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ORIGINAL RESEARCH

Estimates of Biomass and Fixed Carbon at a Rainforest in Panama

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Abstract: This paper presents an estimation of the quantity of carbon fixed in trees in a one hectare (ha) plot at the Cerro Pelado-Gamboa Hydrology Tropical Observatory, which is located in the province of Colon, Panama. The estimation of carbon fixed in trees may provide significant information on carbon flux due to water circulation, which may ultimately enable evaluation of the carbon cycle. All trees larger than 10 cm diameter at breast height (DBH) in the plot were investigated. Carbon fixed within these trees was estimated using a parameterized formula. Tree biomass estimations for the plot were 97.21 Mg ha^{-1}. We identified a rare arboreal pear species (*Euphorbiaceous*) with higher carbon density than other trees in the plot. The presence of this apparently unique species may be due to specific soil characteristics. The method was evaluated by comparing the results with a second study performed in 2011, which resulted in an estimate of net new carbon (biomass) increment (NNCI), which gives 3.88 Mg ha^{-1} year^{-1}. In general, the estimation of the biomass and associated carbon content found in this investigation are useful comparative data for economic evaluation of tropical forests in terms of capacity to capture carbon.

Keywords: biomass, carbon, climate change, net new carbon increment, Panama, rainforest, re-growth

Air, Soil and Water Research 2012:5 79–89

doi: 10.4137/ASWR.S9528

This article is available from http://www.la-press.com.

Introduction

The Kyoto Protocol, established during the United Nations Framework Convention on Climate Change (UNFCCC) in 1997,[1] spotlighted the need for a quantitative understanding of the global capacity of forests to capture and fix carbon. During the convention, shortcomings in data were identified. The cause of these shortcomings was principally the lack of standardized algorithms for estimating the volume of woody biomass in forests.

Schlegel et al[2] defined the major source of carbon-fixing biota and fixed-carbon storage in forests as above-ground biomass (AGB). Several methods have been proposed for determining AGB, which vary significantly in precision. Chave et al[3] compared simple allometric models and proposed specific estimating methods for four tropical ecosystems (dry forest, humid forest, swamp, and very humid forest) and developed two equations for each type of forest, one using the total height of individual trees and the other for when tree height is not known (in addition to other variables). The estimating methods proposed by Chave et al[3] are well accepted as having reasonable precision. This latter study gave a re-evaluation of the quality and the robustness of these models across 2000 tropical trees harvested in 27 sites. The analytical power of these models depends on how well they are validated using tree biomass data obtained directly from destructive crop experiments. The validation was done based on a large dataset collected at sites from dry woodlands to hyperhumid closed-canopy forest and secondary to old-growth forest.[4] The goodness of fit of the Chave et al model was measured by the residual standard error of the fit and by a penalized likelihood criterion. This model estimated accurately the above-ground biomass at most sites; however, the authors included different kinds of forest, such secondary and old-growth forest. Wood specific gravity was a key predictive variable in all these models. Its significance may not be clear if one is interested in guessing the biomass in an old-growth forest dominated by hardwood species, spanning a narrow range of wood densities. Baker et al[5] have shown that disregarding differences in wood density should result in poor overall calculation biomass of the above ground stand. Finally, regression models should not be used beyond their range of validity.[3] The methods employ basal diameter or diameter at breast height (DBH), the wood specific density, and the total height of each individual. Because variables such as wood density vary between species and region, it is important to choose an appropriate model.

In Panama, there are few studies that measure carbon fluxes in humid tropical rainforests or that measure the amount of carbon present in the biomass. Very little is known about tropical forest biomass, and the few studies that are available have covered small areas because they required destructive sampling of the forest.[6] Forests in Panama contain approximately 4800 species of trees and shrubs.[7]

The main objectives of the study reported in this paper are (1) to evaluate the quantity and diversity of tree species, (2) to determine the actual biomass and carbon storage, and (3) to estimate the net new carbon (and biomass) increment in this secondary forest stand.

Method

Study area

The study was conducted at Cerro Pelado-Gamboa (S.1),[8] Colon Province, Panama (9°7′28″N, 79°42′9″W), at an elevation of approximately 160 to 200 m above sea level. For more than 70 years, the US Army used this place as a pilot site for materials, equipment, medicines, and for evaluating conditions in a humid tropical forest. On September 23, 2002, Resolution No. 115-02, ARI (Autoridad de la Región Interoceánica) attached to the Universidad de Panamá (UP) and the Universidad Tecnológica de Panamá (UTP), extended for 20 years the use and administration of former Gamboa Tropical Test Center, covering an area of 751.45 hectares, for the development of scientific and technological research on a tropical environment. During early Panama Canal operations, Cerro Pelado was clear-cut and can now be considered well-established second growth. There is little old-growth forest to be found in the Canal corridor due to human activity that greatly accelerated after 1870.

Cerro Pelado-Gamboa climate

Movement of the inter-tropical convergence zone (ITCZ) and topography are more or less responsible for the rainfall patterns in Gamboa and, indeed, all of Panama. Broadly, the ITCZ is responsible for the rainy seasons closely associated with tropical rain forests.

In Panama, the rainy season generally persists from May until December and the dry season from late December until late April. Panama additionally has a rainfall gradient from the Caribbean to the Pacific, with the Atlantic side receiving significantly more rainfall. The Caribbean receives much more rainfall because the moisture-laden trade winds are primarily oriented from the northeast during the dry season. Gamboa is located in almost exactly the middle of the isthmus and exhibits a marked seasonality in rainfall with an average annual value of 2148 mm.

A detailed climatologically record exists at Gamboa because of Panama Canal operations with rainfall records dating back as far as 1897. Gamboa receives less than 20 mm of rainfall during the months of February and March. October is the wettest month receiving 306 mm of rain on average. In Panama, there is frequently a period of slightly decreased rainfall in July and August known as the veranillo de San Juan. Veranillo de San Juan can last anywhere from one to four weeks and is generally accompanied by an increase of wind speed,[9] but may not be as prevalent in Gamboa. The temperature variability is remarkably small throughout the year with a mean temperature of 26.4 °C. The relative humidity increases and solar radiation decreases as would be expected with the onset of the wet season. Interestingly, the average daily wind speed decreases dramatically with the onset of the wet season.[10]

Cerro Pelado-Gamboa geological features

Panama Isthmus is located on a complex tectonic plate, which rests on a microplate named Block of Panama. On this microplate, four lithospheric plates concur: the Caribbean located to the north, Cocos to the southwest, Nazca to the south, and South America to the east and southeast. The Block of Panama's geographic location between both continents and two oceans has been important for both scientific and economic reasons. Historically, the Panama Isthmus was considered a commercial path of goods that used to come from South America and Europe due to the Spanish conquest during the sixteenth and seventeenth centuries. Following the successful interoceanic canal construction through the isthmus, Panama became a major naval route for the world. Therefore, it was necessary to dam the Chagres River. The Cerro Pelado-Gamboa area is located on a sharp hillslope on this river. The Cerro Pelado areas are affected by the Gatuncillo Formation, which is covered by clay shales, lutites, quartz sandstone, algaelike, and foraminifer limestone. The Gatuncillo Formation is a common geological formation of the Superior Middle Eocene (S.2).[11] Pre-Terciary is another geologically important formation that predominates in this area where lavas, basaltic tuff, and andesites are present and intrusive dioritic and dacitics rocks are found.[8]

Half of the Panama Canal Basin has been deforested, and the official policy in this area is to reforest in anticipation of regaining ecosystem services. Land cover and its manipulation can have collateral impacts, both positive and negative. The positive impacts are referred to as ecosystem services, which include carbon storage, water quantity and quality, and biodiversity. Some negative impacts are water wasting, soil erosion, and wildfires.[12] Basically, the Cerro Pelado area in Gamboa is formed by mature secondary forest. Moreover, inside the Panama Canal watershed there are different kinds of forests and uses, such as disturbed forest, mature forest, mangroves, agricultural uses, and so on (S.3).[13]

A topographic map with contours of the Cerro Pelado-Gamboa area and the study plot are shown in S.4.[13] Basically, the west side of the plot area shows a smooth slope, while the east side is more steeply sloped. Topography of the zone is very varied. Practically flat lands (0% to 3% slope), slightly wavy hills (3% to 15% slope), and lands that are markedly inclined, with slopes between 30% and 60%. The topography of the area where this investigation was carried out show contour lines ranging from 40 meters to 154 meters.[13] True triple canopy conditions typical of pristine tropical catchments are not found on Cerro Pelado, with the situation more accurately described as a two and a half layer canopy. Trees reaching 25 m, with several larger trees reaching 35 m, dominate the average canopy height. By far the most prevalent trees are various species of palm combined with emerging deciduous trees form the secondary canopy layer. Cerro Pelado-Gamboa is reachable from a path. From the top of the path, the hill immediately rises up to a point that forms two flat saddle areas before again rising to the highest peak formally known as Cerro Pelado. Portions of the saddles are remarkably flat given the topography.[10]

Forest inventory

One hectare (ha) of forest was established as a permanent plot for long-term studies. This permanent plot allows for the estimation of the parameters for carbon content analyses, the collection of data on the behavior and distribution of the species that are found in the plot, and modeling of future changes.[14] The long axis of the 1-ha plot is oriented toward magnetic north to ease placement of markers. Within the plot, a grid of 25 quadrants of 20 m × 20 m was marked. In turn, every 20 m × 20 m area was subdivided into 4 sub-quadrants of 10 m × 10 m and into 16 sub-quadrants of 5 m × 5 m. Compasses were used to delimit the plot. Conventional 50 m metric tapes were used to measure distances. Each 20 m corner was marked by a 1.9 cm polyvinyl chloride (PVC) pipe with permanent markings and pink flagging. The 10 m corners were marked with 1.3 cm PVC pipe. The 5 m corners were marked with orange flagging. Within each plot, trees selected for measurement (DBH $\geq$ 10 cm) were marked with aluminum tags fixed to the tree with aluminum nails.

DBH was taken of the principal trunk at a height of 1.30 m from the level of the adjacent soil or base of the tree. In the case that the trunk was irregular at a height of 1.30 m (due to knots or protruding growths), a measurement was taken at the point where the trunk became more cylindrical.

The four different measurements taken for each tree with DBH $\geq$ 10 cm were total height, commercial height, crown deep, and crown diameter. These are described below.

1. Total height is the vertical distance from the level of the adjacent soil up to the highest point where the canopy of the tree is projected.
2. Commercial height is the measurement from the level of the soil (base of the tree) up to the point where the lowest branches occur.
3. Canopy height is the difference between the commercial height and the total height.
4. Canopy radius (r) is the distance from the center or imaginary axis of the silhouette generated by the canopy of a tree towards any point of the perimeter of this circumference. For practical reasons r = D/2, where D represents the diameter of a tree of perfectly circular canopy. The radius of canopy is measured using a conventional longitudinal tape.

For trees with more than one trunk smaller 1.30 m, the principal trunk diameter was measured if the tree's DBH was greater than 10 cm. In this case, the tree was defined as a multiple stem, and additional parameters including total height, commercial height, deep and diameter of crown were taken, as established by Schlegel et al.[2] Two inventories were performed. The first inventory was done in February 2008 and the second one in February 2011. The commercial height and the total height were measured using an electronic clinometers model Haglöf (HEC-MD). All the individuals were identified in situ. When doubts existed about a species' identification, voucher specimens were collected for evaluation by the University of Panama botanist. More than 95% of the trees were successfully identified in situ. To determine the species, each sample was examined meticulously when the trees were tall to assure the identification.

Above- and below- ground biomass estimation

Estimations of above-ground dry biomass (AGB) followed the methodology proposed by Brown and Lugo[6] based on allometric regression equations that were fitted for tropical ecosystems by Chave et al.[3] These allometric equations were applied for species and for each inventory and then added to obtain the total biomass per plot. In the case of humid tropical forests with individual height data, the following equation 1 was used.

$$(AGB)_{\text{est}} = exp\ (-2.977 + ln\ (\rho D^2 H)) \equiv 0.0509\ x\ \rho D^2 H \tag{1}$$

where AGB is above-ground dry biomass (given Mg ha^{-1}), D is the stem diameter, ρ is the specific density of the wood,[15] and H is the total height of the individual tree. Values for each specie's wood specific gravity (density) were obtained from Chave et al.[15] and FAO.[1] When a value for the specific density of any species was not listed in the literature, a standard value of 0.60 g/cm^3 proposed by FAO[16] for the ecosystems of America was used.

The direct determination of the below-ground biomass (BGB) traditionally has been carried out through destructive methods, which are typically labor-intensive and inappropriate for forests within natural reserves. In this study, BGB was estimated using AGB estimates. To determine BGB, AGB was multiplied by a coefficient established by Cairns et al.[17] The coefficient used was a root/shoot ratio of 0.24 for tropical forests, indicating 24% of radicular (root) biomass compared to above ground biomass. The fraction of carbon contained in the total dry biomass is an additional parameter. Values typically used range from 45% to 53%, but a considerable number of countries use 50% value by default. Although the average heavy value of the forest is 49%,[18] in our estimations we used 50% as this is the value more commonly used.

Net new carbon (biomass) increment (NNCI)

The net new carbon increment (NNCI) is that part of the gross primary productivity (GPP) (integrated over the annual period) that is retained by the vegetation as new growth. The NNCI is used to estimate the carbon stock in the canopy.[19] Therefore, this concept differs from the net primary productivity (NPP) that is usually mentioned because it does not take into account losses other than autotrophic respiration.[20] However, if the time scale considered was short, then we could accept both concepts to be comparable. Moreover, the NNCI is estimated by the difference (increment) between total biomass (carbon) for each inventory and divided for the period of time among them. In the present study, the NNCI was obtained from the comparison between the 2008 and 2011 inventories, that is, NNCI = $(C_{2011} - C_{2008})/3$.

Result and Discussion

Forest inventory in 2008

Within the 1 ha plot studies, a total of 384 individual trees with DHB ≥ 10 cm were identified (S.5). A total of 40 species of trees belonging to 31 families were identified of which the family Fabaceae/Mimosoidea (4 species) contributed the largest number of species to the inventory. The species *Pera arborea* Pear (Euphorbiaceous) was the most common individual with 80 individuals, followed by *Oenocarpus mapora* (Arecaceae) with 65 individuals and *Amaioua corymbosa* (Rubiaceae) with 60 individuals. Mean diameter was 20.07 cm, average total height was 19.10 m, average commercial height was 12.42 m, and average crown radius was 2.77 m. Forty multiple stems were measured corresponding mainly to clonal palm *Oenocarpus mapora* (Arecaceae) with 38 stems. The two remaining multiple stems included an *Pera arborea* Pear (Euphorbiaceae) species and a *Roupala montana* (Proteaceae). Regarding the distribution of sizes of 384 trees mapped, 249 had a DBH between 10 and 20 cm, 70 trees had a DBH between 20 and 30 cm, and 65 trees had a DBH greater than 30.0 cm (S.6).

Biomass estimation in 2008

The total estimated dry biomass (Table 1) calculated the amount of carbon present in the 1-ha study plot by using equation (1). The species that contributed the greatest biomass in the study plot were arboreal *Pera arborea* with 45.72 Mg ha^{-1} (AGB) and 10.97 Mg ha^{-1} (BGB), *Enterolobium schomburgkii* with 25.29 Mg ha^{-1} (AGB) and 6.07 Mg ha^{-1} (BGB) and *Vantanea depleta* with 19.38 Mg ha^{-1} (AGB) and 4.65 Mg ha^{-1} (BGB). The AGB of trees found in the Cerro Pelado plot compared favorably with other forests in Panama and Costa Rica, as indicated in (S.7).[16,21,22]

Forest inventory in 2011

The inventory was repeated after the initial study. The methodology was identical to that used in the first study. An added benefit was that the results from the second estimation were compared with the first, allowing a first time quantification of the net new carbon increment (NNCI).

The total estimated dry biomass calculated the amount of carbon present in the 1 ha study plot (S.8). Calculated biomass changed from 194.43 Mg ha^{-1} to 217.73 Mg ha^{-1}, and increased by 10% from 2008 to 2011. The species that contributed the greatest aboveground biomass in the study plot were arboreal Pear (27.16%), *Enterolobium schomburgkii* (15.77%), *Vantanea*

Table 1. Above-ground biomass (AGB), below-ground biomass (BGB), total biomass and total carbon in the 1 ha plot, 2008.

Site	AGB (Mg ha^{-1})	BGB (Mg ha^{-1})	Total biomass (Mg ha^{-1})	Carbon total (Mg ha^{-1})
Cerro Pelado Panama	156.80	37.63	194.43	97.21

Table 2. NNCI in different localities.

Site of study	NNCI (Mg C ha^{-1} y^{-1})	Type of forest	Life zone
Cerro pelado[a]	3.88	Secondary	Tropical rainforest
Magdalena terrace and slope, Colombia[b]	2.6–2.2	Secondary	Tropical evergreen
Limon, Costa Rica[c]	3.1	Secondary	Tropical rainforest

[a]NNCI present study; [b]Fölster et al;[23] [c]Chacon et al.[24]

depleta (12.30%), *Matayba apetala* (10.76%), and *Oenocarpus mapora* (3.99%) (S.9). The rest of the species combined contribute 30.01% of the 175.59 Mg ha^{-1} above ground biomass estimated (S.10).

Net new carbon (biomass) increment (NNCI)

The results from the second estimation were compared with the first, allowing a quantification of net new carbon (biomass) increment (NNCI) (Table 2).[23,24] An NNCI value of 3.88 Mg ha^{-1} year^{-1} was obtained using NNCI = $(C_{2011} - C_{2008})/3 = (108.86–97.21)/3$.[19]

NNCI, 3.88 Mg ha^{-1} year^{-1}, is larger compared with those obtained by Fölster et al (2.2–2.6 Mg ha^{-1} year^{-1}, Table 2)[23] whose study that was conducted in a secondary rainforest in Colombia. This discrepancy may be related to the presence of *Pera arborea* Pear species (Euphorbiaceous) as predominant species that have higher carbon density than the other trees in the plot due to specific soil characteristics. Because the maximum NNCI value reported by Fölster et al[23] was 3.8 Mg ha^{-1} year^{-1} in a primary rainforest, our larger NNCI value may suggest that our study area has similar characteristics as a primary rainforest. In addition to the larger NNCI value compared with a primary rainforest, López-Serrano[25] demonstrated that NNCI value tends to be smaller soon after the forest fire, which means that the initial stage of a secondary rainforest may have similarly small NNCI. Therefore, our larger NNCI value, 3.8 Mg ha^{-1} year^{-1}, may be expected not to be in the initial stage, which also suggests that the characteristics of our study area has reached a steady state, like a primary rainforest.

Conclusions

The estimation of the biomass and associated carbon content found in this investigation are useful comparative data for economic evaluation of tropical forests in terms of capacity to capture carbon.

A rare *Pera arborea* Pear species (Euphorbiaceous) with higher carbon density than other trees in the plot was found. The presence of this apparently unique species may be due to specific soil characteristics.

A first estimation of the NNCI gives 3.88 Mg ha^{-1} year^{-1}. Moreover, our larger NNCI value may suggest that our study area has similar characteristics as a primary rainforest. Therefore this comparative study can be used as baseline for new future research developments at Cerro Pelado-Gamboa that will allow *Pera arborea* there fine NNCI values for the 750 ha for over longer time periods.

Acknowledgments

We would like to acknowledge the editorial services provided by Sustainable Sciences Institute (SSI), in particular the revisions and comments made by Eng. Dana Brock an SSI volunteer. Also, the authors would like to acknowledge Dr. Keisuke Nakayama from Kitami Institute of Technology in Japan for his wise comments and suggestions. Furthermore, we express our gratitude to the editor and the two anonymous referees of this paper for their beneficial comments. Moreover, thanks to all CIHH members who contributed and helped carry out this project to its successful completion.

Author Contributions

Conceived and designed the experiments: RA, RP, FRLS. Analysed the data: RA, RP, DV, FRLS, KE. Wrote the first draft of the manuscript: RP. Contributed to the writing of the manuscript: JF, RA, and FRLS. Agree with manuscript results and conclusions: RP, JF, DV, ENV, KE, RA, FRLS, FLO. Jointly developed the structure and arguments for the paper: RP, JF, FRLS. Made critical revisions and approved final version: FRLS, FLO. All authors reviewed and approved of the final manuscript.

Funding

The authors are grateful for the financing granted by Secretaría Nacional de Ciencia y Tecnología e Innovación (SENACYT) (endorsed Proposal—code COL07-011). This research was partially supported by the US Army Research Office through grant W911NF-07-1-0389 to the University of Wyoming. This contribution has been co-funding by Spanish government (MICINN, AGL2011-27747 research project) and FEDER funds.

Competing Interests

Author(s) disclose no potential conflicts of interest.

Disclosures and Ethics

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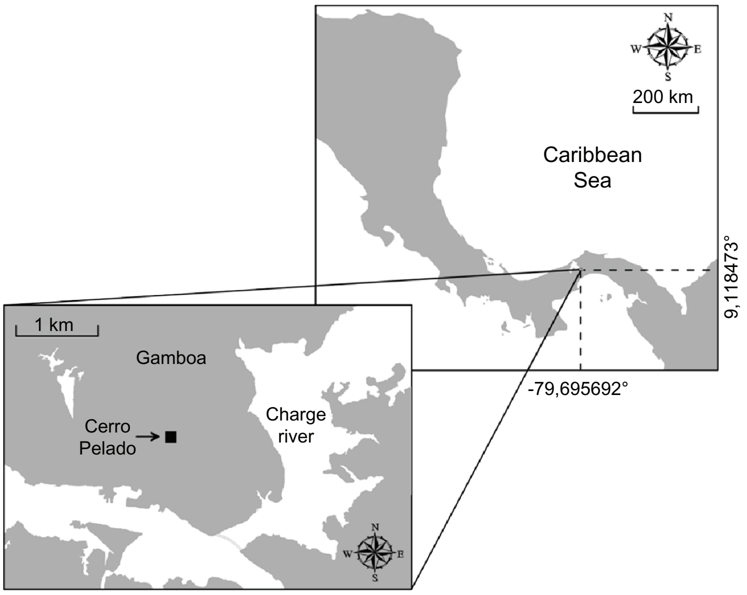
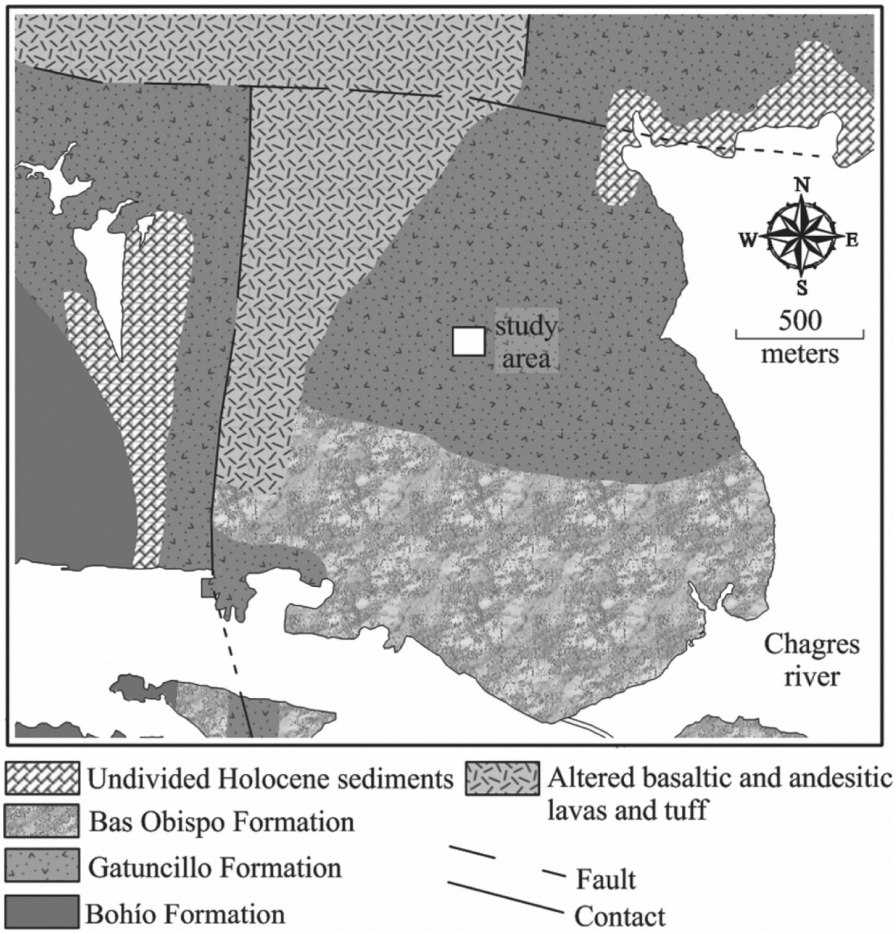
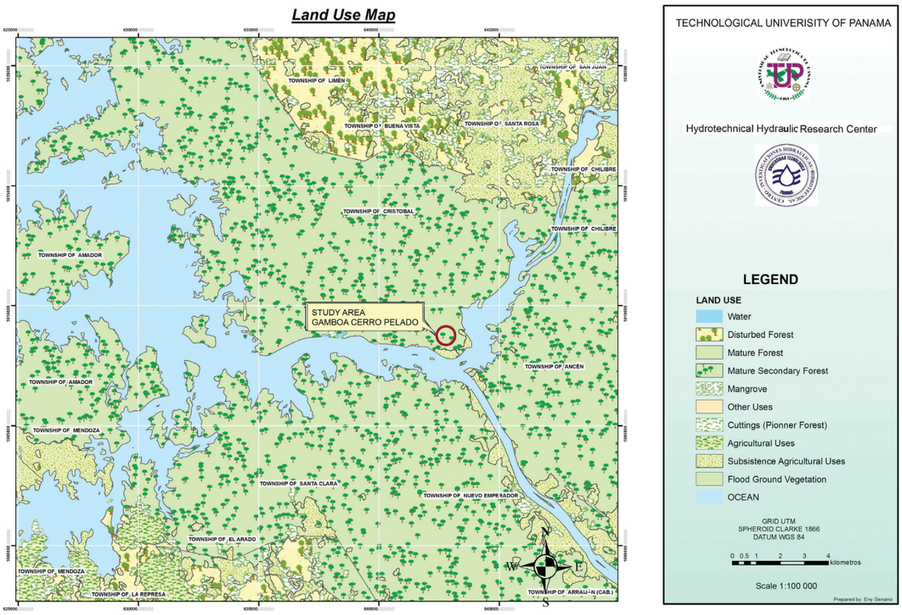
Supplementary Materials



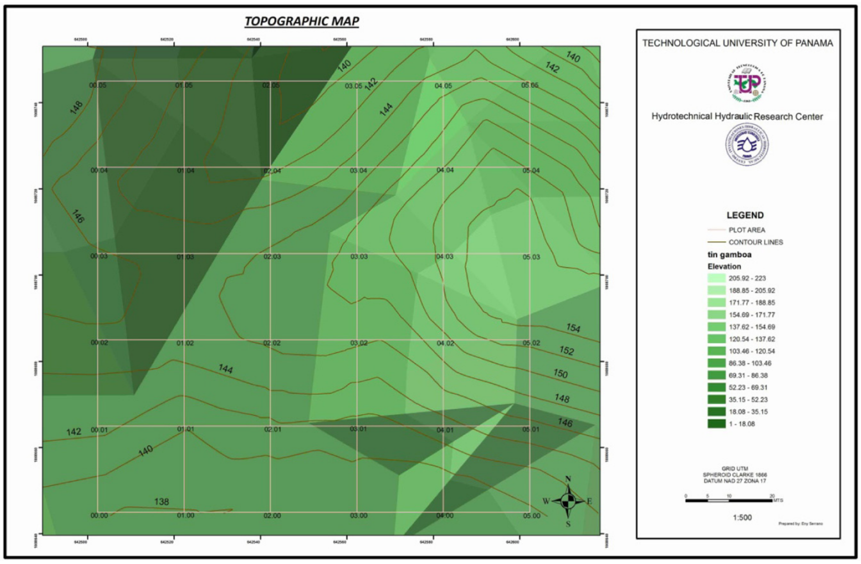
S.1. Cerro Pelado-Gamboa area geographic location, Panama Canal watershed in Mojica et al.[8]



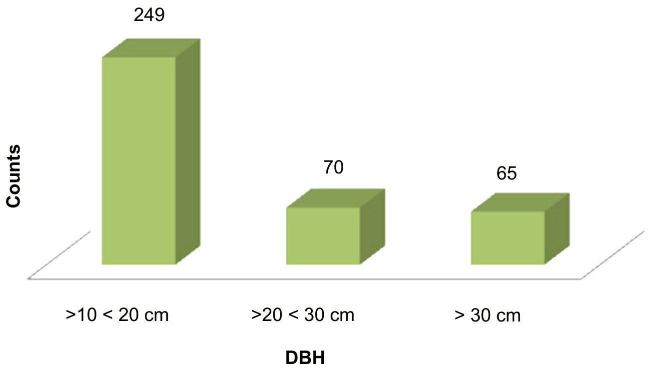
S.2. Geological map of Cerro Pelado-Gamboa, its surroundings and study area from Stewart et al.[11]



S.3. Land use map, Cerro Pelado-Gamboa in the Panama Canal watershed, from Serrano et al.[13]



S.4. Topographic map of Cerro Pelado-Gamboa with contour lines and the plot area grid from Serrano et al.[13]



S.6. Tree size distribution of diameter at breast height (DBH) of 384 trees in the plot Cerro Pelado-Gamboa, 2008.

S.5. Trees by family and specie with DHB ≥ 10 cm, 2008.

Family	Specie	Frequency
Annonaceae	*Xylopia frutescens*	2
Arecaceae	*Oenocarpus mapora*	65
Bignoniaceae	*Jacaranda copaia*	6
	Tabebuia guayacan	3
Bombacaceae	*Pachira sessilis*	6
Boraginaceae	*Cordia panamensis*	2
Burseraceae	*Protium panamense*	5
Chrysobalanaceae	*Hirtella americana*	2
Clusiaceae	*Calophyllum longifolium*	2
Combretaceae	*Terminalia amazonia*	2
Ebenaceae	*Diospyros artanthifolia*	1
Erythroxylaceae	*Erythroxylum macrophyllum*	1
Euphorbiaceae	*Pera arborea*	80
Fabaceae/Cae.	*Tachigali versicolor*	3
Fabaceae/Mim.	*Abarema barbouriana*	1
	Enterolobium schomburgkii	9
	Inga pezizifera	6
	Inga thibaudiana	3
Fabaceae/Pap.	*Vatairea erythrocarpa*	5
Flacourtiaceae	*Lindackeria laurina*	7
Humiriaceae	*Vantanea depleta*	24
Lacistemataceae	*Lacistema aggregatum*	1
Lauraceae	*Beilschmiedia pendula*	1
	Nectandra purpurea	1
	Ocotea cernua	1
Malpighiaceae	*Byrsonima spicata*	1
Melastomataceae	*Henriettella tuberculosa*	1
Meliaceae	*Guarea guidonia*	1
Moraceae	*Perebea xanthochyma*	15
	Maquira guianensis	1
Myristicaceae	*Virola sebifera*	16
	Virola multiflora	2
Myrsinaceae	*Myrsine coriacea*	1
Myrtaceae	*Myrcia gatunensis*	5
Proteaceae	*Roupala montana*	5
Rubiaceae	*Alseis blackiana*	1
	Amaioua corymbosa	60
Sapindaceae	*Matayba apetala*	22
Theaceae	*Ternstroemia tepezapote*	8
Vochysiaceae	*Vochysia ferruginea*	6

S.7. Above-ground biomass (AGB) in different localities, 2008.

Site of study	AGB (Mg ha^{-1})	Type of forest	Life zone
Cerro Pelado[a]	156.80	Secondary	Tropical rainforest
Reserva Forestal Montuoso[b]	163.00	Secondary	Broadleaved
Reserva Forestal Montuoso[b]	235.50	Primary	Semideciduous transition lowland rainforest Broadleaved
Panama (general)[c]	169–945	Secondary	Semideciduous transition lowland rainforest Tropical rainforest
Zona del Canal, Panama[d]	277.91	Secondary	Tropical rainforest
Barro Colorado, Panama[d]	286.77	Primary	Tropical rainforest
La Selva, Costa Rica[d]	160.00	Primary	Very humid tropical forest
La Selva, Costa Rica[d]	147.70	Secondary	Very humid tropical forest

[a]Present study; [b]Arcia and Garibaldi;[21] [c]FAO;[16] [d]Drake et al.[22]

S.8. Above-ground biomass (AGB), below-ground biomass (BGB), total biomass, and total carbon in the 1 ha plot, 2011.

Site	AGB (Mg ha^{-1})	BGB (Mg ha^{-1})	Total biomass (Mg ha^{-1})	Carbon total (Mg ha^{-1})
Cerro Pelado Panama	175.59	42.14	217.73	108.86

S.9. Main biomass contributions by species in the 1 ha plot at Cerro Pelado-Gamboa, 2011.

Specie	AGB (Mg ha^{-1})	BGB (Mg ha^{-1})
Pera arborea	47.69	11.45
Enterolobium schomburgkii	27.69	6.65
Vantanea depleta	21.60	5.18
Matayba apetala	18.90	4.54
Oenocarpus mapora	7.01	1.68

S.10. Biomass values from other species present in the plot, Cerro Pelado-Gamboa, 2011.

Specie	AGB (Mg ha^{-1})	BGB (Mg ha^{-1})	Total (Mg ha^{-1})
Abarema barbouriana	0.50	0.12	0.62
Alseis blackiana	0.41	0.10	0.51
Amaioua corymbosa	6.50	1.56	8.06
Beilschmiedia pendula	0.07	0.02	0.09
Byrsonima spicata	0.29	0.07	0.37
Calophyllum longifolium	1.54	0.37	1.91
Cordia panamensis	1.02	0.25	1.27
Diospyros artanthifolia	0.08	0.02	0.10
Erythroxylum macrophyllum	0.07	0.02	0.09
Guarea Guidonia	0.05	0.01	0.06
Henriettella tuberculosa	0.20	0.05	0.25
Hirtella Americana	0.32	0.08	0.39
Inga pezizifera	1.68	0.40	2.08
Inga thibaudiana	1.70	0.41	2.10
Jacaranda copaia	6.24	1.50	7.73
Lacistema aggregatum	0.06	0.01	0.07
Lindackeria laurina	1.34	0.32	1.67
Maquira guianensis	0.15	0.04	0.19
Myrcia gatunensis	0.26	0.06	0.32
Myrsine coriacea	2.35	0.56	2.92
Nectandra purpurea	0.18	0.04	0.22
Ocotea cernua	0.33	0.08	0.41
Perebea xanthochyma	2.03	0.49	2.52
Pachira sessilis	1.62	0.39	2.01
Protium panamense	0.34	0.08	0.42
Roupala Montana	1.52	0.37	1.89
Tabebuia guayacan	0.43	0.10	0.54
Tachigali versicolor	1.86	0.45	2.31
Terminalia Amazonia	3.21	0.77	3.98
Ternstroemia tepezapote	1.32	0.32	1.64
Vatairea erythrocarpa	9.68	2.32	12.00
Virola sebifera	1.39	0.33	1.73
Virola multiflora	1.25	0.30	1.55
Vochysia ferruginea	2.43	0.58	3.02
Xylopia frutescens	0.26	0.06	0.33
Totals	52.70	12.65	65.35