



Workshop

Improving Biomass Estimation Methods for the Amazon

15-16 de Outubro de 2015, São José dos Campos, Brasil

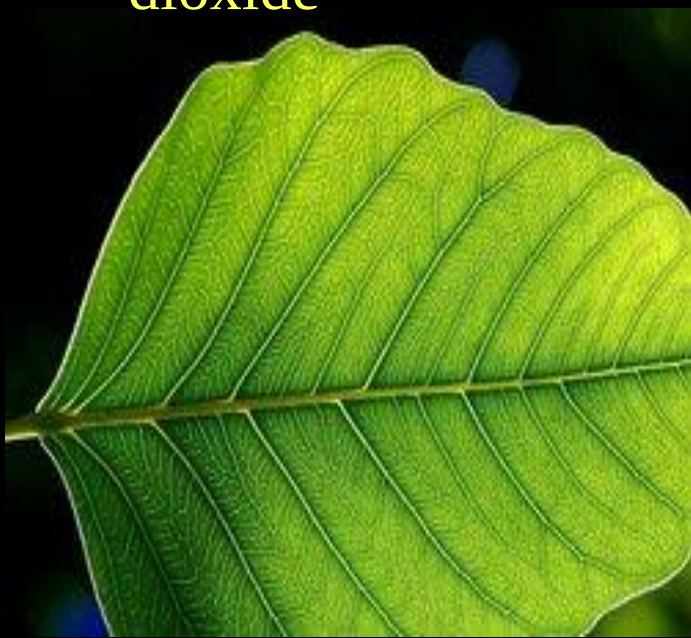
“Components of forest biomass in the quantification of total carbon stocks in Tropical Forests”

Simone Vieira

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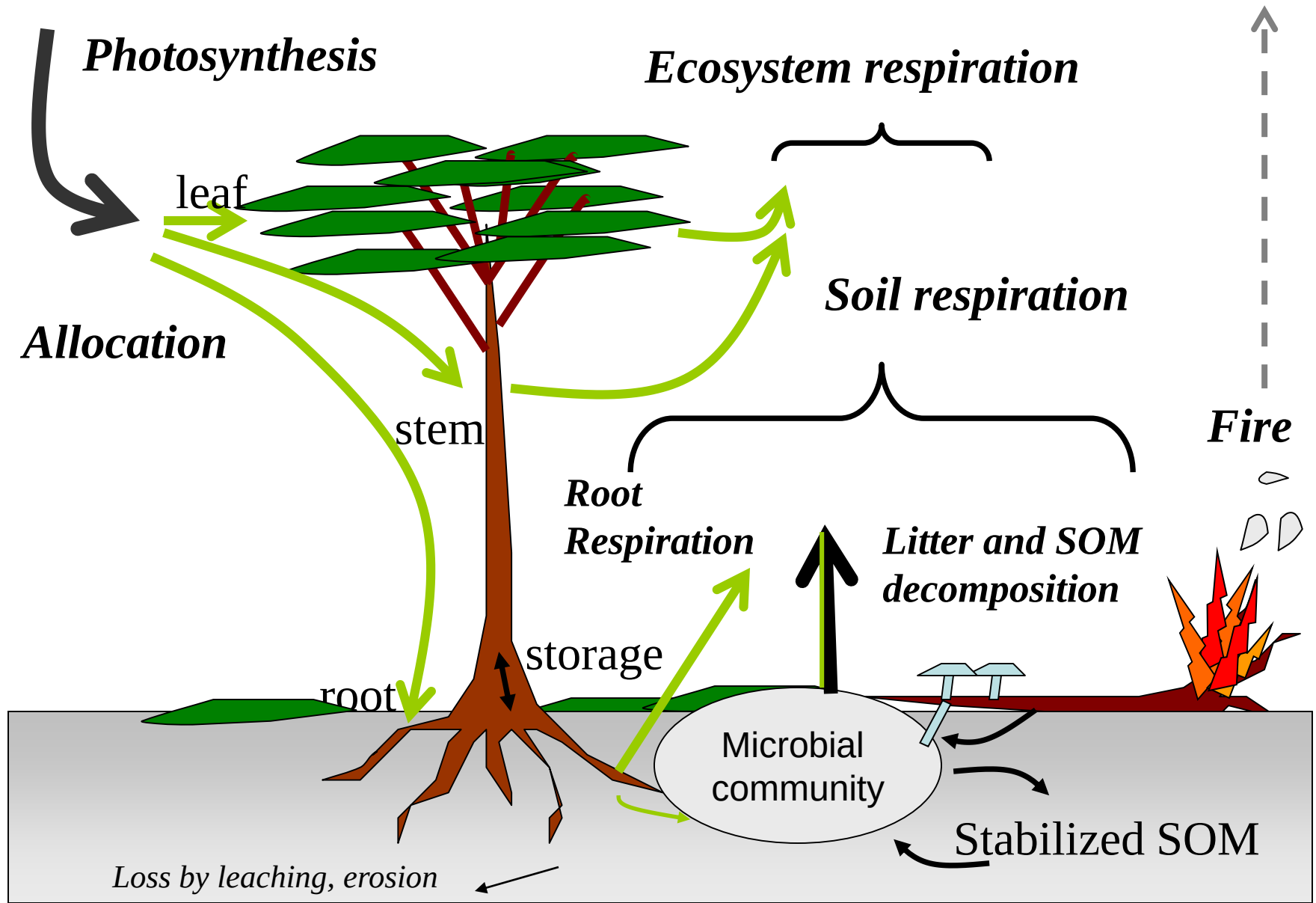


Photosynthesis → ← Respiration



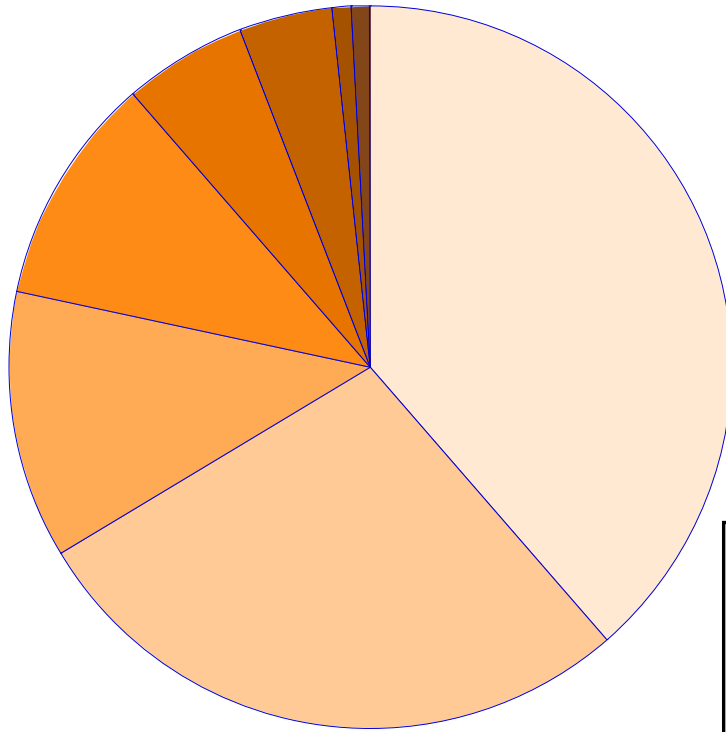
**If Photosynthesis exceeds Respiration,
Carbon dioxide will decrease and carbon is stored in
the ecosystem**

Carbon fixed by photosynthesis allocated to growth can store C for varying periods of time



Carbon Pools in Central Amazon Forest

Data from above and below-ground harvest of trees including roots and published soil organic matter studies.

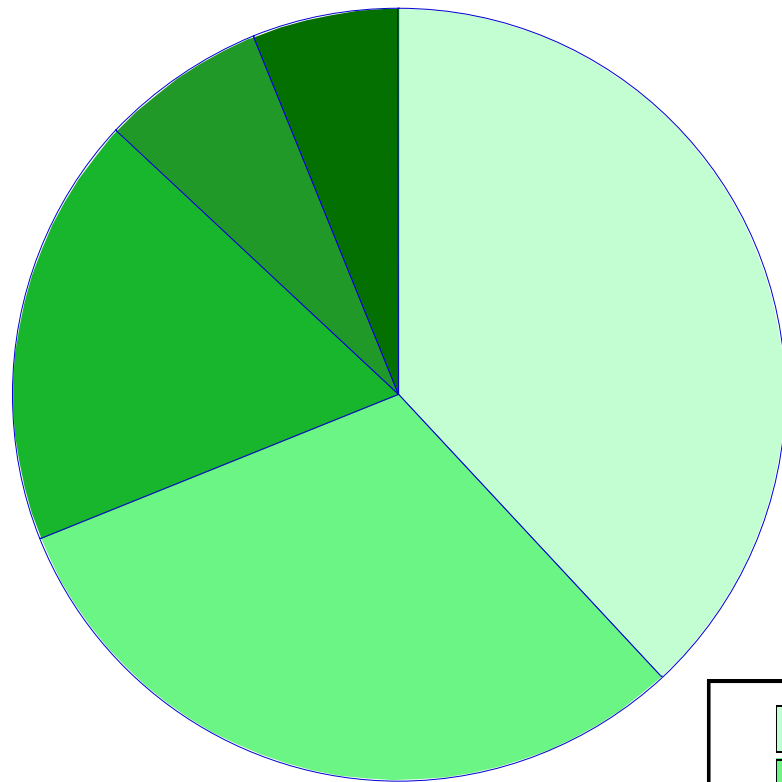


Carbon Storage

- large wood (39%)
- soil (28%)
- fine wood (12%)
- fine roots (10%)
- coarse roots (6%)
- coarse litter (4%)
- leaves etc. (1%)
- fine litter (1%)

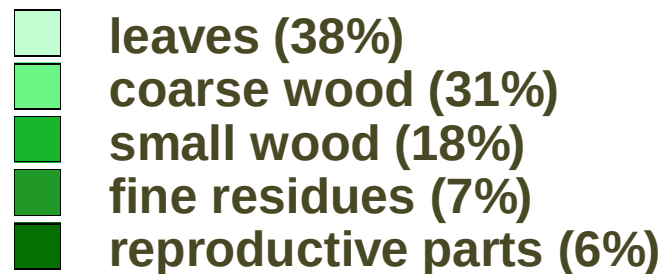
Wood can store a large amount of carbon – but for how long?

Partitioning of NPP in Central Amazon Forest



....and the allocation of net primary production (NPP) to determine the residence time and the capacity for sequestering carbon

Above-Ground NPP



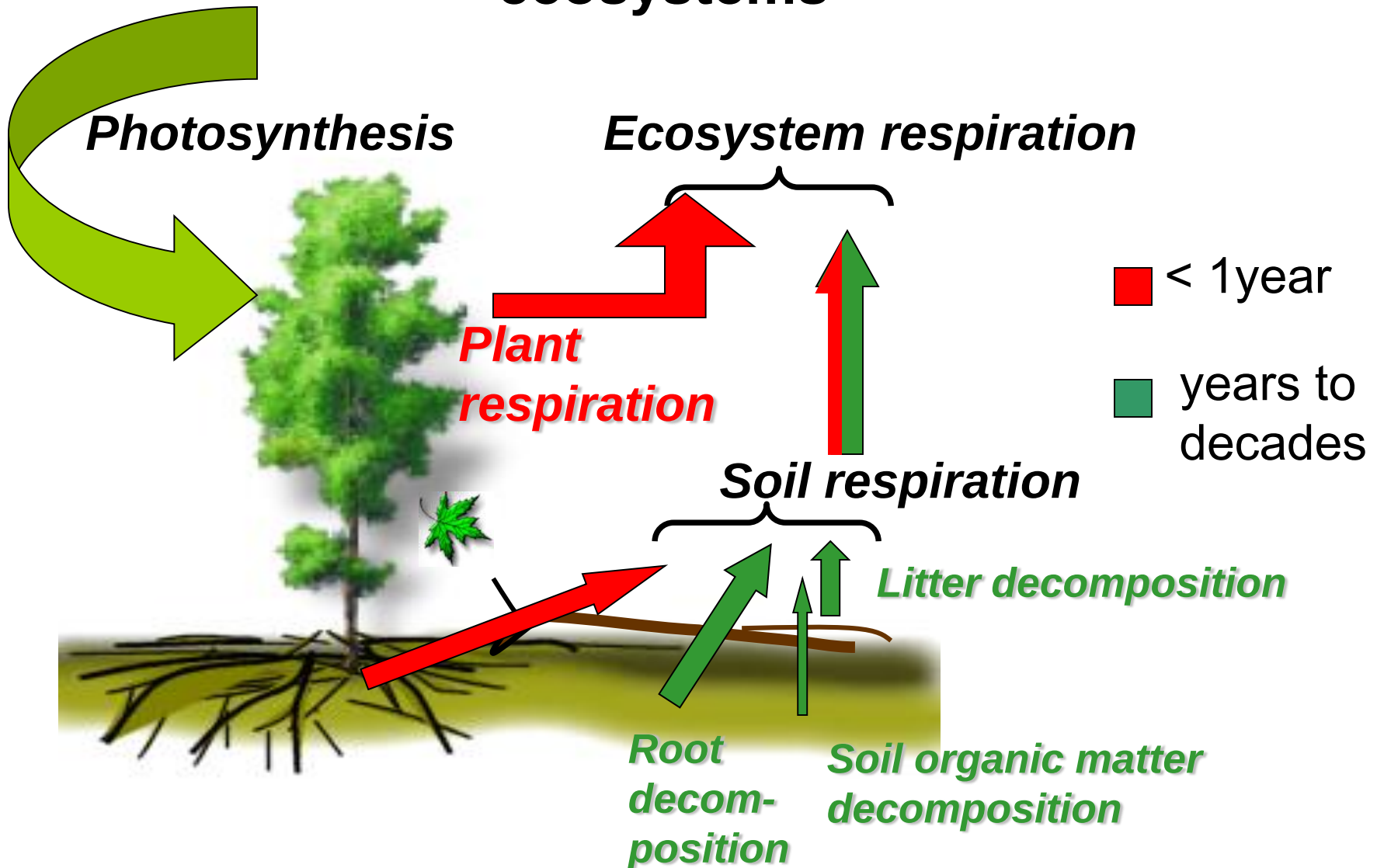
Only large wood and SOM have a high capacity to sequester carbon for long periods of time.

Concentrate on C pools with the greatest potential response on interannual to decadal timescales:

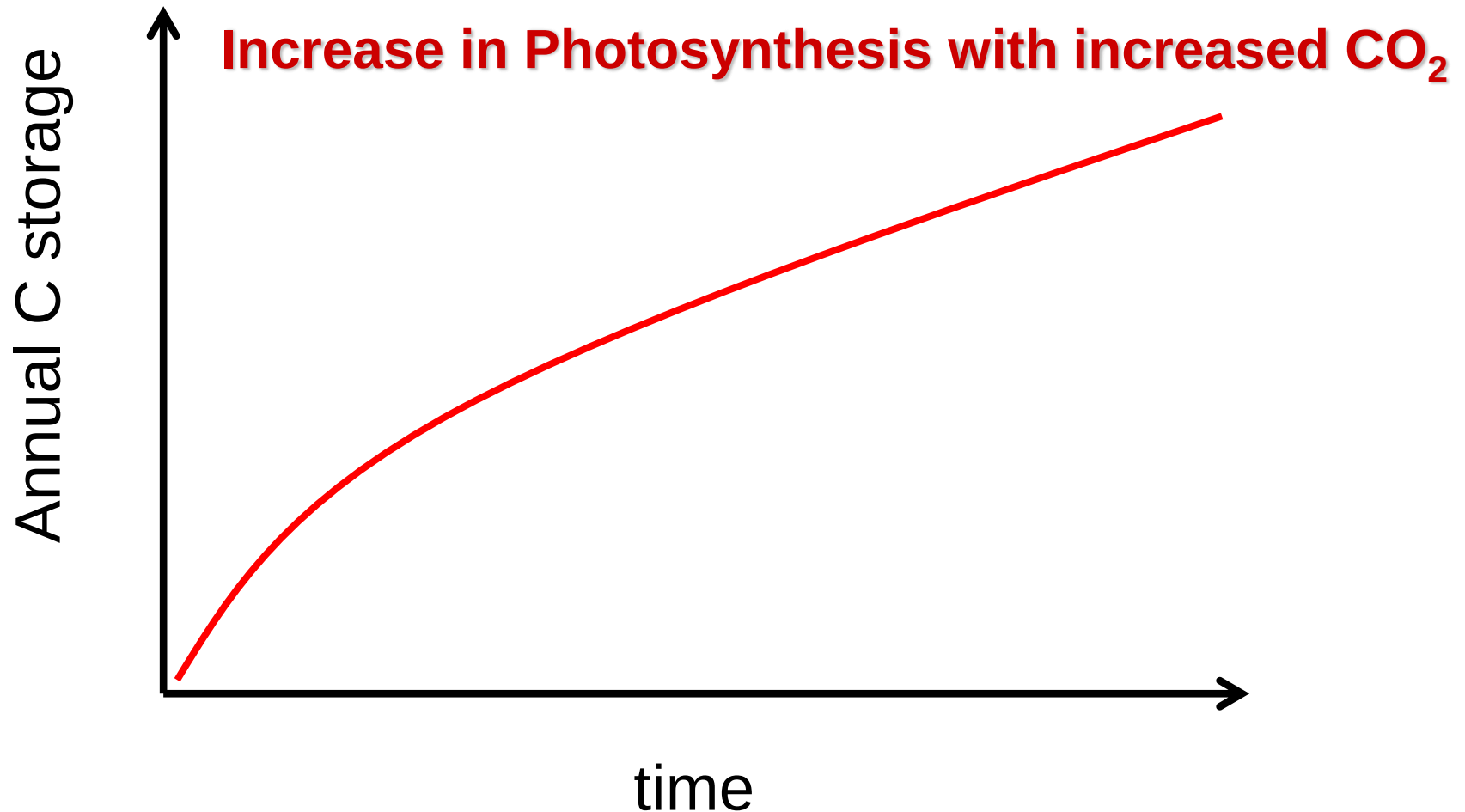
(1) Wood - Slow growth rates mean low C allocation and long residence times

(2) Age of C respired from soils – reflects the ‘fast-cycling’ C pools in litter and soil organic matter

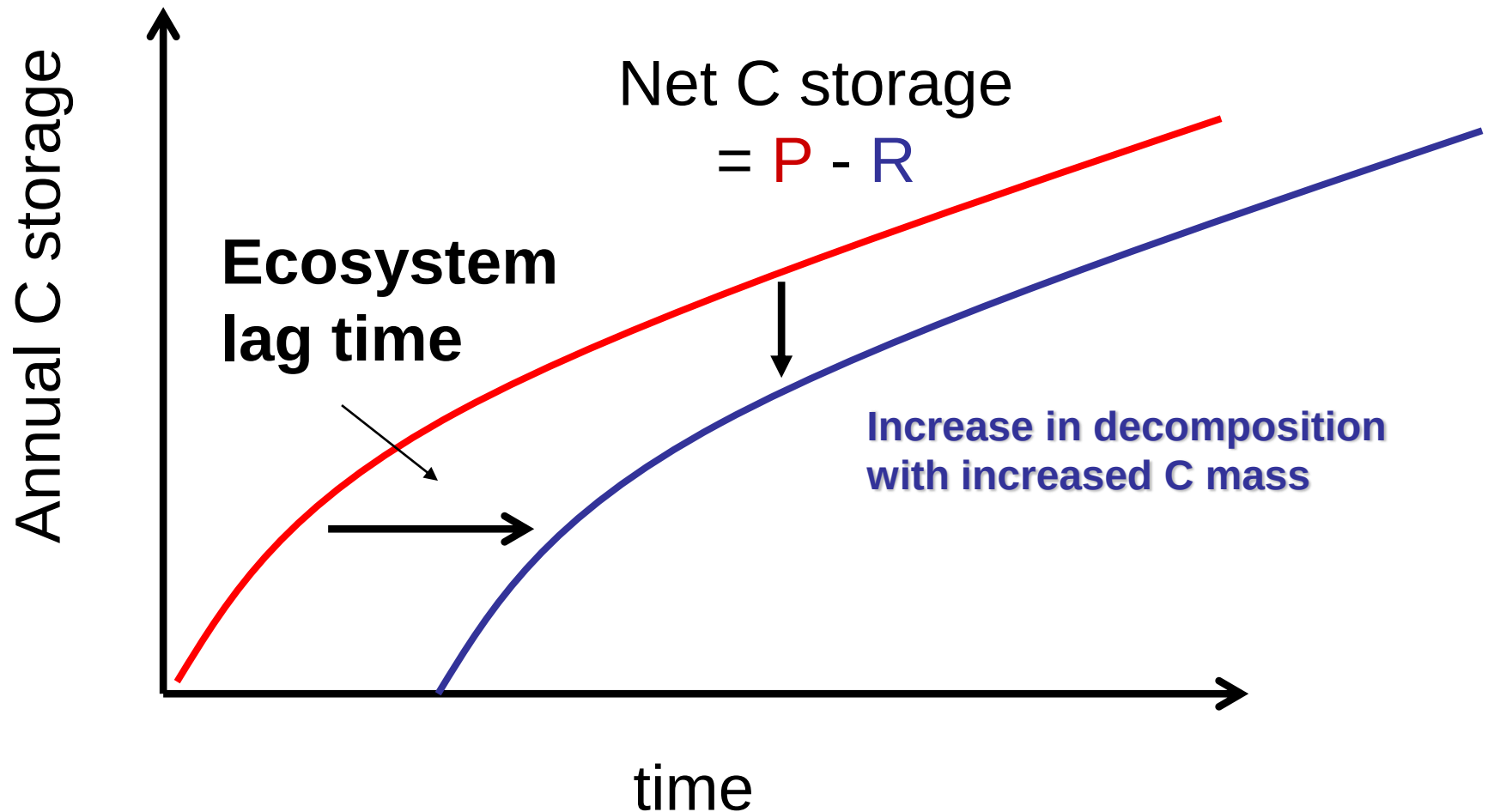
Movement of Carbon through terrestrial ecosystems



The importance of time lags in determining the capacity of an ecosystem to be a sink of carbon



Rate of C storage = f(flux, residence time)



Questions –

What is the capacity for these forests to store C?
Where could it be stored and for how long?

Trees

How old are tropical trees?

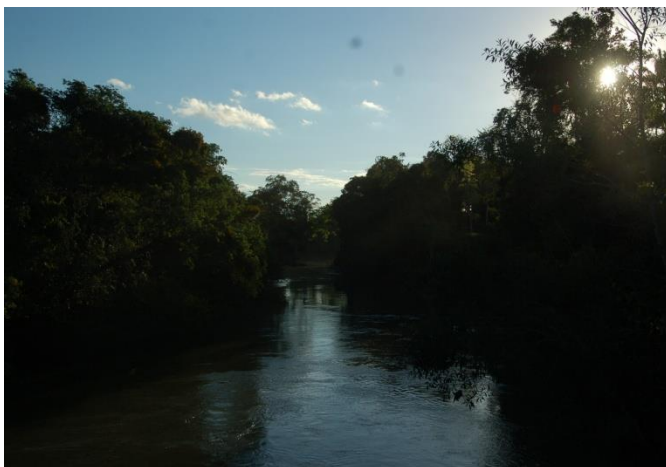
How fast do they grow?

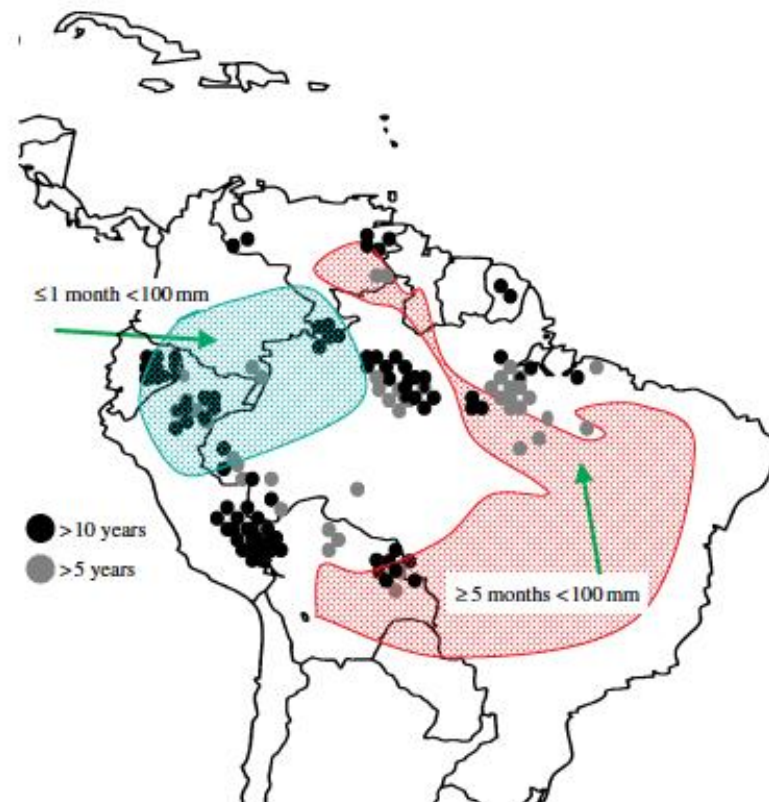
How long do they store carbon?

How do characteristics vary across the Amazon basin?

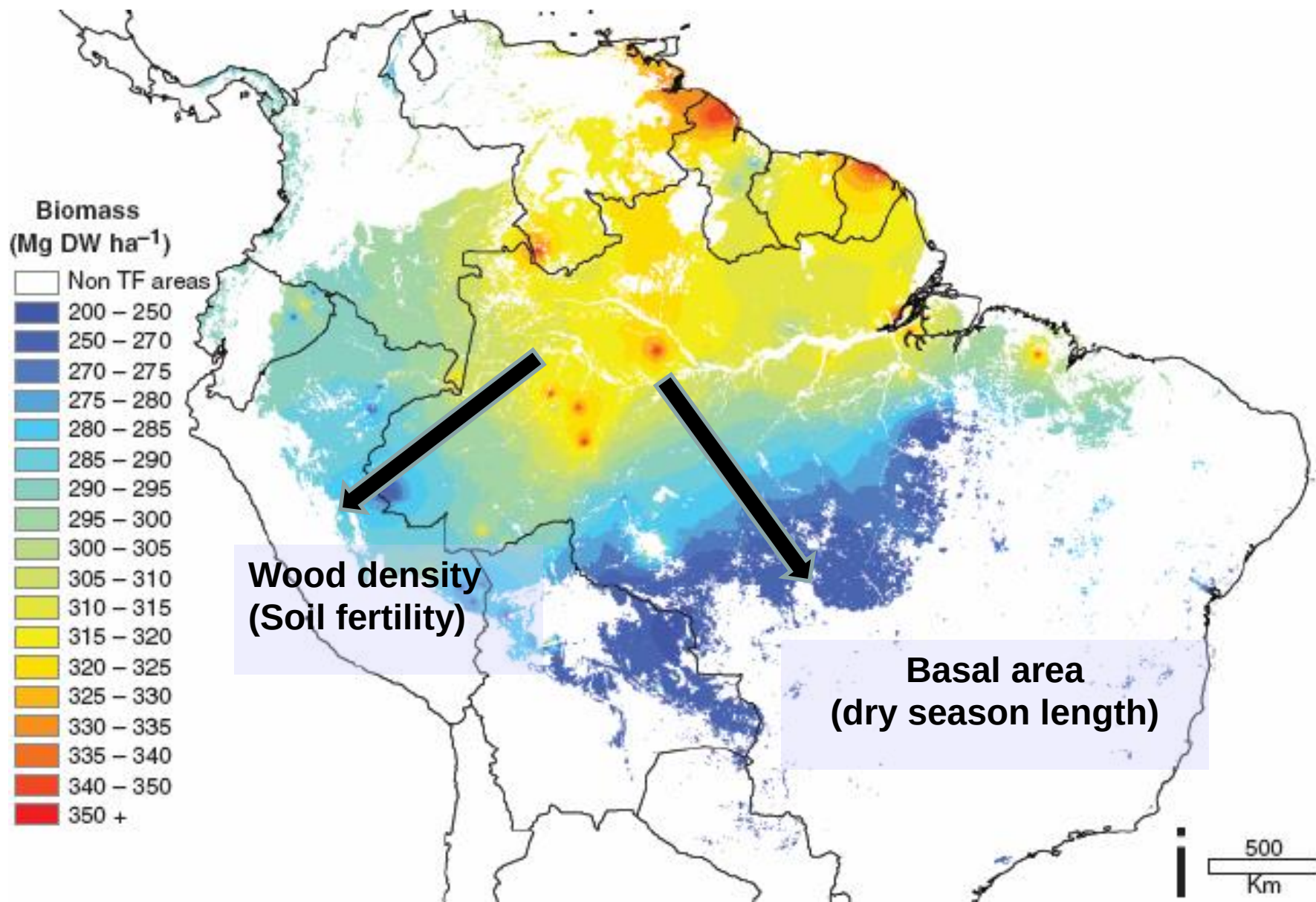


Differences between forests





Above-ground biomass



Malhi et al. GCB (2006)

**Measurement of
tree diameter
during
establishment of
permanent plot**



Summary of floristic attributes

Diversity index	Manaus	Rio Branco	Santarém
Number of individuals per hectare	626	466	460
Number of Families in plot area	52	40	52
Number of Species in plot area	232	164	265
Number of species per hectare	163	127	133
Shannon-Wiener diversity index	4,67	4,42	4.37
Jentsch coefficient	1/8	1/6	1/9
Simpson index	0,02	0,02	0.04
Pielou index	0.86	0.87	0.78
Jaccard similarity index	0,06*	0,05**	0.11***

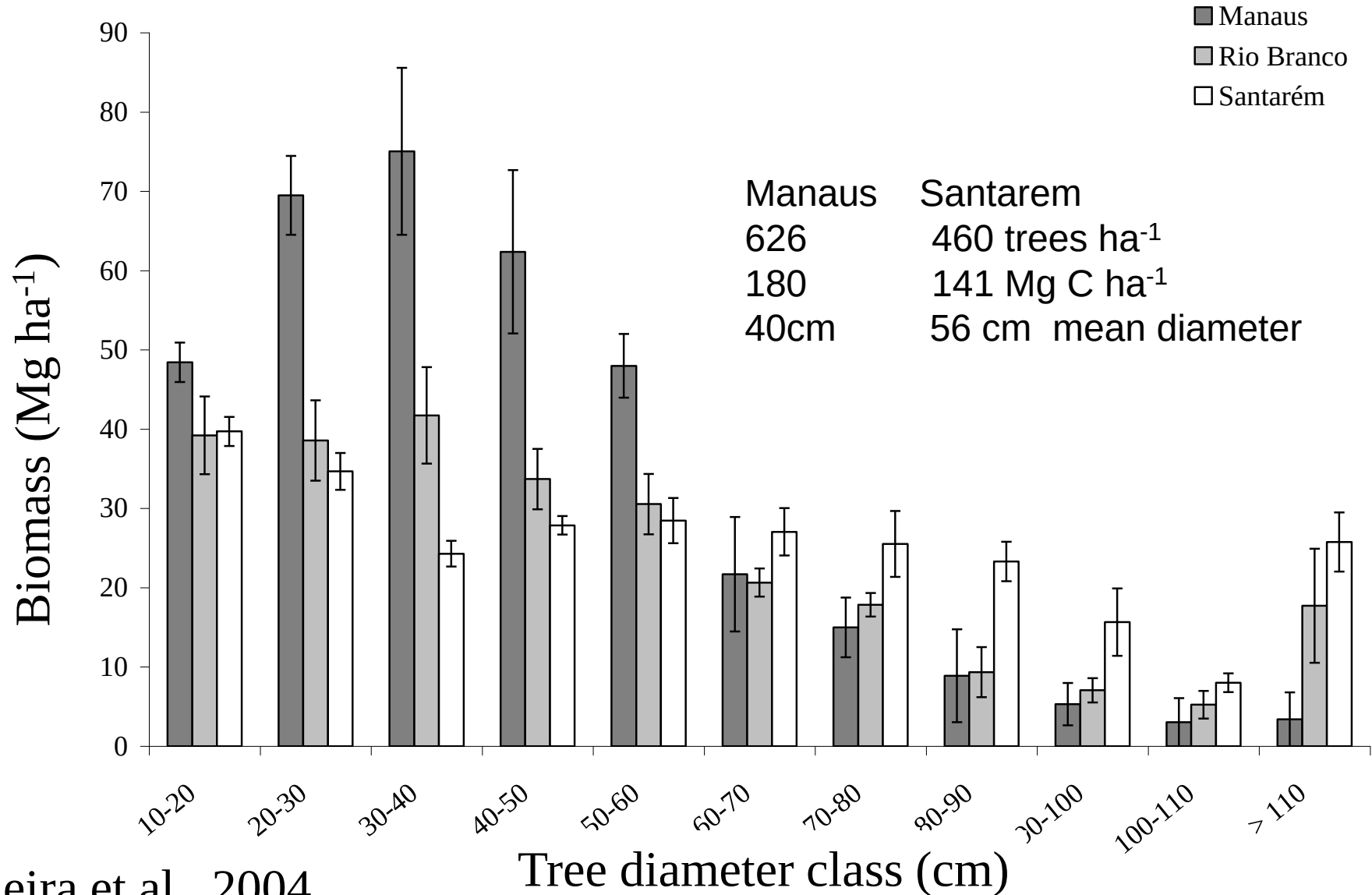
* Similarity Manaus-Santarém

** Similarity Rio Branco-Manaus

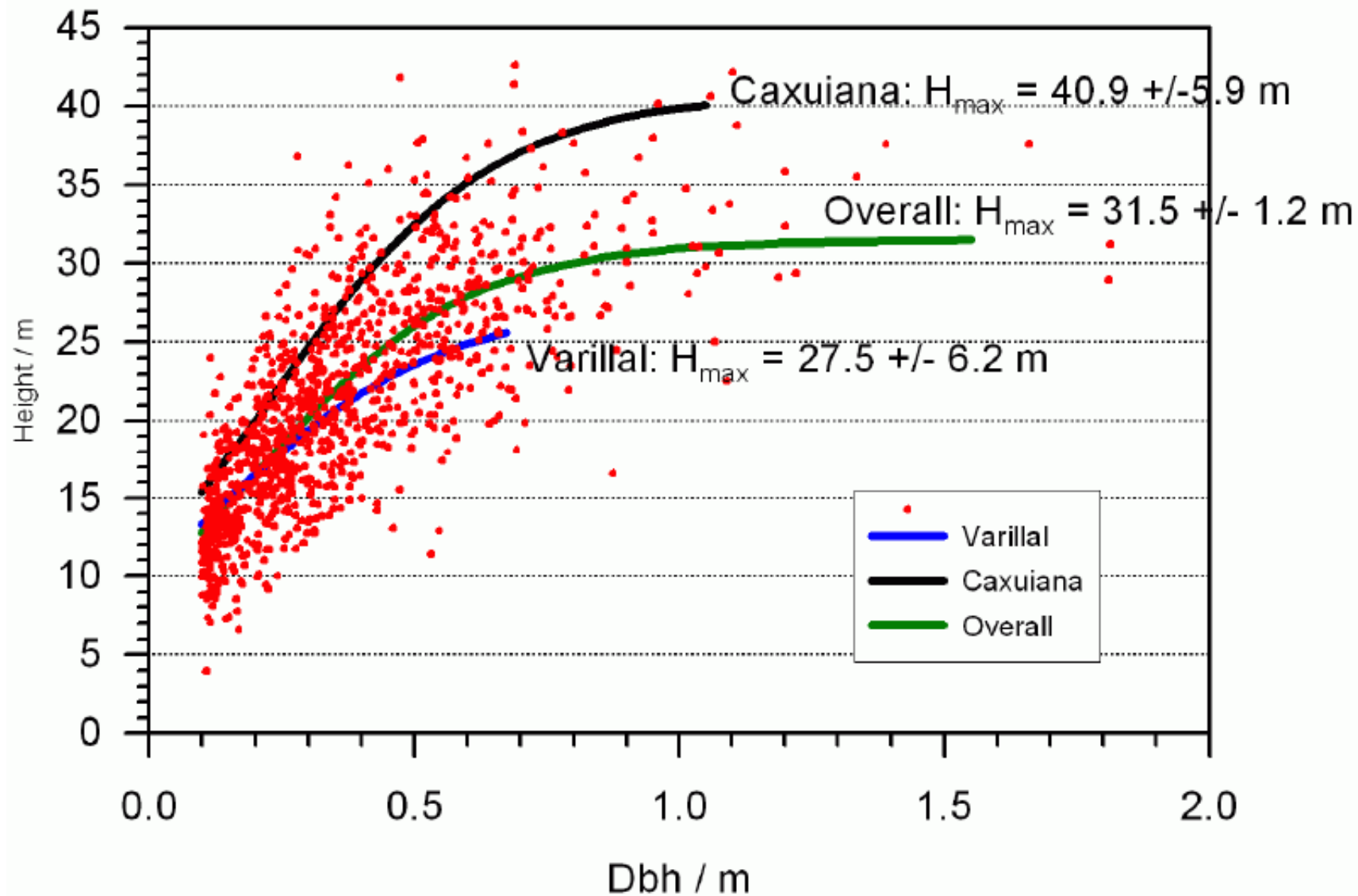
*** Similarity Santarém-Rio Branco

Not all forests in the Amazon are equal

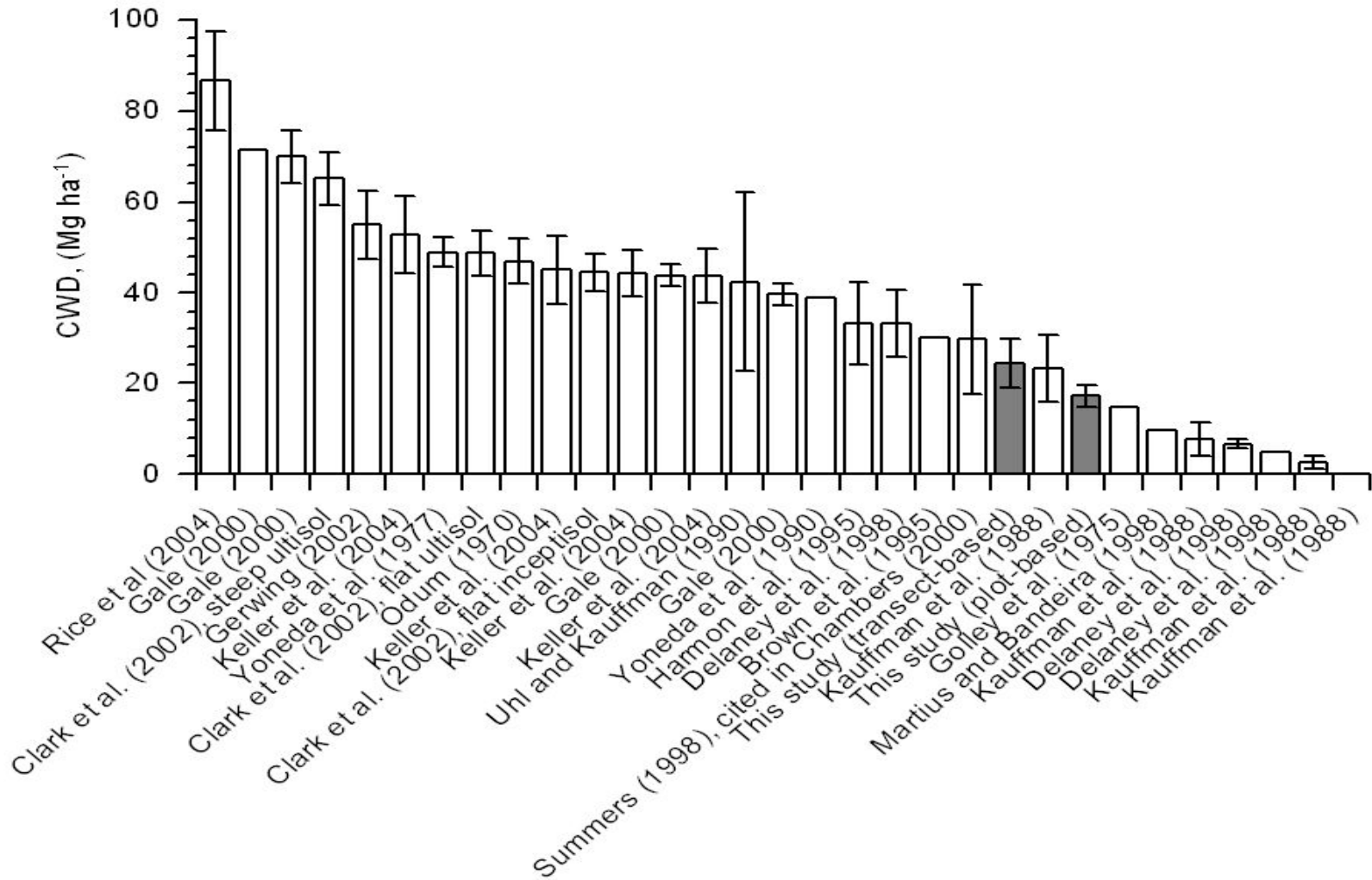
Manaus has more biomass overall, in smaller trees, than sites with a more pronounced dry season



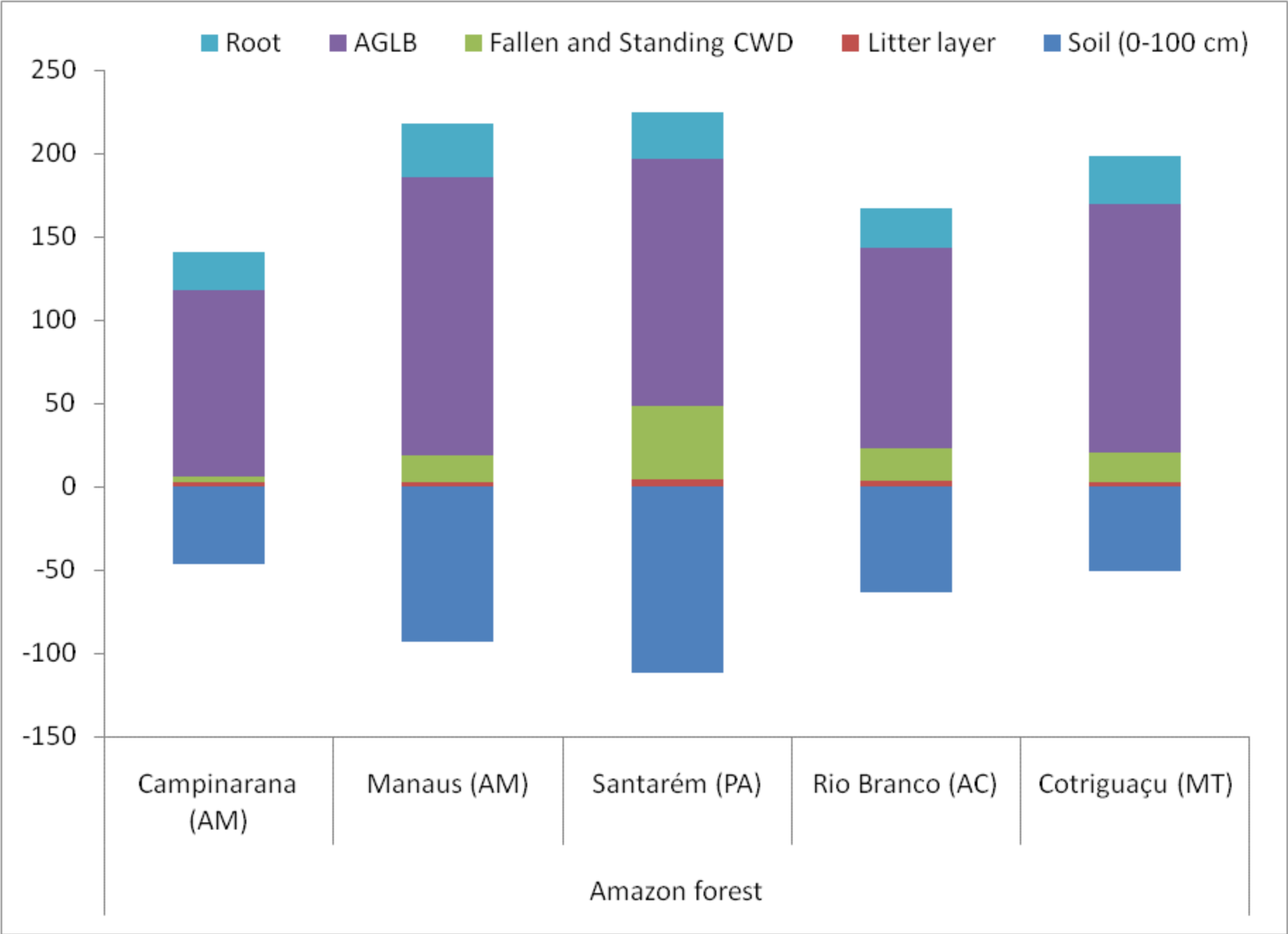
DBH and Height



Coarse woody debris stocks in tropical forests

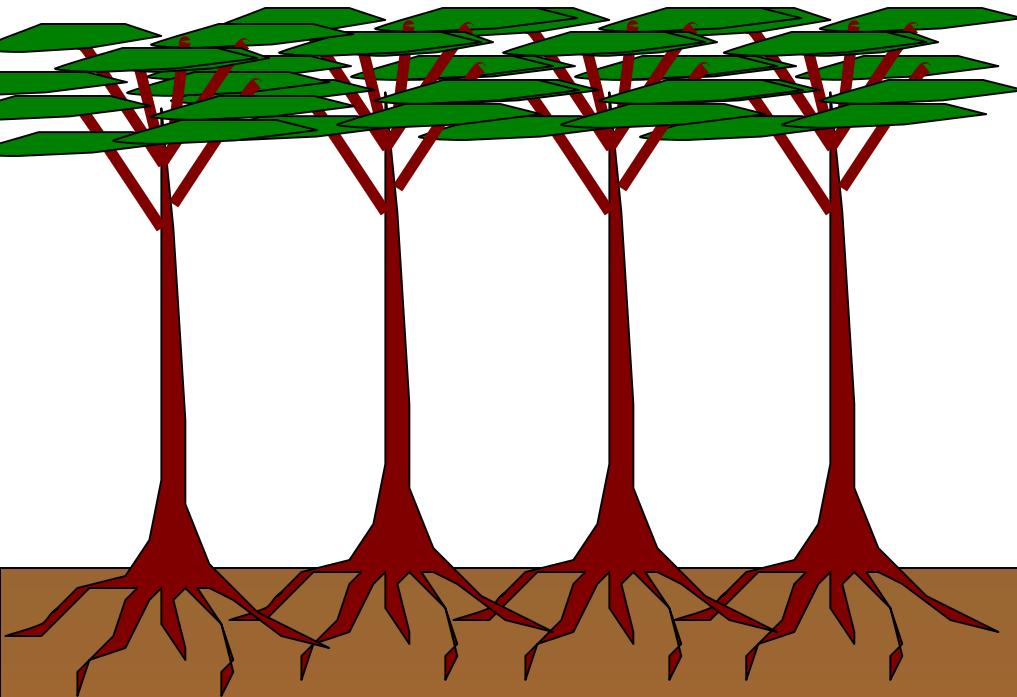


CWD stocks are variable, and up to 33 % of the above-ground biomass stock!



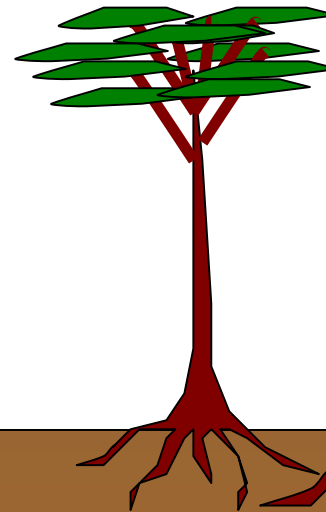
C dynamics differ with forest location

Manaus



Individuals/ha	626
Biomass C MgC/ha	180
Growth MgC/ha/yr	1.6-2.1
Mean age of C (yr)*	260
MRT of C (stock/growth)**	114

Santarém



460

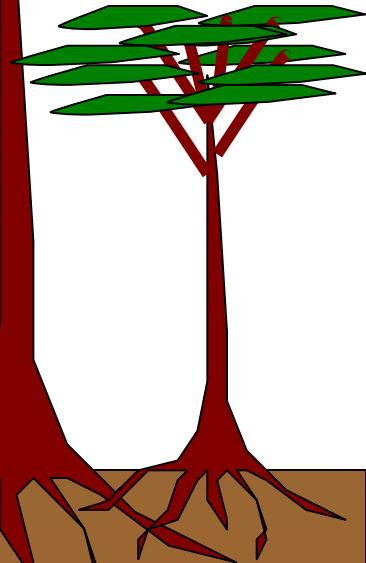
141

2.2 -3.0

220

74

Rio Branco



466

95

3.3-3.4

240

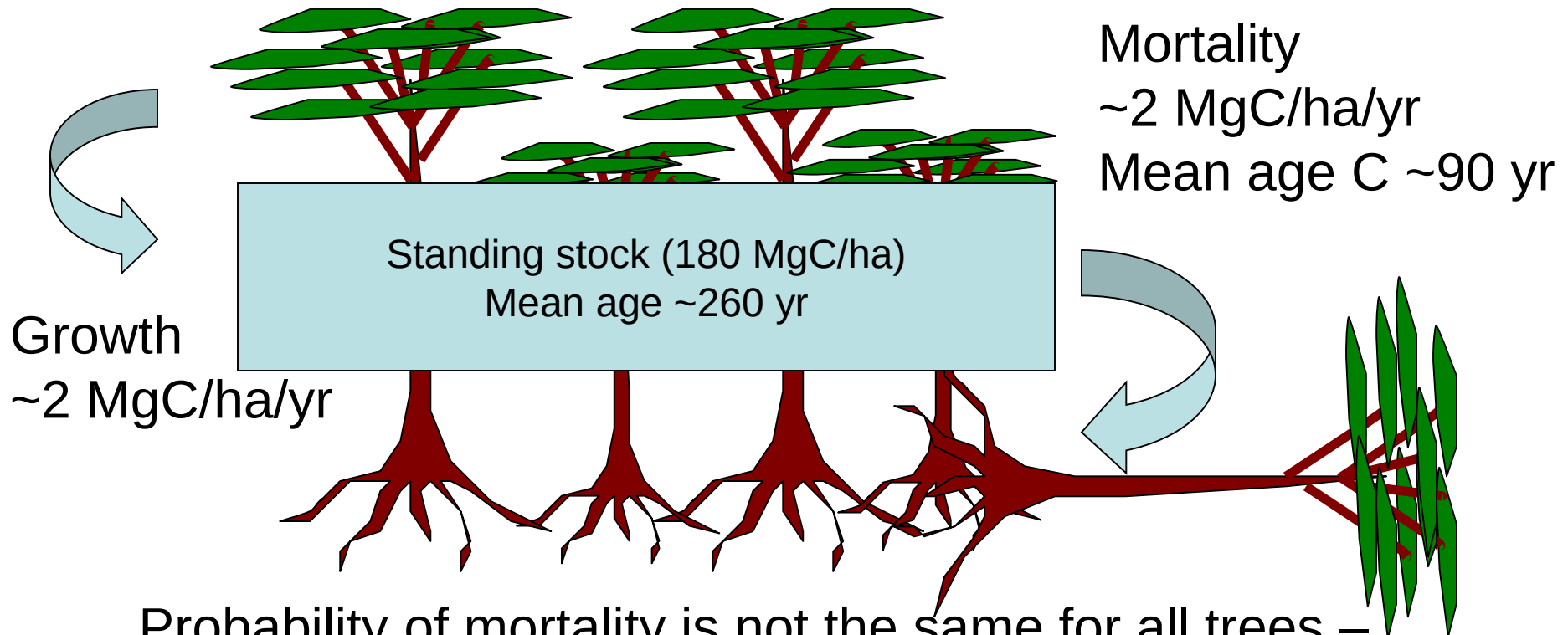
53

* From monte carlo simulations

**biomass-weighted

Data from Vieira et al. 2004

How can MRT of C in wood be less than the mean age of C in standing wood?



Probability of mortality is not the same for all trees –
younger, or faster growing, trees tend to die more frequently
Need better understanding of what causes tree mortality

Changes in the Carbon Balance of Tropical Forests: Evidence from Long-Term Plots

Oliver L. Phillips,* Yadvinder Malhi,* Niro Higuchi,
William F. Laurance, Percy V. Núñez, Rodolfo M. Vásquez,
Susan G. Laurance, Leandro V. Ferreira, Margaret Stern,
Sandra Brown, John Grace

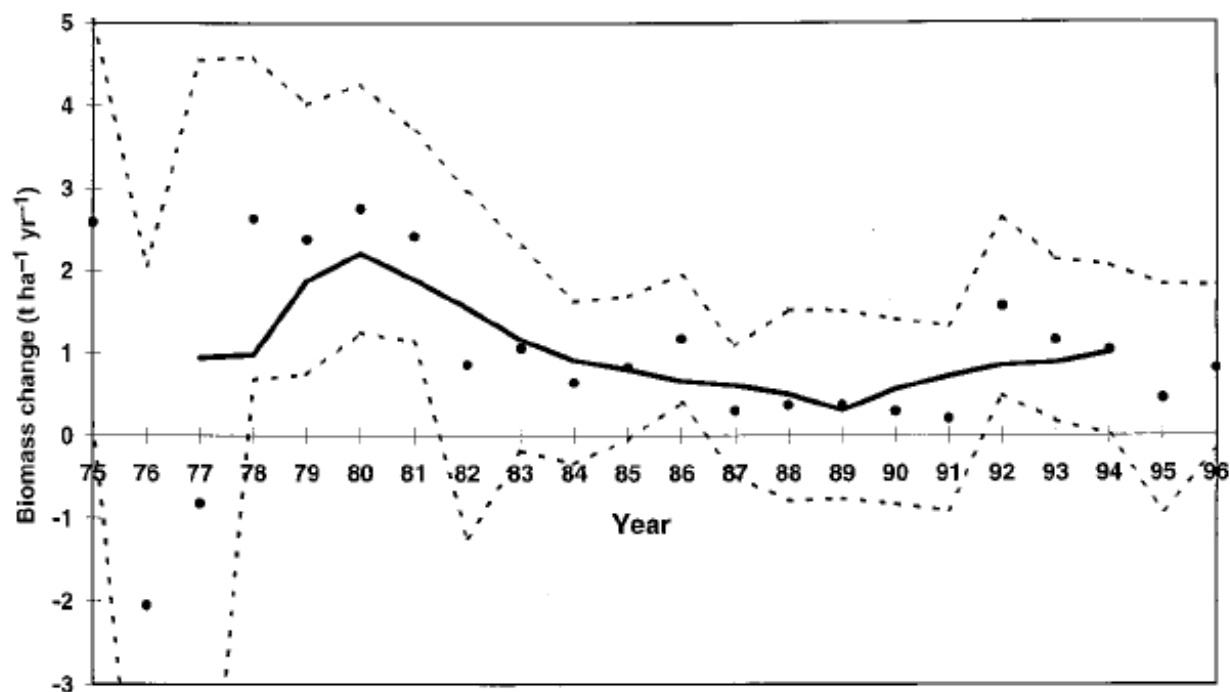


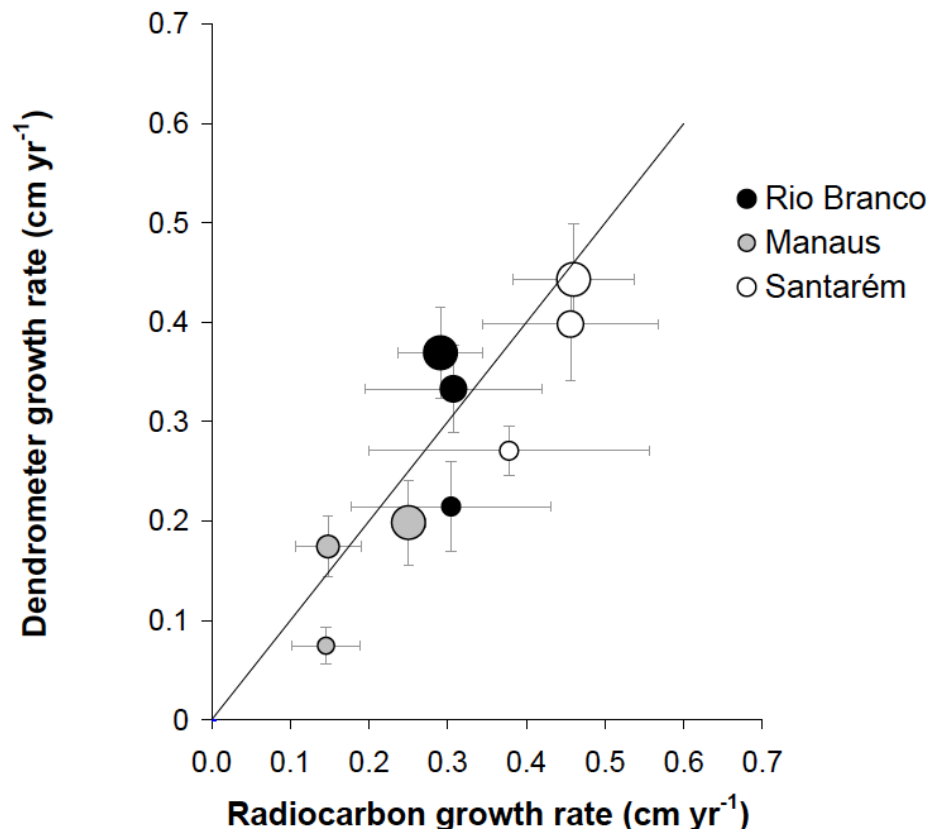
Fig. 1. Annual aboveground biomass change in Amazonian forests, 1975–96. Mean (solid circles), 95% confidence intervals (dotted line), and 5-year moving average (solid line) are shown.

Slow growth rates of Amazonian trees: Consequences for carbon cycling

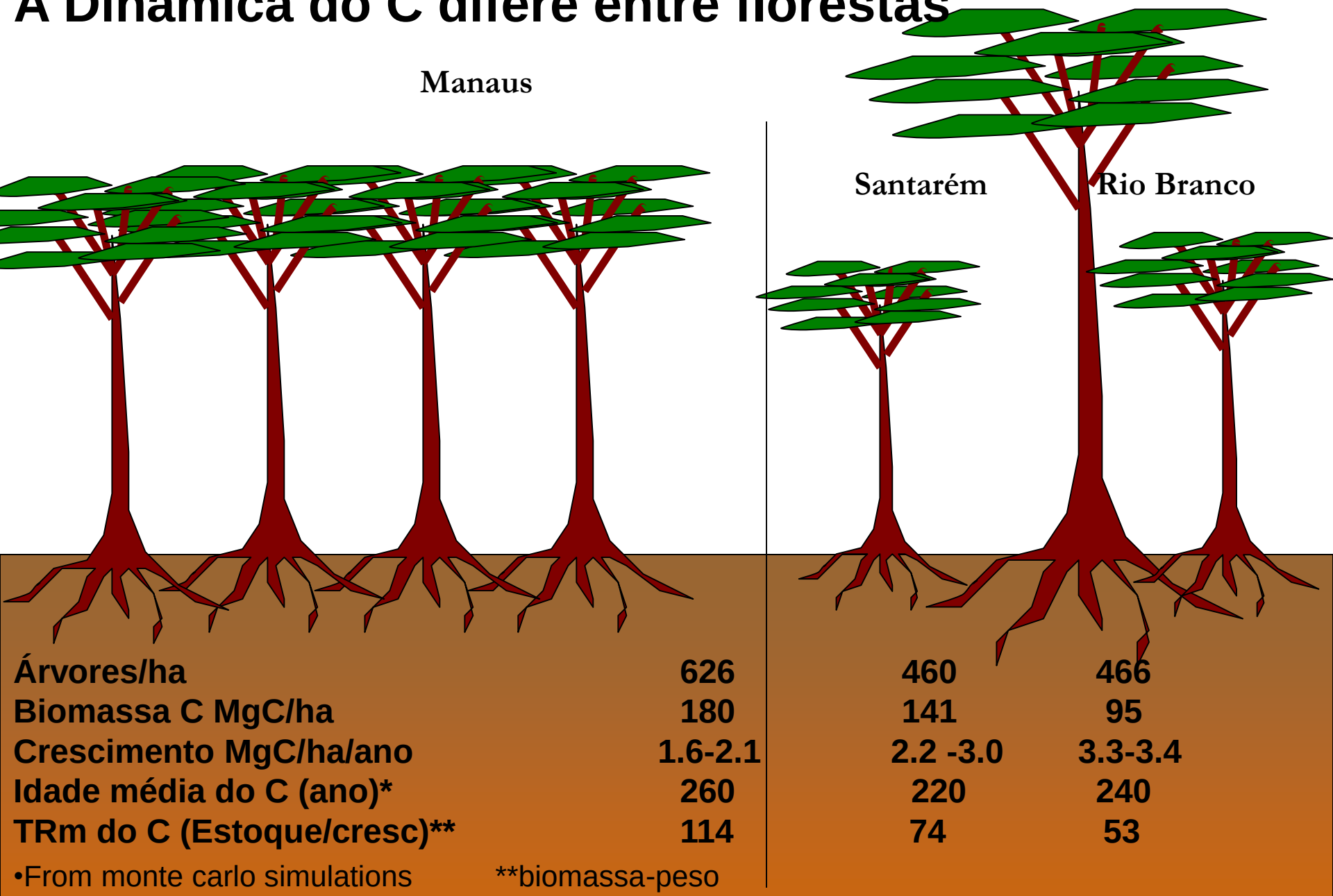
Simone Vieira^{†‡}, Susan Trumbore[§], Plinio B. Camargo[†], Diogo Selhorst[¶], Jeffrey Q. Chambers^{||}, Niro Higuchi^{††},
and Luiz Antonio Martinelli[†]

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Edited by Christopher B. Field, Carnegie Institution of Washington, Stanford, CA, and approved October 20, 2005 (received for review July 21, 2005)



A Dinâmica do C difere entre florestas



Dados de Vieira et al. 2004

Increasing dominance of large lianas in Amazonian forests

Oliver L. Phillips*, Rodolfo Vásquez Martínez†, Luzmila Arroyo‡\$, Timothy R. Baker*, Timothy Killeen‡\$, Simon L. Lewis*, Yadvinder Malhi¶, Abel Monteagudo Mendoza†#, David Neill☆☆, Percy Núñez Vargas#, Miguel Alexiades††, Carlos Cerón‡‡, Anthony Di Fiore§§, Terry Erwin|||, Anthony Jardim\$, Walter Palacios☆, Mario Saldias\$ & Barbara Vinceti¶

NATURE | VOL 418 | 15 AUGUST 2002 | www.nature.com/nature

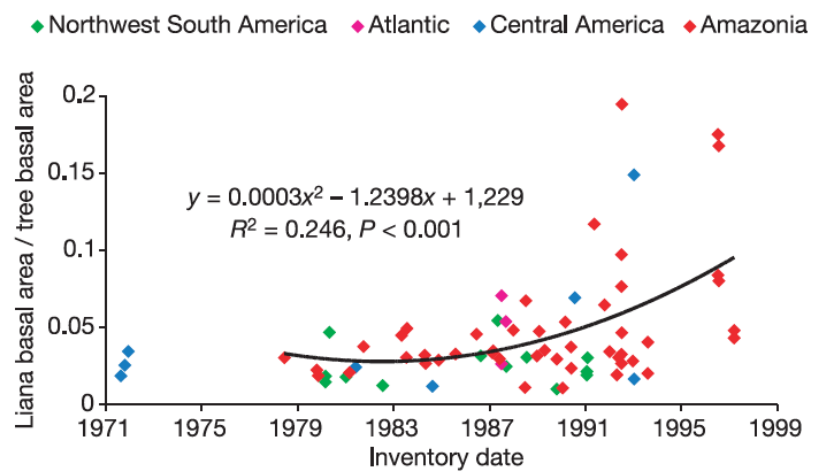
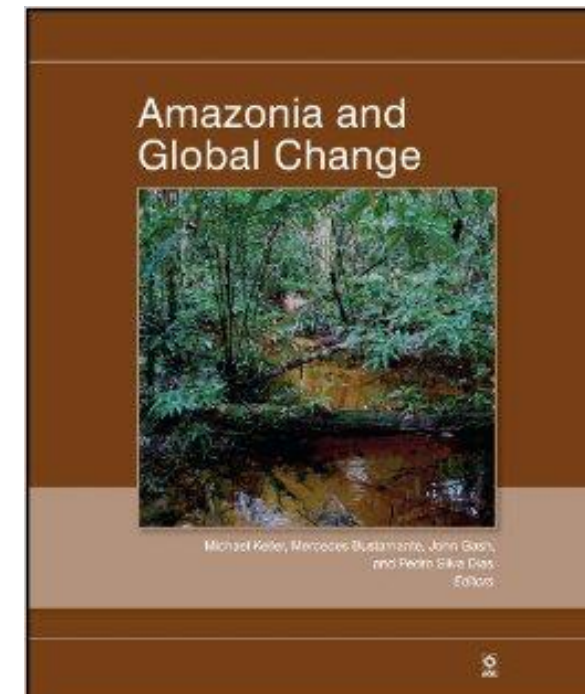
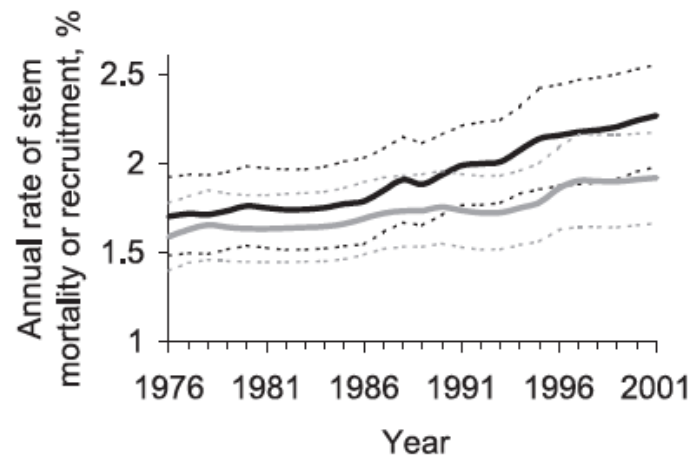


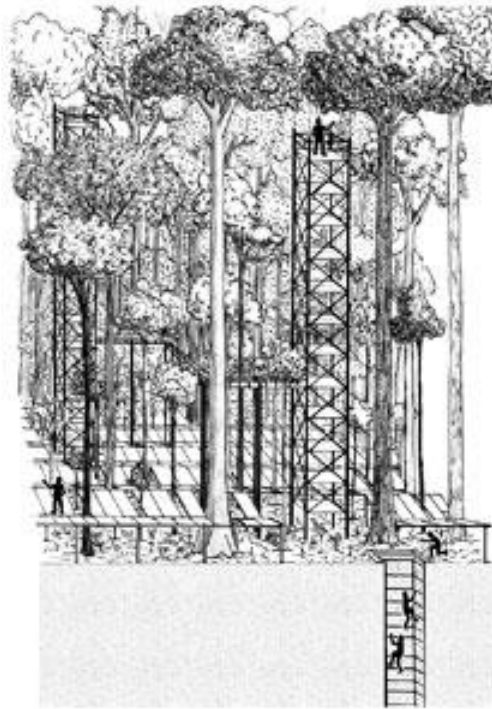
Figure 3 Relative dominance of lianas in neotropical 0.1-ha plots as a function of inventory date. Liana basal area is shown as a fraction of tree basal area for all stems over 2.5 cm in diameter. A polynomial curve is fitted for the Amazonian sites.

Changes in Amazonian Forest Biomass, Dynamics, and Composition, 1980–2002

Oliver L. Phillips,¹ Niro Higuchi,² Simone Vieira,³ Timothy R. Baker,¹ Kuo-Jung Chao,¹ and Simon L. Lewis¹



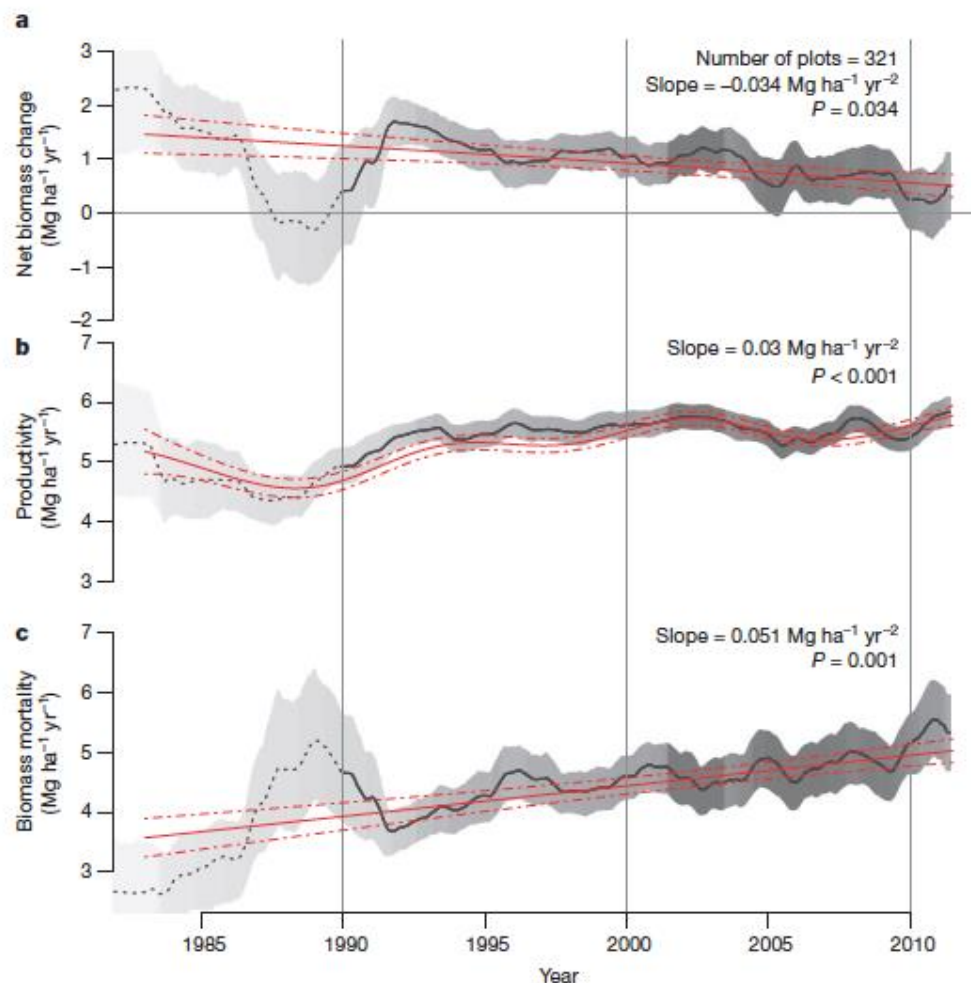
Mortalidade de Árvores Grandes é **Rápida**, enquanto que Crescimento é **Lento**

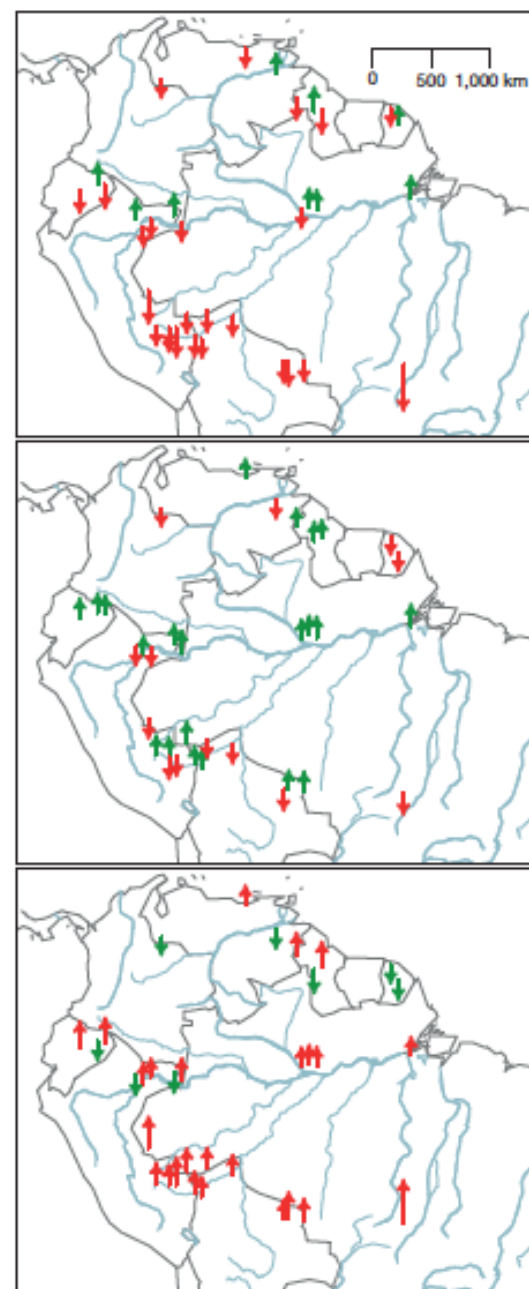
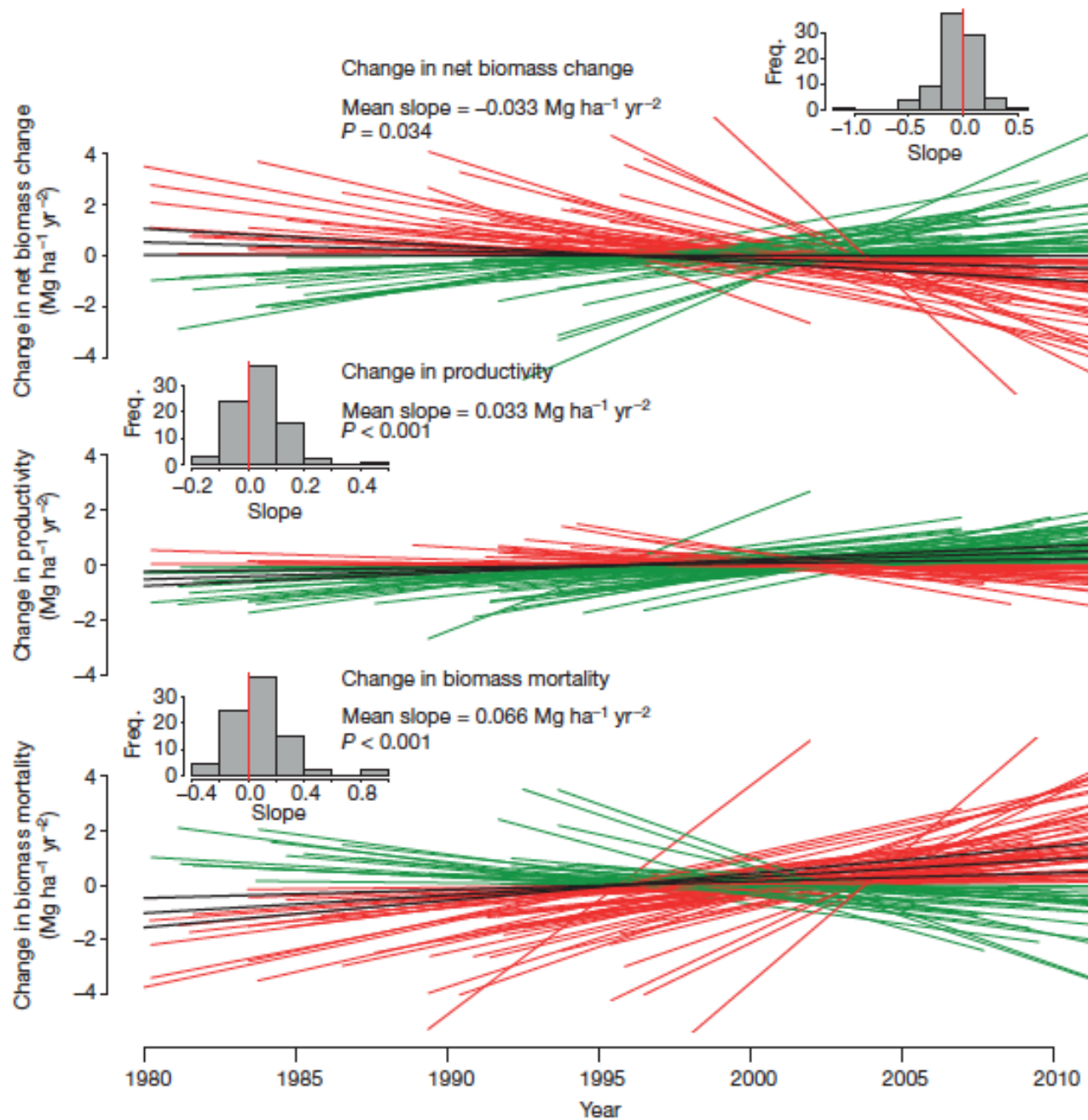


Nepstad et al. 2007. Mortality of large trees and lianas following experimental drought in an Amazon forest. *Ecology*. 2007 Sep;88(9):2259-69.

Long-term decline of the Amazon carbon sink

A list of authors and their affiliations appears at the end of the paper





ARTICLE

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OPEN

Hyperdominance in Amazonian forest carbon cycling

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Table 1 | Hyperdominance of stem abundance and carbon cycling in the Amazon.

	Full data set				Productivity data set				
	Plots	Species	No. of hyperdominants (%)		Plots	Species	No. of hyperdominants (%)		
			Stems	Biomass			Stems	Biomass	Productivity*
Amazon-wide	530	3,458	283 (8.2)	182 (5.3)	221	2,965	250 (8.4)	160 (5.4)	184 (6.4)
Northwestern	123	1,632	199 (12.2)	170 (10.4)	33	1,412	162 (11.5)	138 (9.8)	115 (8.4)
Southwestern	169	1,330	60 (4.5)	64 (4.8)	59	1,185	62 (5.2)	62 (5.2)	66 (5.8)
Guiana Shield	116	1,262	131 (10.4)	62 (4.9)	49	748	92 (12.3)	36 (4.8)	52 (7.1)
East-Central	69	1,386	157 (11.3)	101 (7.3)	56	1,317	152 (11.5)	96 (7.3)	117 (9.1)
Brazilian Shield	53	890	82 (9.2)	55 (6.2)	26	698	39 (5.6)	23 (3.3)	30 (4.5)

Number and percentage of species that contribute 50% of stem numbers, aboveground biomass and aboveground productivity for the whole data set and split by region.
*If a tree dies before the second census, it will contribute to biomass and stems but will not have a productivity value, hence the percentage value is calculated from a slightly smaller total number of species (2,883).

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Table 2 | Top 20 most dominant species by aboveground woody biomass.

Family	Species	Biomass (Mg)	% Total biomass	Cumulative % biomass	Rank by stem abundance	Rank by productivity*
Fabaceae	<i>Eperua falcata</i>	2,217	1.93	1.93	8	8
Lecythidaceae	<i>Eschweilera coriacea</i>	2,142	1.87	3.80	2	2
Lecythidaceae	<i>Bertholletia excelsa</i>	1,498	1.31	5.11	243	4
Vochysiaceae	<i>Qualea rosea</i>	1,452	1.27	6.37	30	88
Lauraceae	<i>Chlorocardium rodiei</i>	1,340	1.17	7.54	71	13
Fabaceae	<i>Vouacapoua americana</i>	1,340	1.17	8.71	27	5
Goupiaceae	<i>Goupia glabra</i>	1,299	1.13	9.84	61	10
Burseraceae	<i>Tetragastris altissima</i>	908	0.79	10.64	10	6
Fabaceae	<i>Dicorynia guianensis</i>	898	0.78	11.42	56	16
Arecaceae	<i>Iriartea deltoidea</i>	847	0.74	12.16	1	1
Moraceae	<i>Pseudolmedia laevis</i>	819	0.71	12.87	4	3
Lecythidaceae	<i>Eschweilera sagotiana</i>	784	0.68	13.55	22	62
Sapotaceae	<i>Pradosia cochlearia</i>	736	0.64	14.19	176	275
Chrysobalanaceae	<i>Licania alba</i>	724	0.63	14.83	17	90
Caryocaraceae	<i>Caryocar glabrum</i>	689	0.60	15.43	149	50
Apocynaceae	<i>Aspidosperma excelsum</i>	648	0.57	15.99	74	14
Sapotaceae	<i>Pouteria guianensis</i>	625	0.54	16.54	55	53
Fabaceae	<i>Swartzia polyphylla</i>	624	0.54	17.08	203	19
Fabaceae	<i>Dicymbe altsonii</i>	623	0.54	17.62	233	9
Olacaceae	<i>Minquartia guianensis</i>	623	0.54	18.17	29	21

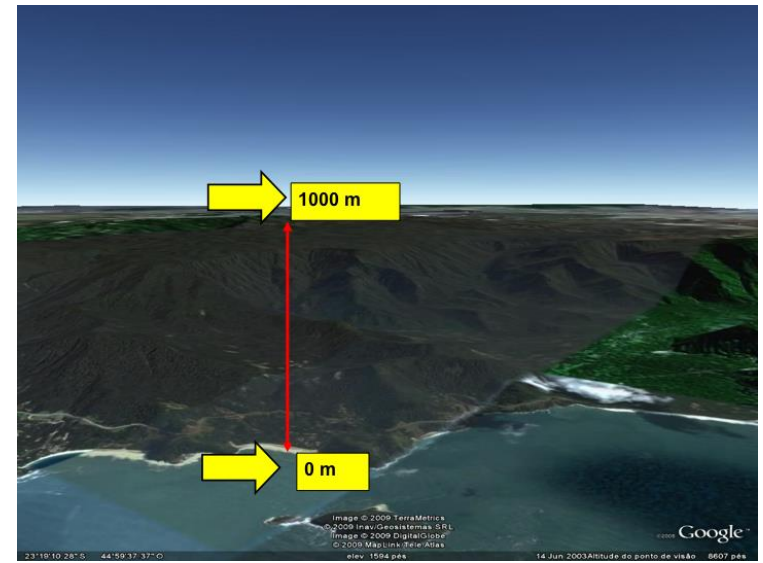
*Productivity ranks are based on the 221 plot productivity data set.

Gradient:

Latitudinal

Longitudinal

Altitudinal

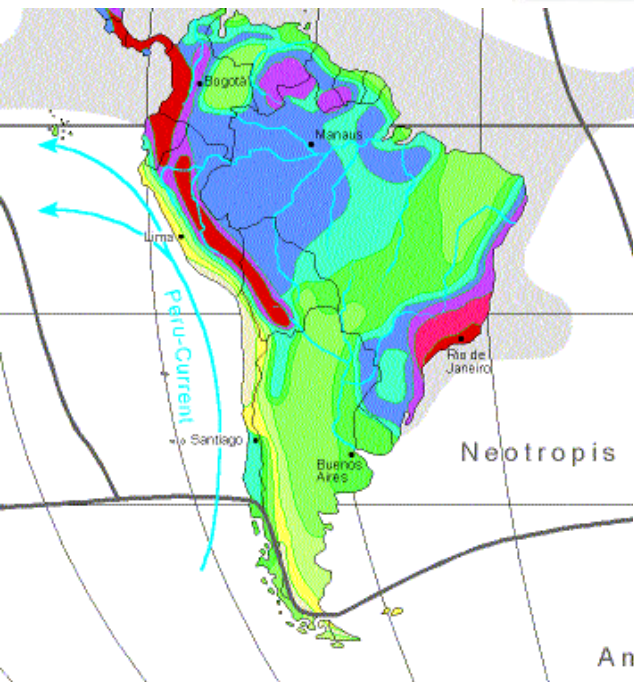
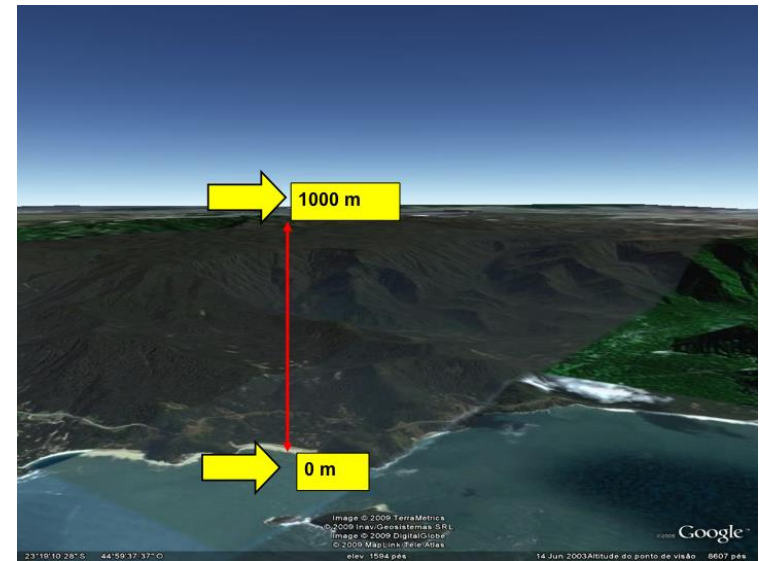


Gradiente:

Latitudinal

Longitudinal

Altitudinal



Diversity Zones (DZ): Number of species per 10.000km²

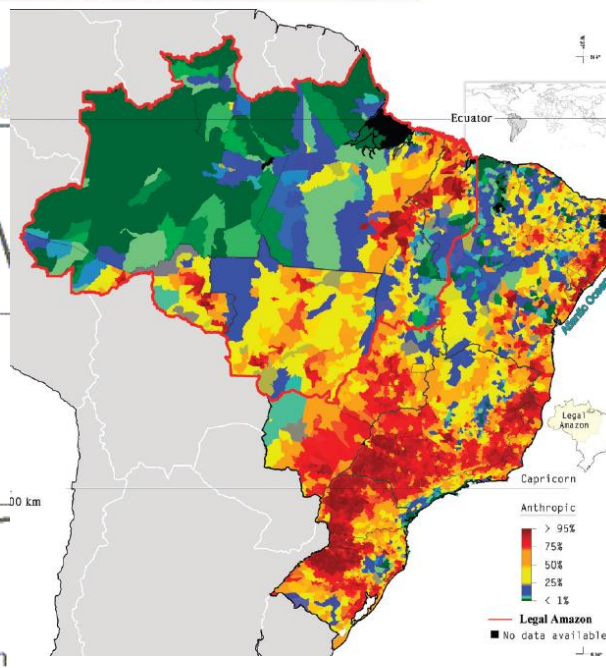
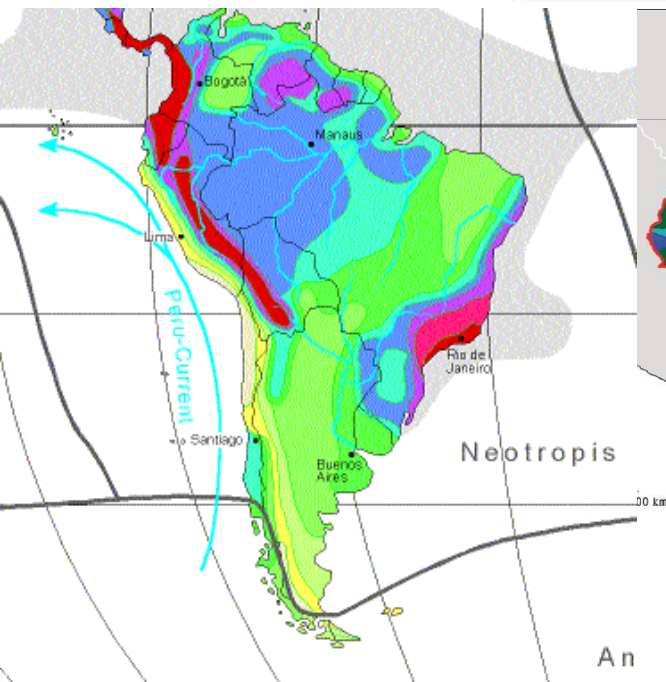
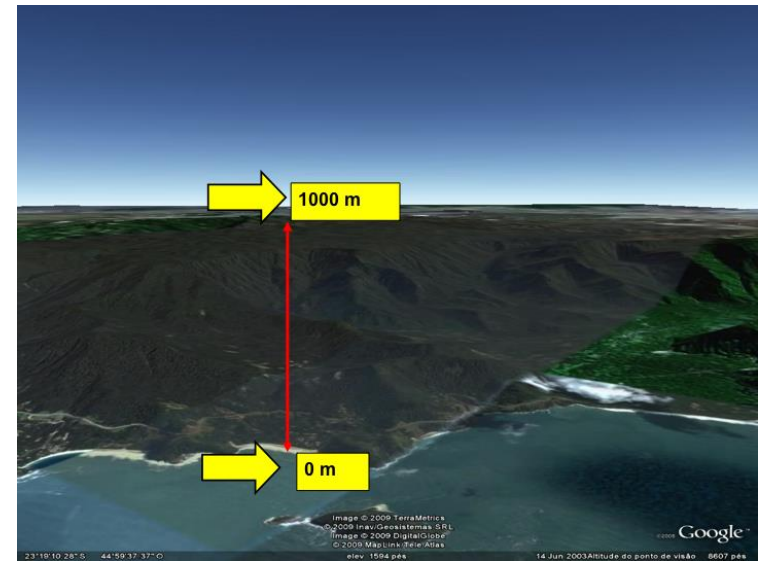


Gradiente:

Latitudinal

Longitudinal

Altitudinal

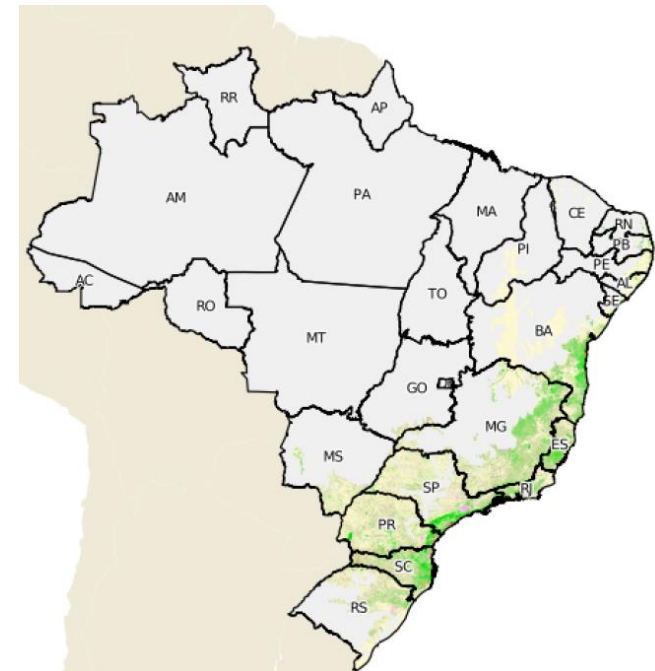
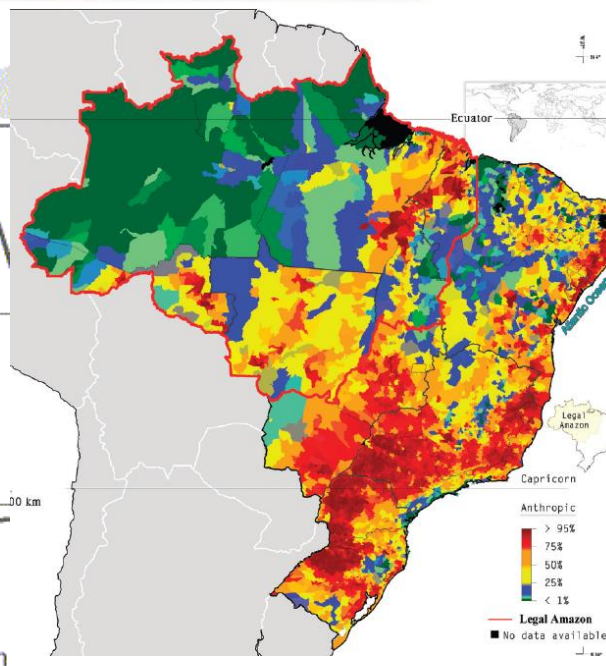
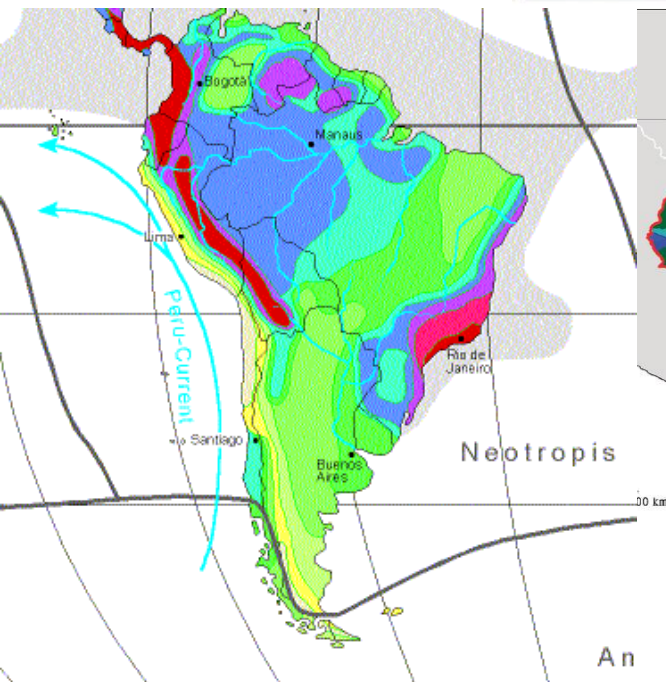
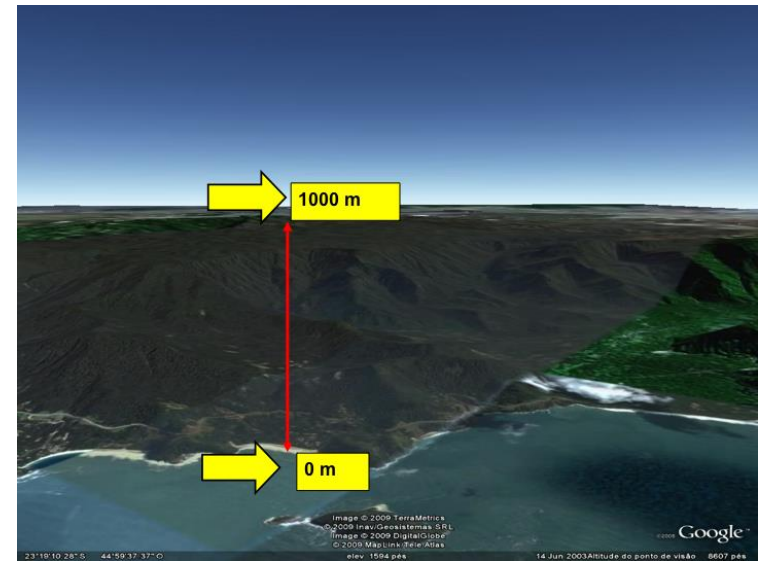


Gradiente:

Latitudinal

Longitudinal

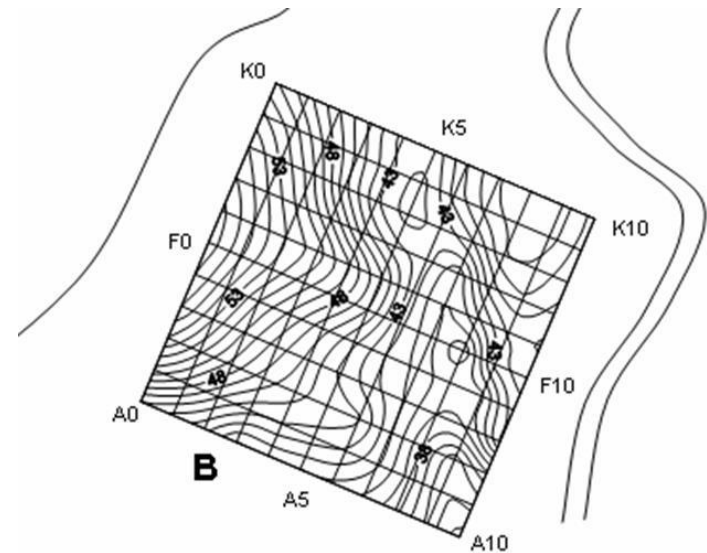
Altitudinal



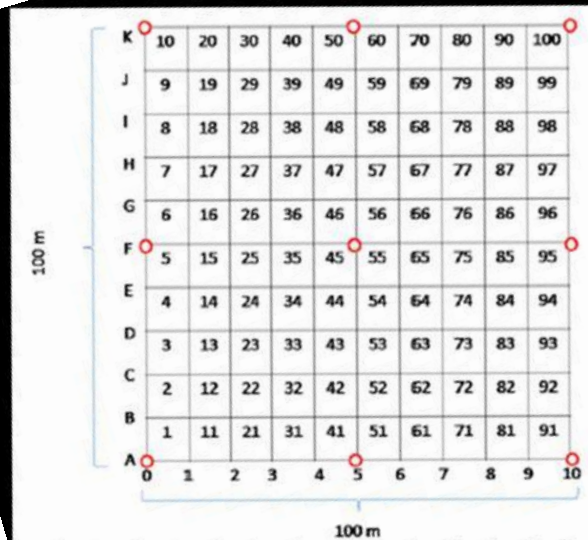


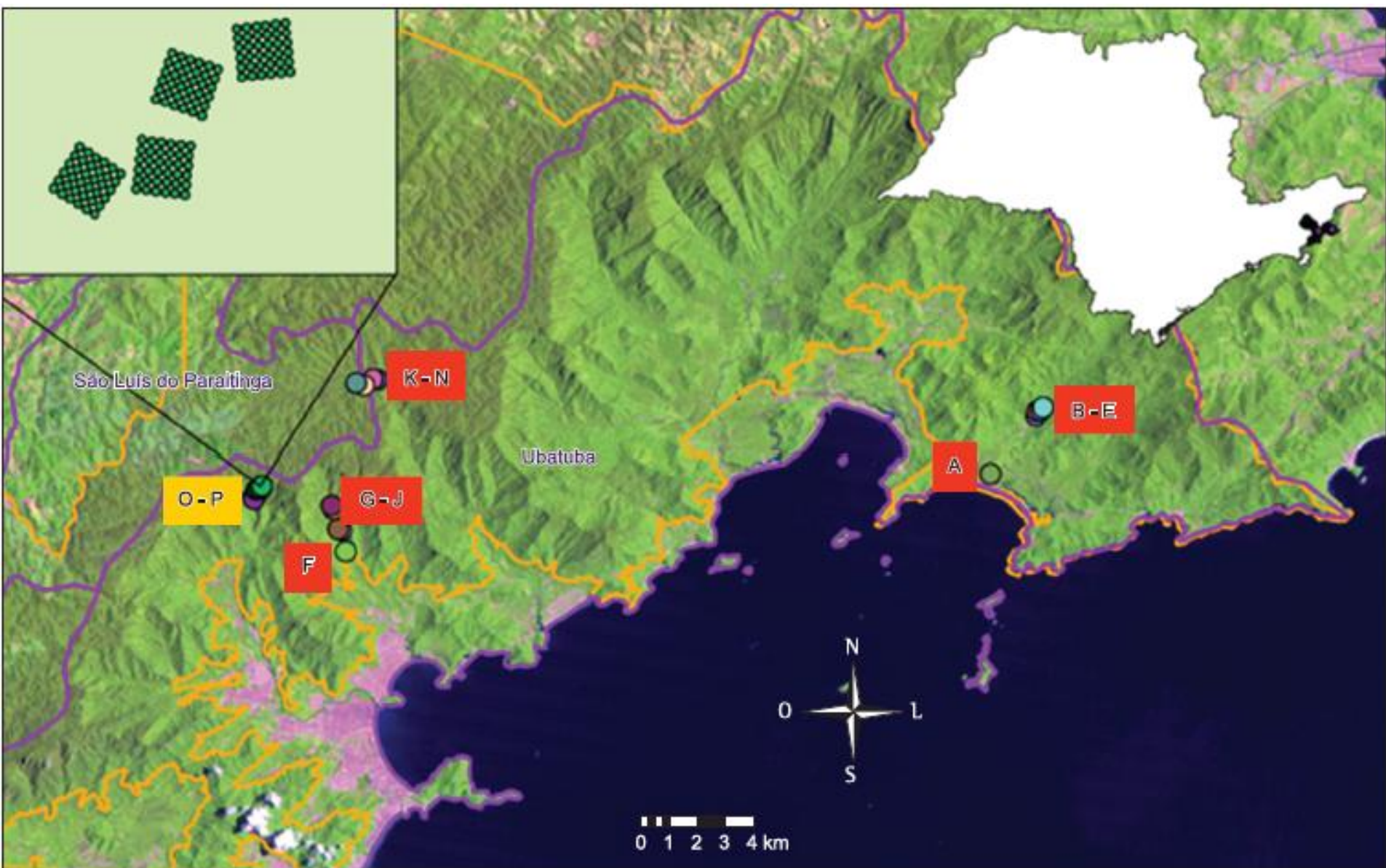
Projeto Temático

Composição florística, estrutura e funcionamento da Floresta Ombrofila Densa dos Núcleos Picinguaba e Santa Virginia do Parque Estadual da Serra do Mar, São Paulo, Brasil



- 14 parcelas (100x100 m)
- 4 conjuntos de 4 parcelas (25x25m)
- PAP $\geq 15,0$ cm

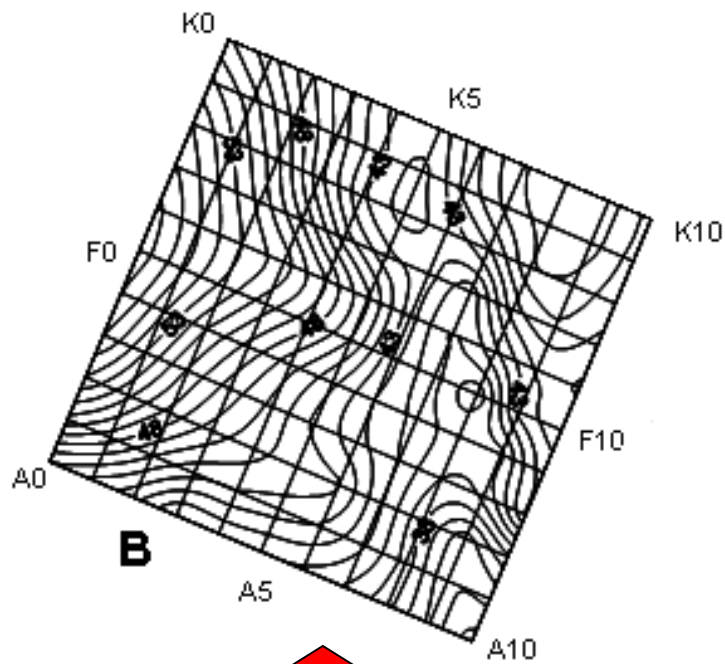




Restinga

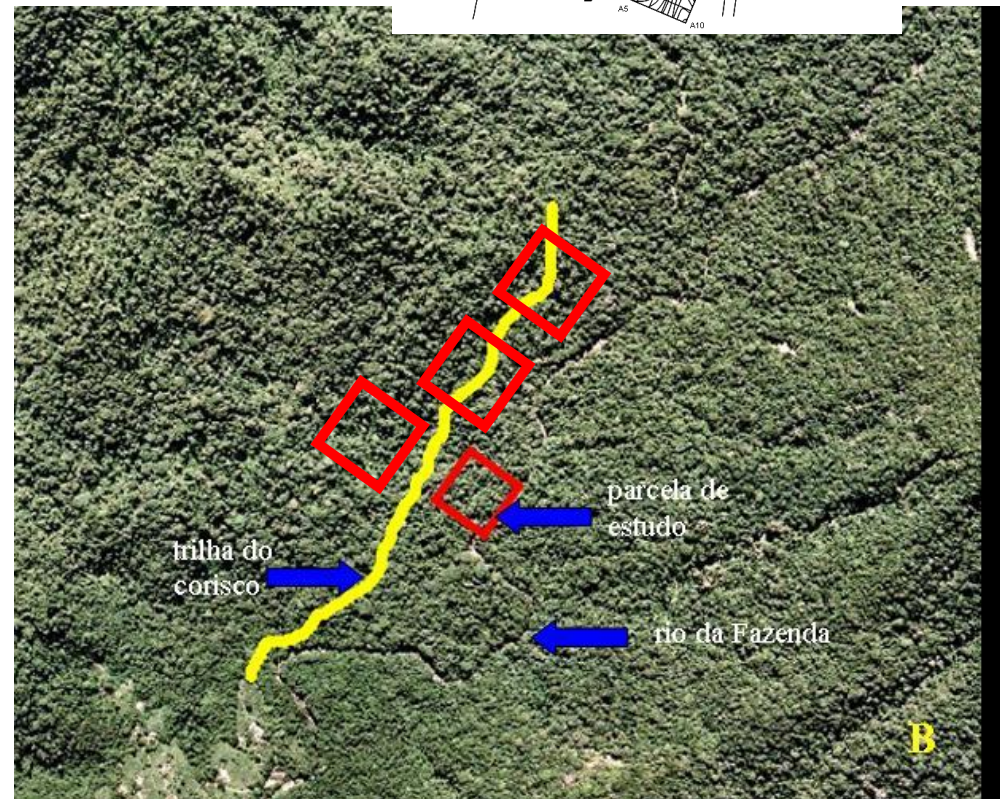
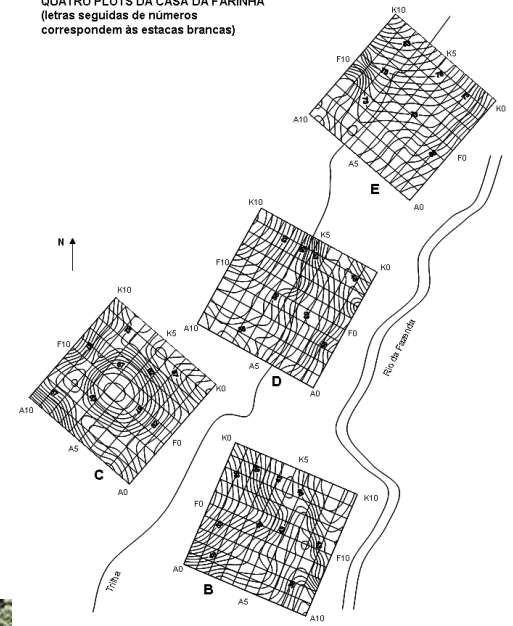


- FOD Terras Baixas
- PARCELAS B, C, D e E



50 m alt.

QUATRO PLOTS DA CASA DA FARINHA
(letras seguidas de números
correspondem às estacas brancas)

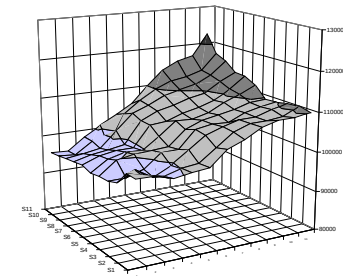


Floresta Ombrófila Densa Terras Baixas

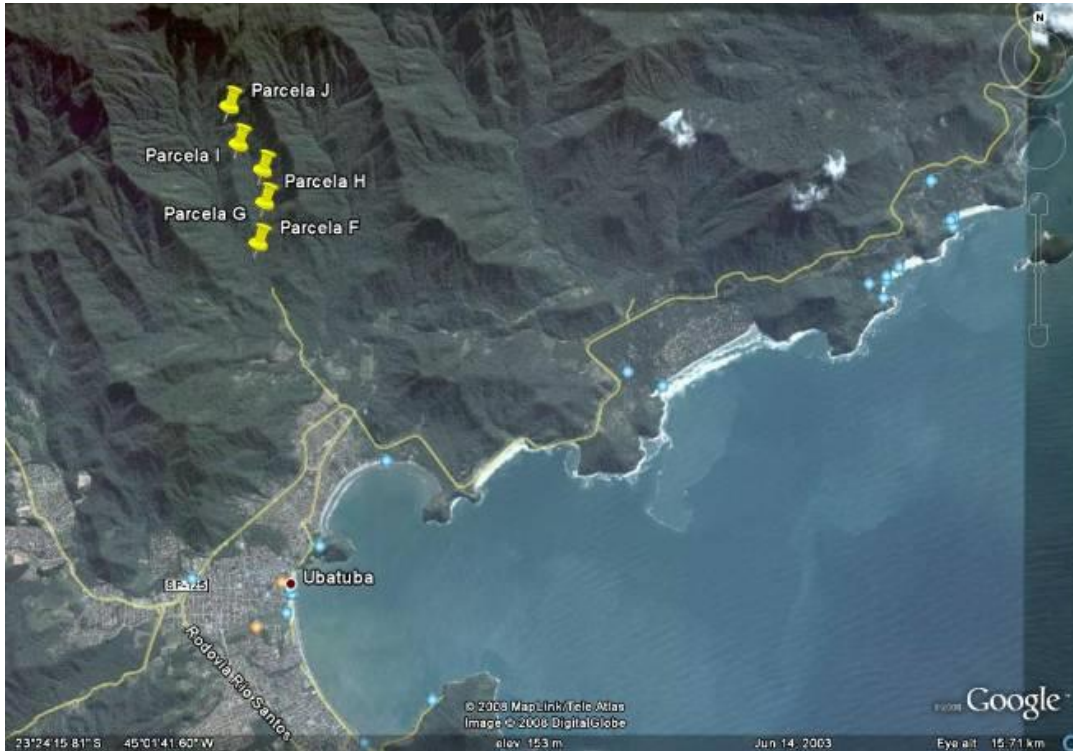
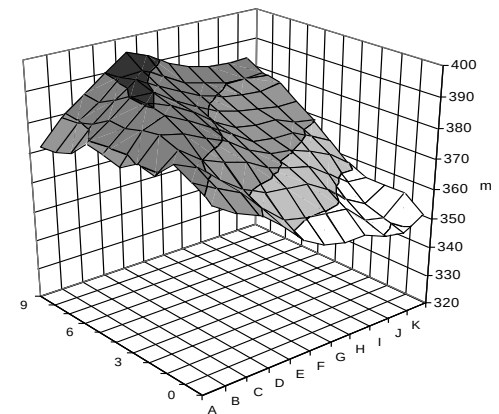


- FOD Submontana
- PARCELAS F, G, H, I e J

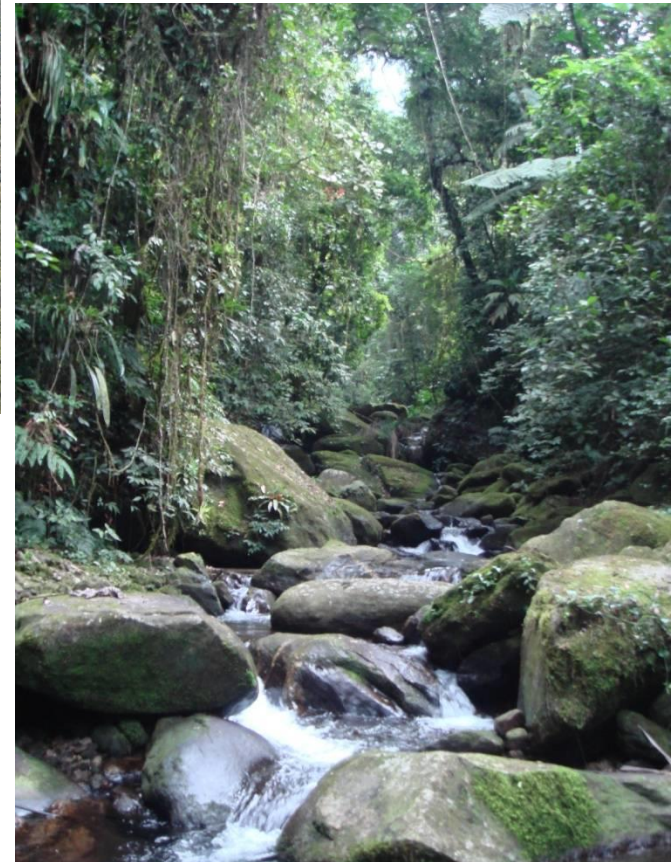
Topografia da parcela F- Capricórnio



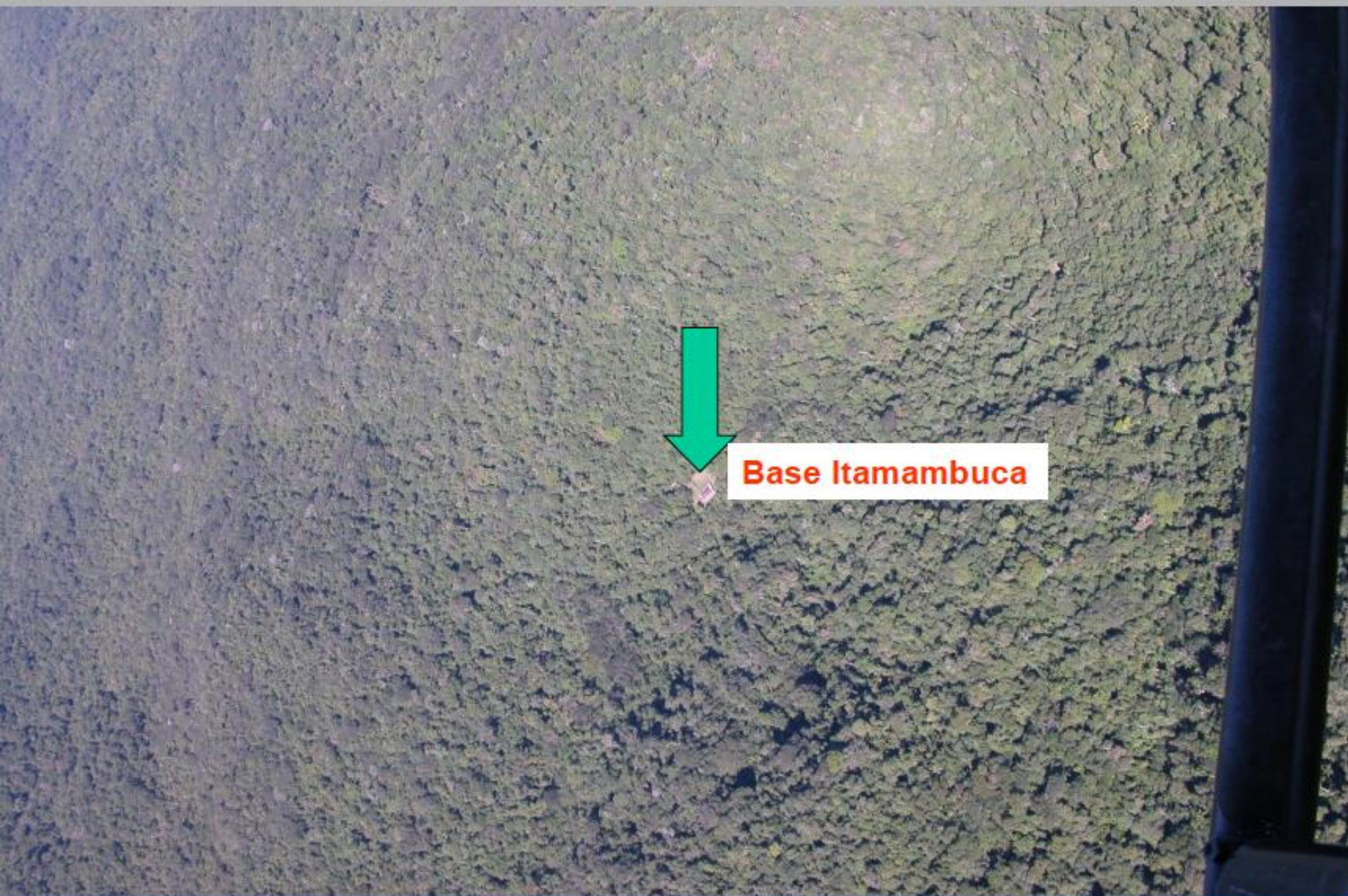
topografia da parcela J - Capricórnio



Floresta Ombrófila Densa Submontana



Montane Ombrophylous Dense Forest



Floresta Ombrófila Densa Montana



~25000 Indivíduos amostrados
~ 500 espécies arbóreas

Resitinga

TB1

TB2

TB3

SM1

SM2

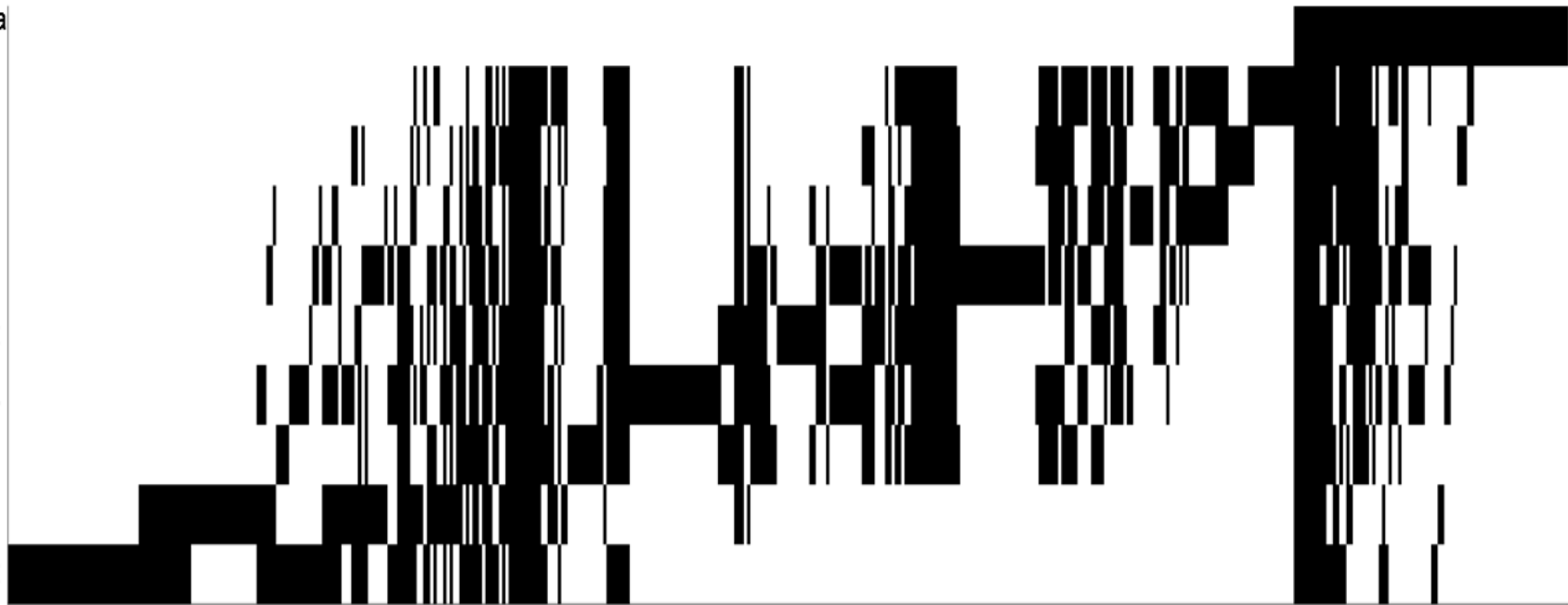
SM3

SM4

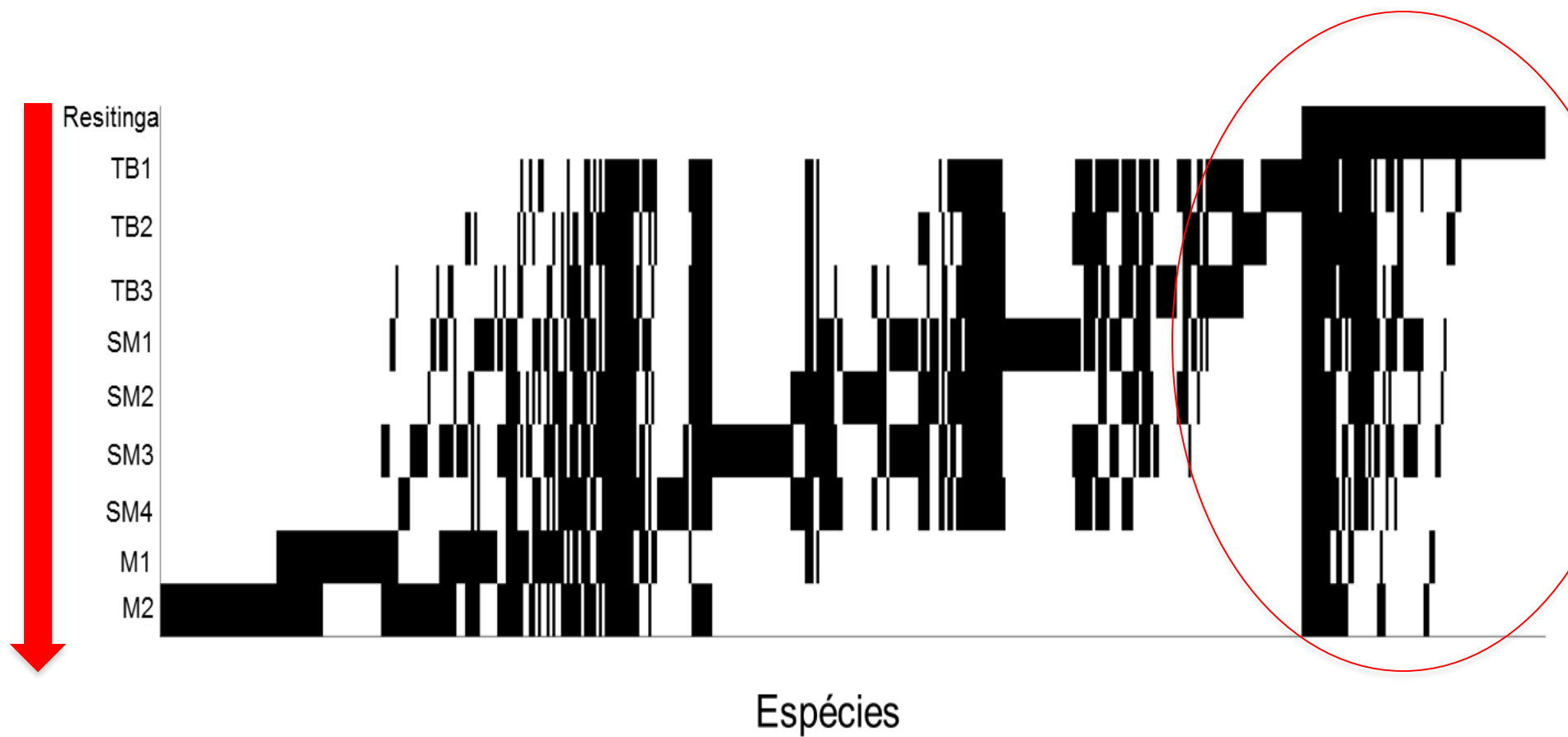
M1

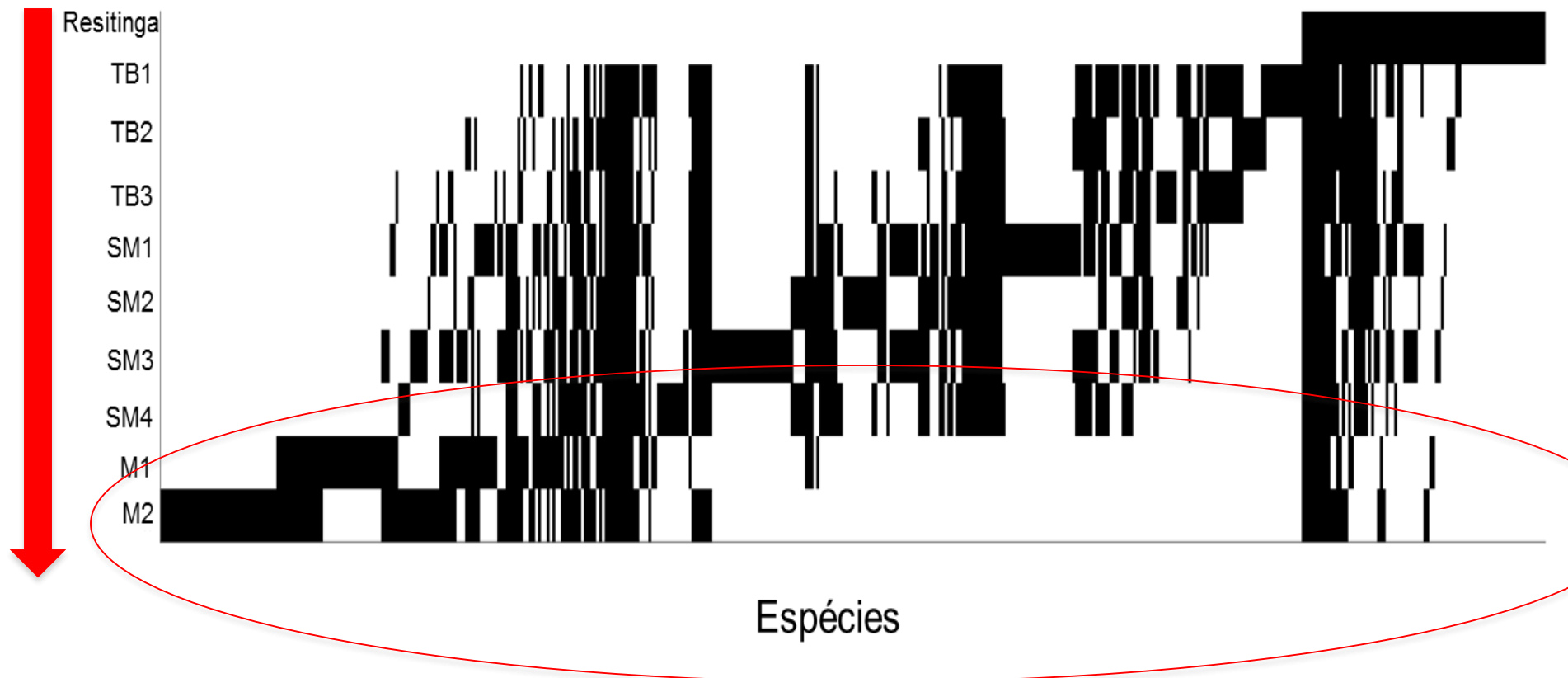
M2

Espécies









Portanto, existem muitas espécies que só ocorrem em uma extremidade do gradiente, outras só na outra extremidade, enquanto algumas espécies apresentam distribuições variadas ao longo do gradiente.

Forest structure and live aboveground biomass variation along an elevational gradient of tropical Atlantic moist forest (Brazil)

Luciana F. Alves^{a,b,*}, Simone A. Vieira^c, Marcos A. Scaranello^c, Plinio B. Camargo^c, Flavio A.M. Santos^d, Carlos A. Ioly^d, Luiz A. Martinelli^c

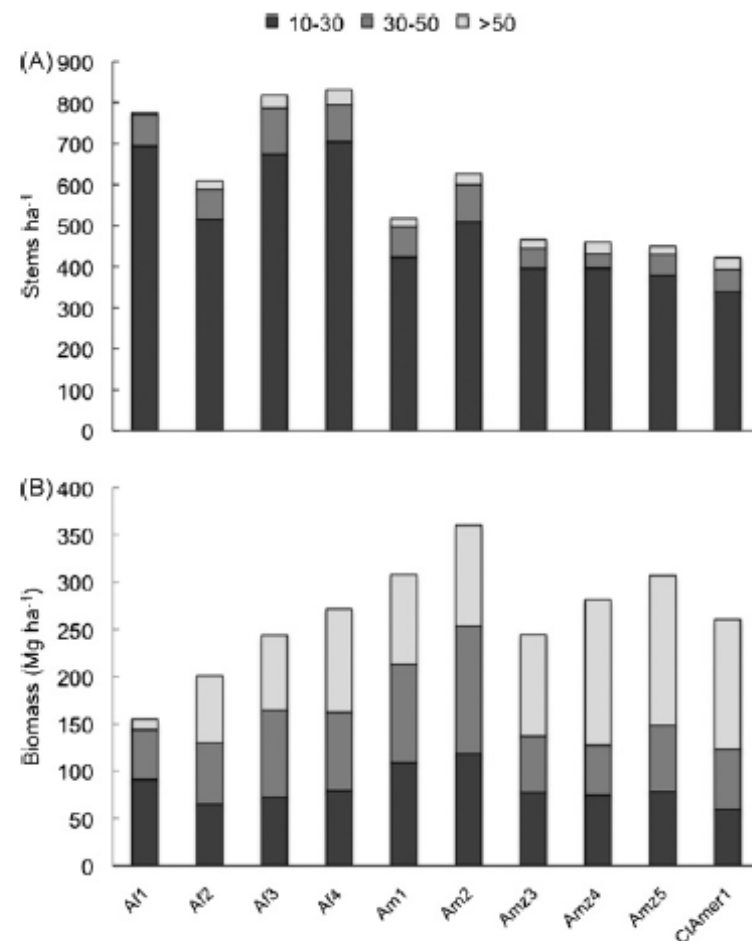
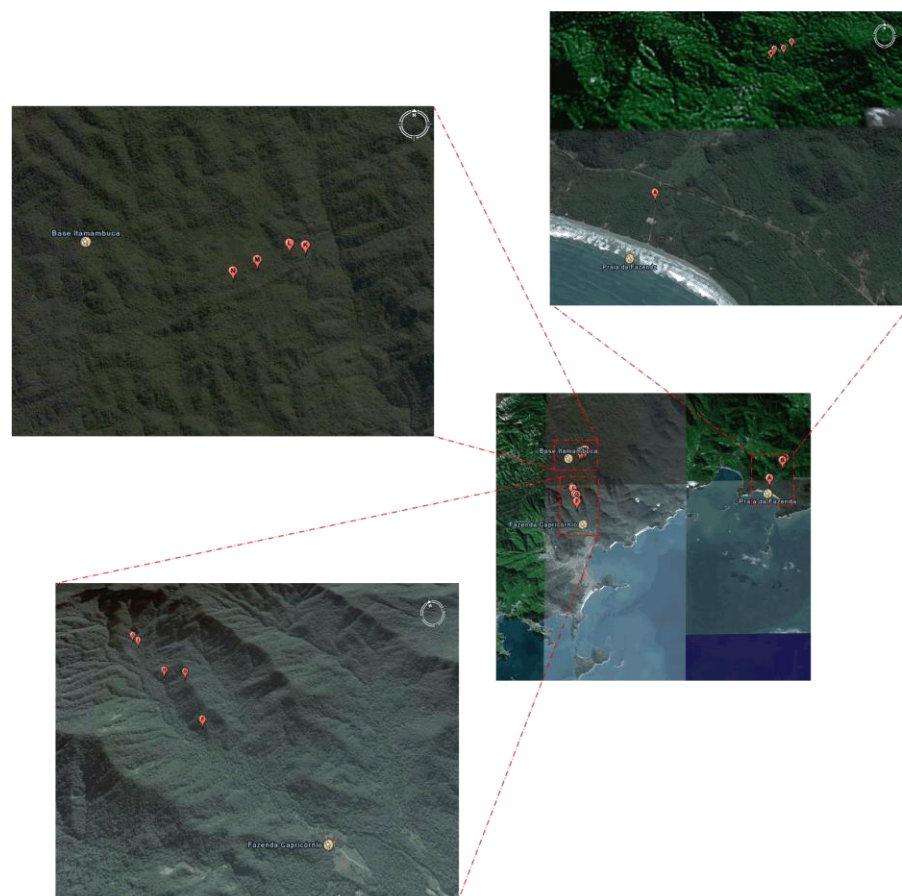


Fig. 4. Distribution of (a) number of stems (ha^{-1}) and (b) biomass (Mg ha^{-1}) by size class (dbh cm) for Atlantic selected Neotropical forests. Atlantic forest (this study): Af1 (*restinga*), Af2 (lowland), Af3 (submontane), Af4 (montane). Amazonia: Am1, Manaus (Castilho et al., 2006); Am2, Manaus (Vieira et al., 2004); Am3, Santarém (Vieira et al., 2004); Am4, Rio Branco (Vieira et al., 2004); Am5, Rondônia (Cummings et al., 2002). Central America: CtAmer1, Panamá (Chave et al., 2003).

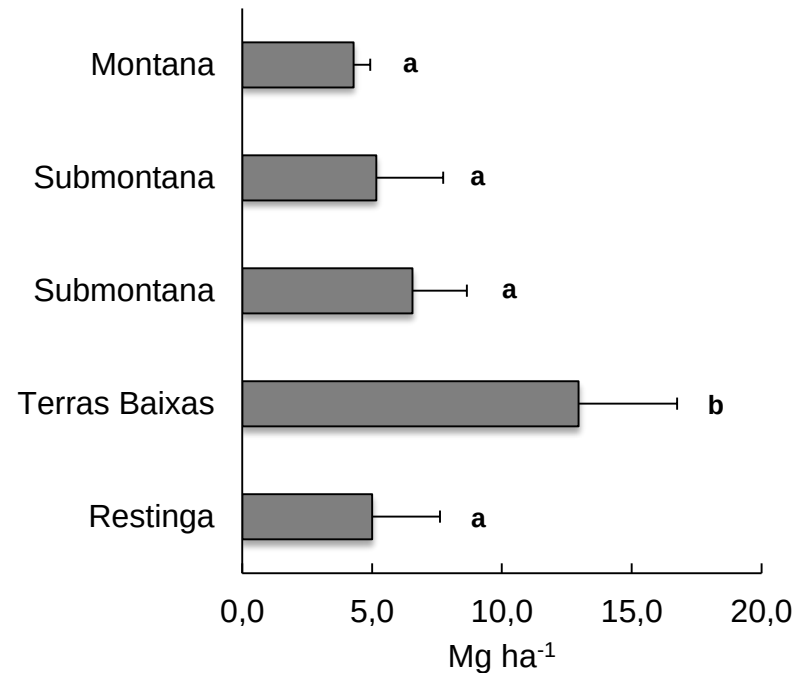
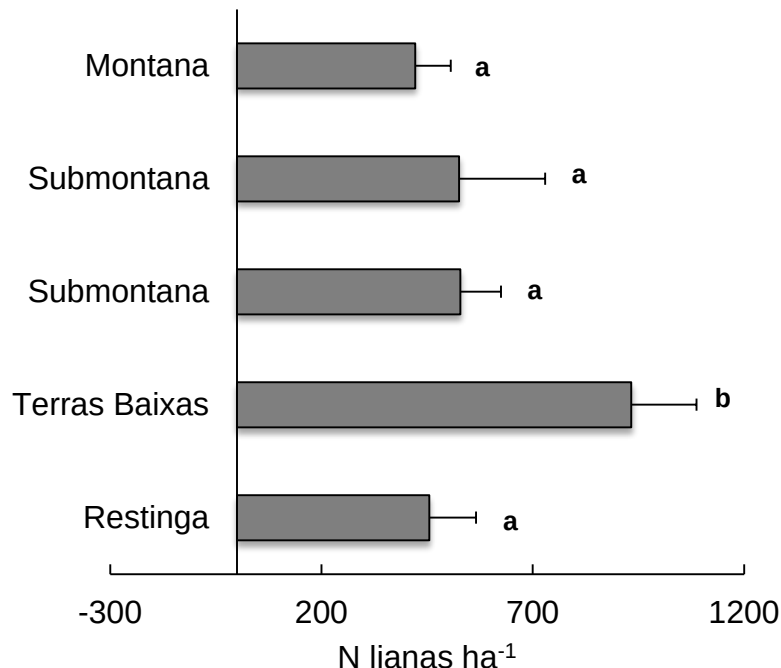
Luciana F. Alves · Marco A. Assis · Juliano van Melis
Ana L. S. Barros · Simone A. Vieira
Fernando R. Martins · Luiz A. Martinelli
Carlos A. Joly

Variation in liana abundance and biomass along an elevational gradient in the tropical Atlantic Forest (Brazil)

Received: 7 June 2011 / Accepted: 15 November 2011
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Liana Biomass

Liana - 1,7-5,6 % of total forest biomass (living above ground)



Stocks of carbon and nitrogen and partitioning between above- and belowground pools in the Brazilian coastal Atlantic Forest elevation range

Simone A. Vieira^{1,2}, Luciana F. Alves^{3,4}, Paulo J. Duarte-Neto⁵, Susian C. Martins¹, Larissa G. Veiga⁶, Marcos A. Scaranello¹, Marisa C. Picollo¹, Plinio B. Camargo¹, Janaina B. do Carmo⁶, Eráclito Sousa Neto¹, Flavio A. M. Santos⁷, Carlos A. Joly⁷ & Luiz A. Martinelli¹

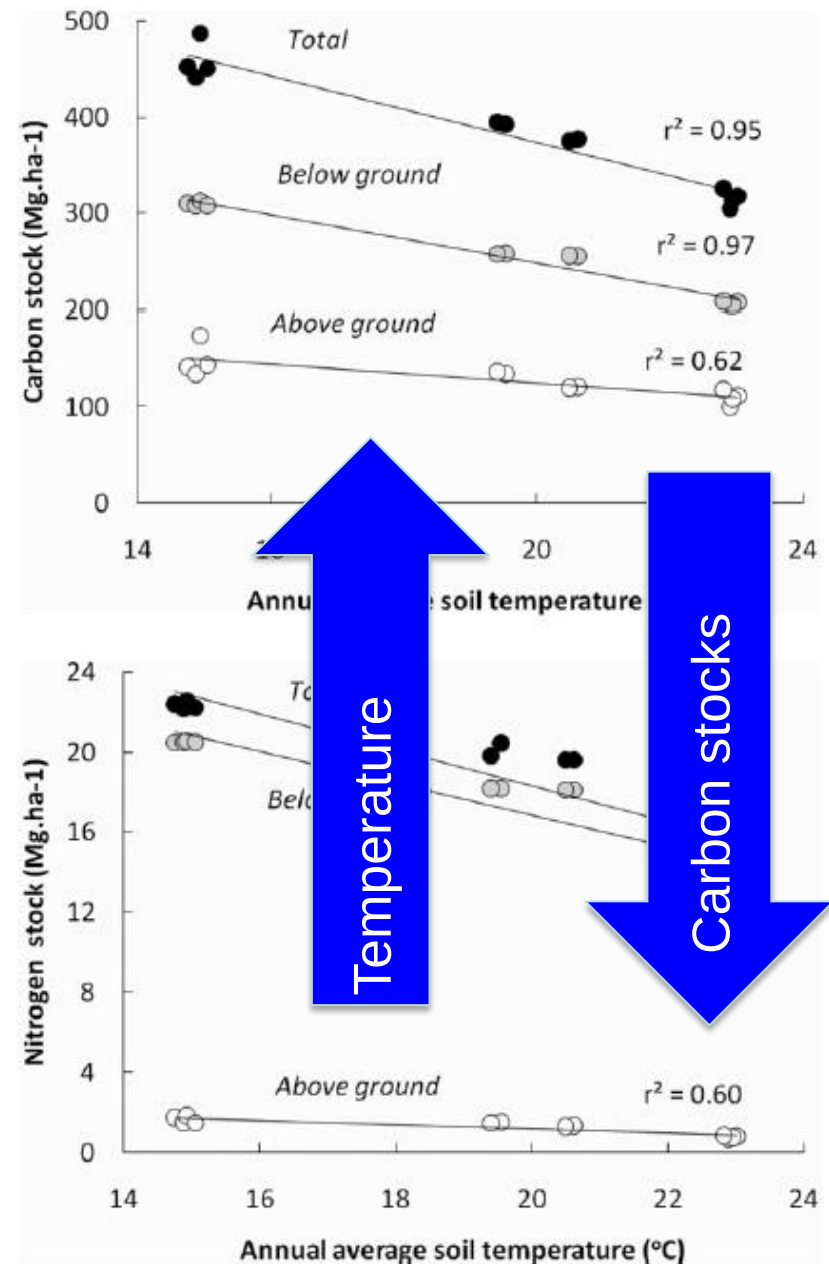
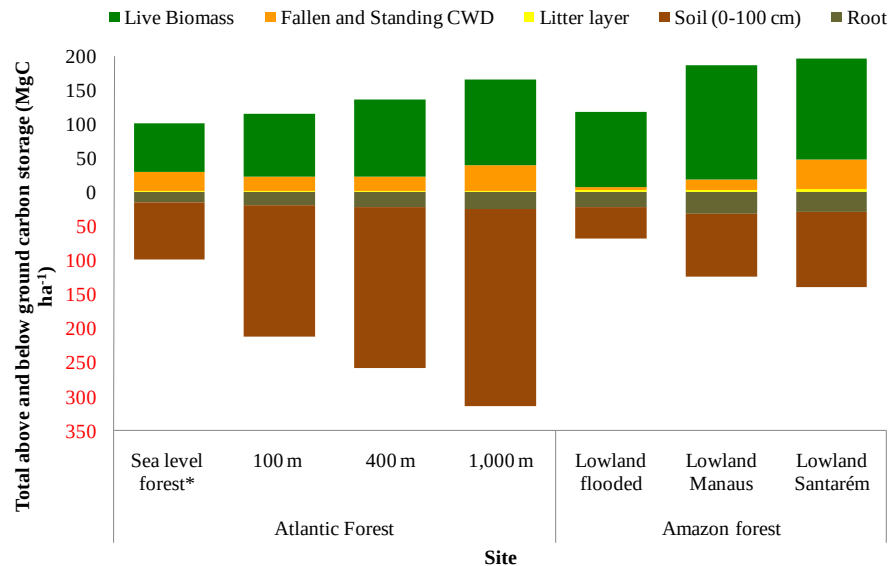
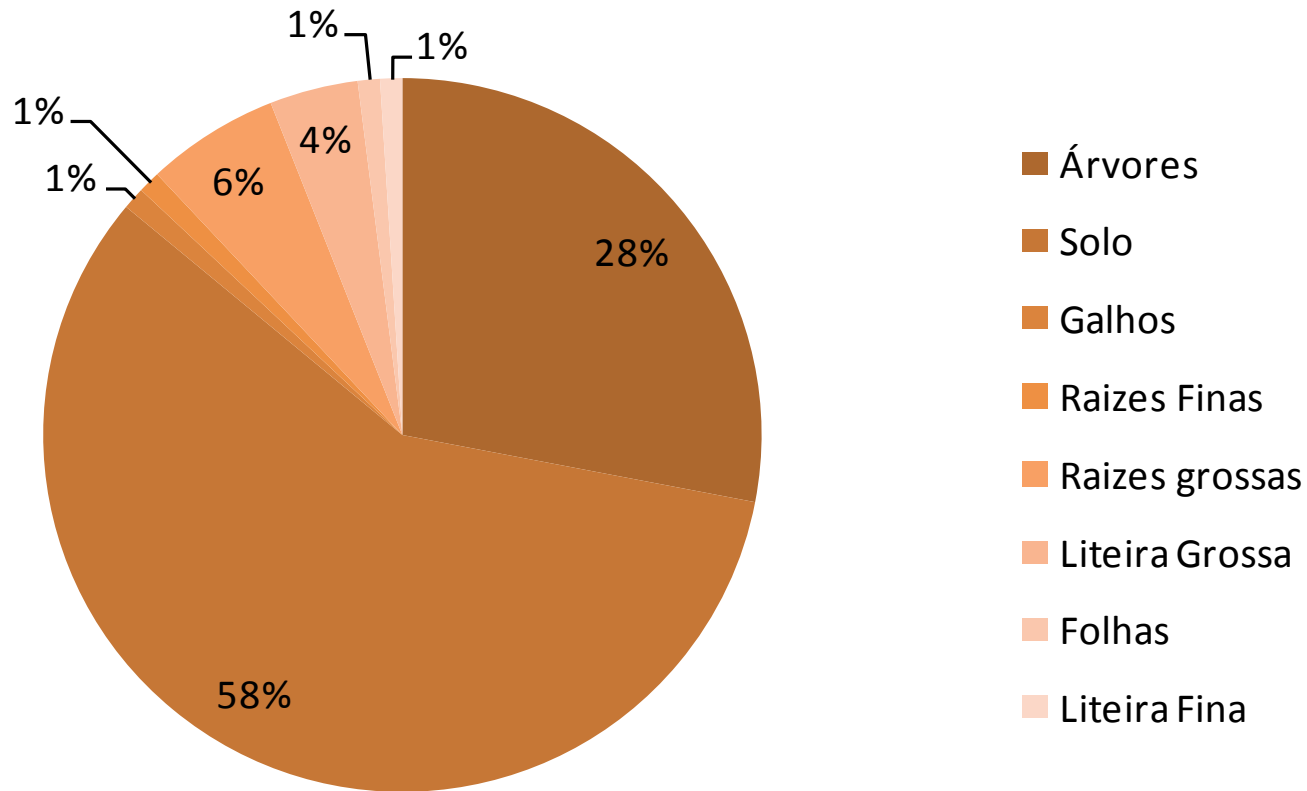


Figure 3. Linear fit to observed data of nitrogen and carbon stocks against soil temperature.

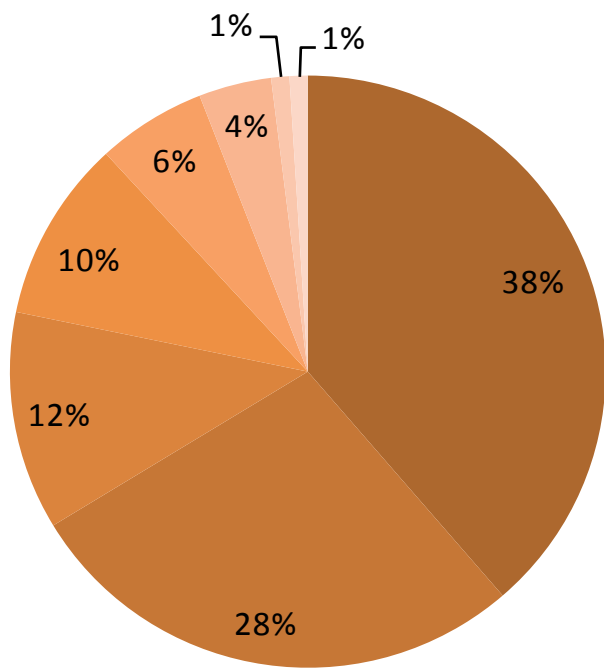
Carbon Pools in Montane Atlantic Forest

Carbon Storage

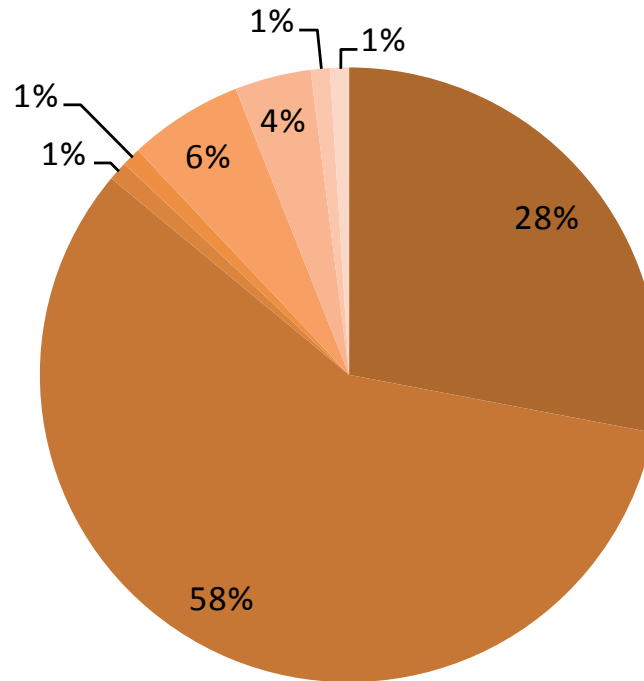


Soil can storage the large amount of carbon

Amazônia



- Árvores
- Solo
- Galhos
- Raizes Finas
- Raizes grossas
- Liteira Grossa
- Folhas
- Liteira Fina



- Árvores
- Solo
- Galhos
- Raizes Finas
- Raizes grossas
- Liteira Grossa
- Folhas
- Liteira Fina

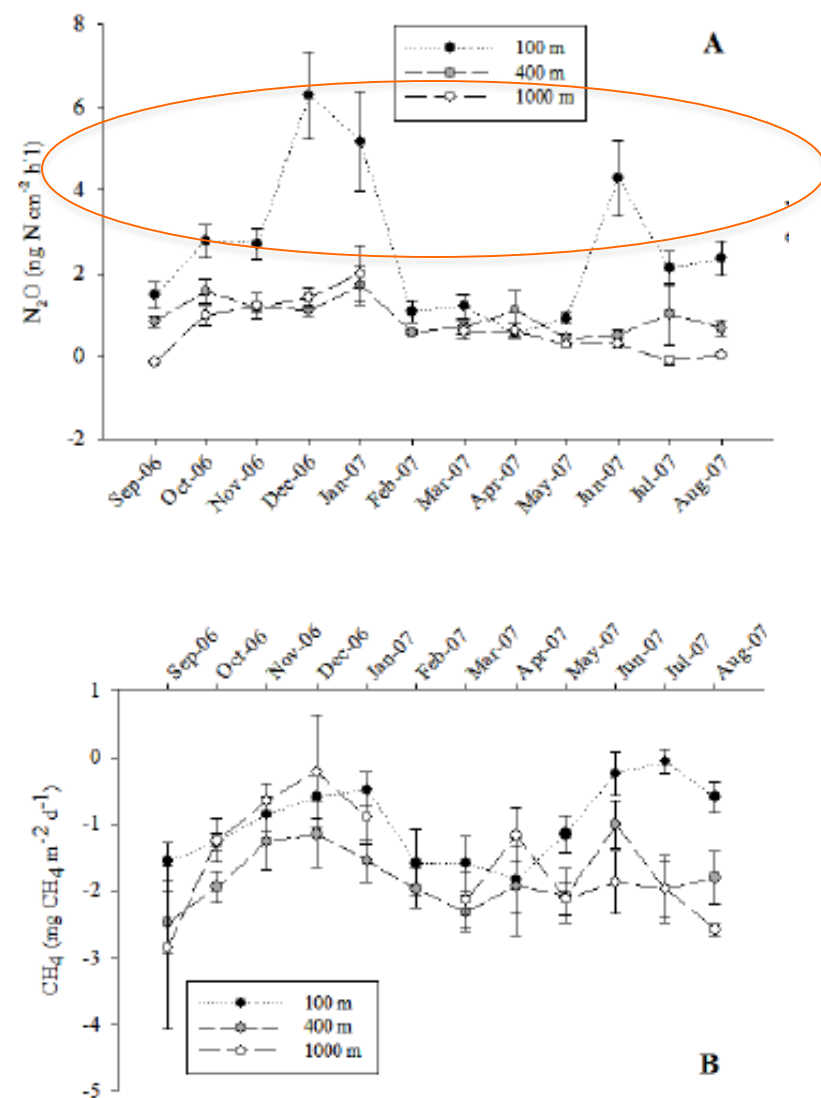
Mata Atlântica

This discussion paper is/has been under review for the journal Biogeosciences (BG).
 Please refer to the corresponding final paper in BG if available.

Soil-atmosphere exchange of nitrous oxide, methane and carbon dioxide in a gradient of elevation in the coastal Brazilian Atlantic forest

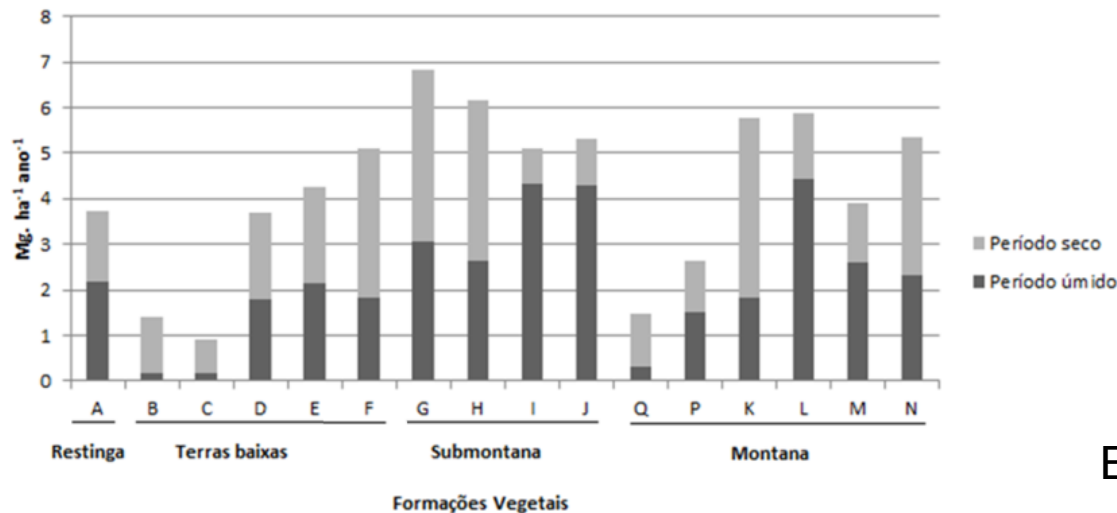
E. Sousa Neto¹, J. B. Carmo², M. Keller³, S. C. Martins¹, L. F. Alves⁴,
 S. A. Vieira¹, M. C. Piccolo¹, P. Camargo¹, H. T. Z. Couto⁵, C. A. Joly⁶, and
 L. A. Martinelli¹

Os Fluxos de N_2O e CH_4 também são afetados pela temperatura – são maiores nas florestas mais quentes





Variação sazonal na produção de Madeira Morta na FOD Atlântica



3,99 Mg ha⁻¹ ano⁻¹

4,44 Mg ha⁻¹ ano⁻¹

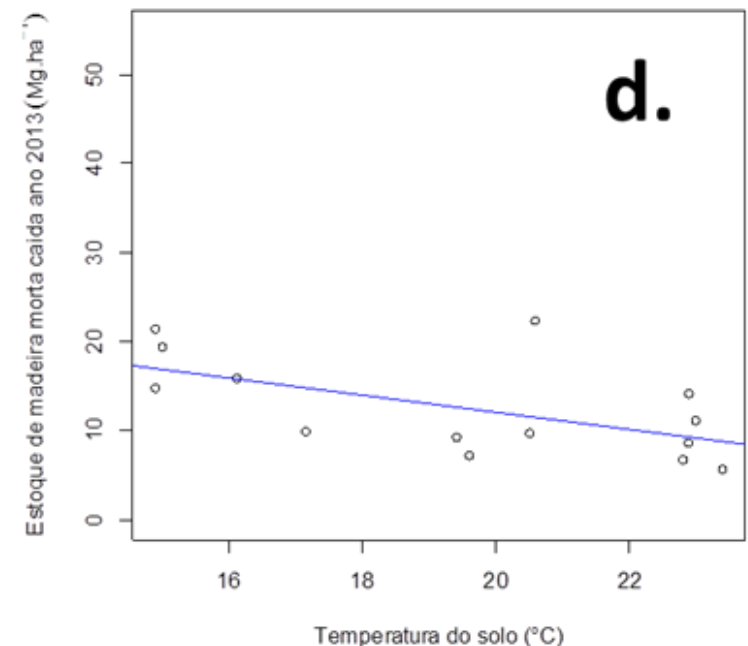
Estoque de MM na FOD Atlântica

Ano 2013

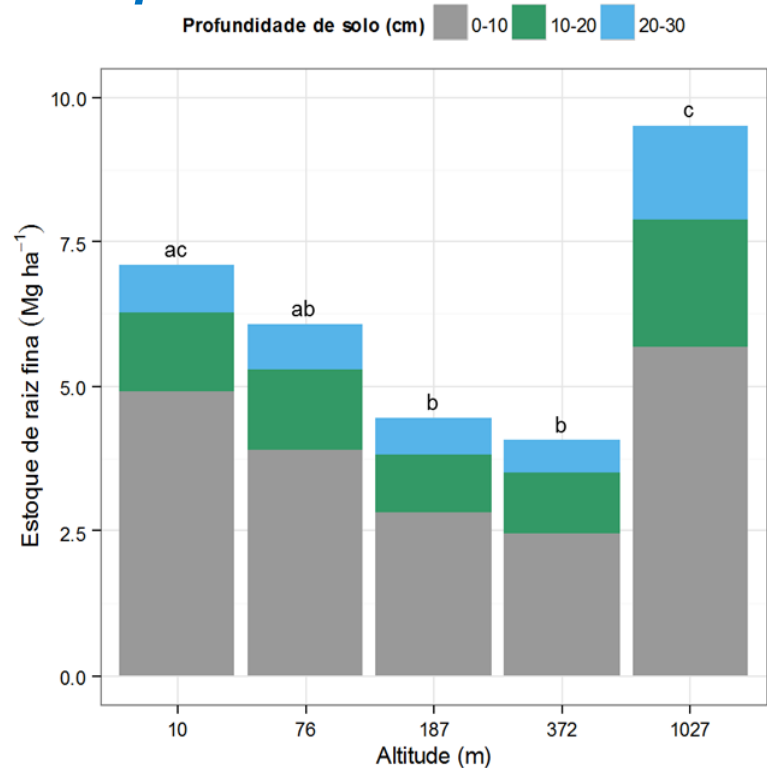
$R^2=0,34$; $p=0,03$

$y=31,3-x0,96$

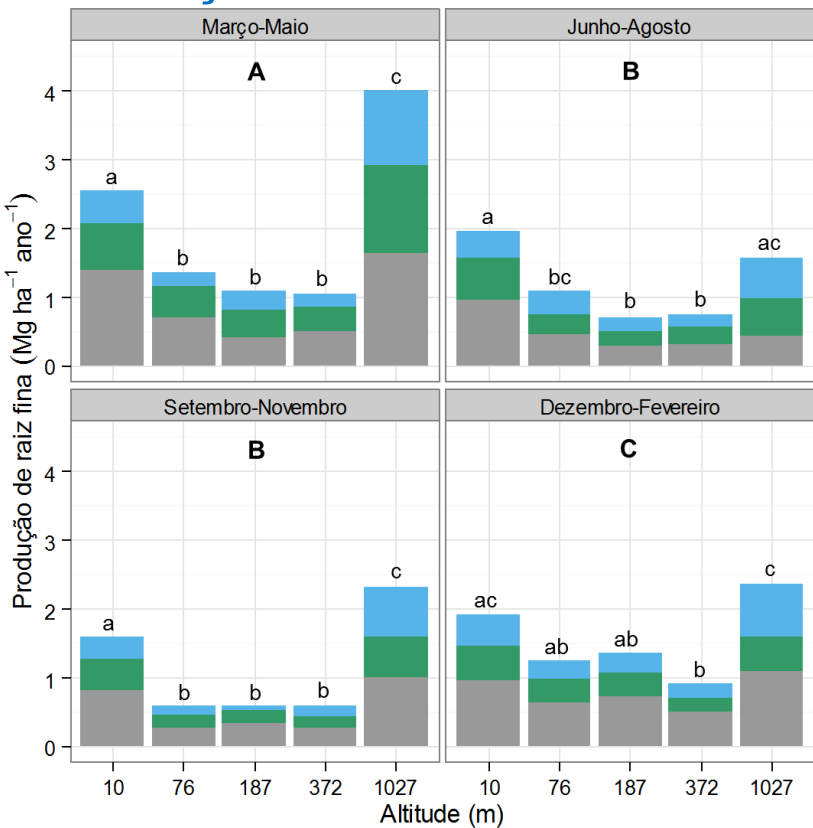
Estoque médio de MM: **16,2 Mg ha⁻¹**



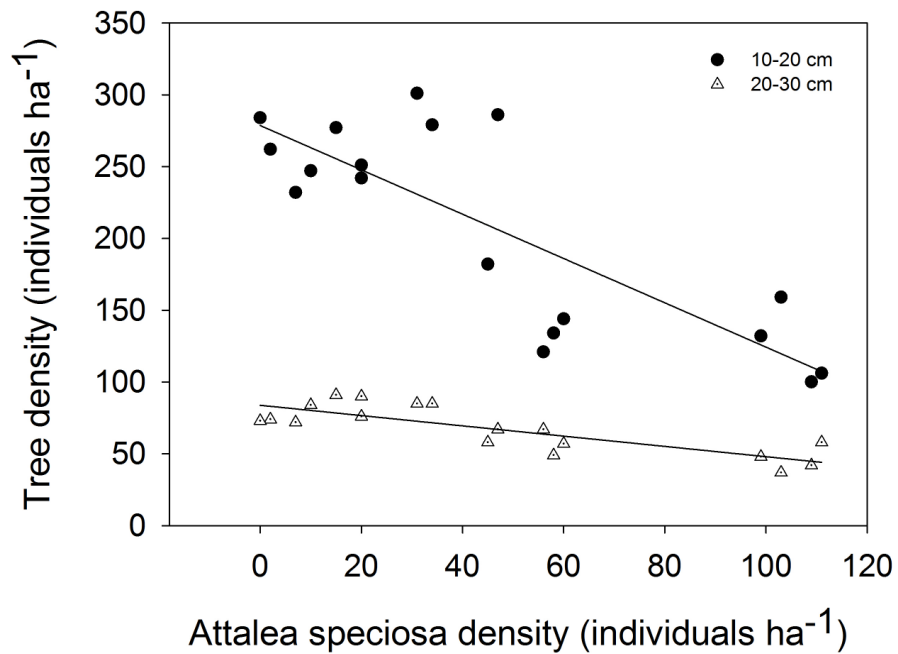
Estoque raiz fina



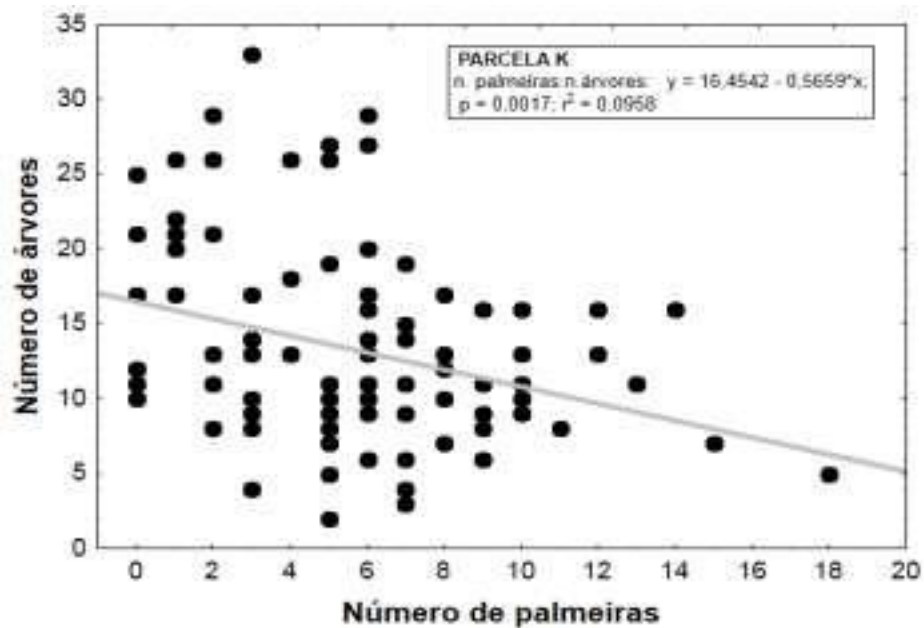
Produção



Altitude	Produção (Mg ha ⁻¹ ano ⁻¹)	Tempo de residência (ano ⁻¹)
Restinga (10m)	8,0	0,57
Lowland (76m)	4,2	0,32
Submontane (187m)	3,8	0,33
Submontane (372m)	3,5	0,35
Montane (1066m)	10,0	0,56



Scaranello et al.



Vieira et al.

Forest structure and live aboveground biomass variation along an elevational gradient of tropical Atlantic moist forest (Brazil)

Luciana F. Alves^{a,b,*}, Simone A. Vieira^c, Marcos A. Scaranello^c, Plinio B. Camargo^c, Flavio A.M. Santos^d, Carlos A. Iolvi^d, Luiz A. Martinelli^c

Table 3

Stocks of live aboveground biomass (AGB) and stem density of trees, palms and tree ferns sampled along the elevational gradient of tropical moist forest (Atlantic forest, Brazil). Values are means and bootstrapped 95% confidence intervals (in parenthesis); $n = 4$ 1-ha plots replicate for each forest type, except for *restinga* forest ($n = 4$ 0.25-ha plots).

Forest type	Trees		Palms		Tree ferns		Total	
	Stems (ha^{-1})	Biomass (Mg ha^{-1})	Stems (ha^{-1})	Biomass (Mg ha^{-1})	Stems (ha^{-1})	Biomass (Mg ha^{-1})	Stems (ha^{-1})	biomass (Mg ha^{-1})
Stems ≥ 4.8 cm								
<i>Restinga</i>	1459 (1254, 1768)	163.5 (142.1, 184.6)	167 (117, 201)	2.8 (1.8, 3.5)	0	0	1626 (1467, 1885)	166.3 (144.4, 187.0)
Lowland	1035 (1008, 1360)	204.8 (187.1, 220.3)	178 (140, 231)	3.9 (2.9, 4.7)	17 (7, 25)	0.2 (0.05, 0.24)	1230 (1170, 1298)	208.9 (192.6, 224.0)
Submontane	1488 (1328, 1644)	247.7 (231.1, 260.6)	227 (186, 284)	6.0 (4.6, 8.4)	11 (9, 15)	0.1 (0.09, 0.50)	1727 (1517, 1926)	253.8 (235.7, 269.6)
Montane	1230 (1108, 1317)	271.3 (241.3, 314.4)	423 (341, 506)	11.1 (9.0, 13.2)	71 (53, 84)	0.8 (0.43, 1.15)	1723 (1454, 1834)	283.2 (253.0, 325.2)
Stems ≥ 10 cm								
<i>Restinga</i>	763 (627, 876)	154.0 (129.8, 176.9)	12 (9, 14)	0.9 (0.3, 1.4)	0	0	775 (650, 890)	154.8 (129.9, 178.3)
Lowland	543 (522, 551)	198.4 (180.7, 211.6)	57 (36, 70)	2.4 (1.7, 3.1)	11 (3, 15)	0.1 (0.03, 0.18)	610 (587, 632)	200.9 (185.5, 216.4)
Submontane	721 (616, 824)	239.3 (223.0, 304.5)	92 (64, 142)	4.3 (3.0, 6.3)	5 (1, 7)	0.05 (0.01, 0.76)	818 (690, 965)	243.6 (226.1, 257.9)
Montane	589 (551, 642)	262.7 (233.6, 304.5)	215 (173, 246)	8.6 (6.3, 9.9)	28 (15, 47)	0.5 (0.12, 0.76)	831 (791, 846)	271.7 (243.0, 311.6)

Bamboo
~17 Mg ha⁻¹



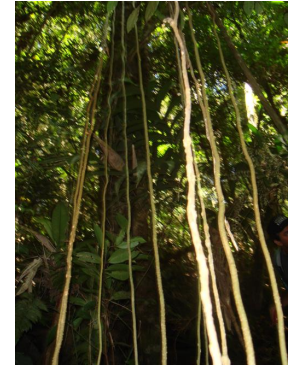
Palm
~10 Mg ha⁻¹



Fern
~1 Mg ha⁻¹



Liana
~5 Mg ha⁻¹



CWD
~16 Mg ha⁻¹



Fine Root
~10 Mg ha⁻¹



Litterlayer
~2 Mg ha⁻¹



Epiphytes
~3 Mg ha⁻¹



 ~ 64 Mg ha⁻¹

Modelo alométrico capaz de estimar a biomassa de epífitas vasculares em Floresta de Restinga.

$$\ln P \sim -6,77 + 1,56 * \ln DAP + 1,57 * \ln ICE$$

Onde:

$\ln$ = logaritmo natural

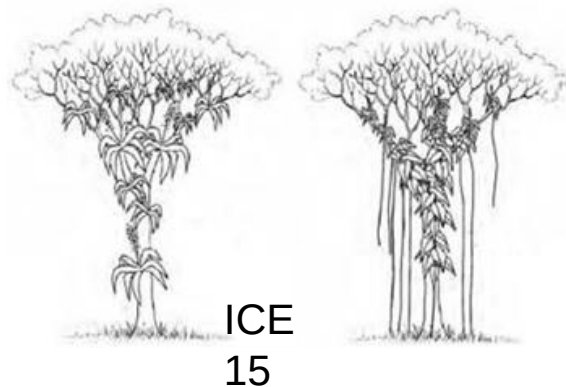
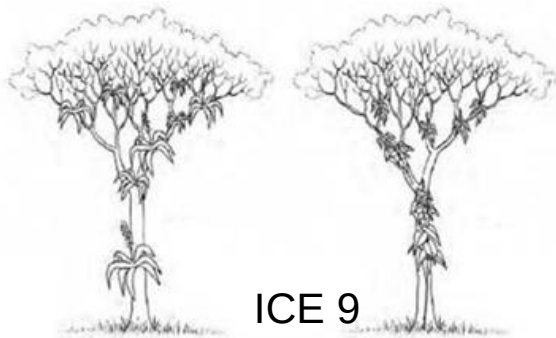
P = peso seco (kg)

DAP = diâmetro à altura do peito (cm)

ICE = índice de cobertura por epífitas
(para $ICE \geq 1$)

ÍNDICE DE COBERTURA POR EPÍFITAS: **ICE**

(Kersten, 2006 e Blum, 2010).



ÍNDICE CATEGÓRICO:

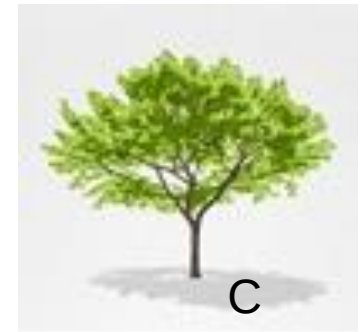
A1 (copa tipo A e ICE =1);

B1 (copa tipo B e ICE=1);

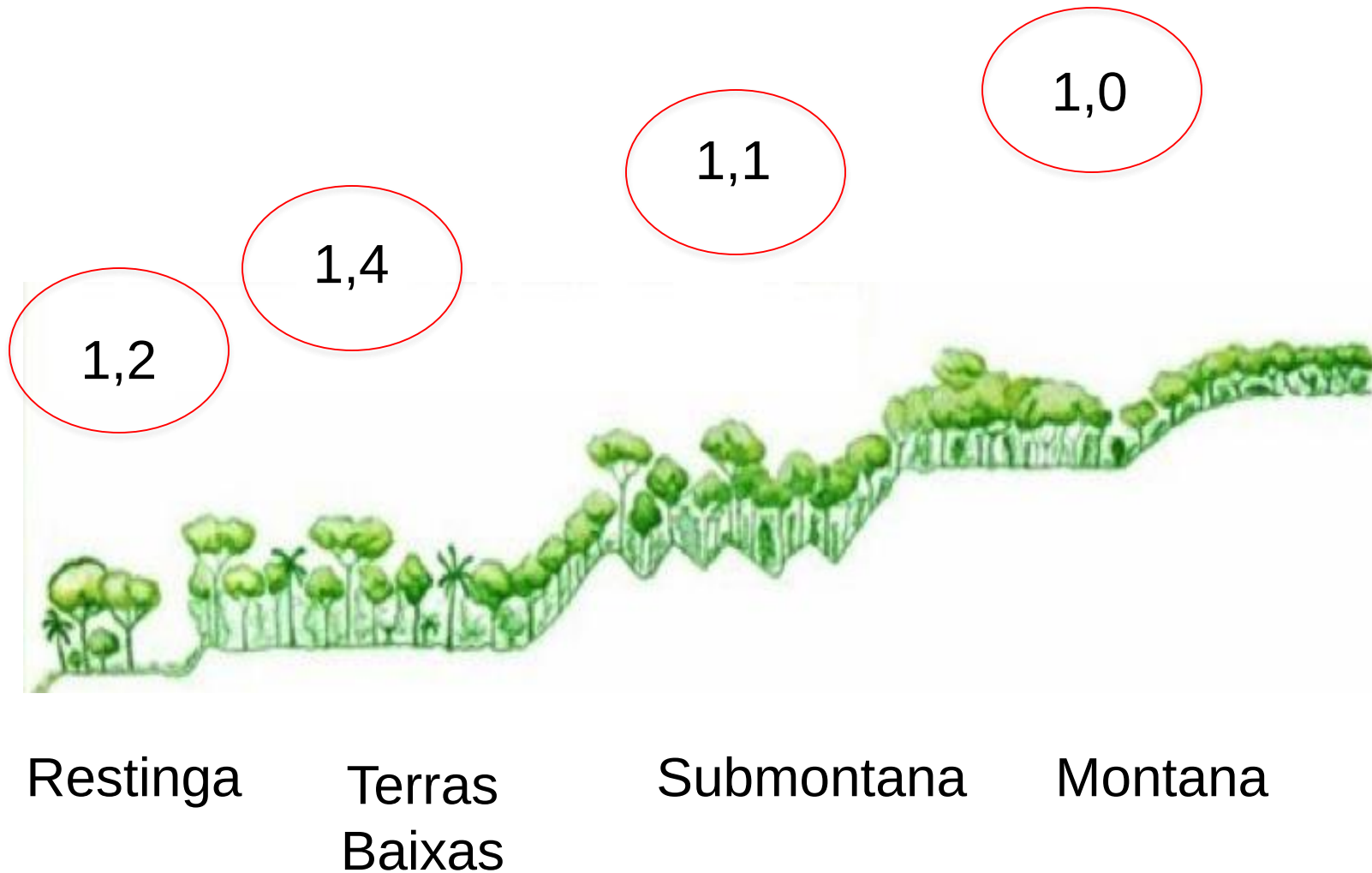
C1; A2; B2; C2; A5; ... C15.

BIOMASSA: ÍNDICE CATEGÓRICO
+ DAP

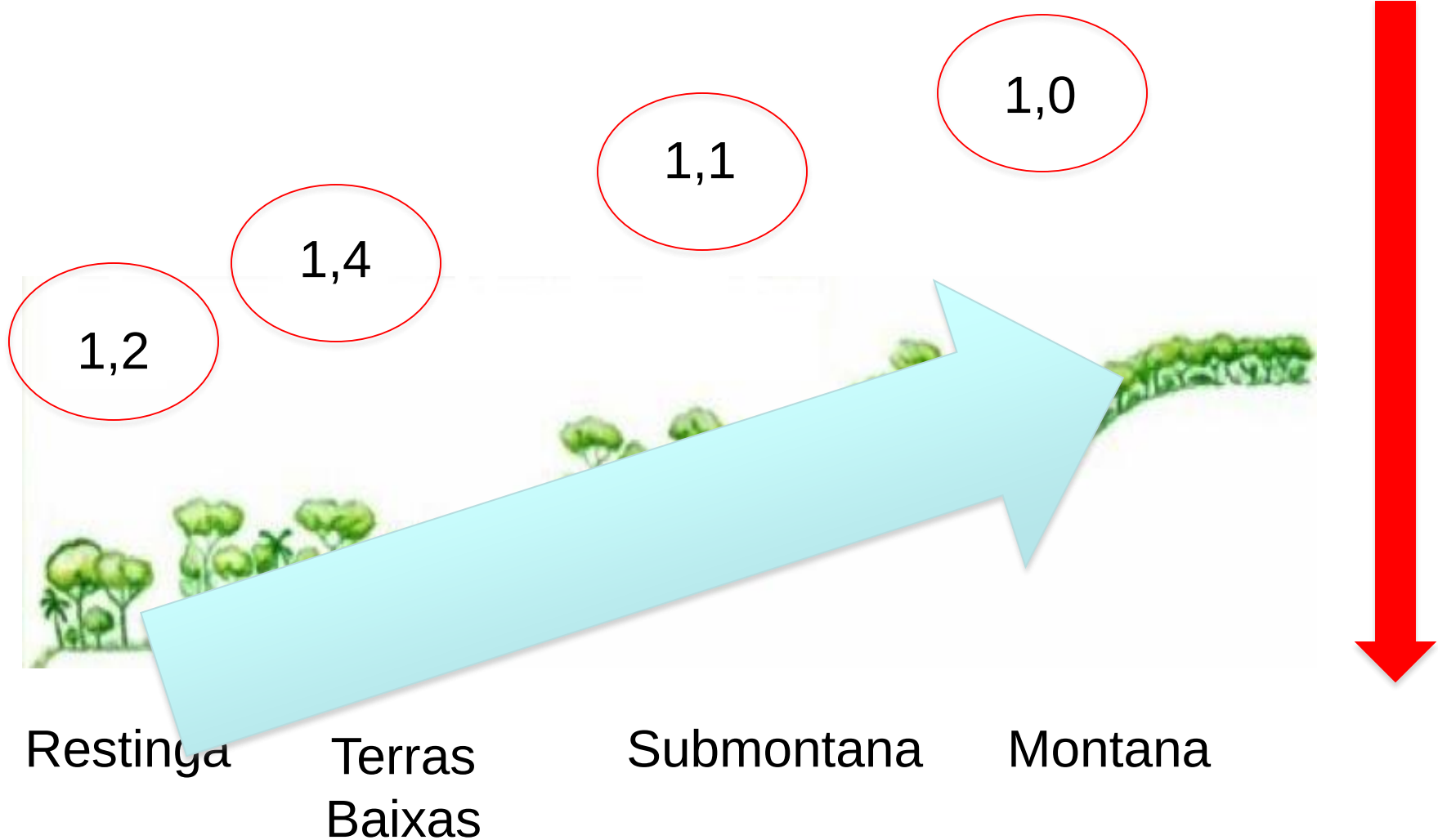
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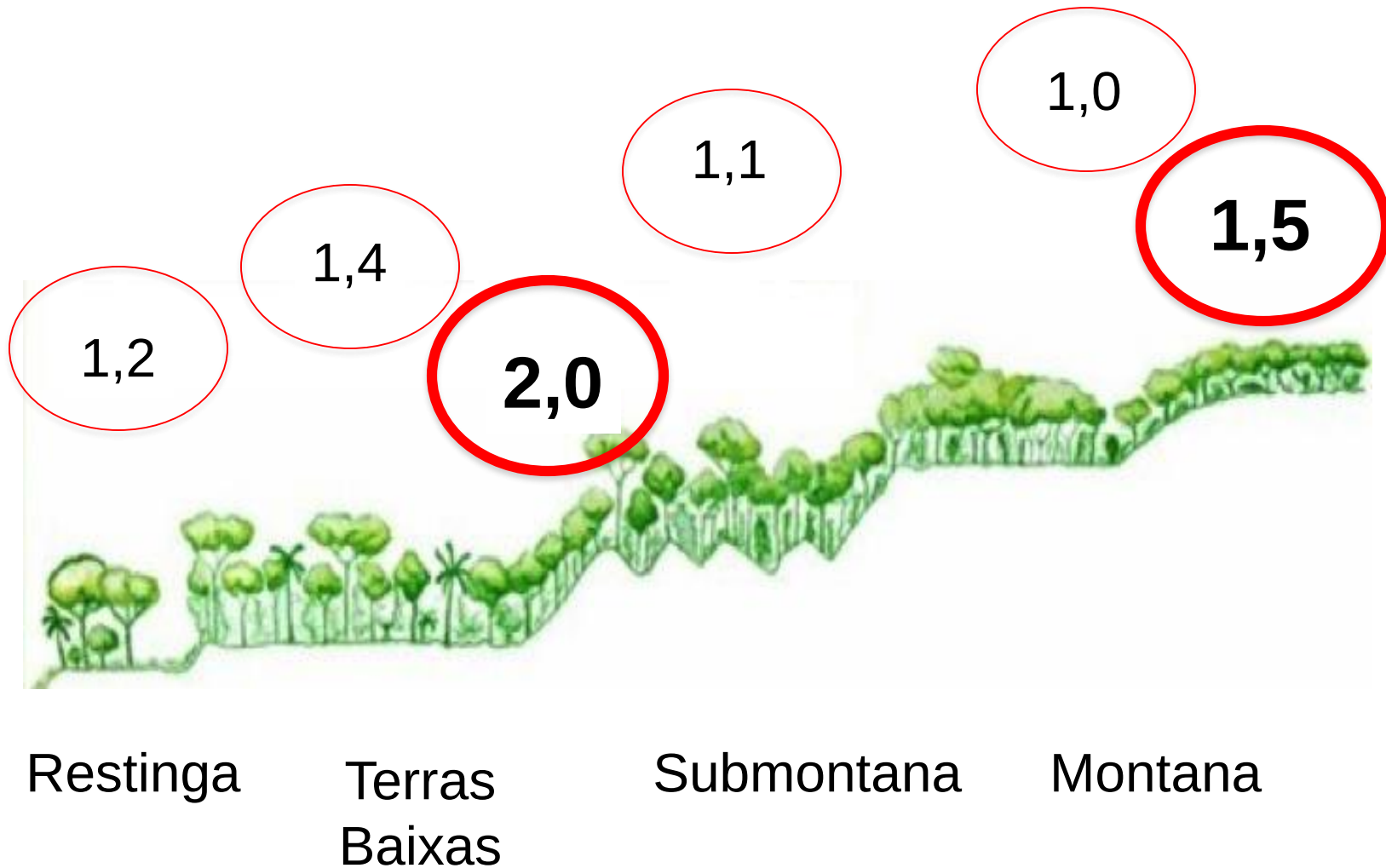
Taxa de crescimento arbóreo ao longo de um gradiente altitudinal de Mata Atlântica (mm ano^{-1})



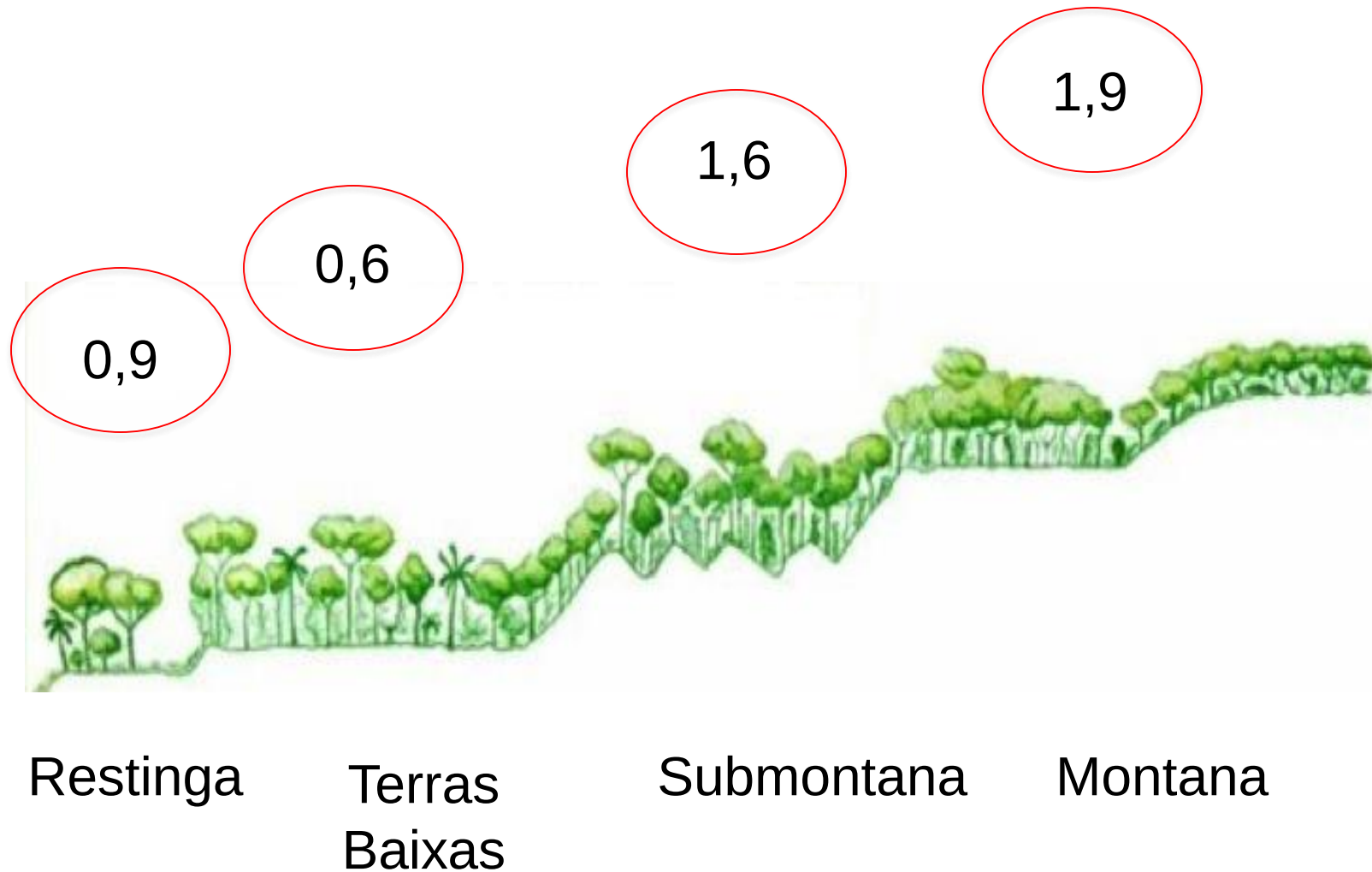
Taxa de crescimento arbóreo ao longo de um gradiente altitudinal de Mata Atlântica (mm ano^{-1})



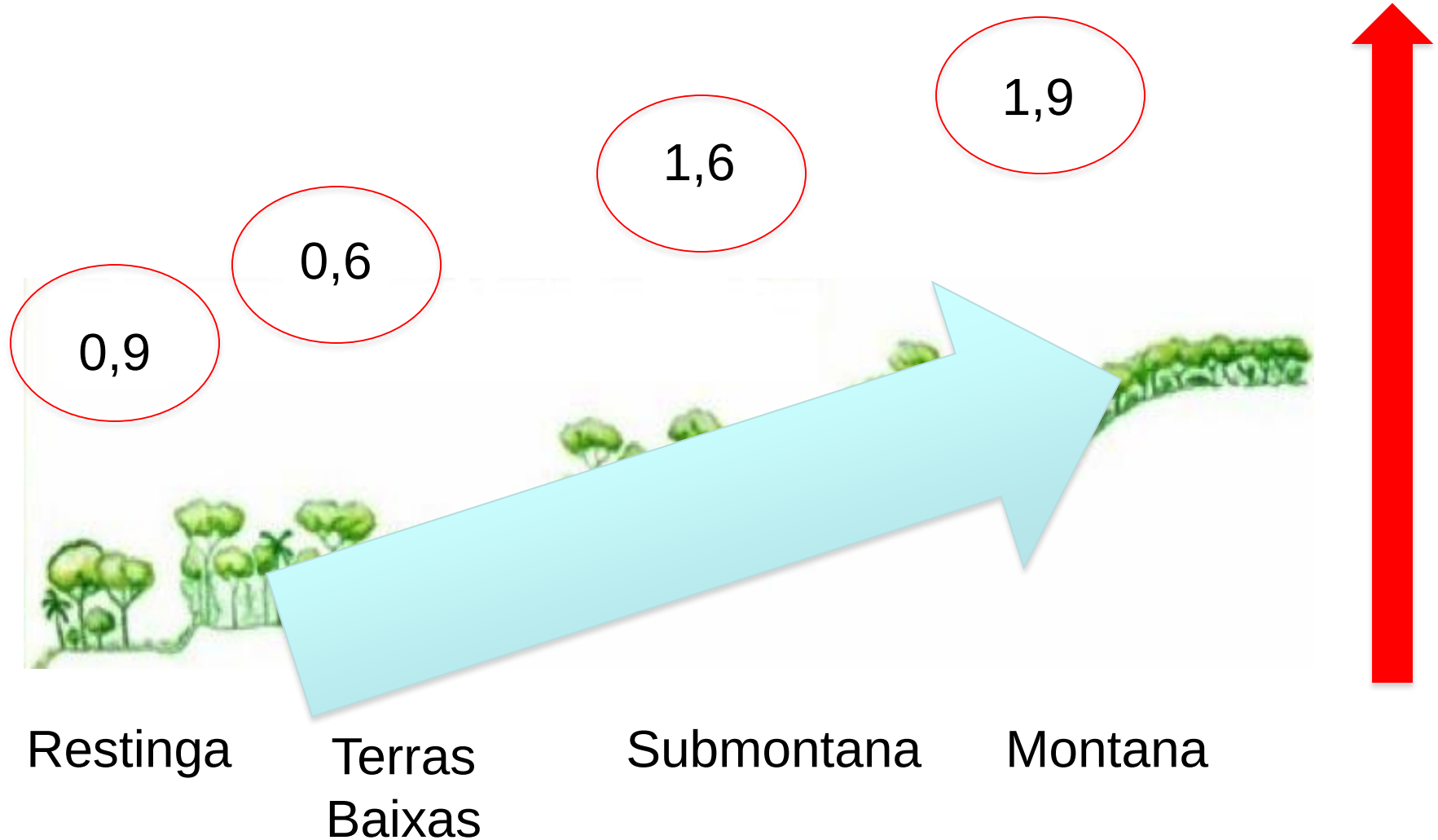
Taxa de crescimento arbóreo ao longo de um gradiente altitudinal de Mata Atlântica (mm ano^{-1})



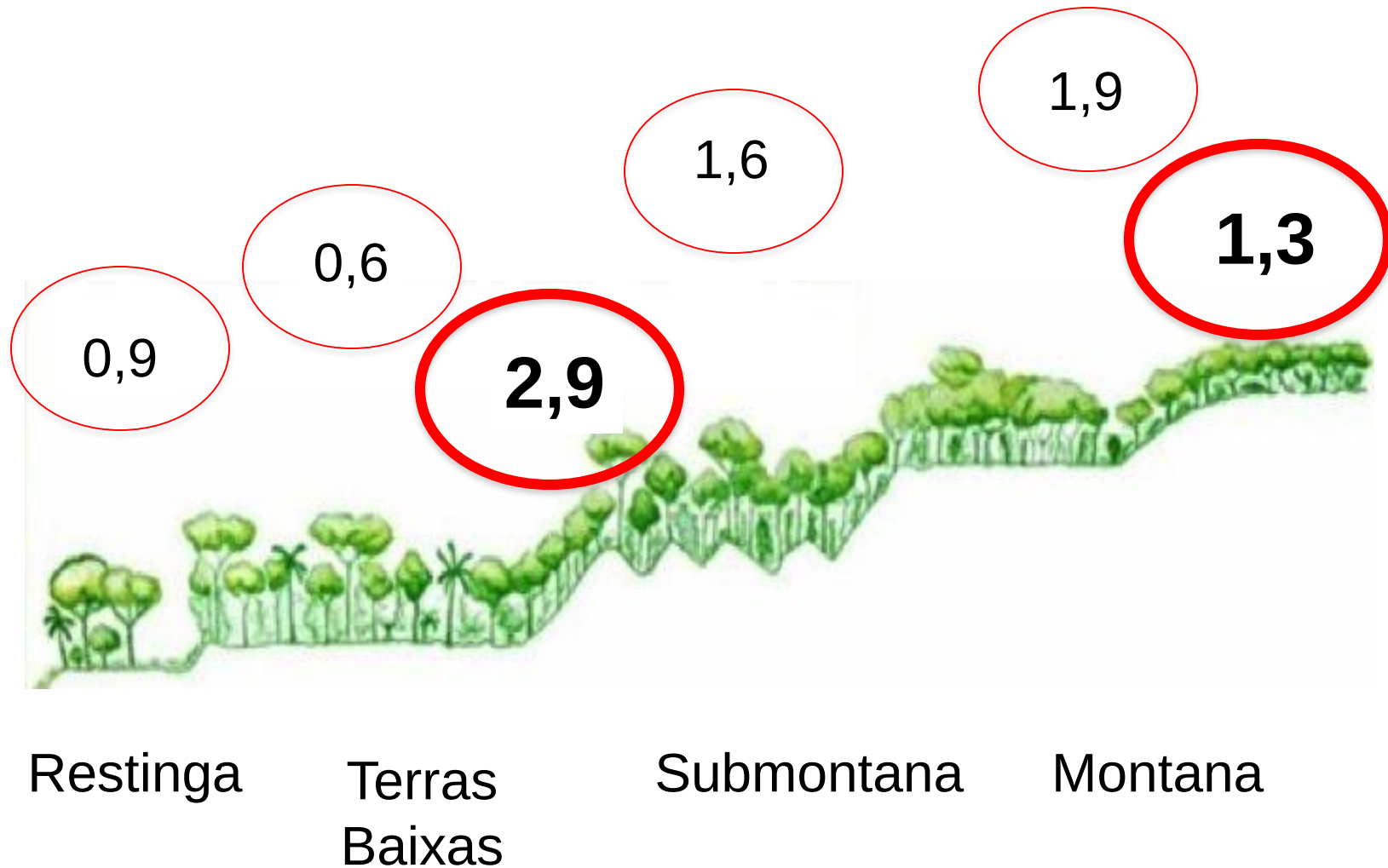
Balanço de carbono ao longo de um gradiente altitudinal de Mata Atlântica ($\text{Mg ha}^{-1} \text{ ano}^{-1}$)



Balanço de carbono ao longo de um gradiente altitudinal de Mata Atlântica ($\text{Mg ha}^{-1} \text{ ano}^{-1}$)



Balanço de carbono ao longo de um gradiente altitudinal de Mata Atlântica ($\text{Mg ha}^{-1} \text{ ano}^{-1}$)



Conclusions: Models of forest dynamics need to account for:

- Low allocation of C to wood growth
- Differences in wood dynamics and forest structure across the tropical forest
- Heterogeneity of C in wood pools (age of standing stock > age of C in dying wood)
- Lag times between photosynthesis and respiration; mostly due to longevity of plant leaf and root tissues

