

Continuous forest inventory – CFI - system in use in the State of Amazonas, Amazon region, Brazil

by

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ALLOMETRY ?

OK !

DATA SET FOR ALLOMETRY (Manaus site)

	Above-ground			Below-ground (coarse roots)		
Primary forest	DBH (cm)	height (m)	FB (kg)	DBH (cm)	height (m)	FB (kg)
Minimum	5.0	5.6	8.29	5.0	5.9	1.26
maximum	120.0	41.4	25634	85.0	34.5	2709
n	(494)	(494)	(494)	(131)	(131)	(131)
Secondary 14	DBH (cm)	height (m)	FB (kg)	DBH (cm)	height (m)	FB (kg)
Minimum	5.0	4.2	7.54	5.2	7.6	0.523
maximum	33.1	27.0	1562	23.1	20.0	78.7
n	(252)	(252)	(252)	(30)	(30)	(30)
Secondary 23	DBH (cm)	height (m)	FB (kg)	DBH (cm)	height (m)	FB (kg)
Minimum	5.0	3.9	5.38	5.2	7.4	0.676
maximum	37.2	27.0	1690.18	27.5	22.1	71.8
n	(349)	(341)	(341)	(35)	(35)	(35)

FB = fresh biomass

FRESH BIOMASS (FB) – PRISTINE DENSE CORRELATION MATRIX

	FB_{roots}	FB_{abg}	FB_{total}	DBH	H_{total}
FB_{roots}	1				
FB_{abg}	0.92	1			
FB_{total}	0.95	0.99	1		
DBH	0.85	0.95	0.94	1	
H_{total}	0.58	0.73	0.71	0.85	1

Obs.: all correlations are highly significant ($p < 0.0001$) – Bonferroni Test.

DATA SET FOR ALLOMETRY (Manaus site)

“CAMPINARANA” or HEAT FOREST

	Above-ground			Below-ground (coarse roots)		
Campinarana	DBH (cm)	height (m)	FB (kg)	DBH (cm)	height (m)	FB (kg)
Minimum	5.0	7.0	9.4	5.0	7.0	1.9
maximum	50.2	28.7	5,659	50.2	28.7	758
n	100	100	100	100	100	100

FB = fresh biomass; and height = total height

FRESH BIOMASS - CAMPINARANA CORRELATION MATRIX

	FB _{roots}	FB _{abg}	FB _{total}	DBH	H _{total}
FB _{roots}	1				
FB _{abg}	0.94	1			
FB _{total}	0.99	0.99	1		
DBH	0.83	0.90	0.89	1	
H _{total}	0.64	0.70	0.69	0.88	1

Obs.: all correlations are highly significant ($p < 0.0001$) – Bonferroni Test.

PRIMARY FOREST WATER CONTENTS ⇔ 774 samples

Tree parts	contribution	water (%)	% weighted
Trunk	0.5802	38.8	22.5
Coarse branches	0.1248	40.6	5.1
Fine branches	0.1278	44.9	5.7
Leaves	0.0269	59.7	1.6
Fine roots	0.0306	48.9	1.5
Coarse roots	0.1159	44.5	5.2
Weighted mean			41.6

CARBON CONTENTS 256 samples

Parts	contribution	C (%)	weighted (%)
Trunk	0.8598	48.5	41.7
Coarse roots	0.1159	47.0	5.4
Fine roots	0.0306	45.7	1.4
Weighted mean			48.5

ALLOMETRIC EQUATIONS FOR TOTAL FRESH BIOMASS (ABOVE + BELOW-GROUND) OF PRISTINE FORESTS

$$FB_{\text{total}} = a \text{ DBH}^b$$

Size classes	n	min FB in kg	max FB in kg	r ²	a	b
FB tot: All trees DBH ≥ 5cm	231	11	10,218	0.94	2.329	1.921
FB tot : All trees DBH ≥ 20cm	60	387	10,218	0.89	3.186	1.844
FB tot: Trees 10 ≤ DBH < 20cm	58	78	591	0.79	0.336	2.443
FB tot: Trees 5 ≤ DBH < 10cm	113	11	331	0.35	0.283	2.543
Only beg DBH ≥ 5cm	231	1.3	2,709	0.94	0.032	2.563

FB tot = above + below-ground fresh biomass in kg
BEG = below-ground fresh biomass

West, G.B. et al. 1999. A general model for the structure and allometry of plant vascular systems. *Nature* 400 (issue 6745): 664-667.

"For tall trees, the correction factor for general model is smaller than for small trees."

Final recommendations for Amazonian forests n = ?

Pristine or managed dense forest (n = 131):

Total => $FB_{\text{total}} = 2.718 * \text{DBH}^{1.877}$; Adjusted $r^2 = 0.94$

Below-ground => $FB_{\text{total}} = 0.047 * \text{DBH}^{2.475}$; Adjusted $r^2 = 0.95$

Pristine "campinarana" or "heat forest" (n = 100):

Total => $FB_{\text{total}} = 0.177 * \text{DBH}^{2.651}$; Adjusted $r^2 = 0.96$

Below-ground => $FB_{\text{total}} = 0.006 * \text{DBH}^{2.97}$; Adjusted $r^2 = 0.89$

Secondary forests – 14 and 23 years old (n = 65):

Total => $FB_{\text{total}} = 0.351 * \text{DBH}^{2.353}$; Adjusted $r^2 = 0.88$

Below-ground => $FB_{\text{total}} = 0.064 * \text{DBH}^{2.08}$; Adjusted $r^2 = 0.71$

Total = total fresh biomass = above + below-ground biomass

For different sites we are using the dominant height (Loetsch et al., 1973) to correct the equation of Manaus

RUNNING COSTS OF DATA COLLECTION: TOTAL BIOMASS (ABOVE + BELOW-GROUND)

quadrate	n	days	COSTS FOR		
			quadrate (R\$)	tree (R\$)	tree (US\$)
1	15	29	9.280,00	618,67	294,60
2	19	35	11.200,00	589,47	280,70
3	17	40	12.800,00	752,94	358,54
4	13	30	9.600,00	738,46	351,65
5	11	24	7.680,00	698,18	332,47
6	11	21	6.720,00	610,91	290,91
7	13	22	7.040,00	541,54	257,88
8	7	45	14.400,00	2.057,14	979,59
9	12	24	7.680,00	640,00	304,76
total	118	270	86.400,00	7.247,32	3.451,10
Mean	13	30	9.600,00	805,26	383,46
deviation	3,6	8,4	2696,37	474,59	226,00
CI 95%	2,3	5,5	1761,59	310,06	147,65

Quadrate of 100 m²

CONTINUOUS FOREST INVENTORY C F I

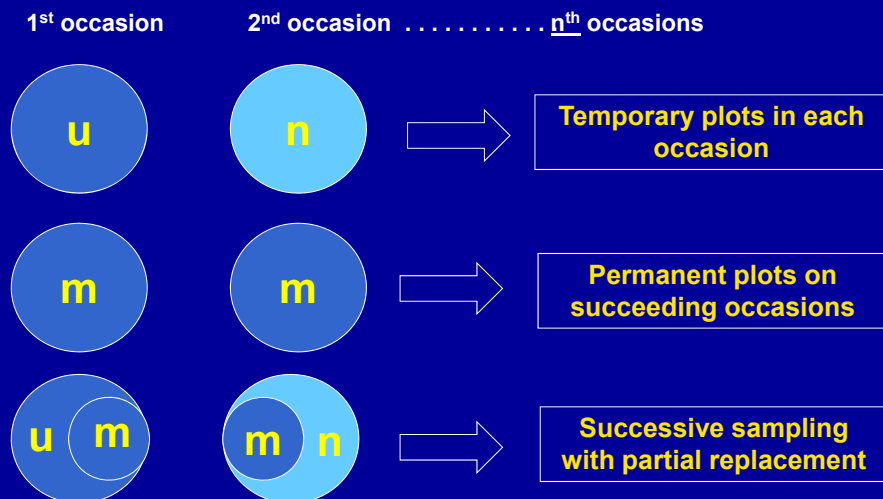
C F I ESTIMATIONS

1. CARBON STOCKS

- ✓ All living biomass or C above the soil including stem, stump, branches, bark, seeds, and foliage => **Above-ground biomass or C**
- ✓ All living biomass or C of live roots. Fine roots of less than 2mm diameter are excluded because these often cannot be distinguished empirically from soil organic matter or litter => **Below-ground biomass or C**
- ✓ All non-living woody biomass or C not contained in the litter, either standing, lying on the ground, or in the soil => **Dead wood biomass or C**

2. CARBON STOCK CHANGES OVER TIME

C F I alternatives



Source: Husch, Miller and Beers (1972)

OUR INSPIRATION

Asner, G.P. Knapp, D.E. Broadbent, E.N., Oliveira, P.J.C., Keller, M. and Silva, J.N.M. **2005**. Selective Logging in the Brazilian Amazon. **Science** 310: 480-482.

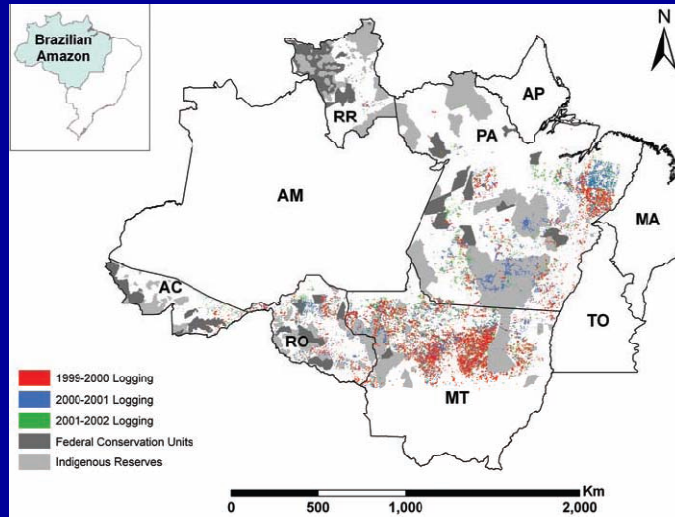
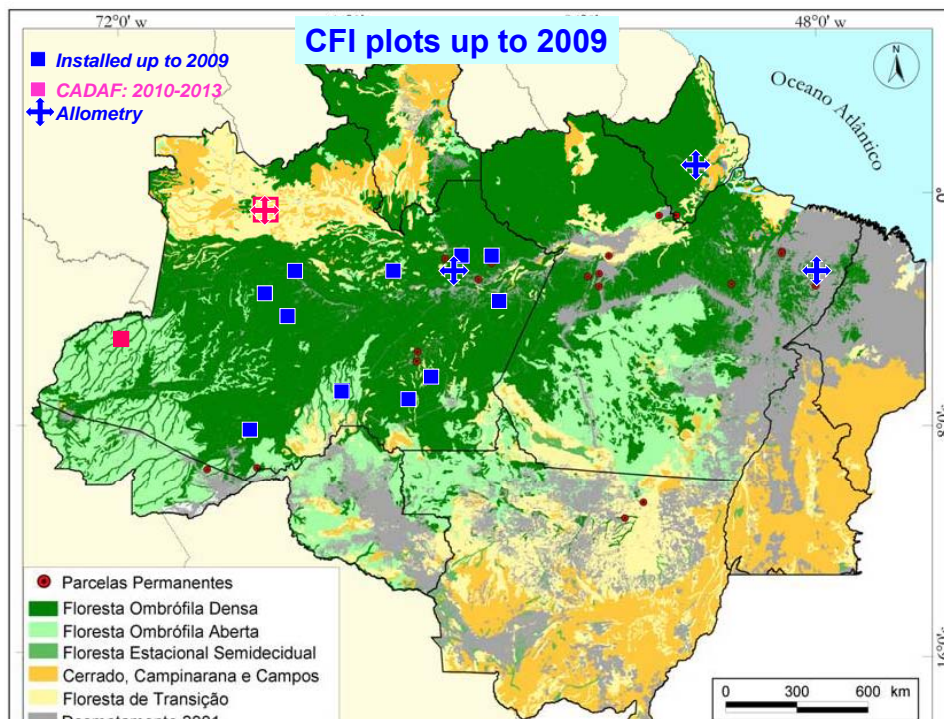


Fig. 1. Spatial distribution of selective logging in five timber-production states of the Brazilian Amazon for the year intervals 1999–2000 (red), 2000–2001 (blue), and 2001–2002 (green). The states of Amazonas (AM), Amapá (AP), Tocantins (TO), Maranhão (MA), and the southern nonforested part of Mato Grosso were not included in the analysis. Light gray areas show the extent of indigenous reserves; dark gray areas delineate federal conservation lands as of 1999 (29). RR, Roraima; PA, Pará; MT, Mato Grosso; RO, Rorônia; AC, Acre.



PRELIMINARY RESULTS FOR AMAZONAS STATE

Site	year	size (m)	s.u.(n)	area (ha)	min dbh	C tot (t)
1. Resex Baixo Juruá	2006	20x125	83	20,75	10	161,28
2. Rio Preto da Eva	2005	100x100	15	15,00	10	177,39
3. Fonte Boa	2004	20x125	72	18,00	10	167,57
4. Jutai	2004	20x125	64	16,00	10	164,01
5. FE Maués	2005	20x125	100	25,00	10	135,27
6. Resex Auti-Paraná	2007	20x125	107	26,75	10	184,51
7. UHE Balbina	1982	20x250	120	60,00	20(*)	157,46
8. Trombetas	1982	20x125	60	15,00	20(*)	178,83
9. Manacapuru	2004	20x125	32	8,00	20(*)	152,60
10. ZF-2, Manaus	2007	100x100	3	3,00	10	198,07
11. ST-Manejo	2005	20x125	87	21,75	10	114,68
12. MIL Madeireira	2005	20x125	185	46,25	10	139,64
13. Colégio Adventista	2004	20x125	40	10,00	10	139,92
14. Resex Capanã	2008	20x125	82	20,50	10	153,07
15. Resex Rio Unini	2009	20x125	90	22,50	10	164,60
16. Flona Pau-rosa	2009	20x125	81	20,25	10	177,10
17. RDS Juma	2009	20x125	115	28,75	10	161,30
mean and CI (95%)			1336	378		160.4 ± 9.7

TIPS FOR C F I IMPLEMENTATION:

- ✓ Plot size => 20 x 125 m => 2,500 m²
- ✓ Field crew: 2 foresters, 2 mateiros, 3 guys for trails, 3 extra guys (painting, cleaning), 1 botanist + 1 helper
- ✓ Running costs to install one permanent plot => US\$ 168.91 ± 36.02
- ✓ Crew productivity: 8 psp per day

NEX STEPS

Under **C A D A F** (Carbon Dynamics of Amazonian Forests) Project (2010 – 2014)

JICA => INPA and INPE

JST => FFPRI and University of Tokyo

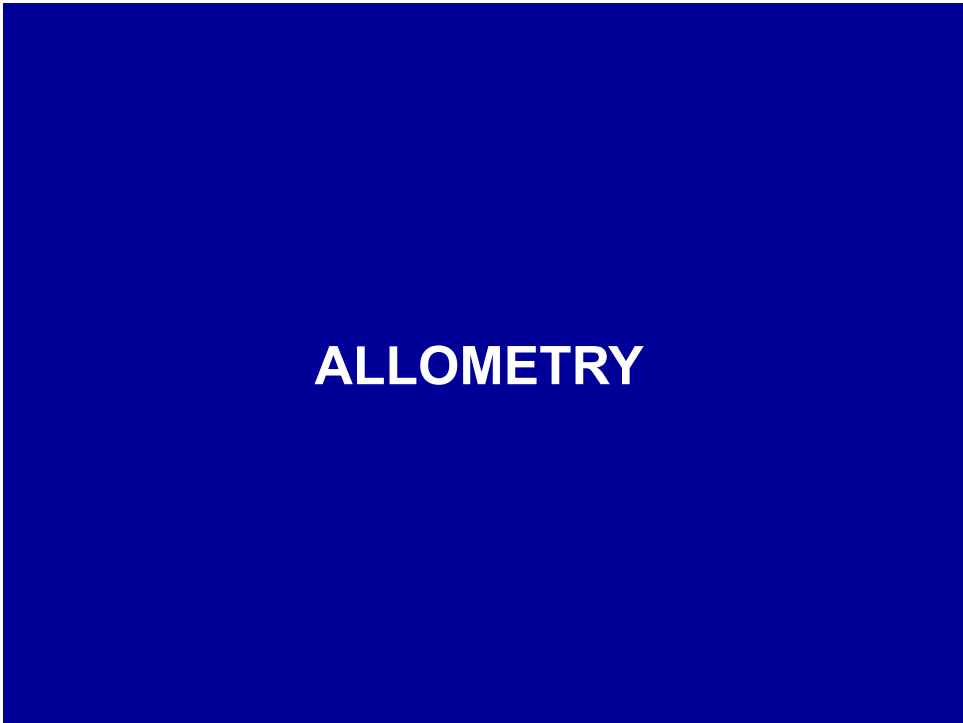
Outputs:

- 1. Installation of 200 new sample plots of ¼ ha each, and re-measuring c.a. 1,000 old plots*
- 2. Geo-processing INPA's Continuous Forest Inventory*

JICA = Japan Int' Cooperation Agency; **INPA** = Nat'l Institute for Research in the Amazon; **INPE** = Nat'l Institute for Spatial Research; **JST** = Japan Science and Technology; **FFPRI** = Forestry and Forest Products Research Institute

THANK YOU !

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**we have to fell down and weight piece by piece
piece => TRUNK BIOMASS, for ex.**



**Samples for
contents of
H₂O, C and
nutrients and
age**

FINE AND COARSE BRANCHES AND LEAVES



Coarse branch



Fine branches

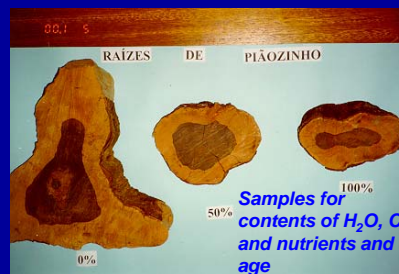


**Coarse branch
weighting**

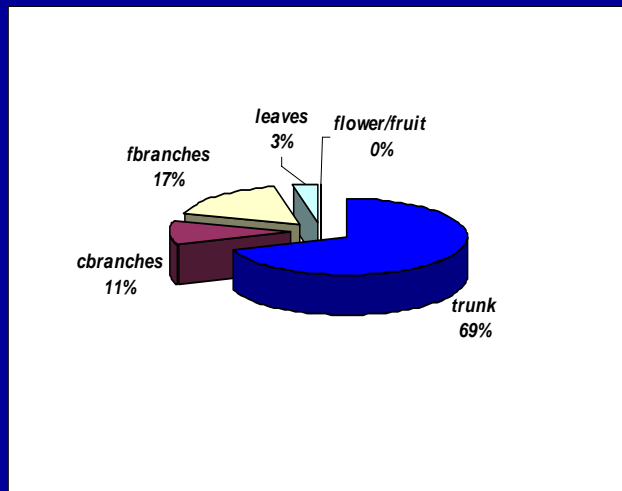


leaves

BELOW-GROUND (COARSE ROOTS)



CONTRIBUTION OF EACH TREE PART FOR THE TOTAL BIOMASS - IN % PRIMARY FOREST



THEN ...

FOREST INVENTORY



CONTINUOUS FOREST INVENTORY

VARIABLES RECORDED:

- 1) SPECIES
- 2) DBH
- 3) RECRUITMENT
- 4) MORTALITY

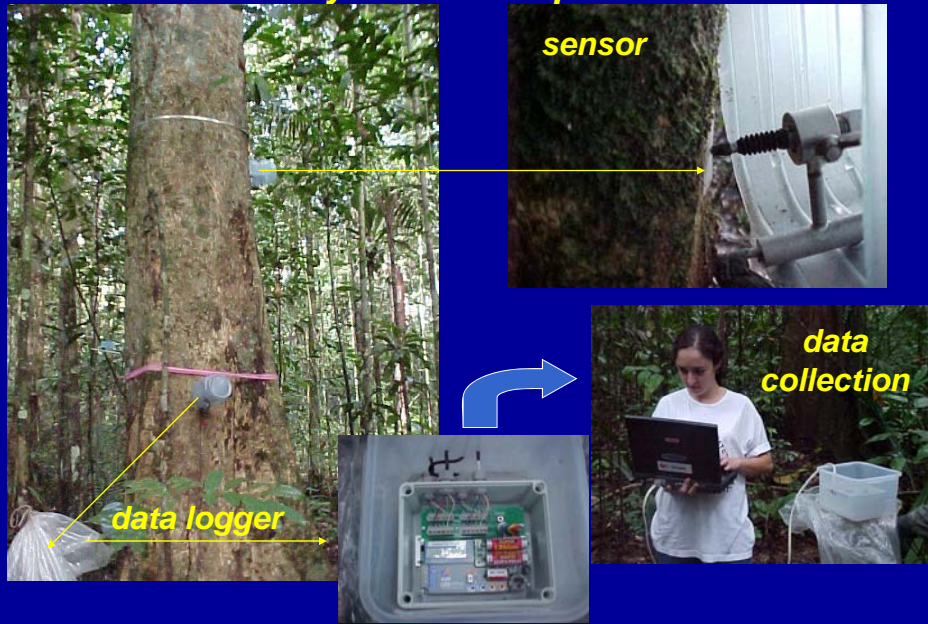
ANNUALLY



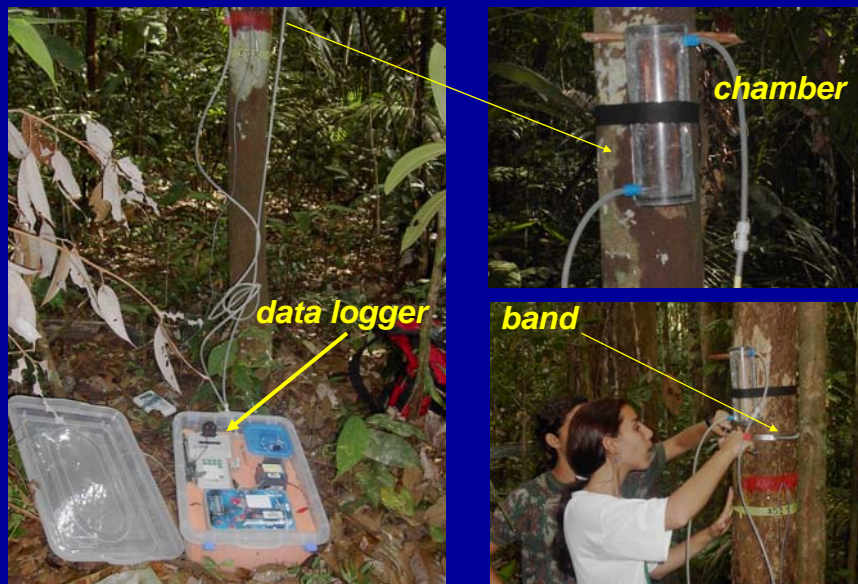
DENDROMETRIC BANDS



AUTOMATED DENDROMETERS *daily dbh development*



TRUNK RESPIRATION *instantaneously*



PHOTOSYNTHESIS & RESPIRATION - instantaneously



**ALLOMETRIC EQUATIONS FOR TOTAL FRESH BIOMASS
(ABOVE + BELOW-GROUND) OF PRISTINE FORESTS**

$$\ln \text{FB}_{\text{total}} = a + \ln \text{DBH}$$

Size classes	n	min FB	max FB	r ²	a	b
FB tot: All trees DBH ≥ 5cm	231	11	10,218	0.97	-1.283	2.512
FB tot : All trees DBH≥20cm	60	387	10,218	0.87	-0.096	2.175
FB tot: Trees 10≤DBH<20cm	58	78	591	0.80	-1.103	2.436
FB tot: Trees 5≤DBH<10cm	113	11	331	0.71	-1.604	2.677
Only beg DBH≥5cm	231	1.3	2,709	0.92	-3.557	2.564