la producción de sus semillas y 3) un método para describir adecuadamente los correspondientes cultivares. Esta grave deficiencia motivó la publicación de la obra de referencia, por parte de dos instituciones internacionales y el Comité Técnico Regional de Semillas de América Central y el Caribe.

"Metodología para obtener semillas de alta calidad: arroz, frijol, maíz, sorgo" es una colección de materias extraídas de varias fuentes bibliográficas. El trabajo editorial estuvo a cargo de las Unidades de Semillas y de Apoyo en Comunicación e Información, del Centro Internacional de Agricultura Tropical –CIAT–, con sede en Cali, Colombia.

En el prólogo nos dice que la obra ofrece orientaciones o sugerencias de aplicación práctica, adecuadas a las condiciones agronómicas y culturales de América Central y el Caribe, aunque se admite que aquéllas son susceptibles de interpretación al aplicarlas en diferentes países o situaciones particulares. No obstante, se espera que "contribuyan a unificar las normas y los estándares que incrementen el uso de mejores semillas para bien de la agricultura regional" (ibíd., p. x).

Consideramos que un documento de esta naturaleza y con objetivos tan bien definidos, está plenamente justificado. Por tanto, debería tener muy buena acogida entre fitomejoradores de los mencionados cultivos y entre estudiantes avanzados de Agronomía y Biología, pues el libro también es didáctico.

La primera parte es un refrescamiento de conceptos útiles para hacer una descripción satisfactoria de cualquier cultivar. Desafortunadamente, y lo decimos con pesar, la traducción al español es sumamente deficiente. No se tiene que ser muy hábil en el manejo de nuestra lengua materna ni en redacción técnica, para descubrir la cantidad de errores que ahí existen; algunos son muy elementales, como por ejemplo: la repetición de ideas y conceptos clásicos cuya comprensión es fácil hasta para técnicos de América Central y el Caribe (los destinatarios); el uso de vocablos incorrectos, como "variedad", "progenie" y "efectos", en vez de cultivar, descendencia y factores (con relación a "progenie", permítasenos recordar que en español significa CASTA, ASCENDENCIA, lo que, obviamente, es opuesto a descendencia). Pero el uso de frases innecesariamente largas es quizá el error más frecuente en todo el libro; esto lo consideramos perjudicial porque causa confusión en el lector. Sin ánimo de querer sentar cátedra en Fitotecnia, estimamos nuestra obligación consignar aquí que la representación de fenotipo (véase la p. 5) por medio de la igualdad $F = G + A + GA$, es discutible. En efecto, nosotros consultamos tres fuentes bibliográficas recientes y siempre encontramos la misma definición: el fenotipo (F) es producto de la interacción de la constitución genética (G) del individuo, con el ambiente (A). Así, $F = GA$, de donde se deduce que las contribuciones independientes del genoma y el medio que rodea al organismo, están sobrando en la ecuación de referencia. Y así debe ser, pues desde un punto de vista biológico es difícil comprender como un ser vivo puede integrar (metabólicamente), unas veces sí y otras no, herencia y ambiente.

Las cuatro partes siguientes contienen explicaciones y, con mucho detalle, instrucciones para efectuar la toma de datos en los respectivos cultivos. Finalmente, en la quinta parte se dan las guías y requisitos para la producción de las cuatro clases de semilla. Al igual que en el resto del libro, aquí hubiera sido agradable encontrar, además de la excelente información técnica, mayor uniformidad de estilo tanto en la redacción del texto como en la confección de tablas, mejor uso del español y menos repeticiones. Sinceramente esperamos que esas fallas editoriales sean corregidas en una próxima edición de "Metodología para obtener semillas de calidad: arroz, frijol, maíz, sorgo", pues el documento es realmente útil y necesario.

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