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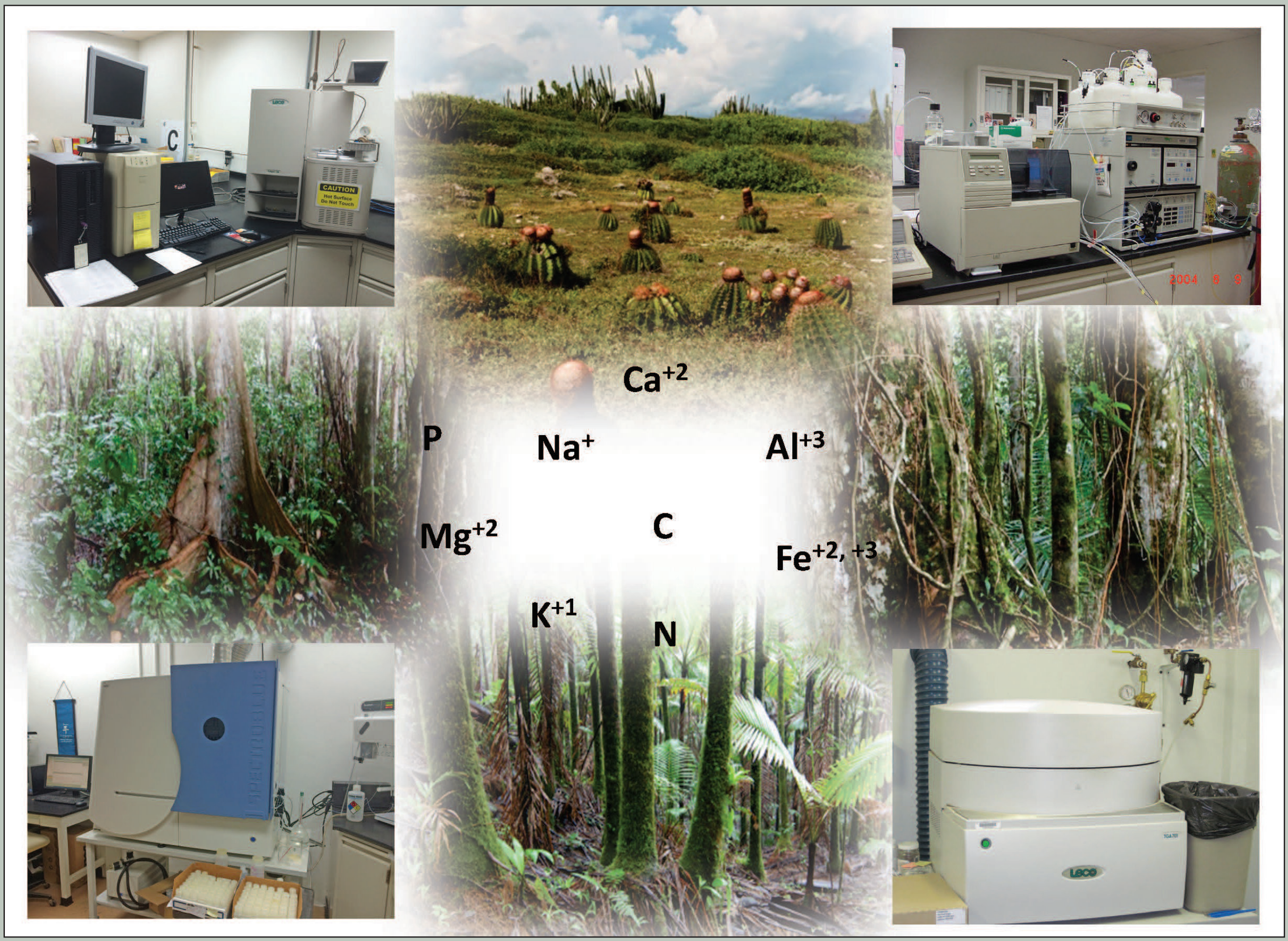
Chemical and Physical Analyses of Selected Plants and Soils From Puerto Rico (1981–2000)



Forest Service

International Institute of Tropical Forestry

General Technical Report IITF-GTR-45

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INTERNATIONAL
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Compilers

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Chemical and Physical Analyses of Selected Plants and Soils From Puerto Rico (1981–2000)

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Abstract

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This report contains the results of analyses conducted at the chemistry laboratory of the International Institute of Tropical Forestry in Puerto Rico from 1981 to 2000. The data set includes 109,177 plant analyses and 70,729 soil analyses. We report vegetation chemical data by plant part, species, life zone, soil order, geology, or parent material. Soil data are reported by depth, soil order, geology or parent material, and life zone. These data are summarized to facilitate interpretation and highlight the mean and range of values obtained.

Keywords: Plant, soil, chemical, element, tropical.

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We thank Ernesto Medina, Michael Keller, Jorge Frangi, Elvira Cuevas, and Fred Scatena for their contributions to quality assurance and quality control in the laboratory. Carmen Marrero, Maribelis Santiago, and Luis Iglesias contributed to the processing and analysis of samples. Institute staff support both the functioning and maintaining of the infrastructure and laboratory facilities. All the work is done in collaboration with the University of Puerto Rico.

Contents

Introduction

The International Institute of Tropical Forestry's chemistry laboratory, established in 1981 in Puerto Rico, has the capacity to analyze total and available elements in soil and plant parts, including aluminum, calcium, carbon, chromium, iron, manganese, magnesium, nickel, nitrogen, phosphorus, potassium, and sulfur as well as ash, loss on ignition, and organic matter. In 1981 the laboratory conducted 93 analyses for two investigators; in 1990, it analyzed samples in 10 projects for 8 investigators for a total of 14,840 analyses. By 2000, the laboratory analyzed samples in 21 projects for 16 investigators, for a total of 47, 614 analyses.

This document contains the results of most analyses conducted at the laboratory from 1981 to 2000. Sanchez et al. (1997) reported results up to 1990, and here we update that report to the year 2000. Our objective continues to be making available in one place all the chemical and physical data that we develop in our laboratory. With the increased importance of the field of ecological stoichiometry (Sterner and Elser 2002), the relevance of data compendia such as this one increases. Most of these data are for vegetation (mostly forests) and soils of Puerto Rico. Not included here (but available in the laboratory) are data for other parts of the world, particularly from Argentina. The chemical composition of plant parts or soil is summarized by plant species, soil order, and geology, or parent material.

Description of the Contents

The elemental concentration is described in terms of mean, standard deviation, and median, maximum, and minimum values. Codes used for the life zones and types of plant parts (tissues) are defined in tables 1 and 2, respectively. The results of the analyses are not discussed in this report. However, we summarize the data to facilitate interpretation and to synthesize the range of values obtained for tropical ecosystems. The range of values for elements in plants and soils are summarized in table 3 (plants) and tables 4 to 6 (soils). Methods of analysis are described in table 7. Table 8 contains the bulk of the vegetation data and table 9 contains the bulk of the soil data, both based on individual studies. Data sources for table 8 and 9 are listed in appendix 1, Tables 8 and 9 are published on the CD.

Study species and identification numbers are listed in appendix 2. Appendices 3 to 5 consist of graphs that show elemental concentration in various plant parts by species. Appendix 6 contains graphs with data about soil samples. The figures show data on mean concentration of elements and other constituents in different types of soil. Data on other characteristics, such as bulk density and effective cation exchange capacity, are also shown. Appendix 7 contains an analysis of leaf chemistry data from different environments.

The next and third version of this report will include analyses from 1981 to 2010, and we welcome comments for improving the presentation of data. We ask for acknowledgment of any use of this information and for copies of reports, articles, or documents resulting from the use of this information.

Table 1—Ecological life zone codes

Code	Ecological region
Lmrf	Subtropical lower montane rain forest
Lmwf	Subtropical lower montane wet forest
Sdf	Subtropical dry forest
Smf	Subtropical moist forest
Srf	Subtropical rain forest
Swf	Subtropical wet forest

Table 2—Codes for the identification of plant part samples (continued)

I. Soil					
II. Vegetation					
1. Trees	A. Leaves	i. Canopy	a. Young	b. Mature	c. Other
		ii. Shade	a. Young	b. Mature	
		iii. Other			
	B. Branches				
	C. Main bole, stem, trunk	i. Bark			
		ii. Heartwood			
		iii. Sapwood			
	D. Twigs				
	E. Roots				
	F. Flowers, fruits				
	G. Miscellaneous				
	H. Leaves, stems				
2. Shrubs	A. Leaves				
	B. Branches				
	C. Main bole, stem, trunk	i. Bark			
	D. Twigs				
	E. Roots				
	F. Flowers, fruits				
	G. Miscellaneous				
	H. Leaves, stems				

Table 2—Codes for the identification of plant part samples (continued)

3. Herbs	A. Leaves	i. Canopy
		ii. Shade
	B. Branches	
	C. Main bole, stem, trunk	i. Bark
	D. Twigs	
	E. Roots	
	F. Flowers, fruits	
	G. Miscellaneous	
	H. Leaves, stems	
4. Climber	A. Leaves	
	B. Branches	
	C. Main bole, stem, trunk	i. Bark
	D. Twigs	
	E. Roots	
	F. Flowers, fruits	
5. Moss		
6. Other	A. Leaves	
	B. Branches	
	C. Main bole, stem, trunk	
	D. Twigs	
	E. Roots	
	F. Flowers, fruits	
7. Coarse woody debris	A. Bark	
	B. Heartwood	
	C. Sapwood	
8. Loose litter	A. Leaves	
	B. Wood	
	C. Flowers, fruits	
	D. Miscellaneous	
9. Litter fall	A. Leaves	
	B. Wood	
	C. Flowers, fruits	
	D. Miscellaneous	

Table 3—Range of chemical concentration data for plants parts

Plant part	Aluminum	Ash	Calcium	Carbon	Cobalt	Copper	Chromium	Iron	Magnesium	Manganese	Nickel	Nitrogen	Phosphorus	Potassium	Sodium	Sulfur	Zinc
	(mg/g)	*(%)*	*(mg/g)*	*(%)*	*(µg/g)*	*(µg/g)*	*(µg/g)*	*(mg/g)*	*(mg/g)*	*(mg/g)*	*(µg/g)*	*(%)*	*(mg/g)*	*(mg/g)*	*(mg/g)*	*(%)*	*(µg/g)*
Bark	3.52-0.01	15.86-0.14	63.48-0.29	54.80-40.00					1.40-0.65	0.24-0.08			0.35-0.17	2.66-0.98			
Bole	13.61-0.01	11.48-0.44	41.60-0.47	54.16-48.12				1.48-0.01	7.00-0.06	0.37-0.01		3.32-0.22	2.00-0.02	31.00-0.42	12.49-10.43	0.54-0.01	
Branches	6.98-0.01	4.53	22.26-0.91	49-41	0.30			0.28-0.01	5.53-0.26	1.36-0.01		1.53-0.03	1.59-0.01	16.20-0.27		0.28-0.01	
Climber								8.85-0.01	14.80-0.43	2.55-0.05	69.75	7.03-0.37	4.47-0.21	89.46-1.12		0.57-0.07	
Coarse woody debris:	0.25-0.05	11.86--2.82	13.79-1.18	51.20-43.96					1.17-0.33			0.31-0.08	0.18-0.08	2.14-0.20			
Bark	4.35-0.09		13.50-6.72					1.40-0.07	2.38-0.36	0.79-0.05			0.47-0.05	3.06-0.58			
Heartwood	0.14-0.01	14.01-1.75						0.15-0.01	1.17-0.25	0.13-0.02		0.31-0.08	0.22-0.04	2.23-0.23			
Sapwood	0.75-0.02		25.37-2.60					1.18-0.02	1.01-0.22	0.97-0.03			0.49-0.07	3.47-0.57			
Flowers and fruits	0.07-0.02		10.05-2.65					21.00-0.04	4.86-0.77	1.01-0.01		2.92-0.36	3.80-0.37	34.34-2.68			
Heartwood	34.80-0.01	21.94-1.15	71.55-0.71	57.24-42.00	5.80-0.30	32.20-1.88		0.08-0.02	1.13-0.32	0.13-0.03		0.24-0.11	0.15-0.03	1.64-0.37			
Leaves:	34.80-0.01	57.55-0.50	49.90-0.36	61-16	4.13-0.10	7.55-2.00	178.00-1.00	5.97-0.01	35.05-0.35	2.10-0.01	181.45-2.35	4.57-0.21	13.87-0.01	61.15-0.43	185.41-0.28	1.67-0.04	52.43-4.84
Canopy	0.03	19.97-0.53	80.02-32.04	52				0.04	1.42	0.04		4.57-0.51	0.84-0.21	10.49-0.80	0.72	0.13	
Mature-canopy	0.17-0.12		15.58-10.16						3.84-2.93			1.80-0.48	5.61-0.21	23.99-0.80			
Mature-shade		17.55-11.83							4.50-3.45	0.06-0.04		1.71-1.42	0.88-0.60	8.73-4.99			
Leaves-other:	0.08-0.03	5.65-4.19	12.13-5.65	54-41				0.21-0.05	4.45-2.04	0.15-0.04		5.08-0.65	1.50-0.86	12.79-6.95	0.66-0.21	0.52-0.31	
Shade	2.07-0.09	17.55-14.28	97.98-46.54						5.94-3.36			1.59-0.93	3.64-0.77	26.38-4.99			
Leaves and stems	7.89-0.06	22.07-4.02	44.95-2.72	55.80-37.80				0.39-0.11	5.67-1.19	0.72-0.05		1.92-1.36	1.98-0.66	41.35-7.25			
Miscellaneous	33.37-2.68	14.57-5.51						7.39-0.09	2.84-1.11	0.40-0.05		2.80-0.87	1.51-0.22	12.42-0.93		0.74-0.28	
Moss			17.07-2.09					27.47-1.82	3.09-0.53	1.42-0.04		1.43-0.24	1.79-0.20	1.79-0.20			
Other	13.73-0.01	16.46-2.10	9.77-1.21	54.82-39.85					8.25-064			1.65-0.78	1.15-0.22	20.68-2.25			
Roots		12.54-6.70						17.62-0.09	17.71-0.44	0.69-0.01		2.07-0.14	2.00-0.11	15.75-1.56	48.24-11.52	0.78-0.04	
Shrubs	2.7-0.01	31.82-0.14	41.92-0.21									0.70-0.52	0.22-0.14	5.90-3.00			
Trunk:			63.48-10.47					0.27-0.01	4.53-0.05	0.33-0.01		2.43-0.06	2.48-0.01	44.13-0.30			
Bark	0.46-0.18		16.19-3.24									0.70-0.20		22.28-5.02			
Sapwood			22.42-0.77					0.50-0.13	1.53-0.039	0.45-0.05		3.39-2.59	0.28-0.12	2.38-0.99			
Twigs									4.33-0.21				1.18-0.02	8.53-4.44			
Loose litter:																	
Flowers andfruits	9.46-0.33	9.59-0.71	18.75-1.97	55.23-43.62				4.57-1.11	7.12-0.77	0.77-0.06		2.36-0.44	2.18-0.25	4.45-0.99	2.27-1.32	0.40-0.13	
Leaves	15.09-0.07	22.66-3.14	36.69-1.38	57.14-37.86				6.01-0.09	6.77-1.10	1.69-0.03		3.96-0.50	1.18-0.01	12.84-1.09		1.55-0.11	
Miscellaneous	20.90-0.15	43.13-5.94	103.03-1.81	46.39-30.71				22.02-0.26	4.87-1.42	1.56-0.05		8.80-0.91	0.95-0.05	9.14-0.23		0.38-0.15	
Wood	6.63-0.13	9.82-1.98	26.99-2.10	54.07-42.23				2.16-0.03	5.05-0.70	1.05-0.03		1.45-0.32	0.85-0.10	7.57-0.46		0.35-0.11	
Litter fall:																	
Flowers and fruits	2.17-0.10	6.01-3.80	8.73-1.13	54.21-43.50				3.32-0.25	3.56-0.09	0.46-0.02		2.33-0.41	5.63-0.27	11.62-0.68	9.77-6.72	0.57-0.21	
Leaves	4.97-0.35	16.46-4.80	38.71-0.28	57.55-41.20				6.26-0.13	6.13-0.37	1.22-0.11		1.96-0.48	0.82-0.15	8.76-0.68	23.93-0.19	0.59-0.15	
Miscellaneous	9.49-0.34	21.90-5.49	15.87-4.43	50.40-36.00				11.59-0.27	4.74-1.25	0.56-0.17		2.44-0.58	1.32-0.31	8.48-2.28		0.46-0.21	
Wood	2.79-0.13	10.43-3.42	25.47-2.52	52.23-44.13				0.55-0.08	3.09-0.81	0.80-0.09		1.14-0.26	0.40-0.07	6.25-0.81		0.37-0.16	

Table 4—Chemical and physical characteristics of alfisols, entisols, and histosols by soil order or parent material

	Alfisols		Entisols		Histosols	
Element	**Depth**	**Value**	**Depth**	**Value**	**Depth**	**Value**
	cm		*cm*		*cm*	
Aluminum (cmol/kg^{-1})	0-30	0.12-0.05			0-40	0.39-0.01
Aluminum (mg/g)			0-30	0.16-0.03	0-20	3.24-0.01
			100-150	0.13-0.05		
Aluminum-total (mg/g)			0-30	23.07-12.44		
			100-150	18.25-9.17		
Bulk density (g/cc)	0-18	1.96-0.45	0-18	1.32-1.11		
Carbon/nitrogen	0-15	747-21			0-40	307-1
Calcium (cmol/kg^{-1})	0-15	49.13-1.24			0-40	19.66-2.56
	15-80	4.99-0.67				
Calcium (mg/g)	0-80	9.83-0.13	0-30	7.53-1.72	0-30	3.93-0.34
Calcium-total (mg/g)			0-150	7.01-4.06		
Carbon (%)	0-15	45.17-28.58	0-30	32.16-7.15	0-30	28.06-0.40
Clay (%)	0-30	26-3	0-30	27-5		
Cobalt-total (mg/g)						
Copper-total (mg/g)						
Chromium-total (mg/g)						
ECEC (cmol/kg^{-1})	0-30	65.79-4.00			0-30	23.95-4.09
Iron (mg/g)	0-30	0.20-0.01	0-20	0.07-0.01	0-40	0.19-0.01
Iron-total (%)			0-150	2.21-1.13		
LOI (%)			0-30	74.90-33.39	0-40	55.91-1.42
Magnesium (mg/g)	0-30	1.85-0.05	0-30	13.19-0.28	0-40	1.82-0.01
Magnesium (cmol/kg^{-1})	0-80	15.44-0.58			0-40	3.34-0.11
Magnesium-total (mg/g)	0-30	14.01-1.63				
Manganese (mg/kg)	0-30	350-16	0-30	250-6	0-30	84-1
Manganese-total (mg/g)			0-150	0.17-0.05		
Nickel-total (mg/g)						
Nitrogen (%)	0-15	1.35-0.06	0-30	1.19-0.28	0-30	3.00-0.01
Organic matter (%)	0-30	20.96-0.35	0-30	3.54-0.60		
pH (H_2O)	0-30	8.86-4.73	0-30	8.26-3.76	0-30	8.26-4.38
pH (KCl)	0-30	7.26-4.69	0-20	4.50-3.66	0-30	7.83-4.08
Phosphorus (mg/kg)	0-30	39-2	0-30	572-20	0-30	16-2
					30-120	

Table 4—Chemical and physical characteristics of alfisols, entisols, and histosols by soil order or parent material (continued)

	Alfisols		Entisols		Histosols	
Element	Depth	Value	Depth	Value	Depth	Value
	cm		*cm*		*cm*	
Phosphorus-total (mg/g)			0-30	0.29-0.09		
Potassium (cmol/kg^{-1})	0-80	0.38-0.06			0-40	0.57-0.03
Potassium (mg/kg)	0-30	292-80	0-30	4850-50	0-30	220-11
Potassium-total (mg/g)			0-30	4.06-2.82		
Sand (%)	0-30	97-41	0-30	86-11		
Silt (%)	0-30	35-1	0-30	58-9		
Sodium (cmol/kg^{-1})	0-15	0.76-0.03			0-30	2.28-0.06
Sodium (mg/kg)	0-30	130-7			0-30	830-12
Sodium-total (mg/g)						
Sulfur (mg/g)			0-150	76.90-16.00	0-40	19.00-0.04

ECEC = effective cation exchange capacity. LOI = loss on ignition. KCI = potassium chloride.

Table 5—Chemical and physical characteristics of inceptisols, limestone, and mollisols by soil order or parent material

	Inceptisols		Limestone		Mollisols	
Element	Depth	Value	Depth	Value	Depth	Value
	cm		*cm*		*cm*	
Aluminum (cmol/kg^{-1})	-50	16.12-0.15	0-24	0.24-0.04	-30	19.42-0.01
	0-30	49.82-7.30			0-10	19.34-1.18
Bulk density (g/cc)	0-30	1.63-0.07	0-23	1.52-0.53	0-30	1.42-0.25
					30-75	1.20-0.65
Carbon/nitrogen	0-30	120-12			0-30	28-11
Calcium (cmol/kg^{-1})	0-25	50.96-0.02			0-30	97.06-0.10
	25-50	6.47-0.01				
Aluminum (mg/g)	0-30	9.70-0.01	0-30	10.99-1.37	0-30	19.41-0.02
	0-30	84.47-0.78	0-23	25.06-7.86	0-23	346.58-1.91
Aluminum-total (mg/g)						
	0-30	19.68-0.32			0-30	46.07-1.41
Clay (%)	0-30	85-5	0-30	77-1	0-30	61-1
Cobalt-total (mg/g)						
Copper-total (mg/g)						
Chromium-total (mg/g)						
ECEC (cmol/kg^{-1})	0-25	62.61-1.52	0-30	59.85-9.00	0-30	117.38-8.00
Iron (mg/g)	0-30	3.370-0.004	0-30	0.39-0.01	0-30	1.590-0.002

Table 5—Chemical and physical characteristics of inceptisols, limestone, and mollisols by soil order or parent material (continued)

	Inceptisols		Limestone		Mollisols	
Element	**Depth**	**Value**	**Depth**	**Value**	**Depth**	**Value**
	cm		*cm*		*cm*	
Iron-total (%)	0-30	8.02-1.18			0-10	5.88-0.15
LOI (%)	0-30	98.18-1.46	0-30	15.25-8.98	0-30	93.18-0.24
Magnesium (mg/g)	0-30	1.48-0.01	0-30	0.77-0.12	0-30	2.52-0.02
Magnesium (cmol/kg^{-1})	0-30	12.37-0.01			0-30	19.72-0.18
Magnesium-total (mg/g)	0-30	31.57-1.34	0-23	9.99-6.96	0-23	14.06-0.21
Manganese (mg/kg)	0-30	195-1	0-30	310-10	0-30	573-7
Manganese-total (mg/g)	0-30	1.71-0.34			0-10	1.14-0.04
Nickel-total (mg/g)						
Nitrogen (%)	0-30	0.76-0.03	0-23	0.38-0.22	0-30	3.14-0.12
Organic matter (%)	0-30	28.16-0.85	0-30	21.01-0.60	0-30	41.32-2.36
	30-100	3.39-0.12	30-100	1.26-0.25		
pH (H_2O)	0-30	9.07-3.78	0-30	7.80-4.23	0-30	8.42-3.45
pH (KCl)	0-30	8.02-3.18	0-30	7.13-4.65	0-30	7.48-3.13
Phosphorus (mg/kg)	0-30	36-1	0-30	95-29	0-30	1010-8
Phosphorus total (mg/g)	0-30	7.22-0.09	0-30	1.12-0.13	0-23	1.42-0.03
	30-100	0.40-0.06	30-100	0.29-0.09		
Potassium (cmol/kg^{-1})	0-30	1.60-0.01			0-30	18.93-0.10
Potassium (mg/kg)	0-30	609-16	0-30	371-90	0-30	7194-36
Potassium-total (mg/g)	0-30	7.96-1.28	0-23	3.72-2.63	0-23	13.89-0.76
Sand (%)	0-30	89-1	0-30	91-3	0-30	80-7
Silt (%)	0-30	64-4	0-30	77-3	0-30	68-11
Sodium (cmol/kg^{-1})	0-25	1.34-0.08			0-30	5.22-0.01
Sodium (mg/kg)	0-25	310-5	0-30	210-21	0-30	1201-4
Sodium-total (mg/g)	0-43	0.47-0.33	0-23	0.99-0.77		
Sulfur (mg/g)	0-30	16.97-0.05			0-30	4.45-0.08

ECEC = effective cation exchange capacity. LOI = loss on ignition. KC1 = potassium chloride.

Table 6—Chemical and physical characteristics of oxisols, ultisols, and vertisols by soil order or parent material

	Oxisols		Ultisols		Vertisols	
Element	**Depth**	**Value**	**Depth**	**Value**	**Depth**	**Value**
	cm		*cm*		*cm*	
Aluminum (cmol/kg^{-1})	0-15	0.23-0.09	0-50	53.01-0.01	0-30	0.06
			50-680	15.42-0.01		
Aluminum (mg/g)			0-40	0.81-0.01		
Aluminum-total (mg/g)			0-30	180.20-6.57		
			50-120	228.20-98.90		
Bulk density (g/cc)	0-18	1.25-0.57	0-30	1.76-0.08		
Carbon/nitrogen	0-15	148-42	0-35	37-6		
			25-120	62-9		
Calcium (cmol/kg^{-1})	0-15	36.75-13.05	0-40	80.75-0.01		
			100-680	14.23-0.37		
Calcium (mg/g)	0-15	7.35-2.61	0-50	62.000-0.003	0-30	4.16
Calcium-total (mg/g)			0-30	16.93-0.03		
			50-120	9.80-0.90		
Carbon (%)	0-30	42.18-34.45	0-35	27.42-0.34		
Clay (%)	0-18	27-25	0-30	89-1	0-30	40-11
Cobalt-total (mg/g)			0-60	0.67-0.38		
Copper-total (mg/g)			0-60	0.04-0.01		
Chromium-total (mg/g)			0-60	8.33-5.10		
ECEC (cmol/kg^{-1})	0-15	40.95-14.66	0-30	90.03-0.16	0-30	38.44
Iron (mg/g)	0-15	0.03-0.01	0-40	13.08-0.002	0-30	0.01
Iron-total (%)			0-30	15.9-0.89		
LOI (%)			0-30	116.41-2.27		
Magnesium (mg/g)	0-15	0.47-0.11	0-30	7.68-0.01	0-30	1.71
Magnesium (cmol/kg^{-1})	0-15	3.95-0.95	0-30	33.9-0.12		
Magnesium-total (mg/g)			0-30	35.03-0.34		
Manganese (mg/kg)	0-15	41-13	0-30	840-1	0-30	40
Manganese-total (mg/g)			0-30	10.22-0.01		
Nickel-total (mg/g)			0-60	3.35-1.51		
Nitrogen (%)	0-15	0.82-0.28	0-30	3.00-0.02		
Organic matter (%)	0-18	14.23-3.34	0-30	44.23-0.25	0-30	3.14
Organic matter (%)						
pH (H_2O)	0-18	7.89-5.43	0-30	4.45-3.64	0-30	8.05
pH (KCl)	0-15	7.37-6.51	0-30	7.68-3.11	0-30	6.99
Phosphorus (mg/kg)	0-15	97-18	0-30	1793-1	0-30	63
Phosphorus (mg/kg)			30-120	230.00-0.44		

Table 6—Chemical and physical characteristics of oxisols, ultisols, and vertisols by soil order or parent material (continued)

	Oxisols		Ultisols		Vertisols	
Element	Depth	Value	Depth	Value	Depth	Value
	cm		*cm*		*cm*	
Phosphorus total (mg/g)			0-30	4.32-0.04		
Phosphorus total (mg/g)			30-120	0.59-0.10		
Potassium (cmol/kg^{-1})	0-15	0.81-0.19	0-30	1.65-0.02		
Potassium (mg/kg)	0-15	307-74	0-30	1905-1	0-30	420
Potassium-total (mg/g)			0-30	13.00-0.79		
Sand (%)	0-18	36	0-30	78-1	0-30	11
Silt (%)	0-18	37	0-30	63-6	0-30	38
Sodium (cmol/kg^{-1})	0-15	0.33-0.04	0-30	2.46-0.01		
Sodium (mg/kg)	0-15	76-10	0-30	567-1	0-30	520
Sodium-total (mg/g)						
Sulfur (mg/g)			0-20	1.80-0.01		

ECEC = effective cation exchange capacity. LOI = loss on ignition. KC1 = potassium chloride.

Table 7—Methods of chemical analysis and references[a]

Sample	Analysis	Reference to method
Soil		
	Available-aluminium, calcium, magnesium, sodium	Hunter 1974
	Available-iron, manganese, phosphorus, potassium	Hunter 1974
	Total-aluminium, calcium, iron, magnesium manganese, phosphorus, potassium, sodium	Huang and Shulte 1985
	Loss on ignition	Wilde et al. 1979
	Nitrogen (macro Kjeldahl) from Jan 1980–1995	Page 1982b
	Nitrogen (macro dry combustion) from Feb 1995–2000	Leco Corp. 2000b form No. 203-821-165
	Organic matter	Page 1982
	pH (H_2O-KCl)	Southern Coop. Series 1983
Vegetation		
	Aluminium, calcium, cobalt, iron, magnesium, manganese, nickel, phosphorus, potassium, sodium	Huang and Shulte 1985 and Chapman and Pratt 1979a
	Ash	Wilde et al. 1979
	Nitrogen (macro Kjeldahl) from Jan 1995–1980	Chapman and Pratt 1979b
	Nitrogen (macro dry combustion) from Feb 1995–2000	Leco Corp. 2000a form No. 203-821-172
	Wood density	ASTM 1968

[a] Details on variations in methodology are available upon request.

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Appendix 1: Data Sources

Data sources are arranged by general area of study. The numbers correspond to sources cited in the tables on the characteristics of plant and soil samples. The sources are cross referenced to species in appendix 2.

Soils

1. Nutrient dynamics of a Puerto Rican subtropical dry forest. Journal of Tropical Ecology. 2: 55–72, 1986
   Investigators: Ariel E. Lugo and P. Murphy
   Location: Guánica Forest, Guánica, Puerto Rico
   Date of collection: 1981–1983

2. Guánica Study #2508
   Investigator: Vicky Dunevitz (Michigan State University)
   Location: Guánica Forest, Guánica, Puerto Rico
   Date of collection: 1982

3. Guánica Study #2508
   Investigator: Dan Nepstad (Michigan State University)
   Location: Guánica Forest, Guánica, Puerto Rico
   Date of collection: 1983

4. Estudio de la colonización en áreas de derrumbes en el Bosque Experimental de Luquillo. In: Lugo, A.E., ed. Los Bosques de Puerto Rico. U.S. Department of Agriculture, Department of Natural Resources;
   University of Puerto Rico, 110–122, 1983
   Investigators: Carmen Varela, D. Ortiz, A. Berríos, and H.J. Álvarez-Science Teacher Association Investigation
   Location: Landslides along PR 191 in Luquillo Experimental Forest, Puerto Rico
   Date of collection: August 1981

5. Structure and dynamics in the Colorado Forest of the Luquillo Mountains of Puerto Rico
   Investigator: Peter Weaver (Michigan State University, Ph.D. dissertation, 1987)
   Location: Luquillo Experimental Forest, Puerto Rico
   Date of collection: December 1981–July 1982

6. Estudio comparativo de algunas propiedades químicas y físicas de suelos de bosque bajo uso natural y plantación
   Investigator: Mary Jeane Sánchez (M.Sc. thesis University of Puerto Rico, Mayagüez Campus)
   Location: Luquillo Experimental Forest, Puerto Rico
   Date of collection: 1985–1986

7. Landslide disturbance and forest regeneration in the Upper Luquillo Mountains of Puerto Rico. Journal of Ecology. 78: 814–832, 1990
   Investigator: Manuel Guariguata
   Location: Luquillo Experimental Forest, Puerto Rico
   Date of collection: June 1988

8. Growth studies of plantations of *Pinus caribaea* var. *hondurensis* in Puerto Rico
   Investigator: Mohammed Zakir Hussain (Yale University, Ph.D. dissertation, 1987)
   Location: Pine plantations, various sites, Puerto Rico
   Date of collection: 1984–1985

9. Studies of ecological and geological factors controlling the pattern of Tabonuco forests in the Luquillo Experimental Forest, Puerto Rico
   Investigator: Khadga Basnet (State University of New Jersey, Ph.D. dissertation, 1990)
   Location: Bisley, Luquillo Experimental Forest, Puerto Rico
   Date of collection: 1988

10. Structure, succession, and soil chemistry of palm forest in the Luquillo Experimental Forest. Tropical forest: Management and Ecology: 142–177, 1995
    Investigators: Ariel E. Lugo, A. Bokkestijn, and F.N. Scatena
    Location: Palm Slope Forest, El Verde (PS-2) and Juan Diego (PS-1): Caribbean National Forest, Puerto Rico
    Date of collection: June 1986

11. Land use and organic carbon content of some subtropical soils. Plant and Soil. 96: 185–196, 1986
    Investigators: Ariel E. Lugo, M.J. Sánchez, and S. Brown
    Location: Various sites, Puerto Rico
    Date of collection: 1982–1984

12. Revegetation on landslides
    Investigator: Jean Lodge
    Location: Large slide next to El Verde Field Station, Puerto Rico
    Date of collection: December 1988

13. Performance of *Anthocephalus chinensis* in Puerto Rico. Canadian Journal of Forest Research. 15: 577–585, 1985
    Investigators: Ariel E. Lugo and J. Figueroa
    Location: Various sites, Puerto Rico
    Date of collection: May 1983

14. Forest plantings in Puerto Rico and Virgin Islands/small leaf mahogany survey
    Investigator: John Francis
    Location: Various sites, Puerto Rico
    Date of collection: 1990

15. Restoration and rehabilitation of tropical forests.
    Investigator: Ariel E. Lugo (Environmental Sciences Course, University of Puerto Rico, Río Piedras Campus)
    Location: Río Mameyes (river basin), Luquillo Experimental Forest, Puerto Rico
    Date of collection: September–October 1989

16. Fauna oligotológica de suelos de la serie Nipe en el Bosque Estatal de Maricao
    Investigator: Hendriekje Hubers (M.Sc. thesis University of Puerto Rico, Mayagüez Campus, 1993)
    Location: Maricao Forest, Puerto Rico
    Date of collection: August 1990

17. Productivity, nutrient cycling, and succession in single- and mixed-species plantations of *C. equisetifolia*, *E. robusta*, and *L.leucocephala* in Puerto Rico. Forest Ecology and Management. 124: 45–77, 1999
    Investigator: John Parrotta
    Location: Toa Baja Experimental Farm, Toa Baja, Puerto Rico
    Date of collection: 1993

18. Protection and planting to accelerate increases in biodiversity on deforested sites
    Investigators: John Francis and J. Parrotta
    Location: Camp Santiago, Salinas, Puerto Rico
    Date of collection: 2000

19. Productivity, nutrient cycling, and succession in single- and mixed-species plantations of *C. equisetifolia*, *E. robusta*, and *L. leucocephala* in Puerto Rico. Forest Ecology and Management. 124: 45–77, 1999
    Investigator: John Parrotta
    Location: Toa Baja Experimental Farm, Toa Baja, Puerto Rico
    Date of collection: December 1996

20. Former land use and tree species affect nitrogen oxide emissions from a tropical dry forest. Oecologia. 130: 297–308, 2002
    Investigator: Heather Erickson
    Location: Guánica Forest, Guánica, Puerto Rico
    Date of collection: May–December 1995

21. Nitrogen oxide fluxes and nitrogen cycling during post agricultural succession and forest fertilization in the humid tropics. Ecosystems. 4: 67–84, 2001
    Investigators: Heather Erickson, M. Keller, and E.A. Davidson
    Location: El Verde Station, Sabana and Mameyes, Luquillo Experimental Forest, Río Grande, Puerto Rico
    Date of collection: 1995–1996

22. Eco-physiological evaluation of drought stress in montane and lowland forests as a result of an unusual dry spell in June 1994
    Investigators: Ernesto Medina and E. Cuevas
    Location: Bisley and East Peak, Puerto Rico
    Date of collection: June 1994

23. Pterocarpus-Punta Viento
    Investigators: Ernesto Medina, E. Cuevas, and A.E. Lugo
    Location: Pterocarpus Forest, Punta Viento; Patillas, Puerto Rico
    Date of collection: August 1994

24. Dwarf mangrove project
    Investigators: Ernesto Medina, E. Cuevas, and A.E. Lugo
    Location: Ceiba, Puerto Rico (entrance through Marina del Rey, about 2 km in the direction of Roosevelt Roads swamp)
    Date of collection: March 1999

25. Pterocarpus soil collection
    Investigators: Ernesto Medina, E. Cuevas, and M. Aide
    Location: Sabana Seca, Puerto Rico
    Date of collection: February 1997

26. Dwarf mangrove project
    Investigators: Ernesto Medina, E. Cuevas, and A.E. Lugo
    Location: Ceiba, Puerto Rico (entrance through Marina del Rey, about 2 km in the direction of Roosevelt Roads swamp)
    Date of collection: December 1995

27. The effects of small-scale and catastrophic disturbance on carbon and nutrient cycling in a lower subtropical wet forest in Puerto Rico
    Investigator: Whendee Silver
    Location: Bisley Watersheds, Carribbean National Forest, Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1993–1999

28. Bisley Gaps soil phosphorus project
    Investigator: Whendee Silver
    Location: In a lower subtropical wet forest, Puerto Rico
    Date of collection: September 1994

29. The role of biodiversity in biogeochemical cycling in a moist subtropical forest in the Luquillo Experimental Forest, Puerto Rico
    Investigator: Lara Kueppers (M.Sc. thesis Standford University, Standford, California, 1996)
    Location: Cubuy, Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1995

30. Archaeological study
    Investigator: Edna Lee Ortiz
    Location: Ensenada Breñas and Cerro Gordo, Vega Alta, Puerto Rico
    Date of collection: November–December 1990

31. Hydrological process in a humid tropical rain forest: a combined experi mental and modelling approach
Investigators: Japp Schellekens (Ph.D. dissertation Vrije University, Amsterdam, 2000)
Location: Bisley Watersheds, Luquillo Experimental Forest, Puerto Rico
Date of collection: June 1997

32. Biogeochemical study of a tropical estuarine lagoon: carbon/nitrogen fluxes
Investigator: Mayra E. Suárez (M.Sc. thesis University of Puerto Rico, Mayagüez Campus)
Location: Joyuda Lagoon, Cabo Rojo, Puerto Rico
Date of collection: 1994–1995

33. Distribution and population ecology and reproductive biology of *Goetzea* elegans Wydler
Investigator: Eugenio Santiago Valentín
Location: Quebradillas, Isabela, Puerto Rico
Date of collection: July 1993

34. Controls on spatial and temporal variability in nitrous oxide fluxes across a tropical rain forest ecosystem in the Luquillo Experimental Forest, Puerto Rico
Investigator: Claire P. McSwiney (Ph.D. dissertation, University of Hampshire May 1999)
Location: Río Icacos basin, Luquillo Experimental Forest, Puerto Rico
Date of collection: January 1998

35. Long-term ecological research watersheds flood-plain study
Investigator: Don Durfee
Location: Río Mameyes, flood plains, Luquillo Experimental Forest, Puerto Rico
Date of collection: August 1991

36. Estudio de la vegetación en afloraciones de serpentinita en el Bosque Estatal de Maricao, Puerto Rico
Investigator: Geraldino Caminero (M.Sc. thesis, University of Puerto Rico, Mayagüez Campus)
Location: Maricao Forest, Maricao, Puerto Rico
Date of collection: February 1991

37. Forest plantings in Puerto Rico and Virgin Islands. Study #2510 *Prunus occidentalis* (Amendrón)
    Investigator: Salvador Alemañy
    Location: Road 191 Km 19, Caribbean National Forest, Puerto Rico
    Date of collection: January 1992

38. Influence of microenvironment of growth and nutrient dynamics of three herbaceous species in the Bisley Experimental Watersheds of Luquillo Experiment Forest, Puerto Rico
    Investigator: Amy Arnold (M.Sc. thesis Tennessee University)
    Location: Bisley, Luquillo Experimental Forest, Puerto Rico
    Date of collection: December 1995–January 1996

39. Performance of *Hibiscus elatus* in Puerto Rico. Commonwealth Forestry Review. 67: 327–338, 1988
    Investigators: John Francis and P. Weaver
    Location: Puerto Rico
    Date of collection: 1987

40. The performance of *Tectona grandis* in Puerto Rico. Commonwealth Forestry Review. 69: 313–323, 1990
    Investigators: Peter Weaver and J. Francis
    Location: Puerto Rico
    Date of collection: 1987

41. Tabonuco Project (*Dacryodes excelsa* Vahl)
    Investigator: Migdalia Álvarez
    Location: Bisley, Vereda Cristal, Puerto Rico
    Date of collection: 1994

42. Ecological aspects of earthworms from Laguna Cartagena, Puerto Rico. Caribbean Journal of Science. 32: 406–412, 1996
    Investigators: Mónica Alfaro and S. Borges
    Location: Lajas, Puerto Rico
    Date of collection: September 1990

43. A comparison of ten provenances of *Eucalyptus deglupta* and *E. Europhylla* in Puerto Rico: growth and survival over 15 years
    Investigators: Ariel. E. Lugo and J. Francis
    Location: Yabucoa and Río Abajo, Puerto Rico
    Date of collection: May–June 1987

44. *Swietenia macrophylla* and *Swietenia macrophylla* x *S. Mahogoni* development and growth: the nursery phase and establishment phase in line planning in the Caribbean Nacional Forest, Puerto Rico
    Investigator: Gerald P. Bauer (M.Sc. thesis New York State University, Syracuse)
    Location: Sabana, Caribbean National Forest, Puerto Rico
    Date of collection: 1985

45. Nutrients and mass in litter and top soil of ten tropical tree plantations. Arboretum Study. Plant and Soil. 125: 263–280, 1990
    Investigators: Ariel E. Lugo, E. Cuevas, and M.J. Sánchez
    Location: Arboretum, Cienaga Alta, Luquillo Experimental Forest, Puerto Rico
    Date of collection: October 1986

46. Nutrient return accumulation in litter of a secondary forest in the coffee region of Puerto Rico. Acta Científica. 13(1-3): 43–74, 1999
    Investigator: Ariel E. Lugo, C. Domínguez, A. Santos, and E. Torres
    Location: Torrecilla secondary forest, Bo. Hincado, Barranquitas, Puerto Rico
    Date of collection: May 1991

47. Comparison of two secondary forests in the coffee zone of central Puerto Rico. Acta Científica. 13(1-3): 27–41, 1999
    Investigators: Nathanial Popper, C. Domínguez, A. Santos et al.
    Location: Bo. Caguana, Utuado, Puerto Rico
    Date of collection: 1996

48. Comparative study of nutrient dynamics of two forest types in Luquillo Experimental Forest
    Investigators: Fu Sheinglei and A.E. Lugo
    Location: El Verde, Luquillo Experimental Forest, Puerto Rico
    Date of collection: July 1995

49. Soil oxygen availability and biogeochemistry along rainfall and topographic gradients in upland wet tropical forest soils Biogeochemistry. 44: 301–328, 1999
    Investigator: Whendee Silver, A.E. Lugo and M. Keller
    Location: Bisley, Puerto Rico
    Date of collection: July 1993

50. Contribution of wood to soil organic matter
    Investigators: Jean Lodge and N. Clum
    Location: El Verde, Puerto Rico
    Date of collection: 1999

51. Estudio comparativo de análisis de nutrientes entre una zona tabacalera y una zona cafetalera que actualmente son bosques secundarios en Naranjito
    Investigator: Ángel Santiago (Francisco Morales High School, Naranjito, Puerto Rico)
    Location: Naranjito, Puerto Rico
    Date of collection: August 2000

52. Luquillo Experimental Forest tree-uproots
    Investigators: Melanie Lenart and F. Scatena
    Location: Luquillo Experimental Forest, Puerto Rico
    Date of collection: December 2000

53. Difference in extrametrical hypha in three coffee cultivars in Puerto Rico
    Investigator: Ligia Lebrón
    Location: Adjuntas, Puerto Rico
    Date of collection: June 1998

54. Cerro de La Rosa soil collection
    Investigators: María Rivera and J.L. Ramírez
    Location: Cerro de la Rosa, Toro Negro Forest, Orocovis, Puerto Rico
    Date of collection: August 2000

55. Monito Gecko (*Sphaeerodactylus micropithecus*) census
    Investigator: Miguel García
    Location: Monito Island, Puerto Rico
    Date of collection: 1994/1998

56. Soil factors in a coffee plantation and a natural pasture
    Investigators: Randall Myster and L. Lebrón
    Location: El Verde, Sabana, Puerto Rico
    Date of collection: May 1999

57. Assessment for available elements, total elements and pH of soils samples
    Investigator: Pedro Robles
    Location: Reserva Nacional JBNERR, Aguirre, Salinas, Puerto Rico
    Date of collection: December 1999

58. Long-term recovery of a Caribbean dry forest after abandonment of different land uses in Guánica, Puerto Rico
    Investigator: Sandra Molina (Ph.D. dissertation, University of Puerto Rico, 1998)
    Location: El Maniel, Guánica, Puerto Rico
    Date of collection: 1992–1993

59. Nutrient concentration and heavy metal accumulations on different soils over serpentine
    Investigators: Julio Figueroa and M.J. Sánchez
    Location: Maricao Forest, Maricao, Puerto Rico
    Date of collection: October 1989

60. Spatial patterns in forest nutrient pools, growth and disturbance-soil collection
    Investigator: Skip Van Bloem
    Location: Guánica Forest, Guánica, Puerto Rico
    Date of collection: September 1998

61. Earth worm project
    Investigator: Sonia Borges
    Location: Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1991–1992

62. Ecological studies of the termites of Puerto Rico
    Investigator: Susan Jones
    Location: Guánica forest, Guánica, Puerto Rico
    Date of collection: 1992–1993

63. Soil macrofauna and litter nutrients in three tropical tree plantations on a disturbed site in Puerto Rico. Forest Ecology and Management. 170: 161–171, 2002
    Investigators: Matthew Warren and X. Zou
    Location: Toa Baja Plantation, Puerto Rico
    Date of collection: February 1998

64. Assessment of productivity and biological nitrogen fixation in mixed-species forest plantation.
    Investigator: John Parrotta
    Location: Toa Baja Plantation, Puerto Rico
    Date of collection: 1989-1992-1993-1996

65. La importancia de los cristales de oxalato de calcio en *Sida rhombifolia* (Malvaceae) como mecanismo de defensa y producto del metabolismo secundario
    Investigator: Brenda Molano (M.Sc. thesis University of Puerto Rico, Rio Piedras Campus)
    Location: Carolina-Canovanas, Puerto Rico
    Date of collection: September 1989

66. Tropic venture
    Investigator: Will Scott
    Location: Patillas, Bo. Muñoz Rivera, adjacent to the Carite Commonwealth Forest, Puerto Rico
    Date of collection: February 1991

Wood decomposition

67. Wood decomposition of *Cyrilla racemiflora* in a tropical montane forest. Biotropica. 26(2): 124–140, 1994
    Investigator: Juan Torres
    Location: Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1989

68. Wood decay in PS-2 and TS-2
    Investigator: Ariel E. Lugo
    Location: El Verde and Juan Diego, Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1982–1986

69. Litter and root dynamics in a tropical pine plantation and an equal age secondary forest-decomposition of woody debris
    Investigator: Sandra Brown
    Location: Guzmán Pine Plantation, Luquillo Experimental Forest, Puerto Rico
    Date of collection: April–October 1988

70. Hydrology, sediment, and nutrient budgets in three humid watersheds in Puerto Rico
    Investigators: Sandra Brown and A.E. Lugo
    Location: Bisley, Luquillo Experimental Forest, Puerto Rico
    Date of collection: September 1991–February 1994

71. Decomposition of leaves from general plant species and the role of fungi in Luquillo Experimental Forest, Puerto Rico
    Investigators: Jean Lodge and M. Santana
    Location: El Verde, Sabana and Bisley; Luquillo Experimental Forest, Puerto Rico
    Date of collection: February 2000

Mangroves

72. Jobanes mangrove
    Investigators: José López and M. Álvarez
    Location: Jobanes Mangrove, Guayama, Puerto Rico
    Date of collection: 1985

73. Jobanes Study—litter fall collection
    Investigators: Ariel E. Lugo and G. Cintrón
    Location: Jobos Bay, Aguirre, Guayama, Puerto Rico
    Date of collection: May–July 1986

74. Jobos Bay—fresh leaves
    Investigator: Ariel E. Lugo
    Location: Jobos Bay, Aguirre, Guayama, Puerto Rico
    Date of collection: December 1986

75. Características morfológicas y químicas de las hojas del *Rhizophora mangle* en un bosque de franja en Las Mareas, Puerto Rico. Acta Científica. I: 20–24, 1987
    Investigators: Honora Serrano and I. Monefeldt
    Location: Santuario Estuarino Jobanes, Las Mareas; Puerto Rico
    Date of collection: 1983

76. *Pterocarpus officinalis*—litter fall
    Investigator: Luis Negrón (Humacao College of University of Puerto Rico)
    Location: Río Antón Ruiz Swamp, Humacao; Puerto Rico
    Date of collection: 1986

77. Soil salinity, sun exposure, and growth of *Acrostichum aureum*, the mangrove fern. Botanical Gazette. 151(1): 41–49, 1990
    Investigators: Ernesto Medina, E. Cuevas, M. Popp, and A.E. Lugo
    Location: Río Grande and Vega Baja, Puerto Rico
    Date of collection: 1986

78. *Pterocarpus*—Punta Viento Study
Investigators: Ernesto Medina, E. Cuevas, and A.E. Lugo
Location: Pterocarpus Forest, Punta Viento; Patillas, Puerto Rico
Date of collection: August 1994

79. Dwarf Mangrove Project—nutrient use efficiency collection
Investigators: Ernesto Medina, E. Cuevas, and A.E. Lugo
Location: Ceiba, Puerto Rico (entrance through Marina del Rey, about 2 km in the direction of Roosevelt Roads)
Date of collection: March 1999

80. Dwarf Mangrove Project—fresh plant tissue collection
Investigators: Ernesto Medina, E. Cuevas, and A.E. Lugo
Location: Ceiba, Puerto Rico (entrance through Marina del Rey, about 2 km in the direction of Roosevelt Roads)
Date of collection: December 1995

81. Dwarf Mangrove Project—nutrient use efficiency leaves collection
Investigators: Ernesto Medina, E. Cuevas, and A.E. Lugo
Location: Ceiba, Puerto Rico (entrance through Marina del Rey, about 2 km in the direction of Roosevelt Roads)
Date of collection: December 1995

82. Dwarf Mangrove Project—biomass collection
Investigators: Ernesto Medina, E. Cuevas, and A.E. Lugo
Location: Ceiba, Puerto Rico (entrance through Marina del Rey, about 2 km in the direction of Roosevelt Roads)
Date of collection: March 1999

83. Salt accumulation by *Pterocarpus officinalis* along a salinity gradient
Investigators: Ernesto Medina, E. Cuevas, and M. Aide
Location: Sabana Seca, Puerto Rico
Date of collection: February 1997

84. Litter nutrients in a *Pterocarpus officinalis* forest
Investigators: Mitch Aide and F. Scatena
Location: Sabana Seca, Puerto Rico
Date of collection: July 1995–July 1997

85. Materia orgánica y nutrientes en la hojarasca de un manglar de franja. Acta Científica. I: 25–29, 1987
Investigators: Carmen Varela and A. Berrios
Location: Jobos, Las Mareas, Puerto Rico
Date of collection: 1984

86. Comparison of the nutrient status of dwarf and riverine mangrove and other tropical forest types
    Investigator: Alicia Miñana (M.Sc. thesis Princeton University, New Jersey)
    Location: Roosevelt Road, Ceiba, Puerto Rico
    Date of collection: September 1983

87. Susceptibility of mangrove wood to the arboreal termite (*Nasutitermes costalis*) in the Piñones State Forest
    Investigator: Teresa Carasquillo
    Location: Piñones Forest, Loiza, Puerto Rico
    Date of collection: August–September 1993

Vegetation

88. Biomass and nutrient accumulation in ten-year-old bryophyte communities inside a flood plain in the Luquillo Experimental Forest, Puerto Rico. Biotropica. 24: 106–112, 1992
    Investigators: Jorge Frangi and A.E. Lugo
    Location: Montane Palm Floodplain Forest, Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1990

89. Population dynamics of *Manilkara bidentata* (A.DC.) Cher. In the Luquillo Experimental Forest, Puerto Rico
    Investigator: Chengxia You (Ph.D. dissertation University of Tennessee)
    Location: El Verde, Luquillo Experimental Forest, Puerto Rico
    Date of collection: February 1987

90. Nutrients and mass in litter and top soil of ten tropical tree plantations
    Investigators: Ariel E. Lugo, E. Cuevas, and M.J. Sánchez
    Location: Arboretum, El Verde, Luquillo Experimental Forest, Puerto Rico
    Date of collection: October 1986

91. Plumeria study
    Investigator: Eva Dávila
    Location: Guánica Forest, Maricao Forest, Ponce and Dorado, Puerto Rico
    Date of collection: 1985

92. Porciento de cenizas en la flora epifitica sobre *Prestoea montana*
    Investigator: Carmen L. Báez (University of Puerto Rico High School)
    Location: Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1985

93. Hurricane damage to a flood plain forest in the Luquillo Mountains of Puerto Rico. Biotropica. 23(4a): 324–335, 1991
    Investigators: Jorge Frangi and A.E. Lugo
    Location: Montane palm floodplain forest, Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1980/1990

94. Comparison of tropical tree plantations with secondary forest of similar age. Ecological Monographs. 62(1): 1–41, 1992 Study 2501-Understory study
    Investigator: Ariel E. Lugo
    Location: Guzmán, Cubuy, Sabana, El Verde, Luquillo Experimental Forest, Puerto Rico
    Date of collection: 1982–1984

95. Decayed roots collection
    Investigators: Patrick Kangas and A.E. Lugo
    Location: El Verde, Luquillo Experimental Forest, Puerto Rico
    Date of collection: August 1986

96. The influence of density on stand development, biomass partitioning and nutrient allocation in *Albizia lebbeck* (L.) Benth. Plantations in Puerto Rico
    Investigator: John Parrotta (Ph.D. dissertation Yale University)
    Location: Toa Baja Experimental Farm, Puerto Rico
    Date of collection: 1985–1986

97. Wood density. SO-ITF-SM-15,32,35,42,44,45,47,48,58,60,69,75,77 in IITF Silvics Manual
    Investigator: John Francis
    Location: Puerto Rico
    Date of collection: 1985–1990

98. Restoration and rehabilitation of tropical forests. Environmental Sciences Course, University of Puerto Rico, Río Piedras Campus
Investigator: Ariel E. Lugo
Location: Río Mameyes (river basin), Luquillo Experimental Forest, Puerto Rico
Date of collection: September–October 1989

99. Nutrient dynamics of a Puerto Rican subtropical dry forest. Journal of Tropical Ecology. 2: 55–72, 1986
Investigators: Peter Murphy and A.E. Lugo
Location: Guánica Forest, Guánica, Puerto Rico
Date of collection: 1981–1983

100. Leaf decomposition study
Investigator: Yiovani Santiago Molina (Naranjito High School)
Location: Bisley Watersheds; Luquillo Experimental Forest, Puerto Rico
Date of collection: 1988

101. Comparison of tropical tree plantations with secondary forest of similar ages. Ecological Monographs. 62(1): 1–41, 1992
Investigator: Ariel E. Lugo
Location: Guzmán, Cubuy, Sabana, El Verde, Luquillo Experimental Forest, Puerto Rico
Date of collection: 1982–1984

102. Mineral content of leaves from trees growing on serpentine soils under contrasting rainfall regimes in Puerto Rico. Plant and Soil. 158: 13–21, 1994
Investigators: Ernesto Medina, E. Cuevas, J. Figueroa, and A.E. Lugo
Location: Maricao Forest, Puerto Rico
Date of collection: June 1990

103. Comparative analysis of the nutritional status of Mahogany plantations in Puerto Rico. In: Lugo, A. E.; Figueroa, J.; Alayón, M., ed. Big-leaf mahogany genetics. Ecology and Management: 129–145
Investigators: Ernesto Medina and E. Cuevas
Location: Puerto Rico
Date of collection: 1986–1987

104. Physiological ecology of dominant woody species in a dry coastal forest on limestone (Guánica) forest
Investigator: Ernesto Medina
Location: Guánica Forest, Puerto Rico
Date of collection: 1986–1987

105. Plasticity of crassulacean acid metabolism (CAM) and biomass allocation of the pantropical *Kalanchoe pinnata* (LAM.) Pers. Acta Cientifica. 12(1-3): 59–66, 1998
Investigator: Ernesto Medina
Location: IITF Nursery, Puerto Rico
Date of collection: 1987

106. Bisley Study—litter fall collection
Investigator: Fred Scatena
Location: Bisley, Luquillo Experimental Forest, Puerto Rico
Date of Collection: 1990–2000

107. MRCE foliar nutrients/fertilizer plots
Investigator: Heather Erickson
Location: El Verde and Pico del Este, Puerto Rico
Date of collection: March–October 1993

108. Nitrogen oxide fluxes and nitrogen cycling during post agricultural succession and forest fertilization in the humid tropics. Ecosystems. 4: 67–84, 2001
Investigators: Michael Keller and H. Erickson
Location: LTER, Sabana, Mameyes, El Yunque, Puerto Rico
Date of collection: 1995–1996

109. Former land-use and tree species affect nitrogen oxide emissions from a tropical dry forest. Oecologia. 130: 297–308, 2002
Investigator: Heather Erickson
Location: Guánica Forest, Guánica, Puerto Rico
Date of collection: March 1996–March 1997

110. Woods Hole Nasa study/clip plots
Investigator: Heather Erickson
Location: Sabana and Mameyes, Puerto Rico
Date of collection: April 1995–1996

111. Long-term ecological research Hurricane Hugo loose litter collection
Investigators: Fred Scatena and J. Lodge
Location: East Peak, Caribbean National Forest, Puerto Rico
Date of collection: September 19, 1989

112. The metabolism of Río Mameyes, Puerto Rico: carbon fluxes in a tropical rain forest river
Investigator: Jorge Ortiz (Ph.D. dissertation University of Colorado)
Location: Río Mameyes Watershed, Luquillo Experimental Forest, Puerto Rico
Date of collection: February 1995–March 1996

113. Litter fall experiment: Sabana 60 years
Investigator: Michael Keller
Location: Sabana, Luquillo Experimental Forest, Puerto Rico
Date of collection: March–October 1997

114. Roots Sabana forest 60 years
Investigator: Michael Keller
Location: Sabana, Luquillo Experimental Forest, Puerto Rico
Date of collection: July 1998

115. Simple and inexpensive method for extracting wood density samples from tropical hardwoods. Tree Planter's Notes. 45(1): 10–12, 1994
Investigator: John Francis
Location: Puerto Rico
Date of collection: 1992–1993

116. *Acromia media* O.F. Cook. SO-ITF-SM-68
Investigator: John Francis
Location: Puerto Rico
Date of collection: 1993

117. *Prunus occidentalis* S.W. SO-ITF-SM-79
Investigator: Salvador Alemañy
Location: Puerto Rico
Date of collection: 1992

118. *Pouteria multiflora* (A.D.C) EYMA. SO-ITF-SM-62
Investigator: John Francis
Location: Puerto Rico
Date of collection: 1993

119. *Roystonea borinquena* O.F. Cook. SO-ITF-SM-55
Investigator: John Francis
Location: Puerto Rico
Date of collection: 1990

120. *Dacroydes excelsa*
Investigator: John Francis
Location: El Verde, Luquillo Experimental Forest, Puerto Rico
Date of collection: October 1991

121. Studies of life history of three herbaceous species in the Bisley Watersheds, Puerto Rico
Investigator: Amy Arnold (M.Sc. thesis Tennessee University)
Location: Bisley, Luquillo Experimental Forest, Puerto Rico
Date of collection: November 1995

122. Effects of nutrient availability and other elevational changes on bromeliad populations and their invertebrate communities in a humid tropical forest in Puerto Rico. Journal of Tropical Ecology. 16: 167–188, 2000
Investigators: Barbara Richardson, M.J. Richardson, F. Scatena, and W.H. McDowell
Location: Tabonuco, Palo Colorado and Dwarf forests Luquillo Experimental Forest, Puerto Rico
Date of collection: 1996

123. Bryophyte communities on different stages of decaying wood
Investigator: Inés Sastre
Location: Bisley Watersheds, Luquillo Experimental Forest, Puerto Rico
Date of collection: 1990–1991

124. Tabonuco Project (*Dacryodes excelsa*)
Investigator: Migdalia Álvarez
Location: Various sites, Puerto Rico
Date of collection: 1994

125. Contrasting light environments and response flexibility of trees in the Luquillo Mountains of Puerto Rico
Investigator: Denny Fernández (Ph.D. dissertation University of Puerto Rico, Rio Piedras Campus)
Location: El Verde, Luquillo Experimental Station, Puerto Rico
Date of collection: May 1996

126. Estimating biomass and carbon content of saplings in Puerto Rican secondary forests. Caribbean Journal of Science. 26: 346–350, 2000
Investigator: John Francis
Location: Various sites, Puerto Rico
Date of collection: 1999

127. Arboretum root standing stock
Investigators: Ariel E. Lugo, E. Cuevas, and M.J. Sánchez
Location: Cienaga Alta, Luquillo Experimental Forest, Puerto Rico
Date of collection: December 1986

128. *Acrocomia media* O.F. Cook. SO-ITF-SM-68
Investigator: John Francis
Location: Punta Salinas, Toa Baja; Puerto Rico
Date of collection: October 1991

129. Nonindigenous bamboo along headwater streams of the Luquillo Mountains, Puerto Rico: leaf fall, aquatic leaf decay and patterns of invasion. Journal of Tropical Ecology. 16: 499–516, 2000
Investigators: Paul O'Connor, A.P. Covich, F.N. Scatena, and L.L. Loope
Location: Bisley watershed, Luquillo Experimental Forest, Puerto Rico
Date of collection: 1997

130. Nutrient return accumulation in litter of a secondary forest in the coffee region of Puerto Rico. Acta Científica. 13(1-3): 43–74, 1999
Investigators: Ariel E. Lugo, C. Domínguez, A. Santos, and E. Torres
Location: Torrecilla secondary forest, Bo. Hincado, Barranquitas, Puerto Rico
Date of collection: 1990–1993

131. Biomasa y nutrientes en raíces y brinzales de un bosque secundario en la zona cafetalera de Utuado. Acta Científica. 13(1–3): 75–87, 1999
Investigators: Ariel E. Lugo, C. Domínguez, and N. Méndez
Location: Bo. Caguana, Utuado, Puerto Rico
Date of collection: February 1998

132. Ecological study of a secondary forest in Caguana, Utuado
Investigators: Ariel E. Lugo and N. Méndez
Location: Bo. Caguana, Utuado, Puerto Rico
Date of collection: 1998–1999

133. Comparative study of nutrient dynamics of two forest types in Luquillo Experimental Forest—loose litter
Investigators: Fu Sheinglei and A.E. Lugo
Location: El Verde, Luquillo Experimental Forest, Puerto Rico
Date of collection: July 1995

134. Seasonal dynamics and succession in a subtropical dry forest
Investigator: Ariel E. Lugo
Location: Guánica forest, Guánica, Puerto Rico
Date of collection: 1992

135. Bisley study—biomass
Location: Bisley, El Yunque, Puerto Rico
Investigator: Fred Scatena
Date of collection: 1989–1999

136. Insects population collection 1999–2000
Investigator: Barbara Richardson
Location: El Verde, Puerto Rico
Date of collection: 1999–2000

137. Nutrients, diversity, and community structure of two phytotelm systems in a lower montane forest, Puerto Rico
Investigators: Barbara Richardson, C. Rogers, and M.J. Richardson
Location: El Verde, Puerto Rico
Date of collection: 1998

138. Physiological characteristic of two tree species growing on a pasture
Investigators: Adisel Montaña and N. Fetcher
Site location: Sabana, Luquillo, Puerto Rico
Date of collection: February 1998

139. Dynamics of organic matter and nutrient return from litter fall in stands of ten tropical tree plantation species. Forest Ecology and Management. 112: 263–279, 1998
Investigators: Elvira Cuevas and A.E. Lugo
Location: Arboretum, Cienaga Alta, Luquillo Experimental Forest, Puerto Rico
Date of collection: 1986–1987

140. Hurricane Georges loose litter
Investigators: Rebeca Ostertag and F. Scatena
Location: Cubuy, Bisley and Guánica, Puerto Rico
Date of collection: 1998–1999

141. Effects of fertilization on plant growth in landslide in the Luquillo Forest
Investigator: Ned Fetcher
Location: Palo Hueco, Luquillo Experimental Forest, Puerto Rico
Date of collection: 1989

142. Changes in necromass and nutrients on the Forest floor of a palm floodplain in forest in the Luquillo mountains of Puerto Rico. Caribbean Journal of Science. 39: 265–272, 2003
Investigators: Ariel E. Lugo and J. Frangi
Location: Montane palm forest, Luquillo Experimental Forest, Puerto Rico
Date of collection: October 2000

143. Reorganization of the palm forest in the Luquillo Experimental Forest, Puerto Rico, 5 years after Hurricane Hugo
Investigator: Jorge Frangi
Location: Montane palm flood plain forest, Luquilo Experimental Forest, Puerto Rico
Date of collection: June 1995

144. Sabana Seca climate study
Investigators: Michael Van Der Molen and F. Scatena
Location: Sabana Seca, Puerto Rico
Date of collection: 1998

145. Pivotal fungal and plant species and its role influencing the rates of decomposition in a tropical forest
Investigators: Mirna Santana and J. Lodge
Location: El Verde, Sabana, Bisley, Luquillo Experimental Forest, Puerto Rico
Date of collection: August 2000

146. Landslide litter decomposition
Investigators: Randall Myster and D. Shaffer
Location: El Verde Field Station, Puerto Rico
Date of collection: February–October 1996

147. Moon phase influence over palm leaves nutrients
Investigators: Fred Scatena and S. Moya
Location: Bisley, El Yunque, Puerto Rico
Date of collection: July–September 2000

148. Mineral content of leaves from trees growing on serpentine soils in Puerto Rico
Investigators: Ernesto Medina, E. Cuevas, J. Figueroa, and A.E. Lugo
Location: Susua Forest, Puerto Rico
Date of collection: August 1993

149. Comparison of the leaf nutrient composition of trees from contrasting soil environments: Susua Forest and Guánica Forest
Investigators: Ernesto Medina, E. Cuevas, and J. Figueroa
Location: Susua forest and Guánica forest
Date of collection: October 1986–January 1992

150. Ontogenic comparison in leaf morphology and physiology of tropical rainforest tree species
Investigator: Shiyun Wen
Location: El Verde, Luquillo Experimental Forest, Puerto Rico
Date of collection: 1999–2000

151. Spatial patterns in forest nutrient pools, growth and disturbance—plant collection
Investigator: Skip Van Bloem
Location: Guánica Forest, Guánica, Puerto Rico
Date of collection: September 1998

152. Soil macro fauna and litter nutrients in three tropical tree plantations on a disturbed site in Puerto Rico. Forest Ecology and Management. 170: 161–171, 2002
Investigators: Matthew Warren and X. Zou
Location: Toa Baja Plantation, Puerto Rico
Date of collection: February 1998

153. Exotic earthworms acelerate plant litter decomposition in a Puerto Rican pasture and a wet Forest. Ecological Applications. 12(5): 1406–1417, 2002
Investigator: Z.G. Liu and X. Zou
Location: Secondary Forest and pine plantation in Guzmán, Luquillo Experimental forest, Puerto Rico
Date of collection: May 1996

154. Fine litterfall and related nutrient inputs resulting from Hurricane Hugo in subtropical wet and lower montane rain forests of Puerto Rico. Biotropica. 23(4A): 336–342, 1991
Investigators: Jean Lodge, F.N. Scatena, C.E. Asbury, and M.J. Sánchez
Location: El Verde, Caribbean National Forest, Puerto Rico
Date of collection: September 1989

155. *Prescottia oligantha*
Investigator: Carlos Rodríguez
Location: Luquillo and Maricao, Puerto Rico
Date of collection: May 1989

156. Above and below organic matter storage and production in a tropical pine plantation and a paired broadleaf secondary forest
Investigators: Elvira Cuevas, S. Brown, and A.E. Lugo
Location: Guzmán, Luquillo Experimental Forest, Puerto Rico
Date of collection: 1987–1989

157. Study of the termite species *N. costalis* in the Piñones Forest
Investigator: Verónica Carrasquillo
Location: Piñones Forest, Loiza, Puerto Rico
Date of collection: December 23, 1992

Appendix 2: List of Species

Table 10—Species, family, growth habit, and source

No.	Name	Family	Growth habit	Source	Group
1	*Acrocomia media*	Arecaceae	Tree	116, 128	Monocot
2	*Acrostichum aureum*	Pteridaceae	Forb/herb	78, 77	Fern
3	*Adiantum latifolium*	Pteridaceae	Forb/herb	135	Fern
4	*Adiantum pyramidale*	Pteridaceae	Forb/herb	135	Fern
5	*Adiantum* spp.	Pteridaceae	Forb/herb	135	Fern
6	*Albizia lebbeck*	Fabaceae	Tree	96	Dicot
7	*Albizia procera*	Fabaceae	Tree	126	Dicot
8	*Alchornea latifolia*	Euphorbiaceae	Tree	68, 97, 135	Dicot
9	*Alchorneopsis floribunda*	Euphorbiaceae	Tree	68	Dicot
10	*Alchorneopsis portoricensis*	Euphorbiaceae	Tree	135	Dicot
11	*Aleurites moluccana*	Euphorbiaceae	Tree	97	Dicot
12	*Allamanda violacea*	Apocynaceae	Shrub/vine	91	Dicot
13	*Alsophila portoricensis*	Cyatheaceae	Tree	135, 143	Fern
14	*Amyris elemifera*	Rutaceae	Tree/shrub	104, 149, 151	Dicot
15	*Andira inermis*	Fabaceae	Tree	94, 135	Dicot
16	*Anetium citrifolium*	Vittariaceae	Forb/herb	135	Fern
17	*Anthocephalus chinensis*	Rubiaceae	Tree	90, 115, 139	Dicot
18	*Ardisia glauciflora*	Myrsinaceae	Tree/shrub	102	Dicot
19	*Ardisia solanacea*	Myrsinaceae	Tree/shrub	126	Dicot
20	*Artocarpus altilis*	Moraceae	Tree	97	Dicot
21	*Asplenium* spp.	Aspleniaceae	Herb	135	Fern
22	*Avicennia germinans*	Verbenaceae	Tree/shrub	74, 78, 80, 87, 157	Dicot
23	*Bambusa* spp.	Poaceae	Tree/shrub	129	Monocot
24	*Bambusa vulgaris*	Poaceae	Tree/shrub	94	Monocot
25	*Beilschmiedia pendula*	Lauraceae	Tree	68	Dicot
26	*Blechnum occidentale*	Acanthaceae		135	Dicot
27	*Bolbitis aliena*	Dryopteridaceae	Forb/herb	135	Fern
28	*Bolbitis nicotianifolia*	Dryopteridaceae	Forb/herb	135	Fern
29	*Bourreria succulenta*	Boraginaceae	Tree/shrub	104, 149, 151	Dicot
30	*Bromeliads*	Bromeliaceae		93, 135	Other
31	*Bryophytes*			88, 123	
32	*Buchenavia tetraphylla*	Combretaceae	Tree	153	Dicot
33	*Bucida buceras*	Combretaceae	Tree	104, 126, 149	Dicot
34	*Bursera simaruba*	Burseraceae	Tree/shrub	97, 102, 104, 149, 151	Dicot
35	*Byrsonima lucida*	Malpighiaceae	Tree/shrub	102, 149	Dicot

Table 10—Species, family, growth habit, and source (continued)

No.	Name	Family	Growth habit	Source	Group
36	*Byrsonima spicata*	Malpighiaceae	Tree/shrub	131	Dicot
37	*Byrsonima wadsworthii*	Malpighiaceae	Tree/shrub	93	Dicot
38	*Calophyllum antillanum*	Clusiaceae	Tree/shrub	59, 94, 101, 126	Dicot
39	*Canna glauca*	Cannaceae	Forb/herb	135	Monocot
40	*Canna* spp.	Cannaceae	Forb/herb	135	Monocot
41	*Capparis cynophallophora*	Capparaceae	Tree/shrub	104, 149	Dicot
42	*Casearia arborea*	Flacourtiaceae	Tree/shrub	94, 101, 135	Dicot
43	*Casearia decandra*	Flacourtiaceae	Tree/shrub	126, 148	Dicot
44	*Casearia guianensis*	Flacourtiaceae	Tree/shrub	126	Dicot
45	*Casearia sylvestris*	Flacourtiaceae	Tree/shrub	94, 148	Dicot
46	*Cassine xylocarpa*	Celastraceae	Tree/shrub	102, 104, 149	Dicot
47	*Casuarina equisetifolia*	Casuarinaceae	Tree	152	Dicot
48	*Cecropia schreberiana*	Cecropiaceae	Tree	107, 123, 129, 135, 141, 146	Dicot
49	*Cecropia* sp.	Cecropiaceae	Tree	146	Dicot
50	*Cissampelos pareira*	Menispermaceae	Shrub/vine	135	Dicot
51	*Cissus erosa*	Vitaceae	Shrub/vine	135	Dicot
52	*Cissus verticillata*	Vitaceae	Shrub/vine	135	Dicot
53	*Citrus sinensis*	Rutaceae	Tree/shrub	97, 101	Dicot
54	*Clibadium erosum*	Asteraceae	Tree/shrub	135	Dicot
55	*Clusia rosea*	Clusiaceae	Tree/shrub	71, 97, 102, 104, 149	Dicot
56	*Cnemidaria horrida*	Cyatheaceae	Shrub/vine	135	Fern
57	*Coccoloba microstachya*	Polygonaceae	Tree/shrub	102, 104, 149,151	Dicot
58	*Coccoloba diversifolia*	Polygonaceae	Tree/shrub	104, 149, 151	Dicot
59	*Coffea arabica*	Rubiaceae	Tree/shrub	53, 94, 131	Dicot
60	*Colubrina arborescens*	Rhamnaceae	Tree/shrub	104, 149	Dicot
61	*Colubrina elliptica*	Rhamnaceae	Tree/shrub	104, 149	Dicot
62	*Commelina diffusa*	Commelinaceae	Forb/herb	135	Monocot
63	*Commelina* spp.	Commelinaceae	Forb/herb	135	Monocot
64	*Conocarpus erectus*	Combretaceae	Tree/shrub	87, 157	Dicot
65	*Cordia borinquensis*	Boraginaceae	Tree/shrub	68, 135	Dicot
66	*Cordia sulcata*	Boraginaceae	Tree/shrub	68, 97	Dicot
67	*Croton poecilanthus*	Euphorbiaceae	Tree	68, 71, 93, 145	Dicot
68	*Ctenitis hirta*	Dryopteridaceae	Forb/herb	135	Fern
69	*Cupania americana*	Sapindaceae	Tree	97	Dicot
70	*Cyathea arborea*	Cyatheaceae	Tree	135	Fern
71	*Cyclopogon cranichoides*	Orchidaceae	Forb/herb	135	Monocot
72	*Cyrilla racemiflora*	Cyrillaceae	Tree/shrub	67, 93	Dicot

Table 10—Species, family, growth habit, and source (continued)

No.	Name	Family	Growth habit	Source	Group
73	*Dacryodes excelsa*	Burseraceae	Tree	68, 71, 94, 100, 101, 107, 120, 123, 124, 135, 153	Dicot
74	*Dacryodes* sp.	Burseraceae	Tree	146	Dicot
75	*Danaea nodosa*	Marattiaceae	Forb/herb	129, 135	Fern
76	*Daphnopsis philippiana*	Thymelaeaceae	Tree/shrub	93	Dicot
77	*Delonix regia*	Fabaceae	Tree	115	Dicot
78	*Dendropanax arboreus*	Araliaceae	Tree/shrub	71	Dicot
79	*Dennstaedtia bipinnata*	Dennstaedtiaceae	Forb/herb	135	Fern
80	*Dennstaedtia obtusifolia*	Dennstaedtiaceae	Forb/herb	135	Fern
81	*Dennstaetdia* spp.	Dennstaedtiaceae	Forb/herb	135	Fern
82	*Dialium guineense*	Fabaceae		115	Dicot
83	*Dieffenbachia seguine*	Araceae	Forb/herb	121	Monocot
84	*Dioscorea polygonoides*	Dioscoreaceae	Vine/forb-herb	135	Monocot
85	*Ditta myricoides*	Euphorbiaceae	Tree/shrub	93	Dicot
86	*Drypetes glauca*	Euphorbiaceae	Tree/shrub	68	Dicot
87	*Enterolobium cyclocarpum*	Fabaceae	Tree	97	Dicot
88	*Erithalis fruticosa*	Rubiaceae	Tree/shrub	104, 149, 151	Dicot
89	*Erythrodes plantaginea*	Orchidaceae	Forb/herb	135	Monocot
90	*Erythroxylum areolatum*	Erythroxylaceae	Forb/herb	104, 149	Dicot
91	*Erythroxylum rotundifolium*	Erythroxylaceae	Tree/shrub	104, 149	Dicot
92	*Eucalyptus patentinervis*	Myrtaceae	Tree	90, 139	Dicot
93	*Eucalyptus robusta*	Myrtaceae	Tree	97, 152	Dicot
94	*Eucalyptus saligna*	Myrtaceae	Tree	90, 139	Dicot
95	*Eugenia borinquensis*	Myrtaceae	Tree/shrub	93	Dicot
96	*Eugenia eggersii*	Myrtaceae	Tree/shrub	93,135	Dicot
97	*Eugenia foetida*	Myrtaceae	Tree/shrub	149	Dicot
98	*Eugenia maleolens*	Myrtaceae	Tree/shrub	104	Dicot
99	*Eugenia monticola*	Myrtaceae	Tree/shrub	126	Dicot
100	*Eugenia rhombea*	Myrtaceae	Tree/shrub	104, 149	Dicot
101	*Eugenia stahlii*	Myrtaceae	Tree/shrub	94	Dicot
102	*Exostema caribaeum*	Rubiaceae	Tree/shrub	102, 104, 149, 151	Dicot
103	*Faramea occidentalis*	Rubiaceae	Tree/shrub	126	Dicot
104	*Ficus citrifolia*	Moraceae	Tree/shrub	55, 97	Dicot
105	Forest floor-logs			95	
106	Forest floor-roots			127	
107	*Genipa americana*	Rubiaceae	Tree	97	Dicot

Table 10—Species, family, growth habit, and source (continued)

No.	Name	Family	Growth habit	Source	Group
108	*Gleichenia* spp. (has various names)	Gleicheniaceae	Forb/herb	135	Fern
109	*Gomidesia lindeniana*	Myrtaceae	Tree/shrub	58	Dicot
110	*Gonzalagunia spicata*	Rubiaceae	Tree/shrub	135, 146	Dicot
111	*Guaiacum officinale*	Zygophyllaceae	Tree	104, 149	Dicot
112	*Guaiacum sanctum*	Zygophyllaceae	Tree	104, 149	Dicot
113	*Guanica forest*			109, 134	
114	*Guapira obtusata*	Nyctaginaceae	Tree/shrub	102	Dicot
115	*Guararibaea turbinata*	Bombacaceae	Tree/shrub	68	Dicot
116	*Guarea glabra*	Meliaceae	Tree/shrub	68, 93, 94, 101	Dicot
117	*Guarea guidonia*	Meliaceae	Tree/shrub	71, 125, 126, 129, 135	Dicot
118	*Guarea ramiflora*	Meliaceae	Tree/shrub	125	Dicot
119	*Guazuma ulmifolia*	Sterculiaceae	Tree/shrub	97	Dicot
120	*Guettarda pungens*	Rubiaceae	Tree/shrub	149	Dicot
121	*Guettarda scabra*	Rubiaceae	Tree/shrub	102, 149	Dicot
122	*Guzmania berteriana*	Bromeliaceae	Forb/herb	135	Monocot
123	*Gymnanthes lucida*	Euphorbiaceae	Tree/shrub	104, 149, 151	Dicot
124	*Heliconia caribaea*	Heliconiaceae	Forb/herb	122, 135, 137	Monocot
125	*Henriettea squamulosum*	Melastomataceae	Tree	93	Dicot
126	*Herbaceous*			135	
127	*Hernandia sonora*	Hernandiaceae	Tree/shrub	90, 139	Dicot
128	*Heteropteris laurifolia*	Malpighiaceae	Tree/shrub/vine	135	Dicot
129	*Heterotrichum cymosum*	Melastomataceae	Tree/shrub	146	Dicot
130	*Hibiscus elatus*	Malvaceae	Tree	90, 97, 139	Dicot
131	*Hillia parasitica*	Rubiaceae	Tree/shrub/vine	135	Dicot
132	*Homalium racemosum*	Flacourtiaceae	Tree	148	Dicot
133	*Hyeronima clusioides*	Euphorbiaceae	Tree/shrub	97	Dicot
134	*Hypolepsis* spp.			135	
135	*Ichnanthus pallens*	Poaceae	Graminoid	135	Monocot
136	*Ichnanthus* spp.	Poaceae	graminoid	135	Monocot
137	*Ilex sideroxyloides*	Aquifoliaceae	Tree	93	Dicot
138	*Inga fagifolia*	Fabaceae	Tree	145	Dicot
139	*Inga laurina*	Fabaceae	Tree	70, 71, 126, 135	Dicot
140	*Inga vera*	Fabaceae	Tree	71, 100, 145, 146	Dicot
141	*Jacquinia berteroi*	Theophrastaceae	Tree/shrub	104, 149, 151	Dicot
142	*Juglans jamaicensis*	Juglandaceae	Tree	115	Dicot
143	*Kalanchoe pinnata*	Crassulaceae	Forb/herb	105	Dicot
144	*Khaya grandifolia*	Meliaceae	Tree	97	Dicot
145	*Khaya nyasica*	Meliaceae	Tree	90, 97, 135, 139	Dicot

Table 10—Species, family, growth habit, and source (continued)

No.	Name	Family	Growth habit	Source	Group
146	*Khaya senegalensis*	Meliaceae	Tree	97	Dicot
147	*Krugiodendron ferreum*	Rhamnaceae	Tree/shrub	104, 149	Dicot
148	*Laguncularia racemosa*	Combretaceae	Tree/shrub	72, 73, 74, 78, 83, 87, 157	Dicot
149	*Leucaena leucocephala*	Fabaceae	Tree/shrub	126, 148, 152	Dicot
150	*Lonchitis hirsuta*	Dennstaedtiaceae	Forb/herb	135	Fern
151	*Maesopsis eminii*	Rhamnaceae	Tree	97	Dicot
152	*Magnolia portoricensis*	Magnoliaceae	Tree	115	Dicot
153	*Magnolia splendens*	Magnoliaceae	Tree	71, 93	Dicot
154	Mahogany plantation			133	
155	*Mangrove*			79	
156	*Manilkara bidentata*	Sapotaceae	Tree	68, 71, 89, 94, 101, 107, 125, 129, 145, 153	Dicot
157	*Marcgravia rectiflora*	Marcgraviaceae		135	Dicot
158	*Marcgravia* spp.	Marcgraviaceae		135	Dicot
159	*Matayba domingensis*	Sapindaceae	Tree	68	Dicot
160	*Megalastrum subincisa*	Dryopteridaceae	Forb/herb	135	Fern
161	*Melicoccus bijugatus*	Sapindaceae	Tree	97	Dicot
162	*Miconia impetiolaris*	Melastomataceae	Tree/shrub	129	Dicot
163	*Miconia prasina*	Melastomataceae	Tree/shrub	68, 94, 126, 131, 138,	Dicot
164	*Miconia racemosa*	Melastomataceae	Tree/shrub	129, 146	Dicot
165	*Miconia* sp.	Melastomataceae	Tree/shrub	146	Dicot
166	*Miconia* spp.	Melastomataceae	Tree/shrub	143	Dicot
167	*Miconia tetrandra*	Melastomataceae	Tree/shrub	92, 94	Dicot
168	*Micropholis chrysophylloides*	Sapotaceae	Tree	92	Dicot
169	*Micropholis garciniifolia*	Sapotaceae	Tree/shrub	92	Dicot
170	*Mikania cordifolia*	Asteraceae	Vine/forb/herb	135	Dicot
171	Mixed-species Guanica forest			99	
172	*Musa paradisiaca*	Musaceae	Tree	135	Monocot
173	*Musa* spp.	Musaceae	Tree	135	Monocot
174	*Myrcia deflexa*	Myrtaceae	Tree/shrub	93, 94, 135	Dicot
175	*Myrcia splendens*	Myrtaceae	Tree/shrub	94, 101, 126	Dicot
176	*Neolaugeria resinosa*	Rubiaceae	?	102	Dicot
177	*Nephrolepsis portoricensis*			135	
178	*Nephrolepis rivularis*			135	
179	*Nepsera aquatica*	Melastomataceae	Shrub-forb/herb	135	Dicot
180	*Ocotea leucoxylon*	Lauraceae	Tree	93, 94, 126, 135	Dicot
181	*Ocotea moschata*	Lauraceae	Tree	97	Dicot

Table 10—Species, family, growth habit, and source (continued)

No.	Name	Family	Growth habit	Source	Group
182	*Ocotea spathulata*	Lauraceae	Tree	93	Dicot
183	*Odontosoria* spp.	Dennstaedtiaceae	Forb/herb	135	Fern
184	*Olyra latifolia*	Poaceae	Graminoid	135	Monocot
185	*Ormosia krugii*	Fabaceae	Tree	68, 135	Dicot
186	*Ouratea littoralis*	Ochnaceae	Tree/shrub	102, 149	Dicot
187	*Palicourea crocea*	Rubiaceae	Tree/shrub	135	Dicot
188	*Palicourea riparia*	Rubiaceae	Tree/shrub	94, 135, 146	Dicot
189	*Panicum maximum*	Poaceae	Graminoid	144	Monocot
190	Pasture			110, 153	
191	*Paullinia pinnata*	Sapindaceae	Vine	135	Dicot
192	*Paullinia* spp.	Sapindaceae	Vine	135	Dicot
193	*Peperomia* spp.	Piperaceae	Forb/herb	135	Dicot
194	*Petitia domingensis*	Verbenaceae	Tree/shrub	149	Dicot
195	*Philodendron angustatum*	Araceae	Vine/forb/herb	135	Monocot
196	*Philodendron scandens*	Araceae	Vine/forb/herb	135	Monocot
197	*Philodendron* spp.	Araceae	Vine/forb/herb	135	Monocot
198	*Phoradendron racemosum*	Viscaceae	Shrub	104, 149	Dicot
199	*Phytolacca icosandra*	Phytolaccaceae	Forb/herb	135, 141	Dicot
200	*Phytolacca rivinoides*	Phytolaccaceae	Forb/herb	135	Dicot
201	*Pictetia aculeata*	Fabaceae	Tree/shrub	102, 104, 149, 151	Dicot
202	*Pilea inaequalis*	Urticaceae	Forb/herb	135	Dicot
203	*Pilea krugii*	Urticaceae	Forb/herb	135	Dicot
204	*Pimenta racemosa*	Myrtaceae	Tree/shrub	126	Dicot
205	*Pine plantation*			153, 156	
206	*Pinus caribaea*	Pinaceae	Tree	69, 90, 101, 115	Gimnosperm
207	*Pinus caribaea hondurensis*	Pinaceae	Tree	139	Gimnosperm
208	*Pinus elliottii*	Pinaceae	Tree	139	Gimnosperm
209	*Pinus massoniana*	Pinaceae	Tree	68	Gimnosperm
210	*Pinus ocarpa*	Pinaceae	Tree	115	Gimnosperm
211	*Piper aduncum*	Piperaceae	Tree/shrub	129	Dicot
212	*Piper glabrescens*	Piperaceae	Tree/shrub	135, 146	Dicot
213	*Piper hispidum*	Piperaceae	Tree/shrub	135, 146	Dicot
214	*Pisonia albida*	Nyctaginaceae	Tree	104, 149	Dicot
215	*Pisonia subcordata*	Nyctaginaceae	Tree	102	Dicot
216	*Pithecellobium dulce*	Fabaceae	Tree/shrub	97	Dicot
217	*Plumeria alba*	Apocynaceae	Tree/shrub	91	Dicot
218	*Plumeria obtusa*	Apocynaceae	Tree/shrub	91	Dicot
219	*Plumeria rubra* (red)	Apocynaceae	Tree/shrub	91	Dicot

Table 10—Species, family, growth habit, and source (continued)

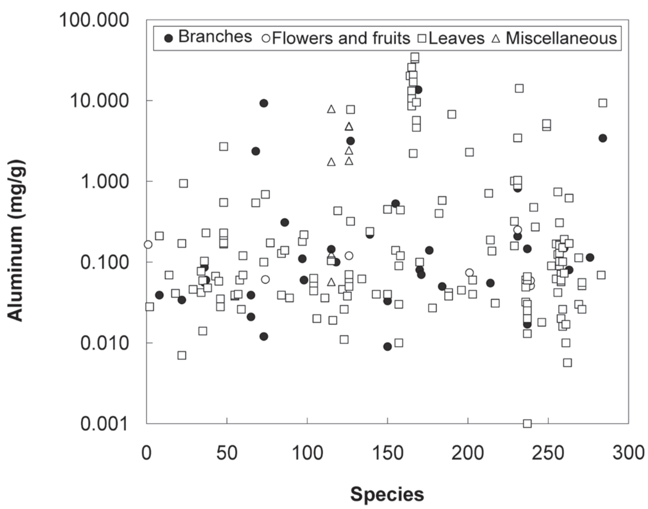
No.	Name	Family	Growth habit	Source	Group
220	*Plumeria rubra* (white)	Apocynaceae	Tree/shrub	91	Dicot
221	*Polybotrya cervina*	Dryopteridaceae	Forb/herb	135	Fern
222	*Polypodium chnoodes*	Polypodiaceae	Forb/herb	135	Fern
223	*Polypodium crassifolium*	Polypodiaceae	Forb/herb	135	Fern
224	*Polypodium* spp.	Polypodiaceae	Forb/herb	135	Fern
225	*Pouteria multiflora*	Sapotaceae	Tree	118	Dicot
226	*Prescotia oligantha*	Orchidaceae	Forb/herb	155	Monocot
227	*Prestoea montana*	Arecaceae	Tree	68, 69, 92, 93, 107, 135, 147, 150	Monocot
228	*Prunus occidentalis*	Rosaceae	Tree	117	Dicot
229	*Psychotria berteriana*	Rubiaceae	Tree/shrub	93, 135, 143, 146	Dicot
230	*Psychotria maleolens*	Rubiaceae	Tree/shrub	143	Dicot
231	*Psychotria* sp.	Rubiaceae	Tree/shrub	94	Dicot
232	*Pteris altissima*	Pteridaceae	Forb/herb	135	Fern
233	*Pterocarpus macrocarpus*	Fabaceae	Tree	97	Dicot
234	*Pterocarpus officinalis*	Fabaceae	Tree	76, 78, 83, 84, 97	Dicot
235	*Rhizophora mangle*	Rhizophoraceae	Tree	72, 73, 74, 75, 77, 78, 80, 81, 82, 85, 86, 87, 157	Dicot
236	*Rourea surinamensis*	Connaraceae	Vine/shrub	135	Dicot
237	*Roystonea borinquena*	Arecaceae	Tree	119	Monocot
238	*Sabicea hirsuta*	Rubiaceae	Vine/shrub	135	Dicot
239	*Sapindus saponaria*	Sapindaceae	Tree/shrub	129	Dicot
240	*Sapium laurocerasus*	Euphorbiaceae	Tree	68, 71, 135, 145	Dicot
241	*Sauvagesia erecta*	Ochnaceae	Shrub-forb/herb	135	Dicot
242	*Schefflera morototoni*	Araliaceae	Tree	35, 68, 71, 94, 126, 135	Dicot
243	*Schizolobium parahybum*	Fabaceae	Tree	97	Dicot
244	*Schlegelia brachyantha*	Bignoniaceae	Vine/shrub	135	Dicot
245	*Scleria canescens*	Cyperaceae	Graminoid	135	Monocot
246	*Scleria* spp.	Cyperaceae	Graminoid	135	Monocot
247	Secondary forest			106, 108, 111, 112, 113, 114, 124, 130, 131, 132, 136, 140, 142, 153, 154, 156	
248	*Securidaca virgata*	Polygalaceae	Vine/shrub	135	Dicot
249	*Selaginella krugii*	Selaginellaceae	Forb/herb	135	Lycopod

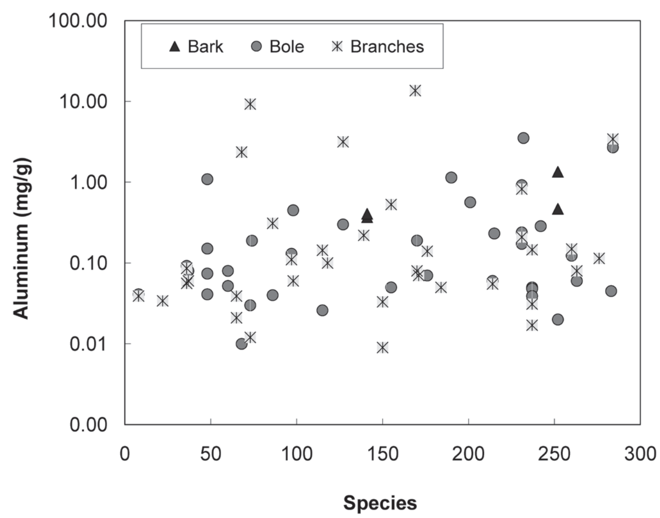
Table 10—Species, family, growth habit, and source (continued)

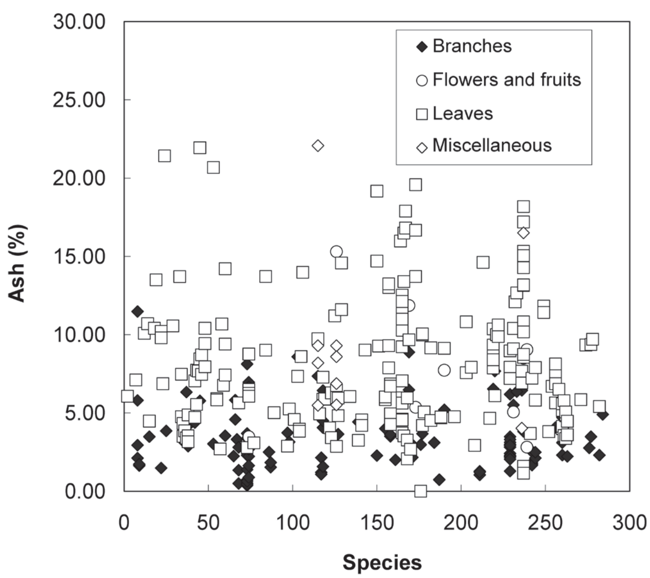
No.	Name	Family	Growth habit	Source	Group
250	*Sloanea berteriana*	Elaeocarpaceae	Tree	67, 70, 135, 150	Dicot
251	*Solanum torvum*	Solanaceae	Tree/shrub	146	Dicot
252	*Spathodea campanulata*	Bignoniaceae	Tree	97, 126	Dicot
253	*Swietenia humilis*	Meliaceae	Tree	103	Dicot
254	*Swietenia macrophylla*	Meliaceae	Tree	90, 94, 101, 103, 104, 129, 139	Dicot
255	*Swietenia macrophylla x mahagoni*	Meliaceae	Tree	103	Dicot
256	*Swietenia mahogoni*	Meliaceae	Tree	102, 103, 149	Dicot
257	*Swietenia* sp.	Meliaceae	Tree	103	Dicot
258	*Syzygium jambos*	Myrtaceae	Tree	94, 101, 126, 129, 131	Dicot
259	*Tabebuia haemantha*	Bignoniaceae	Tree/shrub	102, 149	Dicot
260	*Tabebuia heterophylla*	Bignoniaceae	Tree/shrub	58, 94, 101, 115, 126, 138	Dicot
261	*Tabebuia rigida*	Bignoniaceae	Tree/shrub	93, 107	Dicot
262	*Tabebuia* spp.	Bignoniaceae	Tree/shrub	149	Dicot
263	Tabonuco forest			153	
264	Tabonuco secondary forest			133	
265	*Tectaria trifoliata*	Dryopteridaceae	Forb/herb	135	Fern
266	*Thelypteris deltoidea*	Thelypteridaceae	Gorb/herb	135	Fern
267	*Terebraria resinosa*	Rubiaceae	Shrub	58	Dicot
268	*Terminalia ivorensis*	Combretaceae	Tree	90, 139	Dicot
269	*Ternstroemia stahlii*	Theaceae	Tree/shrub	102, 149	Dicot
270	*Tetragastris balsamifera*	Burseraceae	Tree	135	Dicot
271	*Thelypteris deltoidea*	Thelypteridaceae	Forb/herb	135	Fern
272	*Thespesia grandiflora*	Malvaceae	Tree	126	Dicot
273	*Thouinia striata*	Sapindaceae	Tree/shrub	104, 149	Dicot
274	*Torralbasia cuneifolia*	Celastraceae	Tree/shrub	93	Dicot
275	*Trema micranthum*	Ulmaceae	Tree/shrub	94	Dicot
276	*Trichilia pallida*	Meliaceae	Tree/shrub	71	Dicot
277	*Trichipteris borinquena*	Cyatheaceae	Shrub	135	Fern
278	*Trichipteris procera*	Cyatheaceae	Tree	135	Fern
279	*Trichostigma octandrum*	Phytolaccaceae	Shrub/vine	135	Dicot
280	*Turpinia occidentalis*	Staphyleaceae	Tree	101	Dicot
281	*Urera baccifera*	Urticaceae	Tree/shrub	135	Dicot
282	*Xylosma schwaneckeana*	Flacourtiaceae	Vine/tree/shrub	93	Dicot
283	Young secondary forest			98	
284	*Zanthoxylum flavum*	Rutaceae	Tree/shrub	115	Dicot
285	*Zanthoxylum martinicense*	Rutaceae	Tree/shrub	97	Dicot

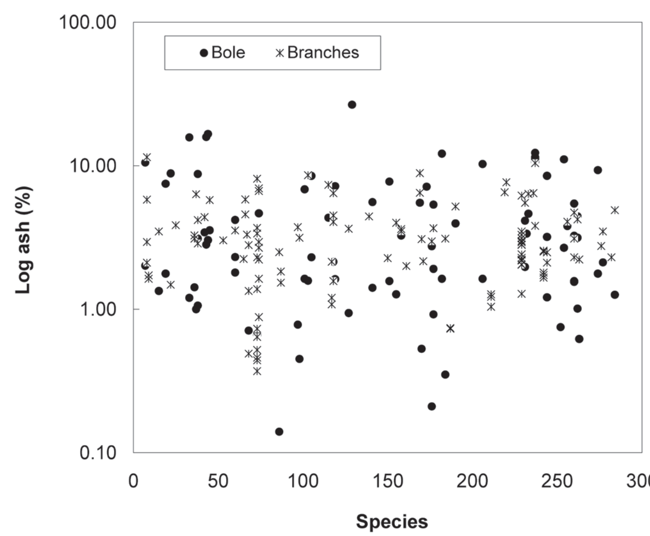
Appendix 3: Elemental Composition by Species in Live Vegetation

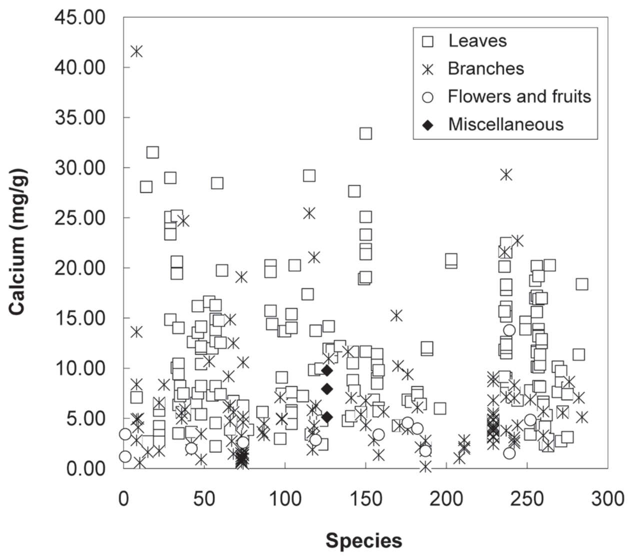
This appendix contains charts of element and ash concentrations, and carbon to nitrogen (C/N) ratios of live vegetation parts by species. Species identification is by code number in appendix 2. The charts are intended to provide a visual idea of the range of element and ash concentration and C/N values and outlier species. Some charts have the Y-axis scale in log scale while others are linear. The charts are arranged in alphabetical order by the Y-axis label.

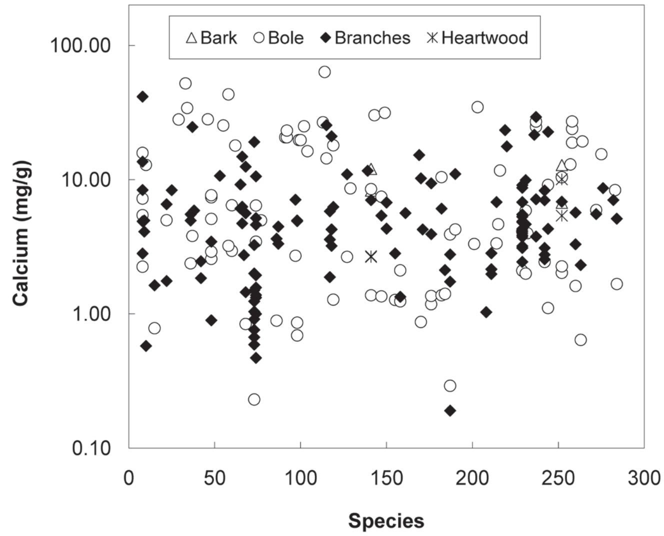


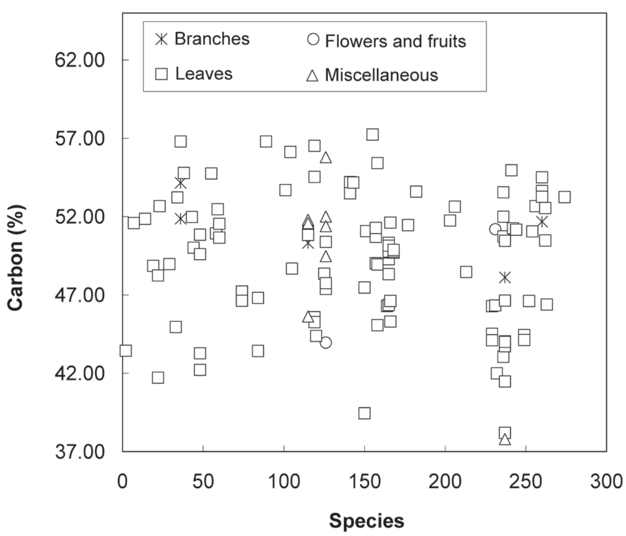


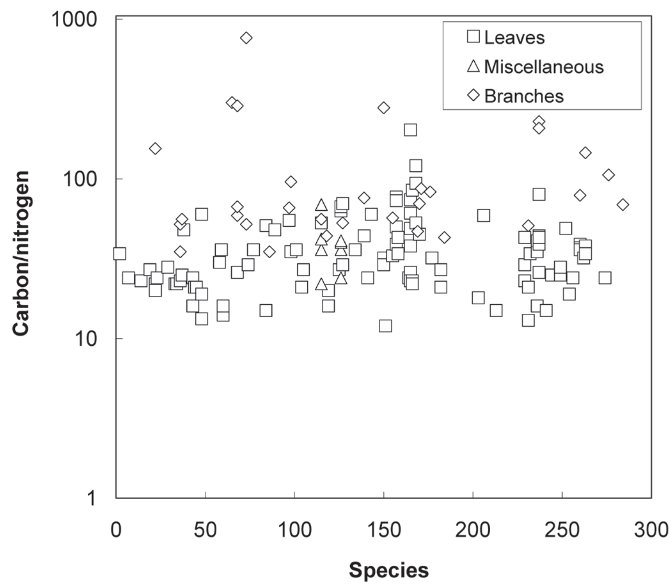


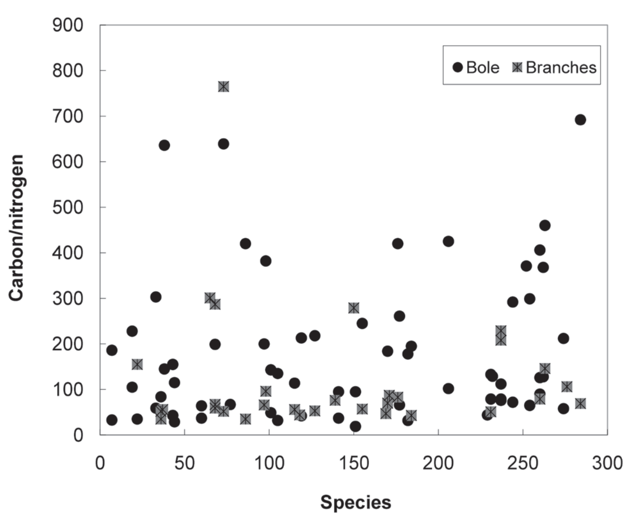


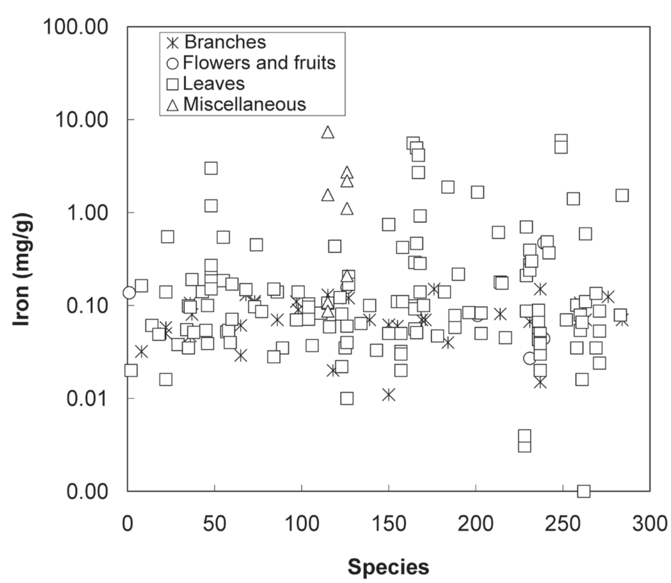

Leaves
Branches
Flowers and fruits
Miscellaneous
Calcium (mg/g)
Species

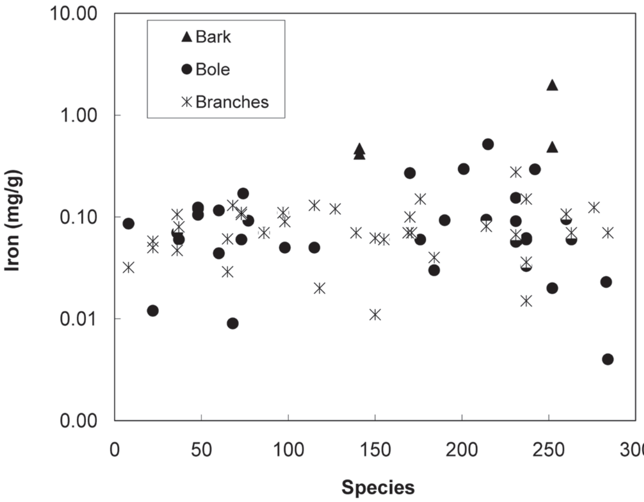

Bark
Bole
Branches
Heartwood
Calcium (mg/g)
Species

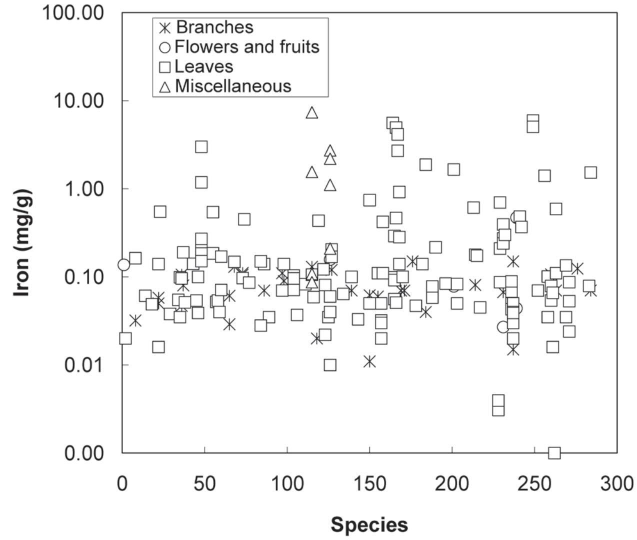

Branches
Flowers and fruits
Leaves
Miscellaneous
Carbon (%)
Species

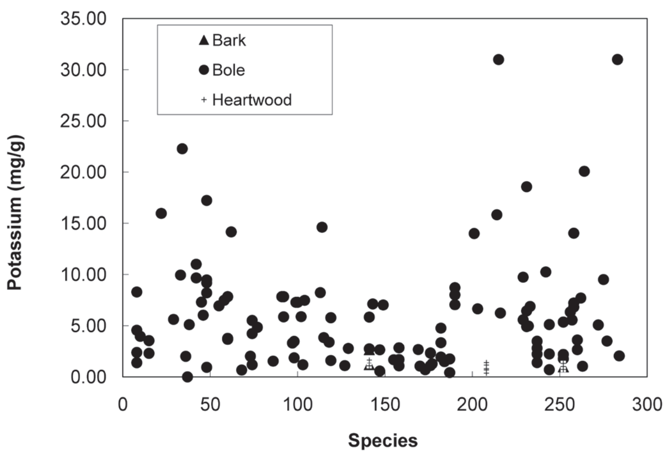

Leaves
Miscellaneous
Branches
Carbon/nitrogen
Species

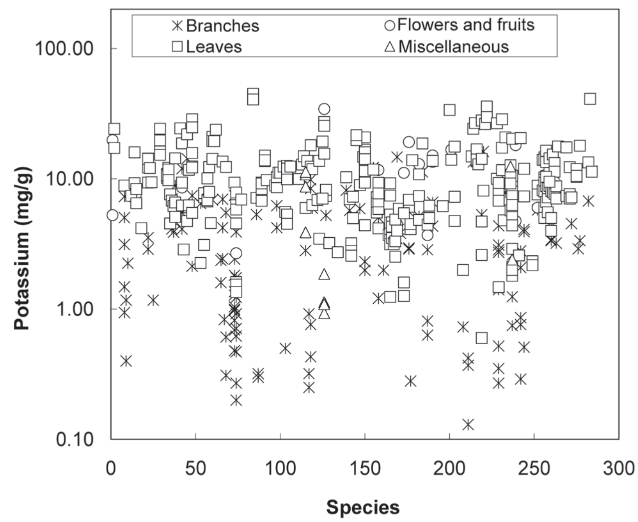

Bole
Branches
Carbon/nitrogen
Species

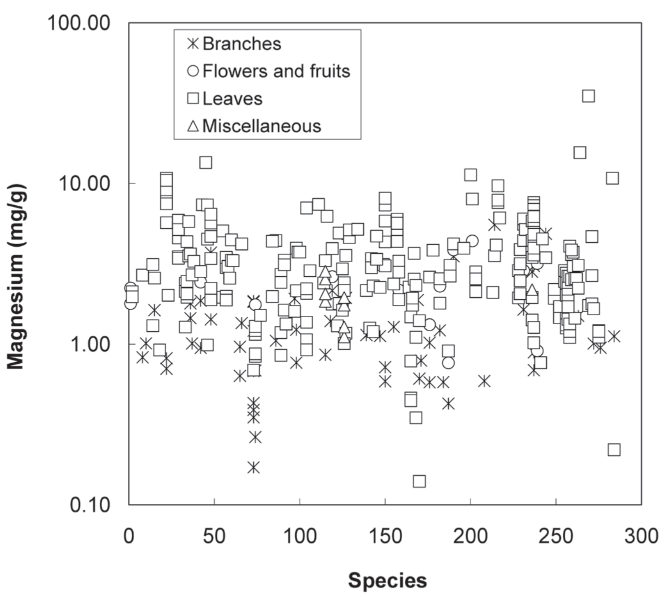

Branches
Flowers and fruits
Leaves
Miscellaneous
Iron (mg/g)
Species

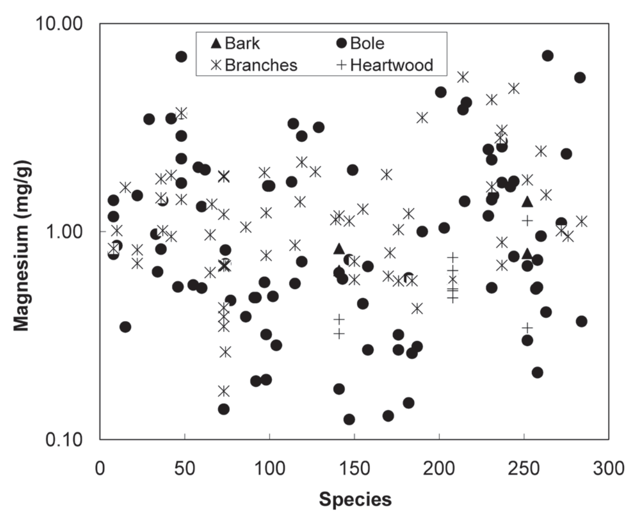

Bark
Bole
Branches
Iron (mg/g)
Species

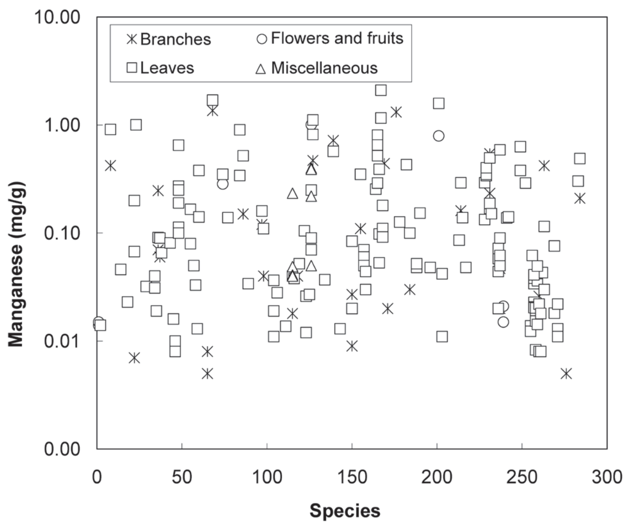

Branches
Flowers and fruits
Leaves
Miscellaneous
Iron (mg/g)
Species


Bark
Bole
Heartwood
Potassium (mg/g)
Species


Branches
Flowers and fruits
Leaves
Miscellaneous
Potassium (mg/g)
Species


Branches
Flowers and fruits
Leaves
Miscellaneous
Magnesium (mg/g)
Species


Bark
Bole
Branches
Heartwood
Magnesium (mg/g)
Species


Branches
Flowers and fruits
Leaves
Miscellaneous
Manganese (mg/g)
Species
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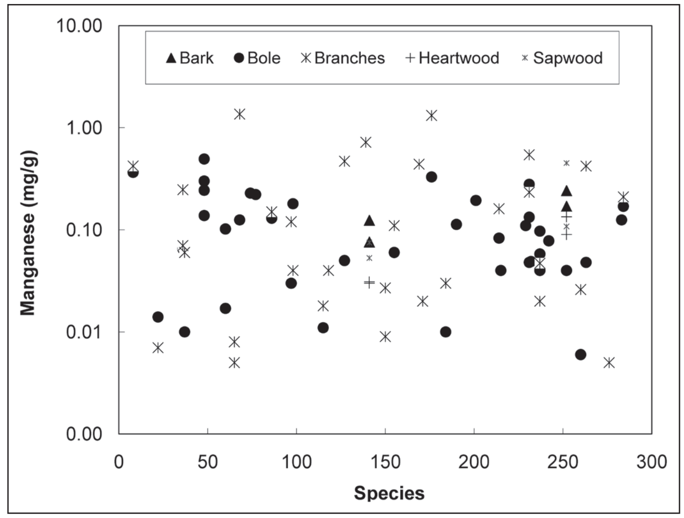
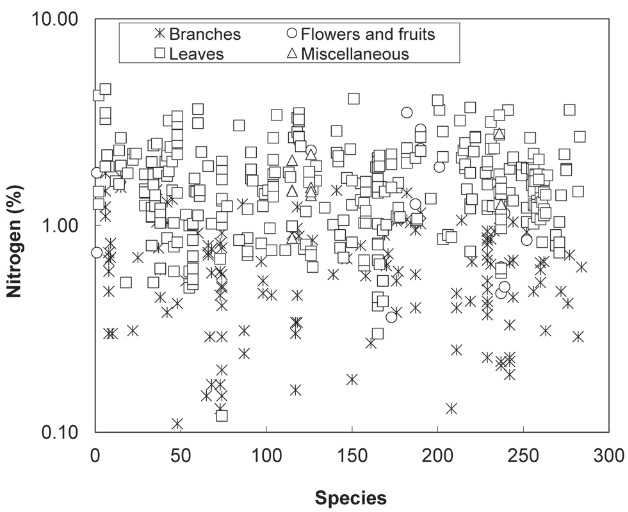
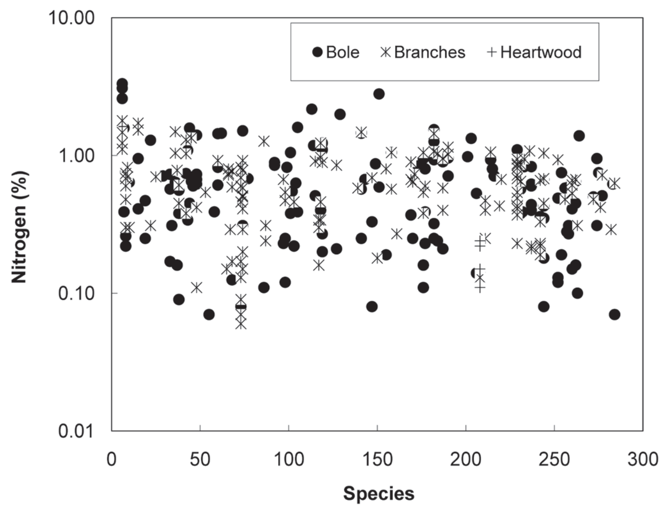
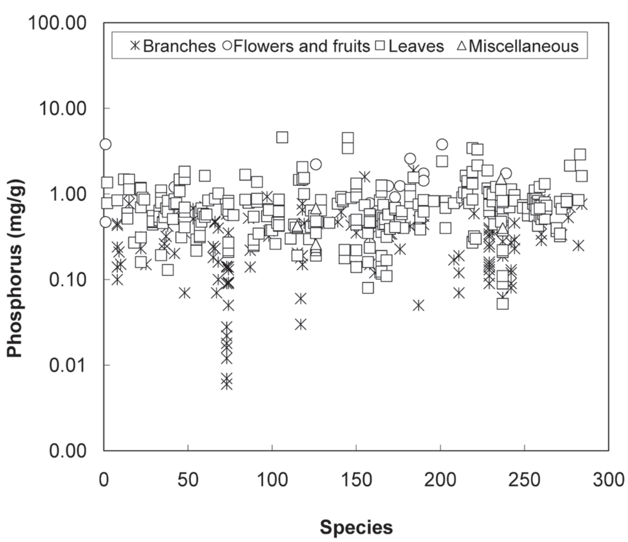
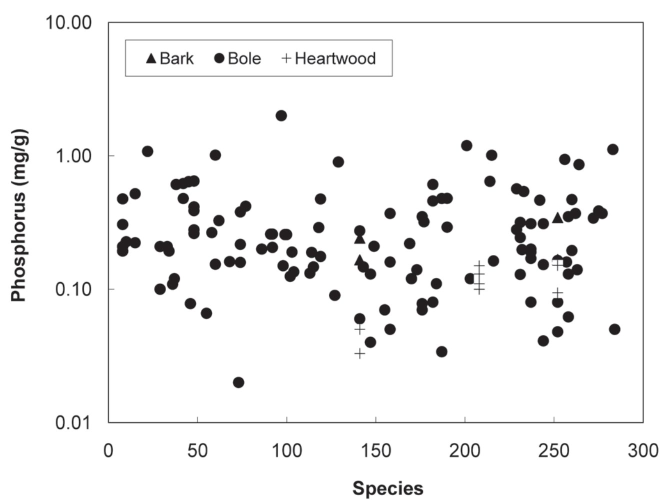
1.00
0.10
0.01
0.00
0
50
100
150
200
250
300


Bark
Bole
Branches
Heartwood
Sapwood
Manganese (mg/g)
Species
10.00
1.00
0.10
0.01
0.00
0
50
100
150
200
250
300


Branches
Flowers and fruits
Leaves
Miscellaneous
Nitrogen (%)
Species
10.00
1.00
0.10
0
50
100
150
200
250
300

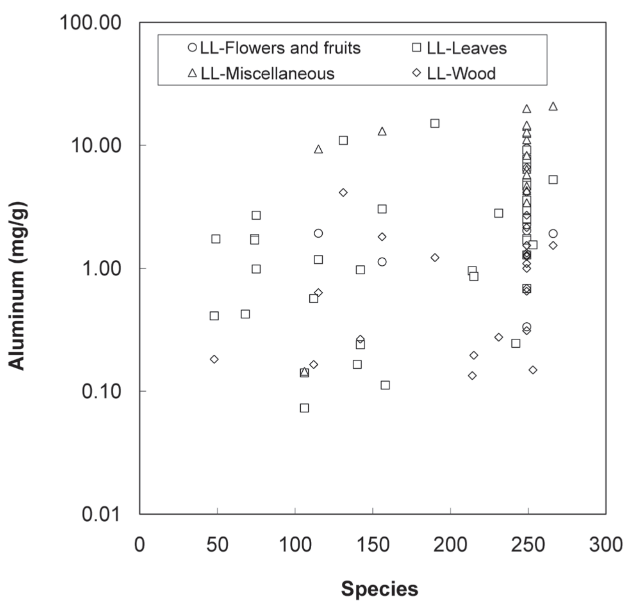

Bole
Branches
Heartwood
Nitrogen (%)
Species
10.00
1.00
0.10
0.01
0
50
100
150
200
250
300

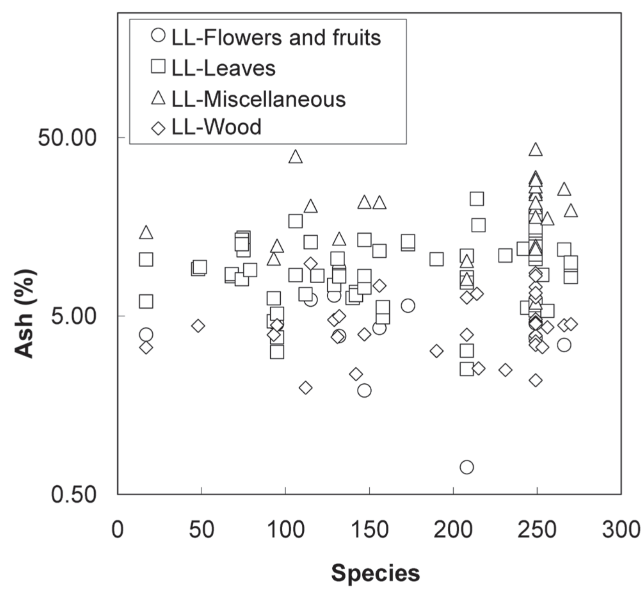

Branches
Flowers and fruits
Leaves
Miscellaneous
Phosphorus (mg/g)
Species
100.00
10.00
1.00
0.10
0.01
0.00
0
50
100
150
200
250
300

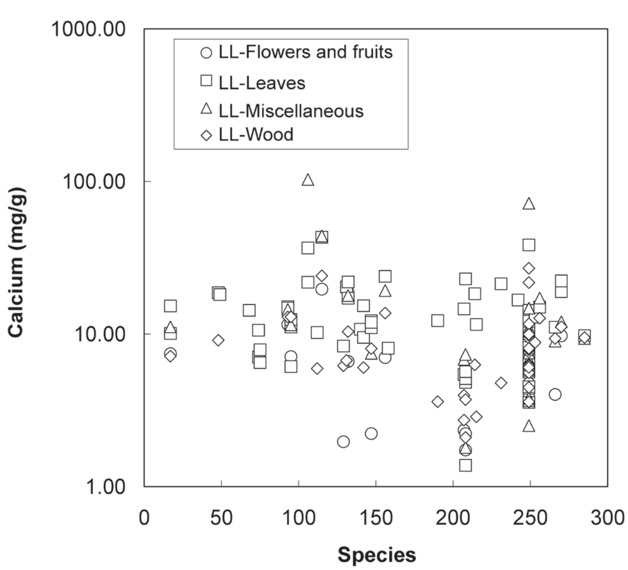

Bark
Bole
Heartwood
Phosphorus (mg/g)
Species
10.00
1.00
0.10
0.01
0
50
100
150
200
250
300

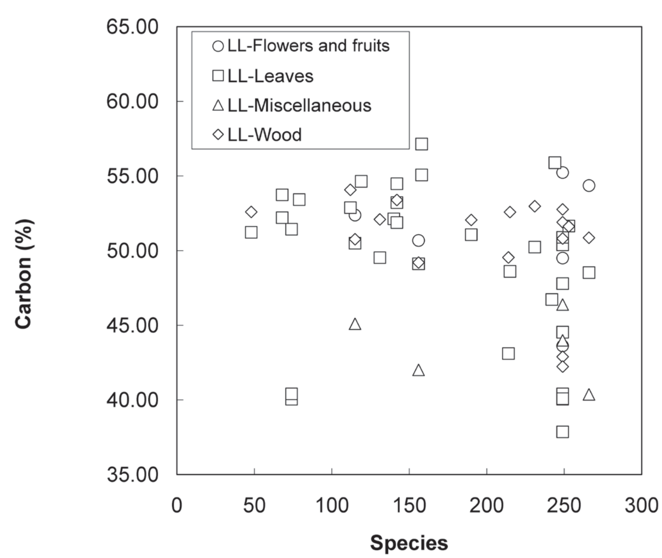
Appendix 4: Elemental Composition by Species in Loose Litter

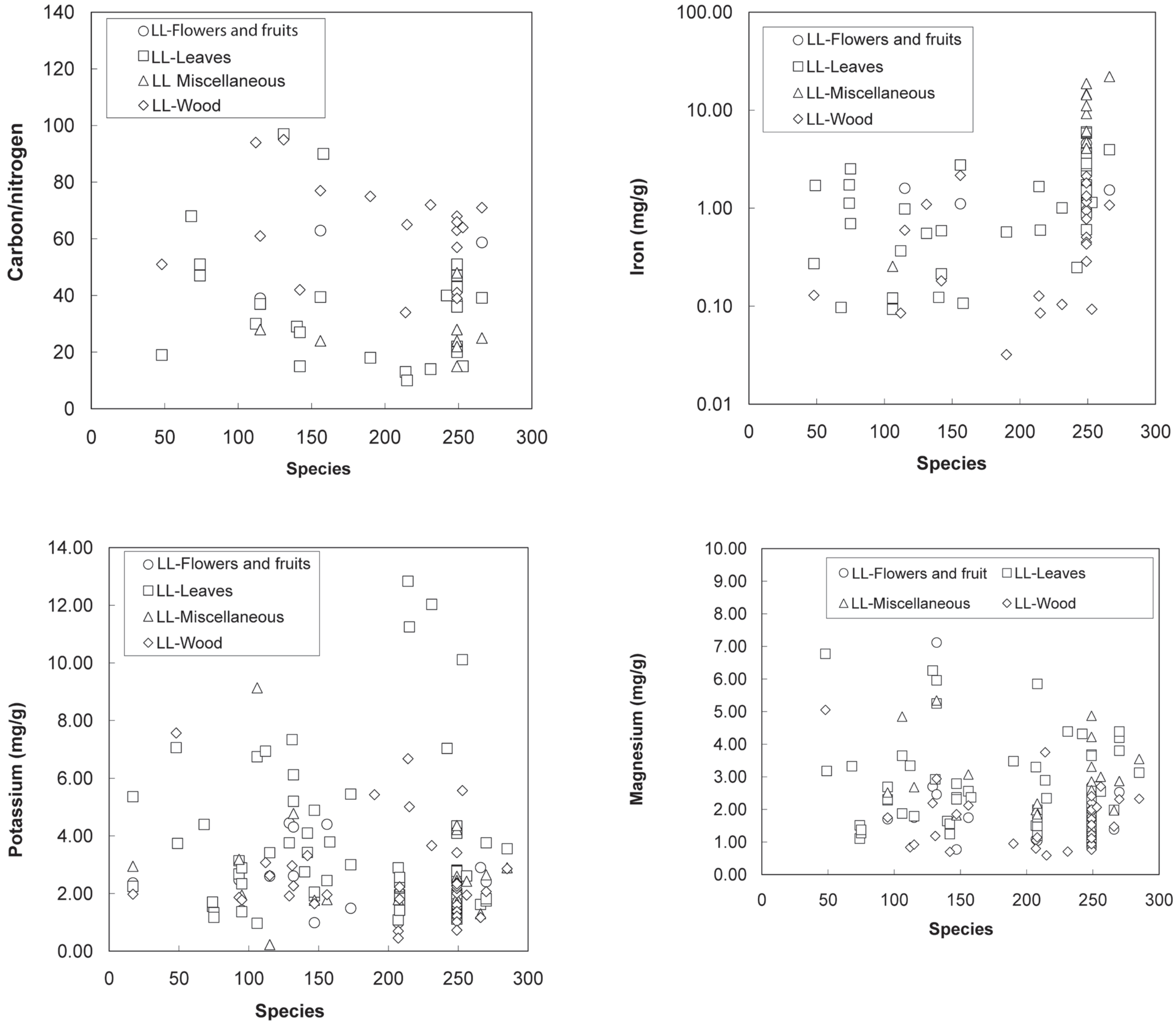
This appendix contains charts of element and ash concentrations, and carbon to nitrogen (C/N) ratios of ground or loose litter (LL) by species. Loose litter is sorted by different components. Species identification is by code number in appendix 2. The charts are intended to provide a visual idea of the range of element and ash concentration and C/N values and outlier species. Some charts have the Y-axis scale in log scale while others are linear. The charts are arranged in alphabetical order by the Y-axis label.

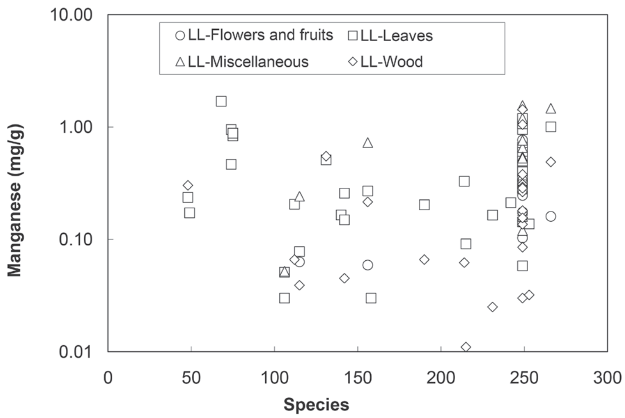


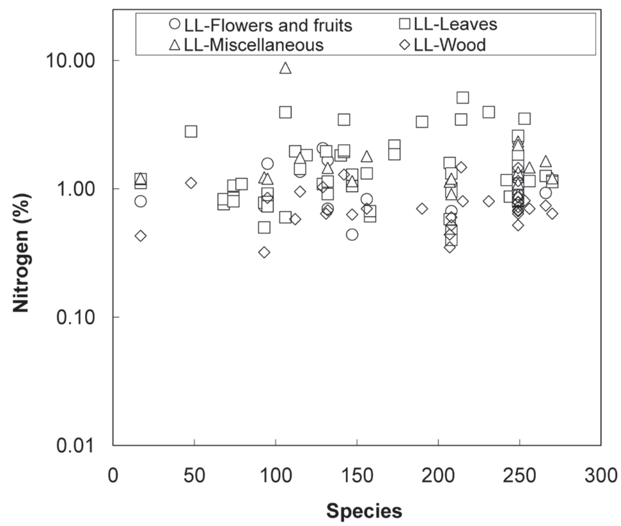


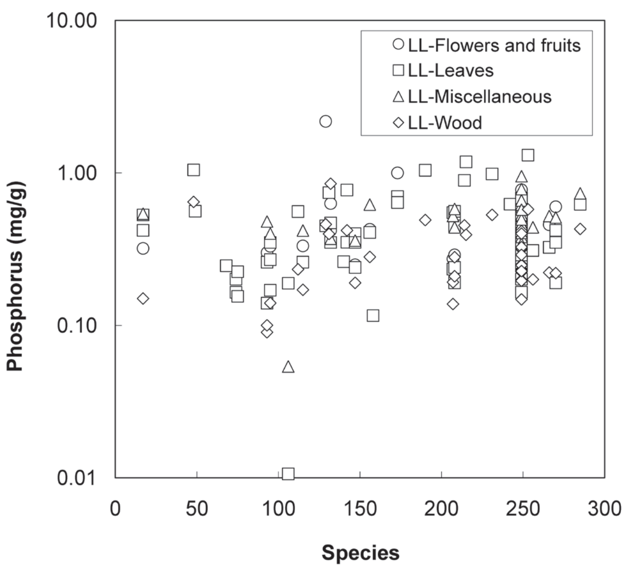





LL-Flowers and fruits
LL-Leaves
LL Miscellaneous
LL-Wood
Carbon/nitrogen
Species
LL-Flowers and fruits
LL-Leaves
LL-Miscellaneous
LL-Wood
Iron (mg/g)
Species
LL-Flowers and fruits
LL-Leaves
LL-Miscellaneous
LL-Wood
Potassium (mg/g)
Species
LL-Flowers and fruit
LL-Leaves
LL-Miscellaneous
LL-Wood
Magnesium (mg/g)
Species

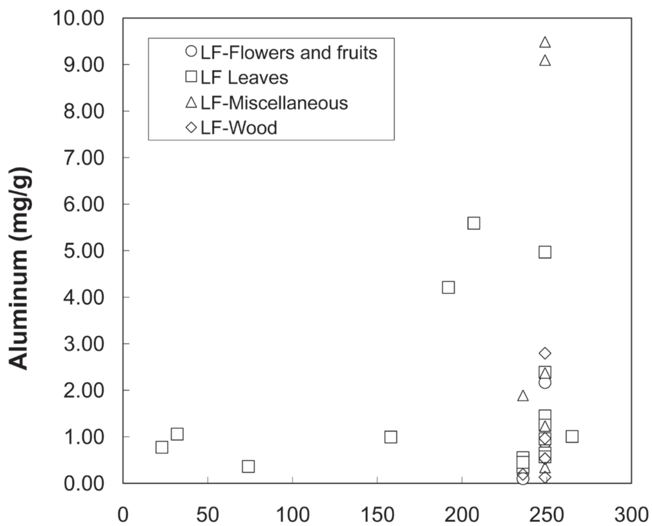

10.00
1.00
0.10
0.01
0
50
100
150
200
250
300
Manganese (mg/g)
Species
LL-Flowers and fruits
LL-Leaves
LL-Miscellaneous
LL-Wood

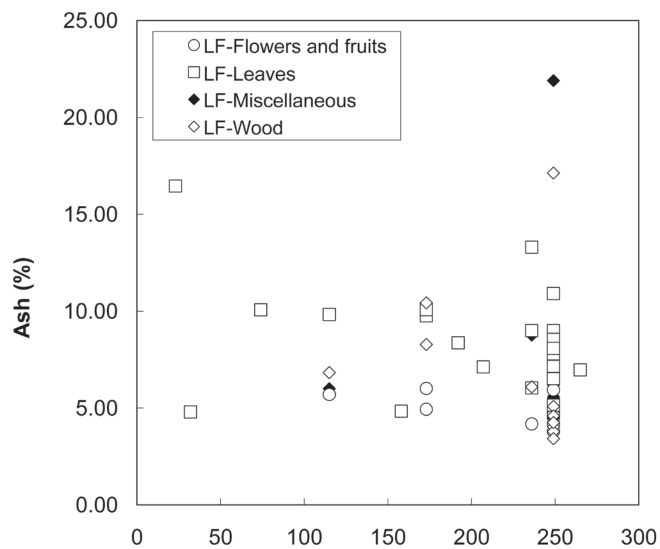

10.00
1.00
0.10
0.01
0
50
100
150
200
250
300
Nitrogen (%)
Species
LL-Flowers and fruits
LL-Leaves
LL-Miscellaneous
LL-Wood

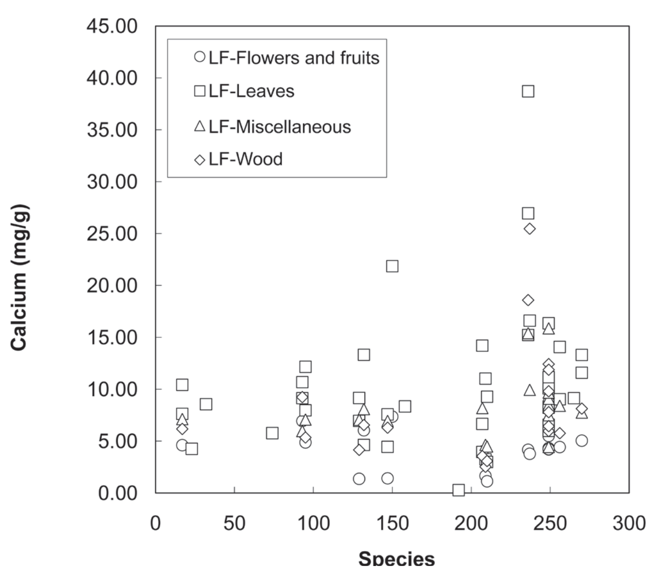

10.00
1.00
0.10
0.01
0
50
100
150
200
250
300
Phosphorus (mg/g)
Species
LL-Flowers and fruits
LL-Leaves
LL-Miscellaneous
LL-Wood

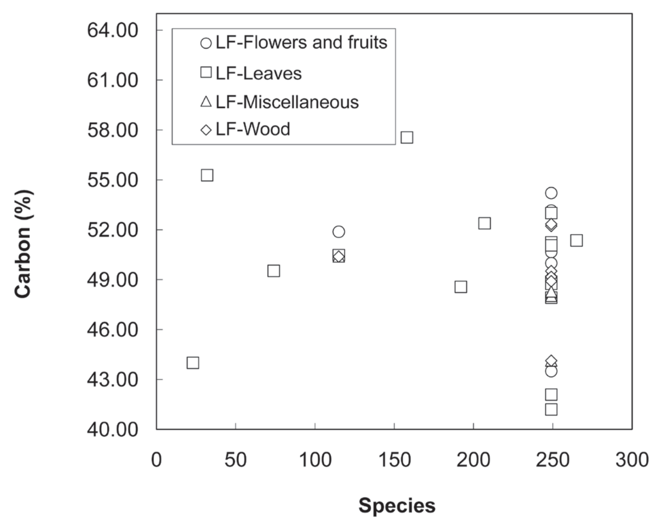
Appendix 5: Elemental Composition by Species in Litter Fall

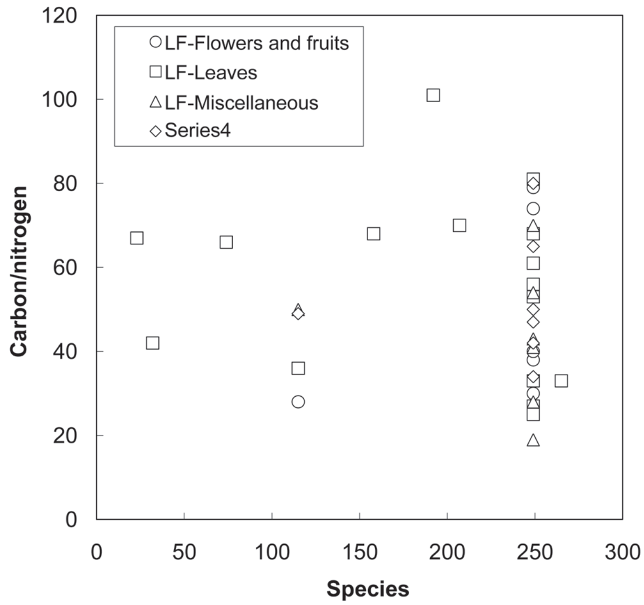
This appendix contains charts of element and ash concentrations, and carbon to nitrogen ratios (C/N) of ground or litter fall (LF) by species is sorted by different components. Species identification is by code number in appendix 2. The charts are intended to provide a visual idea of the range of element and ash concentration and C/N values and outlier species. Some charts have the Y-axis scale in log scale while others are linear. The charts are arranged in alphabetical order by the Y-axis label.

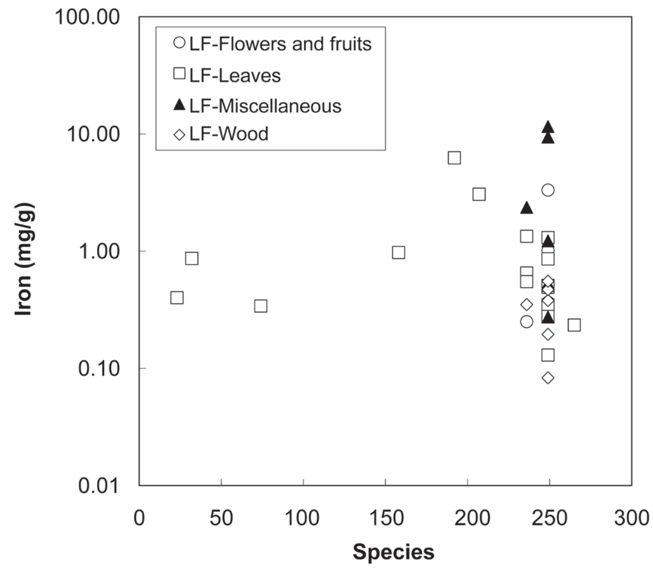


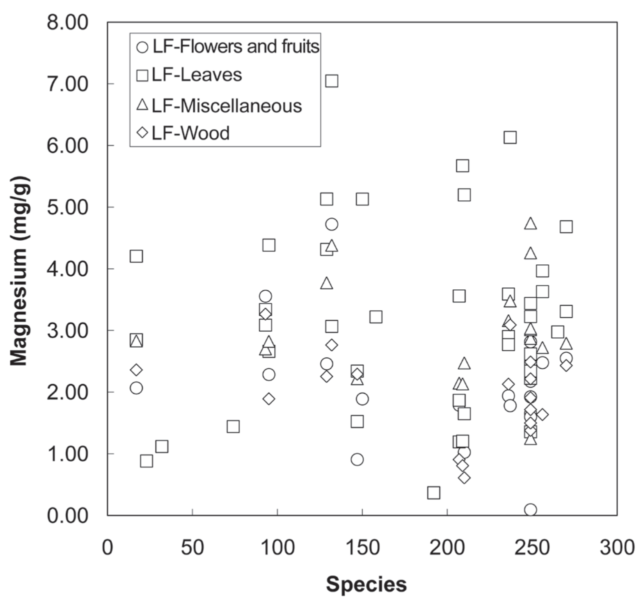


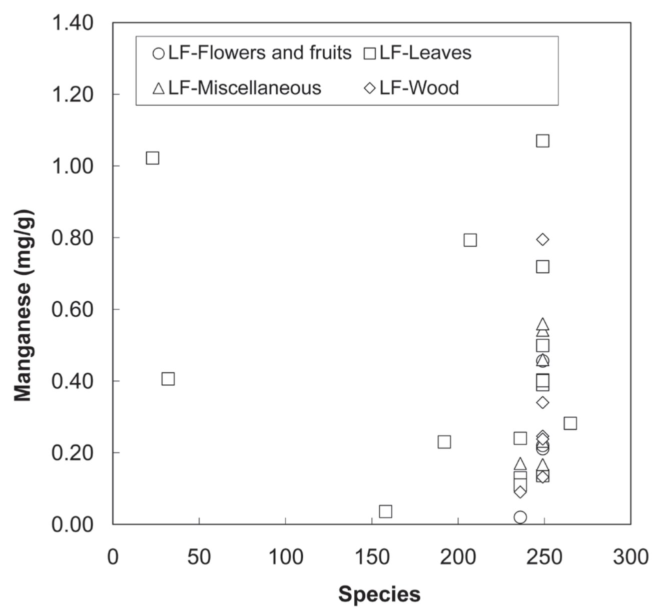


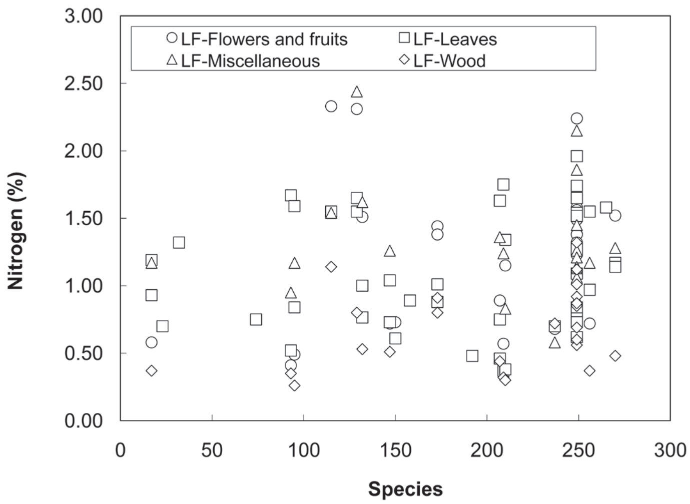


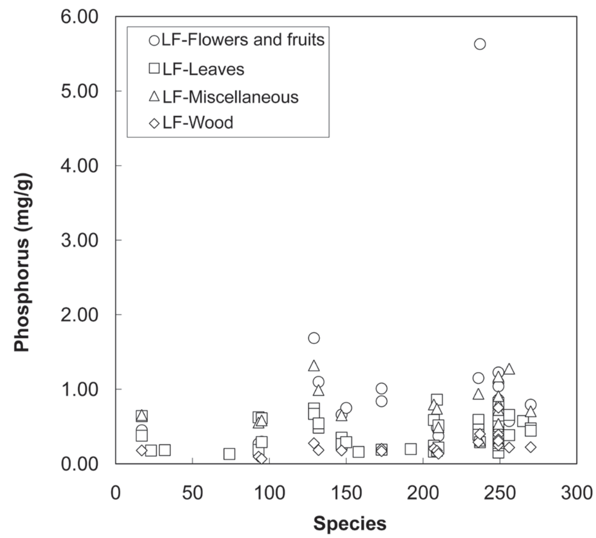

LF-Flowers and fruits
LF-Leaves
LF-Miscellaneous
Series4
Carbon/nitrogen
Species

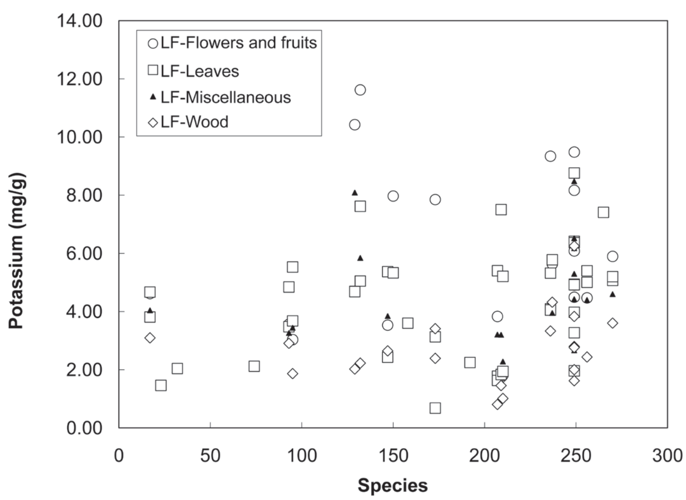

LF-Flowers and fruits
LF-Leaves
LF-Miscellaneous
LF-Wood
Iron (mg/g)
Species


LF-Flowers and fruits
LF-Leaves
LF-Miscellaneous
LF-Wood
Magnesium (mg/g)
Species


LF-Flowers and fruits
LF-Leaves
LF-Miscellaneous
LF-Wood
Manganese (mg/g)
Species

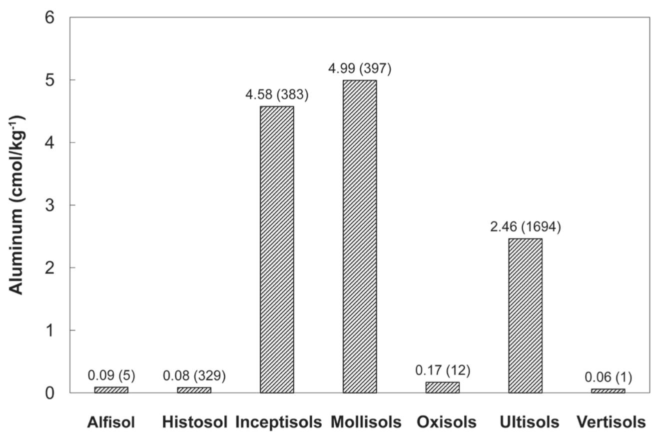

LF-Flowers and fruits
LF-Leaves
LF-Miscellaneous
LF-Wood
Nitrogen (%)
Species

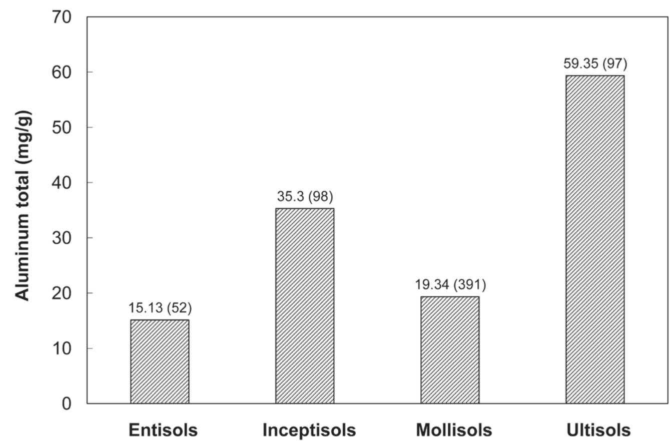

LF-Flowers and fruits
LF-Leaves
LF-Miscellaneous
LF-Wood
Phosphorus (mg/g)
Species

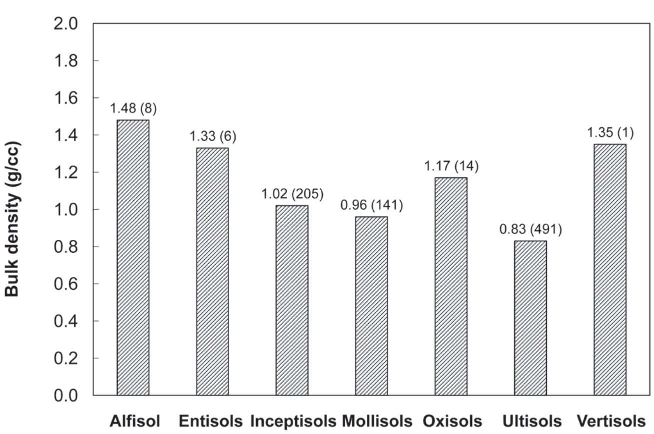

LF-Flowers and fruits
LF-Leaves
LF-Miscellaneous
LF-Wood
Potassium (mg/g)
Species

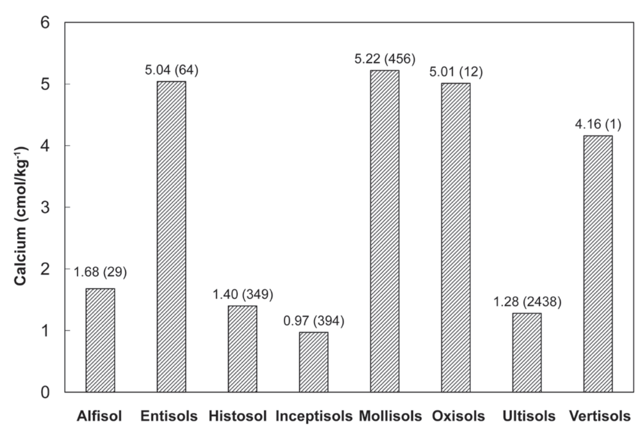
Appendix 6: Elemental Composition by Soil Order

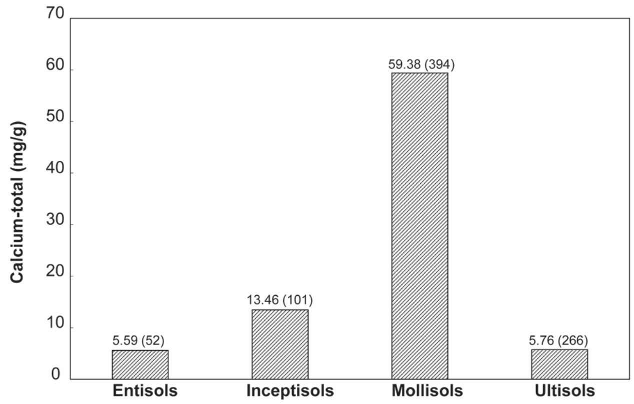
This appendix contains charts of mean values of element concentrations; cation exchange capacity; percentage clay, sand, and silt; loss on ignition; organic matter; and pH of soils by soil order. The number in parenthesis is the number of samples. The charts are intended to provide a visual idea of the range of element and other soil parameters by soil order. The charts are arranged in alphabetical order by the Y-axis label.

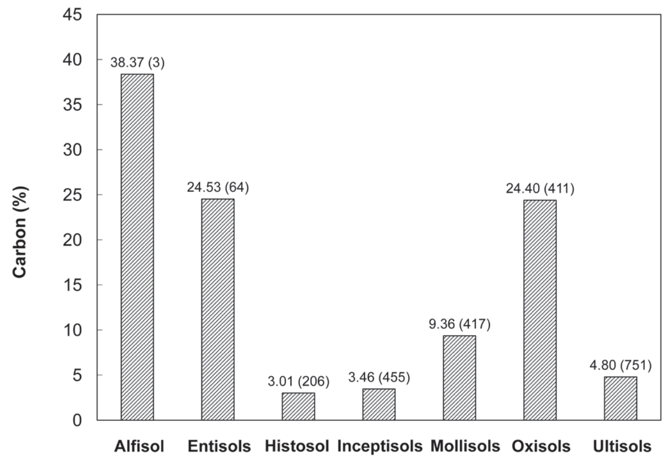


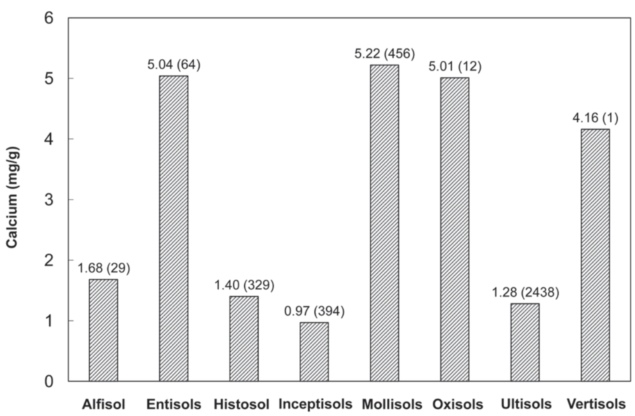


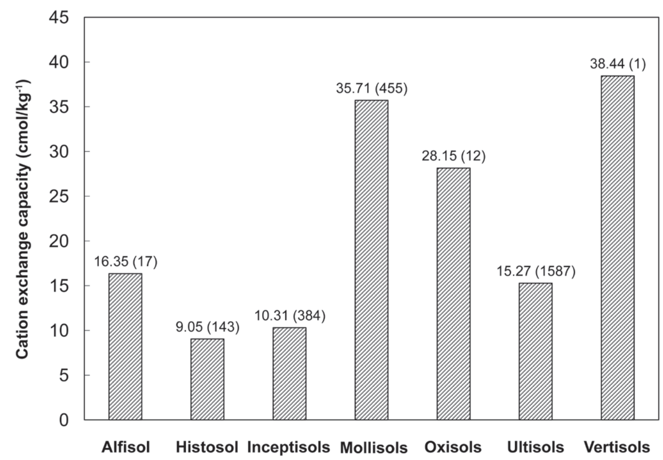


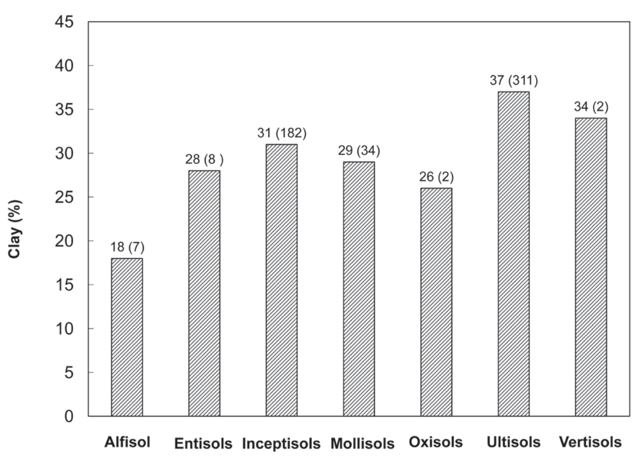


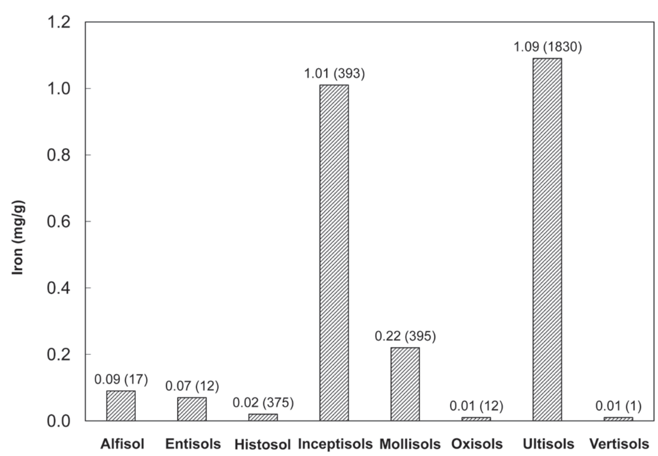

Calcium-total (mg/g)
0
10
20
30
40
50
60
70
5.59 (52)
13.46 (101)
59.38 (394)
5.76 (266)
Entisols
Inceptisols
Mollisols
Ultisols

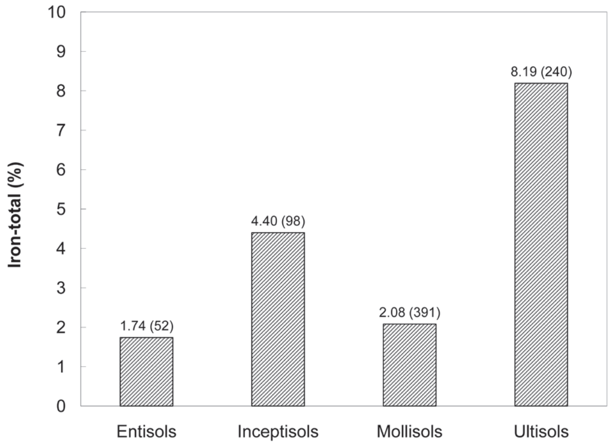

Carbon (%)
0
5
10
15
20
25
30
35
40
45
38.37 (3)
24.53 (64)
3.01 (206)
3.46 (455)
9.36 (417)
24.40 (411)
4.80 (751)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols

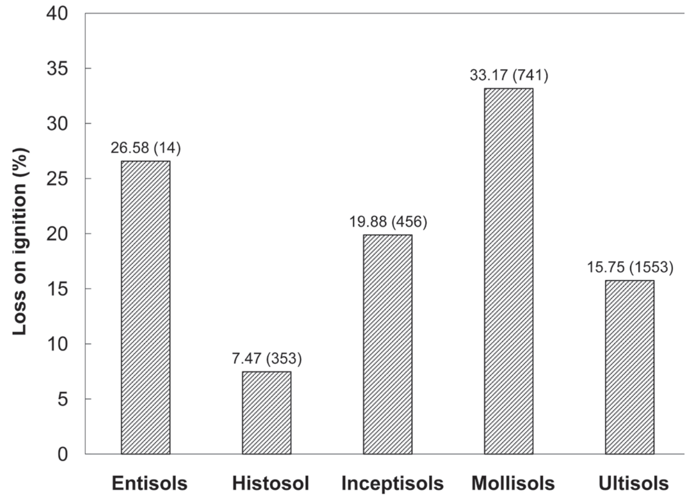

Calcium (mg/g)
0
1
2
3
4
5
6
1.68 (29)
5.04 (64)
1.40 (329)
0.97 (394)
5.22 (456)
5.01 (12)
1.28 (2438)
4.16 (1)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

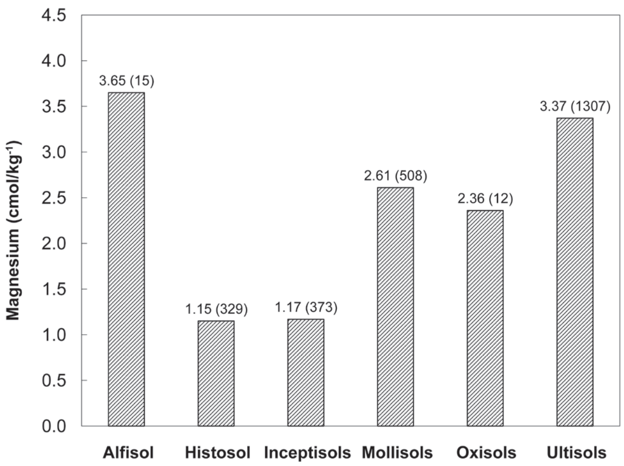

Cation exchange capacity (cmol/kg-1)
0
5
10
15
20
25
30
35
40
45
16.35 (17)
9.05 (143)
10.31 (384)
35.71 (455)
28.15 (12)
15.27 (1587)
38.44 (1)
Alfisol
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

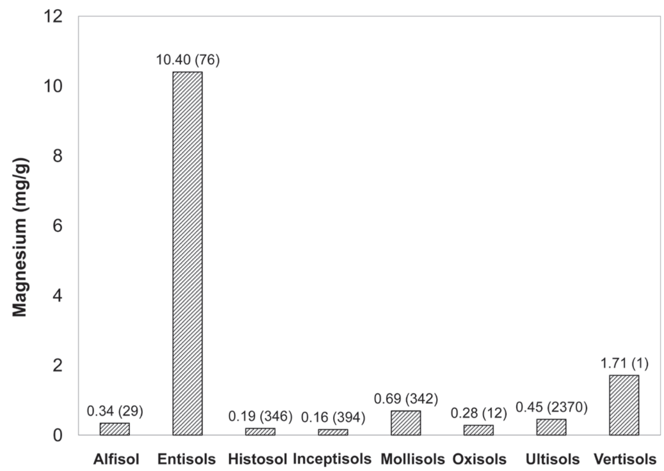

Clay (%)
0
5
10
15
20
25
30
35
40
45
18 (7)
28 (8)
31 (182)
29 (34)
26 (2)
37 (311)
34 (2)
Alfisol
Entisols
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

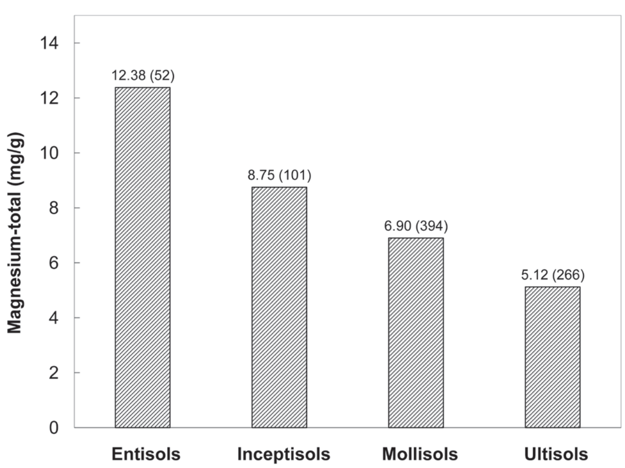

Iron (mg/g)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0.09 (17)
0.07 (12)
0.02 (375)
1.01 (393)
0.22 (395)
0.01 (12)
1.09 (1830)
0.01 (1)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

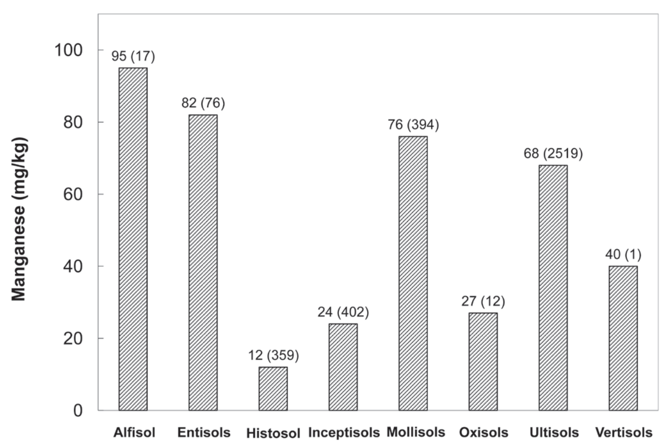

Iron-total (%)
0
1
2
3
4
5
6
7
8
9
10
1.74 (52)
4.40 (98)
2.08 (391)
8.19 (240)
Entisols
Inceptisols
Mollisols
Ultisols

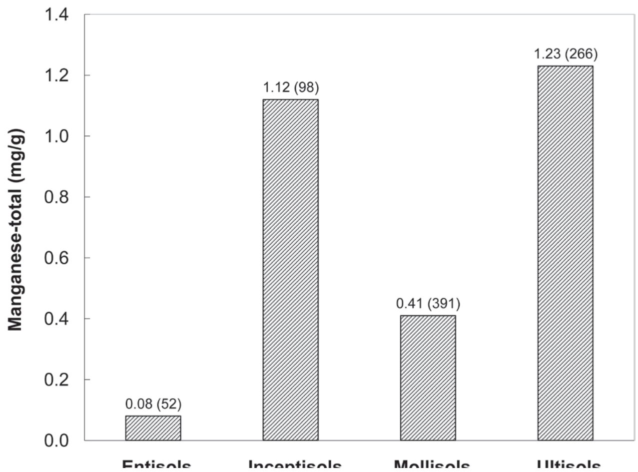

Loss on ignition (%)
0
5
10
15
20
25
30
35
40
26.58 (14)
7.47 (353)
19.88 (456)
33.17 (741)
15.75 (1553)
Entisols
Histosol
Inceptisols
Mollisols
Ultisols

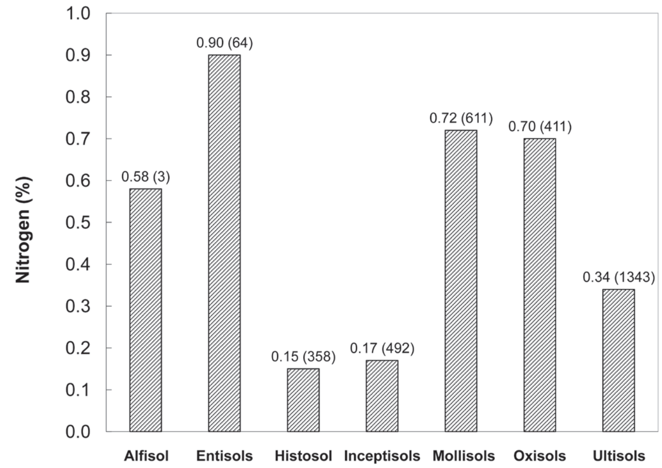

Magnesium (cmol/kg-1)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
3.65 (15)
1.15 (329)
1.17 (373)
2.61 (508)
2.36 (12)
3.37 (1307)
Alfisol
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols

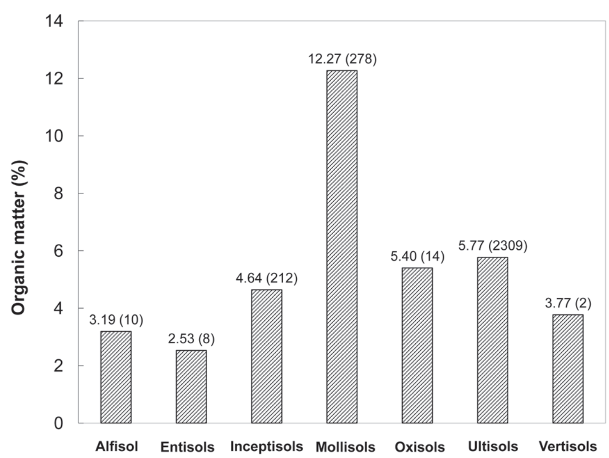

Magnesium (mg/g)
0
2
4
6
8
10
12
0.34 (29)
10.40 (76)
0.19 (346)
0.16 (394)
0.69 (342)
0.28 (12)
0.45 (2370)
1.71 (1)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

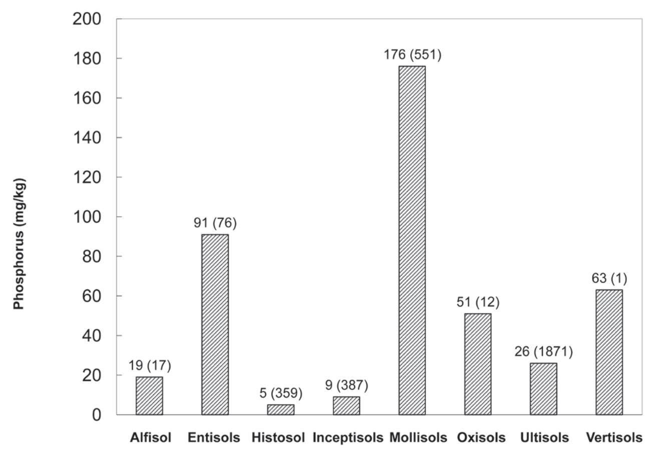

Magnesium-total (mg/g)
0
2
4
6
8
10
12
14
12.38 (52)
8.75 (101)
6.90 (394)
5.12 (266)
Entisols
Inceptisols
Mollisols
Ultisols

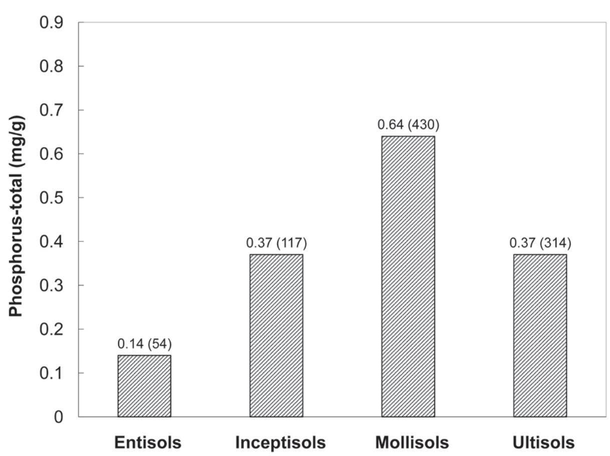

Manganese (mg/kg)
0
20
40
60
80
100
95 (17)
82 (76)
12 (359)
24 (402)
76 (394)
27 (12)
68 (2519)
40 (1)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

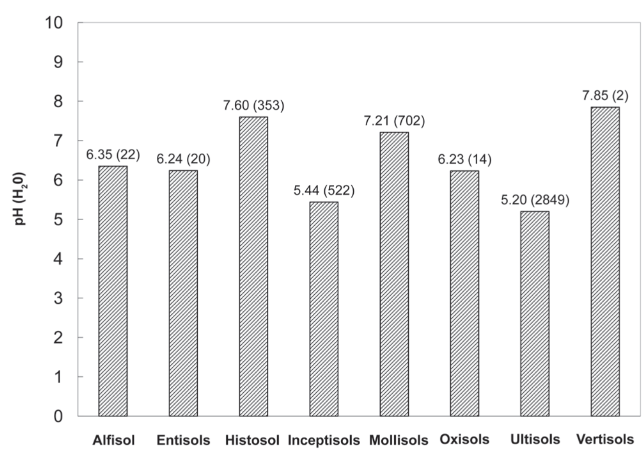

Manganese-total (mg/g)
0.08 (52)
1.12 (98)
0.41 (391)
1.23 (266)
Entisols
Inceptisols
Mollisols
Ultisols

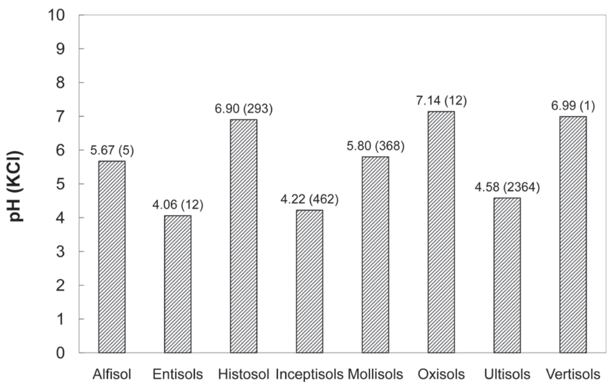

Nitrogen (%)
0.58 (3)
0.90 (64)
0.15 (358)
0.17 (492)
0.72 (611)
0.70 (411)
0.34 (1343)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols

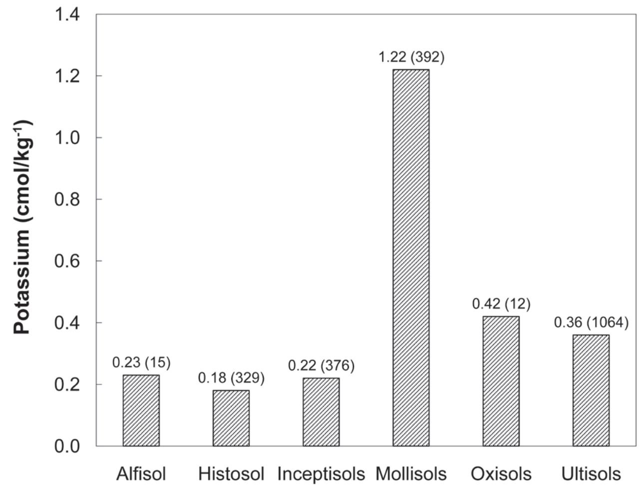

Organic matter (%)
3.19 (10)
2.53 (8)
4.64 (212)
12.27 (278)
5.40 (14)
5.77 (2309)
3.77 (2)
Alfisol
Entisols
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

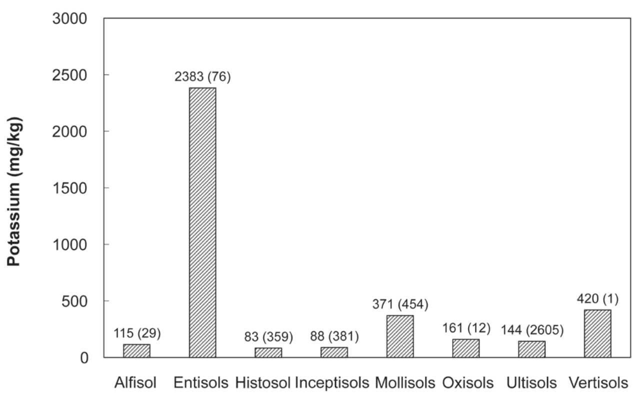

Phosphorus (mg/kg)
19 (17)
91 (76)
5 (359)
9 (387)
176 (551)
51 (12)
26 (1871)
63 (1)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

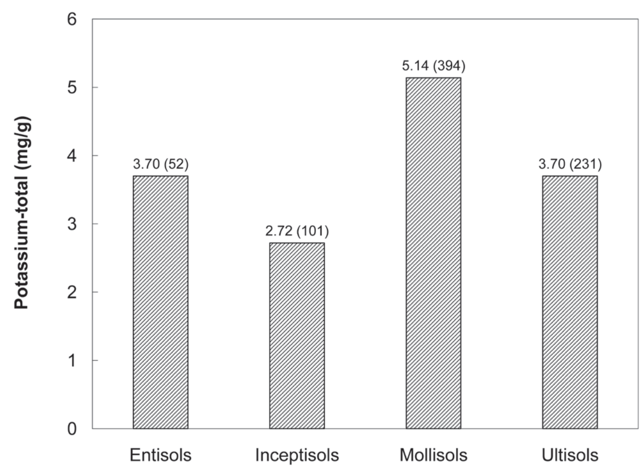

Phosphorus-total (mg/g)
0.14 (54)
0.37 (117)
0.64 (430)
0.37 (314)
Entisols
Inceptisols
Mollisols
Ultisols

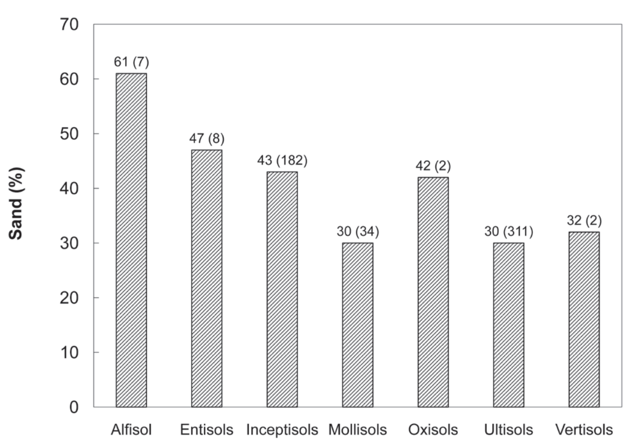

pH (H_20)
6.35 (22)
6.24 (20)
7.60 (353)
5.44 (522)
7.21 (702)
6.23 (14)
5.20 (2849)
7.85 (2)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

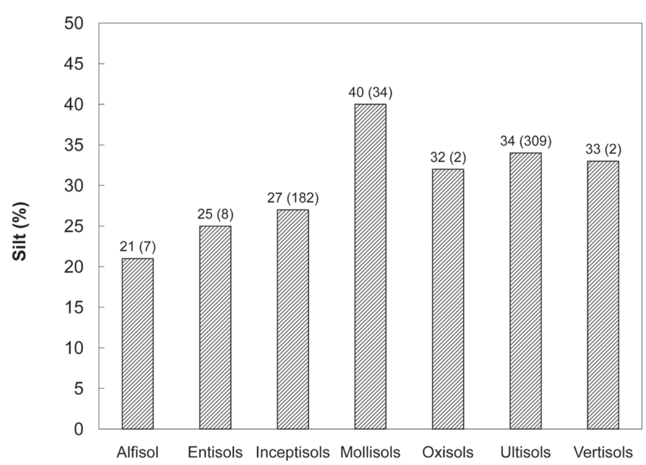

pH (KCl)
5.67 (5)
4.06 (12)
6.90 (293)
4.22 (462)
5.80 (368)
7.14 (12)
4.58 (2364)
6.99 (1)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

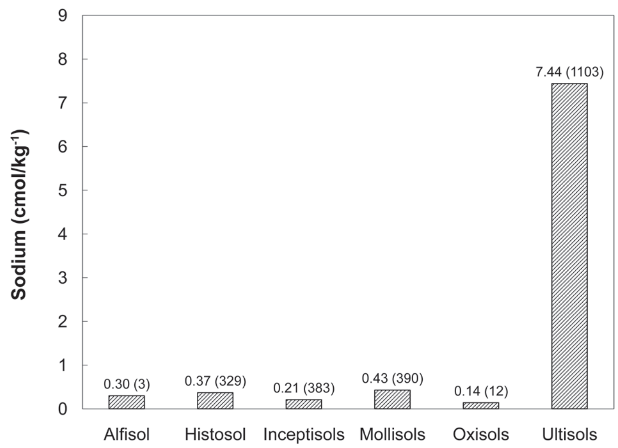

Potassium (cmol/kg-1)
0.23 (15)
0.18 (329)
0.22 (376)
1.22 (392)
0.42 (12)
0.36 (1064)
Alfisol
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols

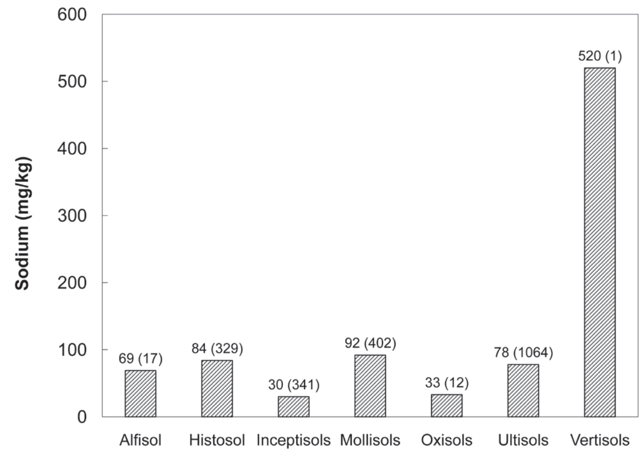

Potassium (mg/kg)
115 (29)
2383 (76)
83 (359)
88 (381)
371 (454)
161 (12)
144 (2605)
420 (1)
Alfisol
Entisols
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols

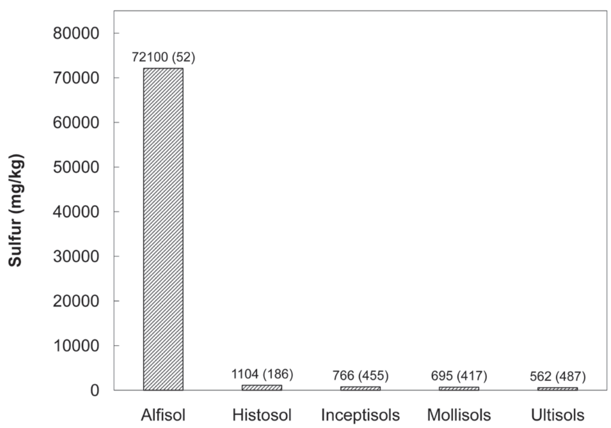

Potassium-total (mg/g)
3.70 (52)
2.72 (101)
5.14 (394)
3.70 (231)
Entisols
Inceptisols
Mollisols
Ultisols


Sand (%)
61 (7)
47 (8)
43 (182)
30 (34)
42 (2)
30 (311)
32 (2)
Alfisol
Entisols
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols


Silt (%)
21 (7)
25 (8)
27 (182)
40 (34)
32 (2)
34 (309)
33 (2)
Alfisol
Entisols
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols


Sodium (cmol/kg-1)
9
8
7
6
5
4
3
2
1
0
0.30 (3)
0.37 (329)
0.21 (383)
0.43 (390)
0.14 (12)
7.44 (1103)
Alfisol
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols


Sodium (mg/kg)
600
500
400
300
200
100
0
69 (17)
84 (329)
30 (341)
92 (402)
33 (12)
78 (1064)
520 (1)
Alfisol
Histosol
Inceptisols
Mollisols
Oxisols
Ultisols
Vertisols


Sulfur (mg/kg)
80000
70000
60000
50000
40000
30000
20000
10000
0
72100 (52)
1104 (186)
766 (455)
695 (417)
562 (487)
Alfisol
Histosol
Inceptisols
Mollisols
Ultisols

Appendix 7: Elemental Composition of Species From Contrasting Environments in Puerto Rico

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Introduction

The laboratory analyzed leaf samples obtained from a variety of sites in Puerto Rico including karstic areas in Guánica, Caguana, and Monito island; serpentine areas in Susúa and Maricao; several forested sites in the Luquillo mountains (Sabana, Bisley, El Verde); and mangrove and forested swamp sites in Punta Viento (Patillas), Jobos (Salinas), Humacao, and Sabana Seca. Frequently, species were repeatedly sampled within the same project on separate dates or in different projects. The samples were collected to satisfy descriptive requirements of specific projects and researchers, and were not designed to answer explicit questions or to test a priori hypotheses on nutrient relations. Therefore, the leaf data set does not represent a balanced set of families, species, or sites. In addition, there are no precise indications about leaf age, light exposure, or position in the canopy. I assumed that the sample set was constituted by adult leaves, not severely attacked by herbivores, and represented fully functional photosynthetic units. In spite of the obvious limitations, the data set is large enough to allow certain questions to be answered:

1. Are there common distribution patterns of ash and mineral elements in adult leaves obtained from contrasting ecosystems such as karst, serpentine, saline swamps, or wet volcanic sites?
2. Are families, and or species uniform in their patterns of accumulation of ash and mineral elements?
3. Are there significant correlations between element concentrations?
4. How do leaf nutrient ratios such as carbon/nitrogen, C/phosphorus, and N/P ratios compare with those reported from other tropical forests?
5. Are there patterns in the ratios of alkaline and earth alkaline metals?

Methods

The leaf samples were analyzed to determine the concentrations of ash, C, N, sulfur (S), potassium (K), magnesium (mg), calcium (Ca), aluminum (Al), and iron (Fe). However, not all the leaf samples have a complete set of analyses. For the purpose of this statistical analysis, all element concentrations are expressed on a molar basis (mmol/kg dry weight), so that element comparisons can be made on an atom instead of weight basis. Transformations of the molar units into weight units are simply accomplished multiplying the value by the atomic weight of the element considered. Analytical methods are described in a separate section of this book.

The distribution of each parameter was determined for the leaf samples grouped by families and species, and for each group the sequence of average values was established. I did not attempt to establish if this sequence was statistically significant because there were not enough replicates from each family, species, or sites to do it properly. However, in each case, I tried to identify emerging ecological or phylogenetic patterns that may lead to further indepth research. For each element, I listed the five species with highest (H) and lowest (L) values. I did not attempt to detect patterns by site of collection, as the description of sites was insufficient for that purpose. However, I did select a group of species characteristic of certain forest types, with a complete set of analyses for N, S, P, K, Ca, and Mg, to explore potential relationships with elemental composition.

Results

The data set contains 143 species distributed among 57 families (table 11). Most species are native to Puerto Rico. Introduced species include trees naturalized in Puerto Rico such as *Spathodea campanulata*, and *Albizia* spp, cultivated for agricultural purposes (*Coffea arabica*, *Citrus sinensis*, and *Syzygium jambos*), and planted for forestry use such as *Swietenia* species and *Khaya nyasica*. *Bambusa* species are planted along many roads of Puerto Rico for border protection. Other species were introduced as garden plants that later escaped and naturalized such as *Kalanchoe pinnata*. The data set used for the following analyses is provided in the addendum.

Patterns of Element Concentration

Ash concentration—

The percentage of ash per species averages 7.8 with a coefficient of variation of nearly 50 percent; the distribution is positively skewed and slightly leptokurtic (fig. 1). The highest percentage of ash values (20 percent) were recorded for *Bambusa vulgaris* and *Citrus sinensis*, and the lowest (<3 percent) was measured in two species of the Colorado forest in the Luquillo mountains (*Cyrilla racemiflora* and *Micropholis chrysophylloides*).

Potassium concentration—

The K concentration averages 296 µmol/kg and the variation coefficient is larger than that of percentage of ash, the highest values correspond to species of the families Araceae and Urticaceae (>1000 mmol/kg), and the lowest values included

Table 11—List of species analyzed in the present report, organized according to families

Family	Species	Family	Species
Apocynaceae	*Allamanda violacea*	**Euphorbiaceae**	*Alchornea latifolia*
	Plumeria alba		*Croton poecilanthus*
	Plumeria obtusa		*Ditta myricoides*
	Plumeria rubra (red)*		*Gymnanthes lucida*
	Plumeria rubra (white)*		*Sapium laurocerasus*
Aquifoliaceae	*Ilex sideroxyloides*	**Fabaceae**	*Albizia lebbeck**
Araceae	*Dieffenbachia seguine**		*Albizia procera**
Araliaceae	*Schefflera morototoni*		*Andira inermis*
Arecaceae	*Prestoea montana*		*Inga laurina*
Bignoniaceae	*Schlegelia brachyantha*		*Inga vera*
	*Spathodea campanulata**		*Leucaena leucocephala**
	Tabebuia haemantha		*Ormosia krugii*
	Tabebuia heterophylla		*Pictetia aculeata*
	Tabebuia rigida		*Pterocarpus officinalis*
	Tabebuia spp.	**Flacourtiaceae**	*Casearia arborea*
Boraginaceae	*Bourreria succulenta*		*Casearia decandra*
	Cordia borinquensis		*Casearia guianensis*
Burseraceae	*Bursera simaruba*		*Casearia sylvestris*
	Dacryodes excelsa		*Homalium racemosum*
	Tetragastris balsamifera		*Xylosma schwaneckeana*
Capparaceae	*Capparis cynophallophora*	**Heliconiaceae**	*Heliconia caribaea*
Cecropiaceae	*Cecropia schreberiana*	**Hernandiaceae**	*Hernandia sonora**
Celastraceae	*Cassine xylocarpa*	**Lauraceae**	*Ocotea leucoxylon*
Clusiaceae	*Calophyllum antillanum*		*Ocotea spathulata*
	Clusia rosea	**Magnoliaceae**	*Magnolia splendens*
Combretaceae	*Bucida buceras*	**Malpighiaceae**	*Byrsonima lucida*
	Laguncularia racemosa		*Byrsonima spicata*
Crassulaceae	*Kalanchoe pinnata**		*Byrsonima wadsworthii*
Cyrillaceae	*Cyrilla racemiflora*	**Malvaceae**	*Khaya nyasica**
Elaeocarpaceae	*Sloanea berteriana*		*Thespesia grandiflora*
Erythroxylaceae	*Erythroxylum areolatum*	**Melastomataceae**	*Henriettea squamulosum*
	Erythroxylum rotundifolium		*Miconia impetiolaris*
Melastomataceae	*Miconia prasina*	**Nyctaginaceae**	*Pisonia subcordata*
	Miconia racemosa	**Ochnaceae**	*Ouratea littoralis*
	Miconia sp.	**Orchidaceae**	*Prescotia oligantha*
	Miconia spp.	**Phytolaccaceae**	*Phytolacca icosandra*
	Miconia tetrandra	**Pinaceae**	*Pinus caribaea*
Meliaceae	*Guarea glabra*	**Piperaceae**	*Piper aduncum*
	Guarea guidonia		*Piper glabrescens*
	Guarea ramiflora		*Piper hispidum*

Table 11—List of species analyzed in the present report, organized according to families (continued)

Family	Species	Family	Species
	*Swietenia humilis**	**Poaceae**	*Bambusa* spp.*
	*Swietenia macrophylla**		*Bambusa vulgaris**
	*Swietenia macrophylla xmahagoni**	**Polygonaceae**	*Coccoloba diversifolia*
	*Swietenia mahagoni**		*Coccoloba microstachya*
	Swietenia sp.*	**Pteridaceae**	*Acrostichum aureum*
	Trichilia palida	**Rhamnaceae**	*Colubrina arborescens*
			Colubrina elliptica
Moraceae	*Ficus citrifolia*		*Krugiodendron ferreum*
Myrsinaceae	*Ardisia glauciflora*	**Rhizophoraceae**	*Rhizophora mangle*
	Ardisia solanacea	**Rubiaceae**	*Coffea arabica**
Myrtaceae	*Eugenia borinquensis*		*Exostema caribaeum*
	Eugenia eggersii		*Faramea occidentalis*
	Eugenia foetida		*Guettarda pungens*
	Eugenia maleolens		*Guettarda scabra*
	Eugenia monticola		*Neolaugeria resinosa*
	Eugenia rhombea		*Palicourea riparia*
	Eugenia stahlii		*Psychotria berteriana*
	Gomidesia lindeniana		*Psychotria maleolens*
	Myrcia deflexa		*Psychotria* sp.
	Myrcia splendens	**Rutaceae**	*Amyris elemifera*
	Pimenta racemosa		*Citrus sinensis**
	*Syzygium jambos**	**Sapindaceae**	*Sapindus saponaria*
Nyctaginaceae	*Guapira obtusata*		*Thouinia striata*
	Pisonia albida		
Sapotaceae	*Manilkara bidentata*	**Families: 57**	
	Micropholis chrysophylloides	**Species: 143**	
Staphyleaceae	*Turpinia occidentalis*		
Theaceae	*Ternstroemia stahlii*		
Theophrastaceae	*Jacquinia berteroi*		
Thymelaeaceae	*Daphnopsis philippiana*		
	Erithalis fruticosa		
Ulmaceae	*Trema micranthum*		
Urticaceae	*Urera baccifera*		
Verbenaceae	*Avicennia germinans*		
	Petitia domingensis		
Viscaceae	*Phoradendron racemosum*		
Zygophyllaceae	*Guaiacum officinale*		
	Guaiacum sanctum		

* Indicates introduced species.

C. sinensis, although this species has one of the highest percentage of ash values (fig. 1).

Calcium concentration—

Average calcium concentration is similar to that of K, but the levels of asymmetry, kurtosis, and coefficient of variation are considerably higher (fig. 1). *Urera baccifera* (Urticaceae) and *Phoradendron racemosusm* (Viscaceae) are within a group of species with the highest Ca concentration (>900 mmol/kg). *Ardisia glauciflora* (Myrsinaceae) lies within the high Ca concentration group (>700 mmol/kg) contrasting with its position regarding K. In the data set, *Kalanchoe pinnata* (Crassulaceae) appears as an outlier regarding Ca concentration. This family is known for its calciotrophic character, and most of their Ca is in soluble form (Kinzel 1983).

Magnesium concentration—

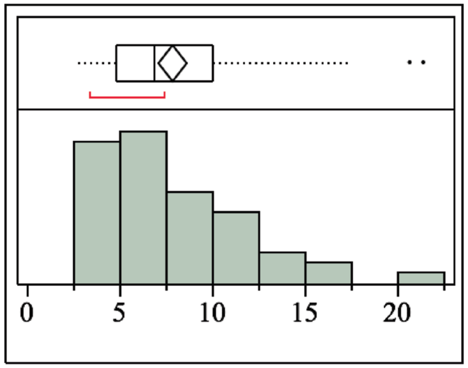
The species of Viscaceae and Urticaceae appear again within the group with the highest element concentration as in the case of K and Ca, although they do not belong to the group with highest ash concentration. *Miconia prasina* (Melastomataceae), *Micropholis chrysophylloides* (Sapotaceae), and *Cyrilla racemiflora* (Cyrillaceae) show very low Mg concentrations (<40 mmol/kg). The distribution of Mg concentrations has similar levels of skewness, kurtosis, and coefficient of variation as those of Ca. Among the species analyzed, it is noteworthy that one Flacourtiaceae, *Casearia sylvestris,* appears in the high group, whereas another, *Xylosma schwaneckeana*, has extremely low concentrations of this element.

Aluminum and Iron concentration—

Distributions of these elements are highly right-skewed, and strongly leptokurtic, indicating that a few species present rather high concentrations compared to the rest (fig. 2). Average Al concentration is 61 mmol/kg, and the variation coefficient amounts to more than 300 percent with high values well above 500 mmol/kg. The *Miconia* species (Melastomataceae) stand out as Al accumulators, as reported for several tropical plant communities (Jansen et al. 2002) (fig. 2).

In the high Al concentration group the Flacourtiaceae, Rubiaceae, and Phytolaccaceae are also included; families known for containing many metal accumulating species. Rubiaceae species are found both in the high (*P. maleolens*) and low (*Guettarda scabra*) concentration groups.

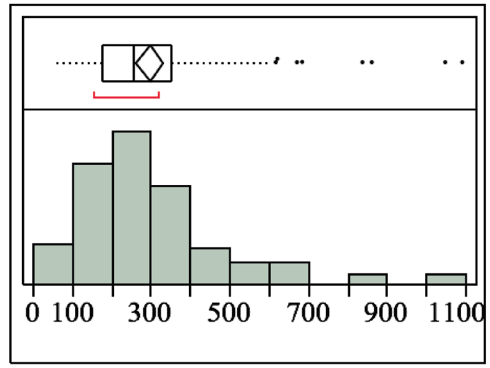
The *Miconia* species are again within the Fe concentrating species >30 mmol/kg), together with *Ocotea spathulata* (Lauraceae), and *Phytolacca icosandra* (Phytolaccaceae). Species of the latter genus have been reported as accumulators of heavy metals, mainly manganese (Baker and Brooks 1989, Yuan et al. 2007).



Species	%Ash
Bambusa vulgaris	**21.4**
Citrus sinensis	**20.7**
***Miconia* sp.**	**17.4**
Laguncularia racemosa	**16.9**
Miconia impetiolaris	**16.0**
Daphnopsis philippiana	3.1
Pinus caribaea	2.9
Eugenia borinquensis	2.9
Cyrilla racemiflora	2.8
Micropholis chrysophylloides	2.7

Mean	7.81
Std Dev	3.87
Median	6.87
Skewness	1.2
Kurtosis	1.6
CV	49.6
N	102

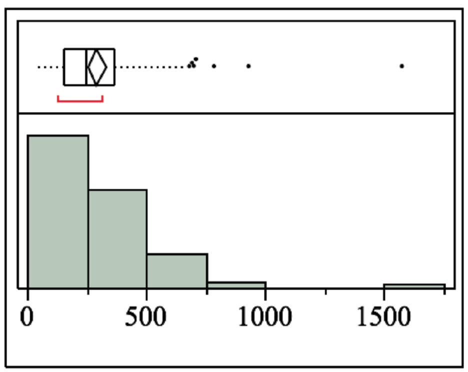
Ash %



Species	K mmol/kg
Dieffenbachia seguine	**1093**
Urera baccifera	**1050**
Phoradendron racemosum	**863**
***Plumeria rubra* (white)**	**839**
Piper hispidium	**686**
Inga vera	73
Homalium racemosum	70
Sapindus saponaria	66
Citrus sinensis	58
Pinus caribaea	51

Mean	296
Std Dev	185
Median	256
Skewness	1.8
Kurtosis	4.4
CV	62.7
N	127

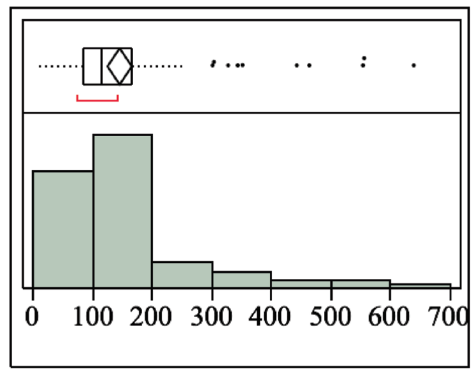
K mmol/kg



Species	Ca mmol/kg
Kalanchoe pinnata	**1575**
Urera baccifera	**931**
Ardisia glauciflora	**786**
Coccoloba diversifolia	**710**
Amyris elemifera	**701**
Acrostichum aureum	67
Tabebuia rigida	64
Ormosia krugii	52
Cyrilla racemiflora	41
Heliconia caribaea	37

Mean	291
Std Dev	215
Median	245
Skewness	2.4
Kurtosis	10.5
CV	73.8
N	116

Ca mmol/kg

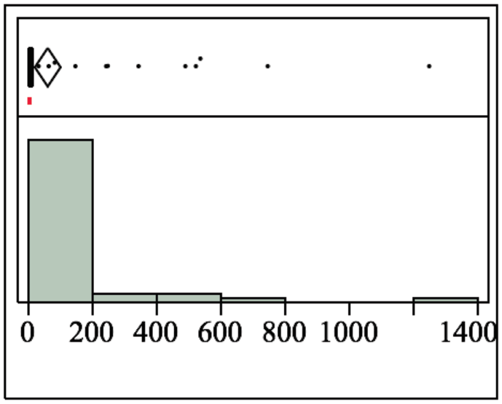


Species	Mg mmol/kg
***Tabebuia* spp.**	**640**
Neolaugeria resinosa	**557**
Casearia sylvestris	**555**
Phoradendron racemosum	**465**
Urera baccifera	**444**
Miconia prasina	33
Micropholis chrysophylloides	32
Sapindus saponaria	32
Cyrilla racemiflora	28
Xylosma schwaneckeana	9

Mean	146
Std Dev	110
Median	117
Skewness	2.4
Kurtosis	6.6
CV	75.7
N	106

Mg mmol/kg

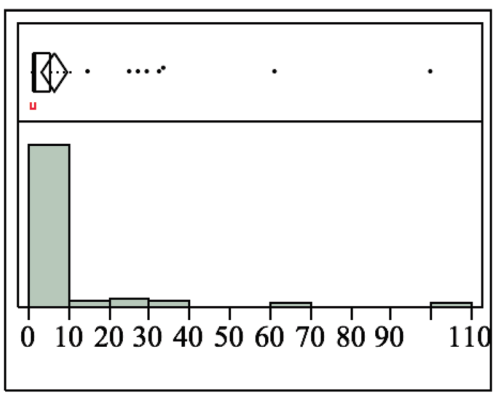
Figure 1—Distribution of concentrations of percentage of ash and major alkaline and earth alkaline metals. The species list includes the five highest and lowest values recorded in the data set. Statistical calculations obtained using JMP 8.



Species	Al mmol/kg
Miconia sp	**1252.0**
Miconia impetiolaris	**748.8**
Miconia prasina	**539.0**
Psychotria maleolens	**525.0**
Miconia racemosa	**492.2**
Guapira obtusata	0.7
Guettarda scabra	0.7
Schlegelia brachyantha	0.7
Tabebuia haemantha	0.5
Tabebuia heterophylla	0.2

Al mmol/kg

Mean	61
Std Dev	187
Median	4
Skewness	4.4
Kurtosis	22.0
CV	305.5
N	84



Species	Fe mmol/kg
Miconia impetiolaris	**100.00**
***Miconia* sp.**	**61.30**
Ocotea spathulata	**33.70**
Miconia racemosa	**32.63**
Phytolacca icosandra	**29.60**
Jacquinia berteroi	0.60
Rhizophora mangle	0.60
Acrostichum aureum	0.40
Prescotia oligantha	0.10
Tabebuia heterophylla	0.00

Fe mmol/kg

Mean	6.4
Std Dev	14.2
Median	1.7
Skewness	4.7
Kurtosis	26.0
CV	223.5
N	81

Figure 2—Distributions of concentrations of aluminum (Al) and iron (Fe). The species list includes the five highest and lowest values recorded in the data set. Statistical calculations obtained using JMP 8.

Nonmetallic elements—

Phosphorus distribution was strongly asymmetric, because a few species have concentrations above the 100 mmol/kg level, resulting therefore in a large coefficient of variation (fig. 3). Among these species, *Ficus citrifolia* (Moraceae) and *Kalanchoe pinnata* (Crassulaceae) have surprisingly high values. The species *A. glauciflora* (Myrsinaceae), *Eugenia rhombea* (Myrtaceae), *Clusia rosea* (Clusiaceae), and *Jacquinia berteroi* (Theophrastaceae) are within the low P concentration group.

Distribution of C concentrations was nearly normal, with a small coefficient of variation, values ranged with narrow limits between 48 to 35 mol/kg (fig. 3). Nitrogen and S were much more variable, with CVs around 45 percent, and levels of skewness and kurtosis departing slightly from normality. The high N concentration group (>2500 mmol/kg) contains one species of Fabaceae (*Leucacena leucocephala*) and species with rather fleshy or thin leaves such as *Phoradendron racemosum* (Viscaceae), *P. icosandra* (Phytolaccaceae), and *Trema micranthum* (Ulmaceae). Again *C. racemiflora* and *C. rosea* appear within the low concentration group.

Average concentration of N (1254 mmol/kg) and S (90 mmol/kg) are above the average concentrations required for normal, healthy growth in cultivated plants, whereas average for P (27 mmol/kg) is about half of that value (see table 4, Epstein 1965).

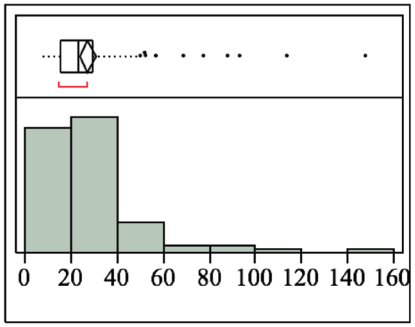
Inter-Element Correlations

Pair-wise correlations (Pearson product-moment correlations between each pair of variables) were highly significant ($p < 0.0001$) and positive between percentage of ash and Ca, Al, and Fe, and negative between percentage of ash and C (table 12). Other elements highly correlated are Fe and Al; P with K, Ca, and N. Nitrogen was significantly correlated with K, P and less so with S.

I applied also a test for nonparametric correlations (Spearman r) to the data set and obtained somewhat different results. As before, percentage of ash was highly correlated with Ca and C. Other significant correlations were obtained between Fe and Al, N with P and K. However, nonparametric coefficients for Ca and P, Ca and K, percentage of ash and Fe were not significant in contrast to the Pearson coefficients (table 12).

Element Ratios, Comparisons With Cultivated Plants and Other Tropical Forests

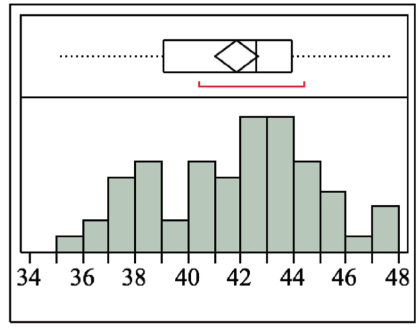
Element ratios calculated from the composition of organisms are useful for estimating functional relationships that relate biological activity with environmental variables (Elser 2006, Elser et al. 2010, Redfield 1958). The study of element



Species	P
Ficus citrifolia	**148**
Kalanchoe pinnata	**114**
Urera baccifera	**94**
***Plumeria rubra* (w)**	**88**
Phytolacca icosandra	**78**
Ardisia glauciflora	9
Eugenia rhombea	8
Clusia rosea	8
Miconia spp.	6
Jacquinia berteroi	6

Mean	27
Std Dev	20
Median	23
Skewness	3.13
Kurtosis	13.21
CV	74.19
N	124

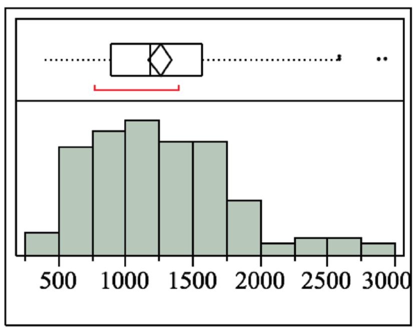
P mmol/kg



Species	C%	C
Magnolia splendens	**57.2**	**47.7**
Byrsonima spicata	**56.8**	**47.3**
Erithalis fruticosa	**56.8**	**47.3**
Exostema caribaeum	**56.1**	**46.8**
Sapindus saponaria	**55.0**	**45.8**
Bucida buceras	45.0	37.5
Guarea ramiflora	44.4	37.0
Laguncularia racemosa	43.5	36.2
Acrostichum aureum	43.4	36.2
Psychotria maleolens	42.0	35.0

Mean	41.9
Std Dev	3.1
Median	42.6
Skewness	-0.22
Kurtosis	-0.63
CV	7.34
N	59

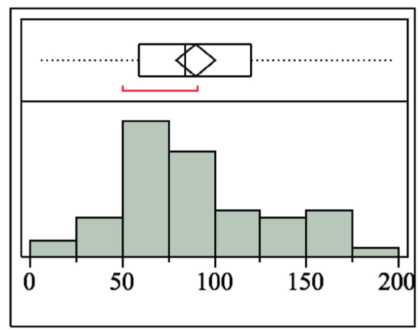
C mol/kg



Species	N
Leucaena leucocephala	**2936**
Phoradendron racemosum	**2886**
Phytolacca icosandra	**2593**
Trema micranthum	**2593**
Sapindus saponaria	**2586**
Heliconia caribaea	529
Cyrilla racemiflora	493
Clusia rosea	468
Miconia spp.	457
Ardisia glauciflora	379

Mean	1254
Std Dev	529
Median	1182
Skewness	0.88
Kurtosis	0.79
CV	42.18
N	134

N mmol/kg



Species	S
Prestoea montana	**197**
Sapindus saponaria	**159**
Guarea guidonia	**158**
Miconia racemosa	**157**
Piper aduncum	**156**
Miconia spp.	36
Psychotria maleolens	34
Tabebuia rigida	34
Laguncularia racemosa	9
Pterocarpus officinalis	7

Mean	90
Std Dev	41
Median	84
Skewness	0.42
Kurtosis	-0.19
CV	45.28
N	57

S mmol/kg

Figure 3—Distribution of concentrations of nonmetallic elements. The species list includes the five highest and lowest values recorded in the data set. Statistical calculations obtained using JMP 8.

Table 12—Significant (p < 0.01) pair-wise (Pearson product-moment) and nonparametric (Spearman r) correlations among elements measured in leaf samples

V1	V2	Correlation	Signif prob	Spearman ρ	Prob > |ρ|	Count
Al	Ash	0.465	<.0001	0.166	0.167	71
C	Ash	-0.558	<.0001	-0.551	<.0001	58
Ca	P	0.337	**0.0003**	-0.044	**0.645**	113
Ca	Ash	0.666	<.0001	0.706	<.0001	85
Ca	K	0.296	**0.001**	0.211	**0.023**	116
Fe	Al	0.732	<.0001	0.864	<.0001	80
Fe	Ash	0.460	**<.0001**	0.107	**0.377**	71
K	P	0.447	<.0001	0.419	<.0001	124
Mg	K	0.373	<.0001	0.328	0.001	106
Mg	Ash	0.268	**0.019**	0.327	**0.004**	76
N	S	0.394	0.002	0.367	0.005	57
N	P	0.552	<.0001	0.671	<.0001	119
N	K	0.412	<.0001	0.447	<.0001	122
N	Ash	0.253	**0.011**	0.344	**<0.001**	101
N	Mg	0.240	**0.015**	0.264	**0.007**	102

Note: Ash in percentage, C in mol/kg, other elements in mmol/kg. In bold correlation coefficients that do not agree with each other at the given p level.

proportions has been the subject of biological stoichiometry, and their variation associated with the environment is treated as ecological stoichiometry (Sterner and Elser 2002).

For tropical forest the C/N and N/P ratios have been frequently discussed within the framework of P limitation (McGroddy et al. 2004). In addition, the ratios of alkaline and earth alkaline metals have also implications for both functional properties of organisms, and ecological relationships between plants and soils (Horak and Kinzel 1971; Kinzel 1989).

Compared to the averages reported for tropical forests (McGroddy et al. 2004) the C/N, C/P and N/P ratios are within the range of variation expected (Table 13). However, the N/P ratio in the present data set is about 20 percent higher than the average for other tropical forests, with a coefficient of variation above 40 percent implying that a large number of samples are limited by P based on N/P ratio, probably affecting plant production capacity.

Depicting the sequence of N/P ratios of the species in the data set shows that at least 75 of the 120 species in the data set have N/P ratios above the assumed P sufficiency range in wild plants (Mc Groddy et al. 2004) (Figure 4).

Table 13—Elemental ratios on a molar basis for the species leaf data set

	$C/N \times 10^{-3}$	C/P	C/S	N/P	N/S	S/P	K/Ca	Mg/Ca
Mean	38.6	2279	700	53.3	20.5	4.7	1.53	0.74
Std dev	18.1	1320	941	22.2	32.6	2.4	1.78	0.70
Std err mean	2.4	190	125	2.0	4.3	0.4	0.17	0.07
Median	35.1	1974	501	49.6	13.8	4.2	1.05	0.53
Skewness	1.5	2.3	5.4	1.6	6.2	1.0	5.12	2.32
Kurtosis	1.9	5.9	31.2	5.7	41.3	1.9	36.33	5.84
CV	46.9	57.9	134.4	41.6	159.1	52.2	115.9	94.7
n	59	48	57	119	57	47	116	106
Mean	35.5	2457		43.4				

McGroddy et al. 2004.

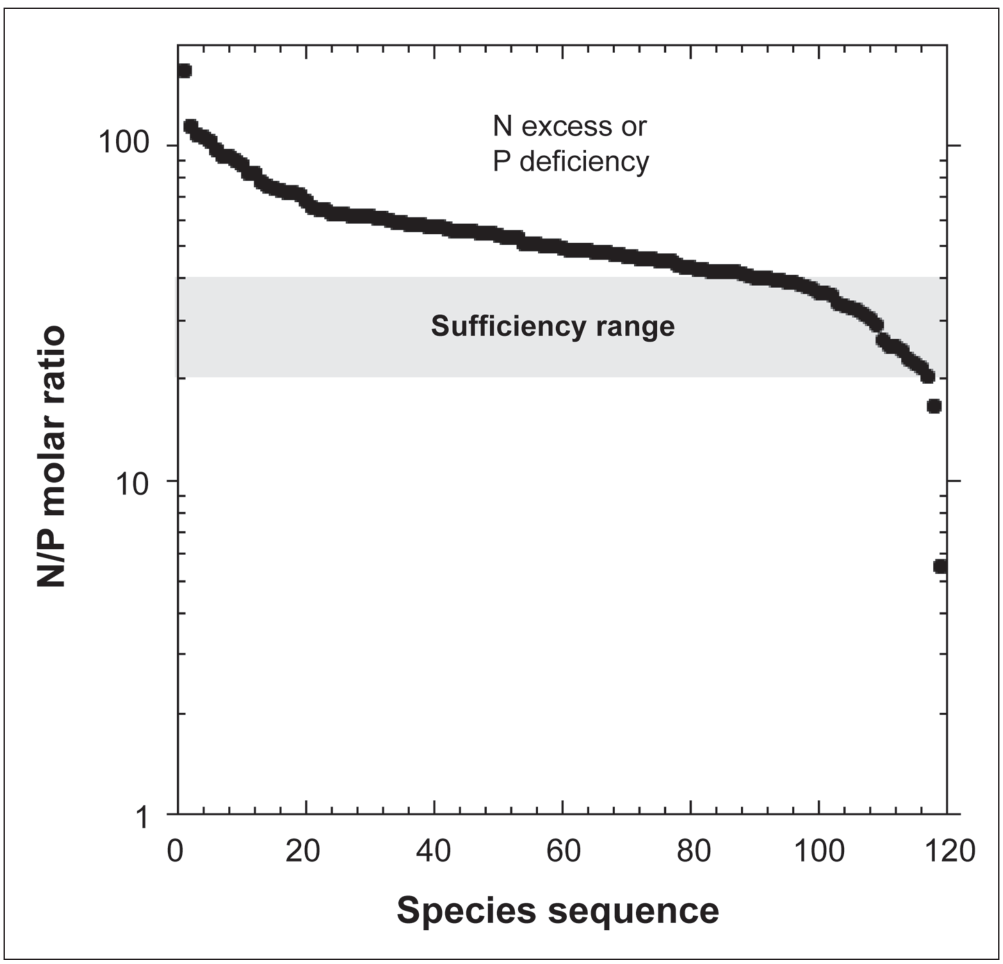


Figure 4—Species in the data set ordered according to their nitrogen/phosphorus (N/P) molar ratio.

I do not have data of C/S and N/S ratios for tropical ecosystems. Based on data from the agronomic literature, I estimate that the average C/S ratio indicates limitations of this element that may reduce its availability during decomposition of leaf litter. The N/S ratios, however, are within the range of sufficiency estimated for normal growth in cultivated plants (Epstein 1965) (table 14). The S/P ratio is about 10 times higher than the agronomic average, indicating high availability of S compared to that of P.

The K/Ca ratio average is very near to the average expected for higher plants (≈ 2). However, the variation coefficient is quite large, indicating strong departure from the rule of K/Ca >1. Ratios below 1 may indicate the presence of calciotrophic plants (*sensu* Horak and Kinzel 1989), or that the samples were obtained from forests on soils with high Ca availability (e.g., calcareous substrates). The potential calciotrophs or Ca accumulators are depicted in figure 5.

Mg/Ca ratios are usually around 0.6, and higher values are to be expected in areas with elevated Mg availability, such as serpentine derived soils. The data set has an average Mg/Ca of 0.7, well within the normal values. However, a number of species have markedly higher values indicating the presence of potential Mg accumulators (fig. 6).

Species Signatures and Variability Among Species and Ecological Groups.

The amount and proportion of mineral elements that constitute a living organism, or a given organ, is related to their physiology and biochemistry and is influenced by the availability of those elements in the environment. More recently the concept of ionome has been introduced and defined “as the mineral nutrient and trace

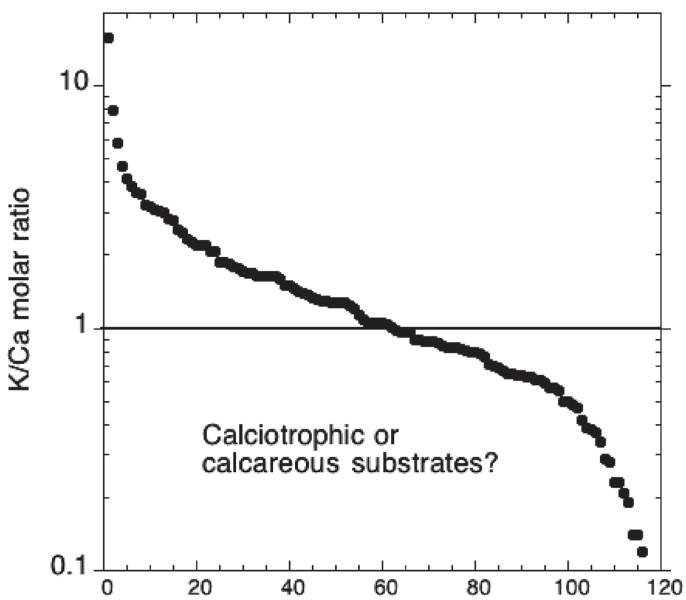
Table 14—Average mineral concentrations of mineral nutrients in plant shoot dry matter that are sufficient for adequate growth (Epstein 1965)

Element	Concentrations	
	mmol/kg	*mg/kg*
Nitrogen	1000	14000
Potassium	250	9970
Calcium	125	5010
Magnesium	80	1944
Phosphorus	60	1858
Sulfur	30	962

Molar ratios

N/K = 4, N/Ca = 8, N/Mg = 12.5, N/P = 17, N/S = 33,

S/P = 0.5, K/Ca = 2, Mg/Ca = 0.6.

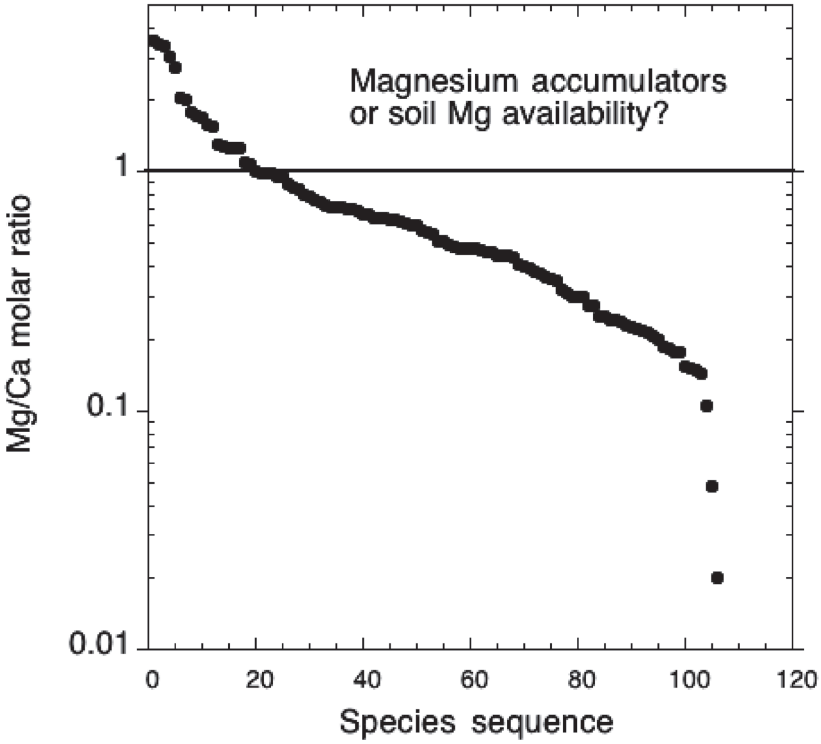


Guarea guidonia	0.98
Myrcia deflexa	0.97
Manilkara bidentata	0.97
Swietenia sp.	0.96
Swietenia mahagoni	0.90
Syzygium jambos	0.90
Tabebuia spp.	0.89
Erithalis fruticosa	0.88
Guaiacum sanctum	0.88
Swietenia macrophylla xmahagoni	0.87
Byrsonima wadsworthii	0.85
Eugenia foetida	0.83
Eugenia maleolens	0.83
Bourreria succulenta	0.83
Cassine xylocarpa	0.82
Miconia prasina	0.81
Byrsonima lucida	0.80
Krugiodendron ferreum	0.80

Erythroxylum areolatum	0.79
Miconia spp.	0.76
Guettarda pungens	0.71
Erythroxylum rotundifolium	0.70
Clusia rosea	0.69
Swietenia macrophylla	0.67
Plumeria obtusa	0.65
Coccoloba microstachya	0.65
Pterocarpus officinalis	0.64
Swietenia humilis	0.64
Xylosma schwaneckeana	0.63
Ficus citrifolia	0.63
Henriettea squamulosum	0.61
Laguncularia racemosa	0.61
Pictetia aculeata	0.59
Gymnanthes lucida	0.57
Bucida buceras	0.57
Rhizophora mangle	0.55
Plumeria alba	0.50
Amyris elemifera	0.50

Ouratea littoralis	0.48
Jacquinia berteroi	0.47
Psychotria maleolens	0.42
Coccoloba diversifolia	0.39
Allamanda violacea	0.38
Sapindus saponaria	0.37
Kalanchoe pinnata	0.34
Hernandia sonora	0.29
Inga vera	0.28
Casearia decandra	0.23
Homalium racemosum	0.23
Miconia impetiolaris	0.21
Miconia racemosa	0.19
Citrus sinensis	0.14
Ardisia glauciflora	0.14
Miconia sp.	0.12

Figure 5—Species in the data set ordered according to their potassium/calcium (K/Ca) molar ratio. The species with ratios <1 are listed.



Pisonia subcordata	3.5
Casearia sylvestris	3.4
Avicennia germinans	3.4
Guapira obtusata	3.0
Neolaugeria resinosa	2.7
Heliconia caribaea	2.1
Phytolacca icosandra	2.0
Cordia borinquensis	1.8
Tabebuia rigida	1.7
Gomidesia lindeniana	1.7
Andira inermis	1.6
Guettarda scabra	1.6
Ditta myricoides	1.3
Casearia arborea	1.3
Prestoea montana	1.3
Tabebuia spp.	1.3
Acrostichum aureum	1.3

Figure 6—Species in the data set ordered according to their magnesium/calcium (Mg/Ca) molar ratio. The species with ratios >1 are listed.

element composition of an organism and represents the inorganic component of cellular and organismal systems" (Salt et al. 2008). Using elemental composition it may be possible to characterize species, identify metabolic syndromes (e.g., cation accumulators), and gain insight into the influence of substrate mineral availability on the regulation of metabolic pathways of species that grow on them.

In higher plants, the proportion of major elements, (excluding C that constitutes about 50 percent of organic matter by weight) have been well studied in cultivated species. The sequence of major element concentrations may be used as a guideline to assess the interspecific and ecological variability of the data set developed by the International Institute of Tropical Forestry Laboratory (see "Addendum").

As an example of the potential application of element profiles to characterize species and ecological sites, I selected a number of species that are major components of some forest types in Puerto Rico and put together in a stack column graph the values for the major elements in leaf tissues (fig. 7). Secondary species appear to be particularly rich in N, whereas species from wet forests have a tendency to lower levels of all the elements considered. Species from karst areas appear subdivided in two groups on the basis of Ca concentration. Mangrove swamp species are

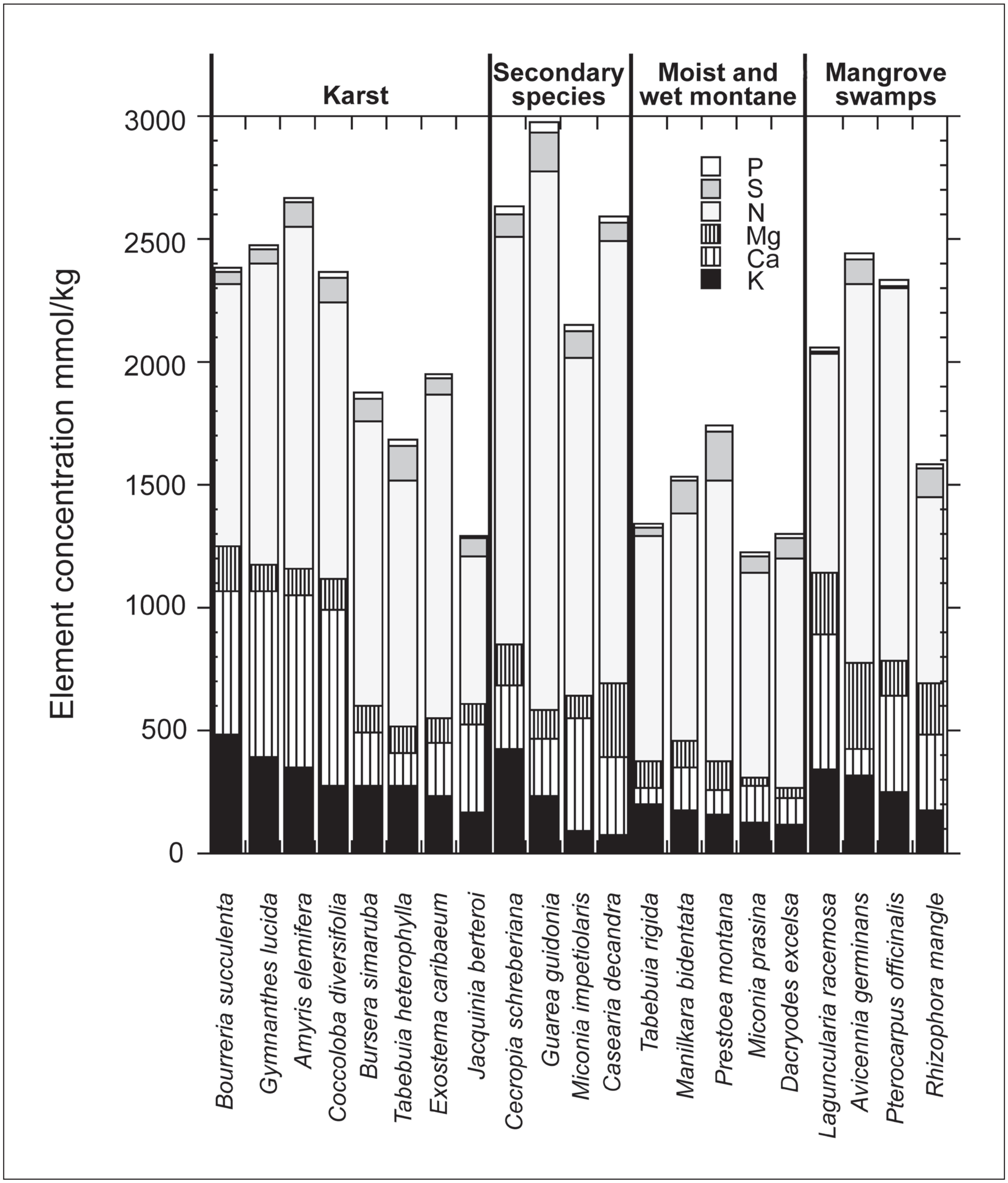


Figure 7—Species element composition “signatures.” Species were separated according to their assumed common occurrence: calcareous soils, moist forests, high montane forest in the Luquillo mountain range, and species from coastal mangroves.

heterogeneous regarding element proportions. In this case, the addition of Na would have separated this group. This representation also allows detection of departure from the general pattern of concentration sequence of plant nutrients (table 14). From the group of species selected, some concentrations stand out: the low concentration of S in *L. racemosa* and *P. officinalis* in spite of their occurrence in S rich soils (mangrove swamps); the small porportion of Mg in *M. prasina* and *D. excelsa*; and the high concentration of Mg relative to Ca in *A. germinans*.

Concluding Remarks

The analysis of the leaf data set compiled by the International Institute of Tropical Forestry laboratory during the 1980–2000 period has given some relevant results regarding:

1. Average and range of variation in the mineral element composition of species belonging to a wide array of families and from different ecological sites.
2. Confirmation of P limitation in the majority of samples analyzed based on the N/P ratios
3. Determination of the distribution of C/S and N/S ratios, parameters that have not been properly evaluated in the current ecological literature on nutrient cycling. The present data set for example, detects comparatively high levels of S in the majority of species analyzed.
4. Identification of Al and Fe accumulators within certain families such as the Melastomataceae, Flacourtiaceae, and Phytolaccaceae.
5. Detection of species departing strongly from the usual K/Ca and Mg/Ca ratios, revealing the probable existence of calciotrophic species.

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Addendum

Data set used for the analyses developed in the text. Ash in percentage, carbon in mol/kg, the other elements in mmol/kg

Species	Ash	C	K	Ca	Mg	Al	Fe	P	C	N	S
Acrostichum aureum	6.07	43.4	529	67	84	1	0.4	34.6	36.17	1664	
Alchornea latifolia			226	177	111	7.8	2.9	27.2		1379	
Albizia lebbeck										2371	
Albizia procera	7.11	51.6							43.00	1564	69
Allamanda violacea	10.09		189	499				47.8		1171	
Amyris elemifera	10.7	51.9	351	701	104	2.6	1.1	18.3	43.25	1393	100
Andira inermis	4.48		189	67	106			42.1		1650	
Ardisia glauciflora	10.41		107	786	38	1.5	0.9	8.7		379	
Ardisia solanacea	13.5	48.9							40.75	1279	59
Avicennia germinans	10	45	320	105	353	3.3	1.4	24.9	37.50	1536	100
***Bambusa* spp.**	6.87	52.7	309	204	83	35	9.8	29.2	43.92	1593	122
Bambusa vulgaris	21.42		240					27.8		1593	
Bourreria succulenta	10.56	49	485	583	186	1.7	0.7	15.4	40.83	1057	56
Bucida buceras	13.71	45	267	470	83			17.8	37.50	893	59
Bursera simaruba	6.11	53.2	277	218	106	2.25	1	25.4	44.33	1157	90
Byrsonima lucida	3.92		155	193	192	1.35	1.2	15		943	
Byrsonima spicata	3.86	56.8	174	140	150	3.8	1.7	17.3	47.33	1779	137
Byrsonima wadsworthii	3.4		158	186	111	8.5	3.4	22		1286	
Calophyllum antillanum	3.85	54.8	222	136	135	1.8	0.9	17	45.67	714	62
Capparis cynophallophora			623					16.5		1457	
Casearia arborea	5.88		292	91	116			26.8		1143	
Casearia decandra	6.63	52	73	315	303	2.5	2.5	25.1	43.33	1807	69
Casearia guianensis	7.68	50							41.67	1714	59
Casearia sylvestris	15.2		341	163	555	2.1	1	41.3		1257	
Cassine xylocarpa	8.08		228	279	142	1.15	1.25	10		579	
Cecropia schreberiana	9.26	46.5	423	259	167	24.733	14.88	35.2	38.75	1657	97
Citrus sinensis	20.68		58	415						807	
Clusia rosea	5.87	54.8	165	240	144	1.4	6.5	7.8	45.67	471	56
Coccoloba diversifolia	10.68	50.9	278	710	126	2.2	1	17.5	42.42	1129	103
Coccoloba microstachya	4.73	52.5	178	273	96	1.25	0.8	15.1	43.75	600	87
Coffea arabica	10.34	51.1	466	249	160	3.5	2.15	35	42.58	1886	153
Colubrina arborescens			497	493	136			18.6		1029	
Colubrina elliptica			608					27.2		1621	
Cordia borinquensis			346	97	173			28.4		1386	
Croton poecilanthus	5.64		315	168		20.1	2.6	32.8		729	
Cyrilla racemiflora	2.79		239	41	28	3.7	1.7	21.4		493	
Dacryodes excelsa	6.89	46.9	116	112	43	25.6	8.1	16.8	39.08	936	78
Daphnopsis philippiana	3.09		177	96	62	6.4	1.5	18.3		886	

Species	Ash	C	K	Ca	Mg	Al	Fe	P	C	N	S
Dieffenbachia seguine	11.36	45.1	1093	285	131	3.05	1.6	41	37.58	1393	56
Ditta myricoides			183	141	182	5.2	2.5	25.5			
Erithalis fruticosa	5.02	56.8	215	245	74	1.3	0.6	10.8	47.33	636	69
Erythroxylum areolatum			363	462	111			33		1386	
Erythroxylum rotundifolium			250	359	55			11.1		1179	
Eugenia borinquensis	2.88		227	74	66	6.7	1.3	17.8		586	
Eugenia eggersii	5.25		263	206	126	8.1	2.5	21		971	
Eugenia foetida			285	342	154			12.2		1014	
Eugenia maleolens			285	342	154			12.2			
Eugenia monticola	4.58	53.7							44.75	1057	50
Eugenia rhombea			317					8.4		693	
Eugenia stahlii	7.34		142					14.9		543	
Exostema caribaeum	3.91	56.1	232	220	101	1.967	1.63	17.7	46.75	1307	72
Faramea occidentalis	8.6	48.7							40.58	1293	81
Ficus citrifolia	13.98		317	505	118	0.7	0.7	148		2450	
Gomidesia lindeniana			255	180	305	1.3	1.5	9.7		543	
Guaiacum officinale			329					14.2		1293	
Guaiacum sanctum			380	434	99			13.1		1229	
Guapira obtusata	4.94		350	85	257	0.7	1.1	47.1		1907	
Guarea glabra	6.58		389	245				57.2		2200	
Guarea guidonia	5.88	50.5	232	236	117	16	7.8	41	42.08	2193	159
Guarea ramiflora		44.4							37.00	1729	
Guettarda pungens	4.05		176	249	54	1.7	2.2	9.6		550	
Guettarda scabra	4.85		220	89	138	0.7	0.95	17		707	
Gymnanthes lucida	11.2	48.4	389	682	103	1.4	0.6	16.9	40.33	1229	59
Heliconia caribaea	5.1	48.5	582	37	76	2.233	0.67	11	40.42	529	75
Henriettea squamulosum	5.39		200	326	97	149.4	3.35	16.3		764	
Hernandia sonora	13.09		82	286	200			24.1		1286	
Homalium racemosum	6.05		70	304	213	2.3	1.1	14.9		871	
Ilex sideroxyloides	3.25		263	119	89	8.9	1.8	24.9		721	
Inga laurina	4.37	53.9	179	130	52			29.9	44.92	1757	97
Inga vera			73	257	131			27.2		1500	
Jacquinia berteroi	9.02	54.2	167	359	80	1.5	0.6	6.2	45.17	600	81
Kalanchoe pinnata			530	1575	166			114		629	
Khaya nyasica			229	140	93			29		1214	
Krugiodendron ferreum			377	471	129			15.6		1671	
Laguncularia racemosa	16.93	43.5	339	555	247	9.1	7.1	22	36.25	893	9
Leucaena leucocephala	9.27	51.1							42.58	2936	137
Magnolia splendens	5.93	57.2	301	171	98	5.2	2	23.9	47.67	1050	69
Manilkara bidentata	5.69	49.8	173	179	110	10.4	4.8	14.4	41.50	921	137

Species	Ash	C	K	Ca	Mg	Al	Fe	P	C	N	S
Miconia impetiolaris	15.98	46.3	95	457	93	748.8	100	27.2	38.58	1371	106
Miconia prasina	7.9	49.3	122	151	33	538.975	2.4	15.3	41.08	836	66
Miconia racemosa	11.13	47.9	106	544	77	492.167	32.63	18.4	39.92	1136	156
Miconia sp.	17.35		81	694	128	1251.95	61.3	15.4			
Miconia spp.	3.76	49.8	91	119	52	245.3	8.03	6.4	41.50	457	37
Miconia tetrandra	9.67		102					18.6		1043	
Micropholis chrysophylloides	2.68		150	107	32	3.7	1.8	12.6		721	
Myrcia deflexa			166	171	108			15.6		943	
Myrcia splendens	8.07	51.5	110					19.5	42.92	936	137
Neolaugeria resinosa	5.06		330	203	557	2.1	1.27	12.5		664	
Ocotea leucoxylon	6.84	53.6	196	186	89	14.8	2.5	30.6	44.67	1543	62
Ocotea spathulata			477	160		21.5	33.7	50.4			
Ormosia krugii			114	52	37			24.4		1514	
Ouratea littoralis	4.71		143	298	118	1.5	1.2	14.9		764	
Palicourea riparia	9.13		351	216	173	250.6	3.9	23.8		1779	
Petitia domingensis	4.76		158	149	163	1.7	1.5	26.6		964	
Phoradendron racemosum			863	651	465					2886	
Phytolacca icosandra			358	163	329	85	29.6	77.8		2593	
Pictetia aculeata	9.19	51.8	302	516	103	1.85	1.2	22.1	43.17	1393	84
Pimenta racemosa	7.92	52.6							43.83	643	50
Pinus caribaea	2.93		51					25.2		629	
Piper aduncum	14.62	48.5	380	348	86	26.3	11	29.5	40.42	2300	156
Piper glabrescens			619	265	146	7	3.2	33.5		1521	
Piper hispidium			686	302	170	5.1	3.1	52.7		1650	
Pisonia albida			380	362	345			36.3		1521	
Pisonia subcordata	4.66		330	71	251	1.1	0.8	25.2		1071	
Plumeria alba	8.92		256	508				49.7		1250	
Plumeria obtusa	6.1		207	317				10.3		957	
Plumeria rubra (red)	10		673	531				9.7		1629	
Plumeria rubra (white)	10.25		839	328				88.3		1914	
Prescotia oligantha			469	276	99		0.1	49.1		1286	
Prestoea montana	7.91	45	161	94	119	18.4	5.97	27.2	37.50	1150	197
Psychotria berteriana	9.75	46.3	491	288	220	66.4	5.43	29.4	38.58	1936	56
Psychotria maleolens	12.1	42	123	294	213	525	5.4	14.3	35.00	886	34
Psychotria sp.	12.67		532					39.1		1686	
Pterocarpus officinalis	7.29	49.8	249	391	141	1.8	1.13	24.4	41.50	1521	6
Rhizophora mangle	11.35	45.9	172	310	206	1.233	0.6	13.7	38.25	764	119
Sapindus saponaria	3.69	55	66	177	32	17.6	8.6	22.6	45.83	2586	159
Sapium laurocerasus	7.22	51.3	525	189	186	10.1	6.6	36.5	42.75	1186	156
Schefflera morototoni	6.86	51.2	246	169	142			29.1	42.67	1321	109

Species	Ash	C	K	Ca	Mg	Al	Fe	P	C	N	S
Schlegelia brachyantha						0.7					
Sloanea berteriana	3.81	46.6	210	139	65	3.3	1.3	20.1	38.83	986	97
Spathodea campanulata	6.7	51.1							42.58	1900	87
Swietenia humilis			283	445	110	4.25		26.7		1236	
Swietenia macrophylla	7.01	52.7	242	360	77	11.2	25.2	24.9	43.92	1136	122
Swietenia macrophylla xmahagoni			295	338	81	5.8		24.1		1179	
Swietenia mahagoni	6.51		203	225	85	1.9	1.2	21.8		864	
***Swietenia* sp.**			280	291	140	2.725		25.6		1307	
Syzygium jambos	4.72	53.8	145	162	140	4.9	1.2	20.4	44.83	964	72
Tabebuia haemantha	4.67		297	82	83	0.5	0.75	19.1		764	
Tabebuia heterophylla	4.53	51.5	275	133	105	0.2	0	28.3	42.92	1007	143
Tabebuia rigida	4.03	46.4	202	64	109	14.65	6.3	22.6	38.67	914	34
Tabebuia spp.			452	506	640					1250	
Ternstroemia stahlii	5.85		230	176	125	1.667	0.97	15.9		621	
Tetragastris balsamifera			184	142	68			21.7		1000	
Thespesia grandiflora	9.34	53.3							44.42	1579	84
Thouinia striata			279	155	48			26.8		1329	
Trema micrantha	9.37		459					69.1		2593	
Trichilia palida	9.71	51.9							43.25	1014	90
Turpinia occidentalis	5.41		341	283				27.4		1043	
Urera baccifera			1050	931	444	2.6	1.4	93.5		1921	
Xylosma schwaneckeana			290	458	9	346.2	27.4	52.3			

Species	C/N	C/P	N/P	C/S	N/S	S/P	K/Ca	Ca/g	Mg/Ca
Acrostichum aureum	22	1045	48				7.90	0.80	1.25
Alchornea latifolia			51				1.28	1.59	0.63
Albizia lebbeck									
Albizia procera	27			627	23				
Allamanda violacea			25				0.38		
Amyris elemifera	31	2363	76	433	14	5.45	0.50	6.74	0.15
Andira inermis			39				2.82	0.63	1.58
Ardisia glauciflora			44				0.14	20.68	0.05
Ardisia solanacea	32			688	22				
Avicennia germinans	24	1506	62	376	15	4.01	3.05	0.30	3.36
Bambusa spp.	28	1504	55	361	13	4.17	1.51	2.46	0.41
Bambusa vulgaris			57						
Bourreria succulenta	39	2652	69	727	19	3.65	0.83	3.13	0.32
Bucida buceras	42	2107	50	633	15	3.33	0.57	5.66	0.18
Bursera simaruba	38	1745	46	490	13	3.56	1.27	2.06	0.49
Byrsonima lucida			63				0.80	1.01	0.99
Byrsonima spicata	27	2736	103	345	13	7.93	1.24	0.93	1.07
Byrsonima wadsworthii			58				0.85	1.68	0.60
Calophyllum antillanum	64	2686	42	732	11	3.67	1.63	1.01	0.99
Capparis cynophallophora			88						
Casearia arborea			43				3.21	0.78	1.27
Casearia decandra	24	1726	72	631	26	2.73	0.23	1.04	0.96
Casearia guianensis	24			703	29				
Casearia sylvestris			30				2.09	0.29	3.40
Cassine xylocarpa			58				0.82	1.96	0.51
Cecropia schreberiana	23	1101	47	401	17	2.75	1.63	1.55	0.64
Citrus sinensis							0.14		
Clusia rosea	97	5855	60	813	8	7.20	0.69	1.67	0.60
Coccoloba diversifolia	38	2424	64	412	11	5.88	0.39	5.63	0.18
Coccoloba microstachya	73	2897	40	501	7	5.78	0.65	2.84	0.35
Coffea arabica	23	1217	54	279	12	4.37	1.87	1.56	0.64
Colubrina arborescens			55				1.01	3.63	0.28
Colubrina elliptica			60						
Cordia borinquensis			49				3.57	0.56	1.78
Croton poecilanthus			22				1.88		
Cyrilla racemiflora			23				5.83	1.46	0.68
Dacryodes excelsa	42	2326	56	501	12	4.64	1.04	2.60	0.38
Daphnopsis philippiana			48				1.84	1.55	0.65
Dieffenbachia seguine	27	917	34	669	25	1.37	3.84	2.18	0.46
Ditta myricoides							1.30	0.77	1.29

Species	C/N	C/P	N/P	C/S	N/S	S/P	K/Ca	Ca/g	Mg/Ca
Erithalis fruticosa	74	4383	59	690	9	6.35	0.88	3.31	0.30
Erythroxylum areolatum			42				0.79	4.16	0.24
Erythroxylum rotundifolium			106				0.70	6.53	0.15
Eugenia borinquensis			33				3.07	1.12	0.89
Eugenia eggersii			46				1.28	1.63	0.61
Eugenia foetida			83				0.83	2.22	0.45
Eugenia maleolens							0.83	2.22	0.45
Eugenia monticola	42			897	21				
Eugenia rhombea			82						
Eugenia stahlii			36						
Exostema caribaeum	36	2641	74	652	18	4.05	1.05	2.18	0.46
Faramea occidentalis	31			500	16				
Ficus citrifolia			0				0.63	4.28	0.23
Gomidesia lindeniana			0				1.42	0.59	1.69
Guaiacum officinale			91						
Guaiacum sanctum			94				0.88	4.38	0.23
Guapira obtusata			40				4.12	0.33	3.02
Guarea glabra			38				1.59		
Guarea guidonia	19	1026	53	265	14	3.88	0.98	2.02	0.50
Guarea ramiflora	21								
Guettarda pungens			57				0.71	4.61	0.22
Guettarda scabra			42				2.47	0.64	1.55
Gymnanthes lucida	33	2387	73	681	21	3.51	0.57	6.62	0.15
Heliconia caribaea	76	3674	48	540	7	6.81	15.73	0.49	2.05
Henriettea squamulosum			47				0.61	3.36	0.30
Hernandia sonora			53				0.29	1.43	0.70
Homalium racemosum			58				0.23	1.43	0.70
Ilex sideroxyloides			29				2.21	1.34	0.75
Inga laurina	26	1502	59	465	18	3.23	1.38	2.50	0.40
Inga vera			55				0.28	1.96	0.51
Jacquinia berteroi	75	7285	97	557	7	13.08	0.47	4.49	0.22
Kalanchoe pinnata			0				0.34	9.49	0.11
Khaya nyasica			42				1.64	1.51	0.66
Krugiodendron ferreum			107				0.80	3.65	0.27
Laguncularia racemosa	41	1648	41	3874	95	0.43	0.61	2.25	0.45
Leucaena leucocephala	15			310	21				
Magnolia splendens	45	1994	44	695	15	2.87	1.76	1.74	0.57
Manilkara bidentata	45	2882	64	302	7	9.53	0.97	1.63	0.61
Miconia impetiolaris	28	1419	50	364	13	3.90	0.21	4.91	0.20
Miconia prasina	49	2685	55	627	13	4.28	0.81	4.58	0.22

Species	C/N	C/P	N/P	C/S	N/S	S/P	K/Ca	Ca/g	Mg/Ca
Miconia racemosa	35	2169	62	256	7	8.48	0.19	7.06	0.14
Miconia sp.							0.12	5.42	0.18
Miconia spp.	91	6484	71	1109	12	5.85	0.76	2.29	0.44
Miconia tetrandra			56						
Micropholis chrysophylloides			57				1.40	3.34	0.30
Myrcia deflexa			60				0.97	1.58	0.63
Myrcia splendens	46	2201	48	313	7	7.04			
Neolaugeria resinosa			0				1.63	0.36	2.74
Ocotea leucoxylon	29	1460	50	716	25	2.04	1.05	2.09	0.48
Ocotea spathulata							2.98		
Ormosia krugii			62				2.19	1.41	0.71
Ouratea littoralis			51				0.48	2.53	0.40
Palicourea riparia			75				1.63	1.25	0.80
Petitia domingensis			36				1.06	0.91	1.09
Phoradendron racemosum							1.33	1.40	0.71
Phytolacca icosandra			33				2.20	0.50	2.02
Pictetia aculeata	31	1953	63	513	17	3.81	0.59	5.01	0.20
Pimenta racemosa	68			878	13				
Pinus caribaea			25						
Piper aduncum	18	1370	78	259	15	5.29	1.09	4.05	0.25
Piper glabrescens			45				2.34	1.82	0.55
Piper hispidium			31				2.27	1.78	0.56
Pisonia albida			42				1.05	1.05	0.95
Pisonia subcordata			43				4.65	0.28	3.54
Plumeria alba			25				0.50		
Plumeria obtusa			93				0.65		
Plumeria rubra (red)			168				1.27		
Plumeria rubra (white)			22				2.56		
Prescotia oligantha			26				1.70	2.79	0.36
Prestoea montana	33	1379	42	191	6	7.22	1.71	0.79	1.27
Psychotria berteriana	20	1312	66	687	34	1.91	1.70	1.31	0.76
Psychotria maleolens	40	2448	62	1020	26	2.40	0.42	1.38	0.72
Psychotria sp.			43						
Pterocarpus officinalis	27	1701	62	6652	244	0.26	0.64	2.77	0.36
Rhizophora mangle	50	2792	56	323	6	8.65	0.55	1.50	0.66
Sapindus saponaria	18	2028	114	288	16	7.04	0.37	5.53	0.18
Sapium laurocerasus	36	1171	32	274	8	4.27	2.78	1.02	0.98
Schefflera morototoni	32	1466	45	391	12	3.75	1.46	1.19	0.84
Schlegelia brachyantha									
Sloanea berteriana	39	1932	49	402	10	4.81	1.51	2.14	0.47

Species	C/N	C/P	N/P	C/S	N/S	S/P	K/Ca	Ca/g	Mg/Ca
Spathodea campanulata	22			488	22				
Swietenia humilis			46				0.64	4.05	0.25
Swietenia macrophylla	39	1764	46	361	9	4.89	0.67	4.68	0.21
Swietenia macrophylla xmahagoni			49				0.87	4.17	0.24
Swietenia mahagoni			40				0.90	2.65	0.38
Swietenia sp.			51				0.96	2.08	0.48
Syzygium jambos	46	2198	47	625	13	3.52	0.90	1.16	0.86
Tabebuia haemantha			40				3.62	0.99	1.01
Tabebuia heterophylla	43	250	0	299	7	0.83	2.07	1.27	0.79
Tabebuia rigida	42	1711	40	1127	27	1.52	3.16	0.59	1.70
Tabebuia spp.							0.89	0.79	1.26
Ternstroemia stahlii			39				1.31	1.41	0.71
Tetragastris balsamifera			46				1.30	2.09	0.48
Thespesia grandiflora	28			527	19				
Thouinia striata			50				1.80	3.23	0.31
Trema micranthum			38						
Trichilia palida	43			478	11				
Turpinia occidentalis			38				1.20		
Urera baccifera			21				1.13	2.10	0.48
Xylosma schwaneckeana							0.63	50.89	0.02

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