What is the importance of large trees to biomass productivity in heterogeneous forests?

Gauthier LIGOT

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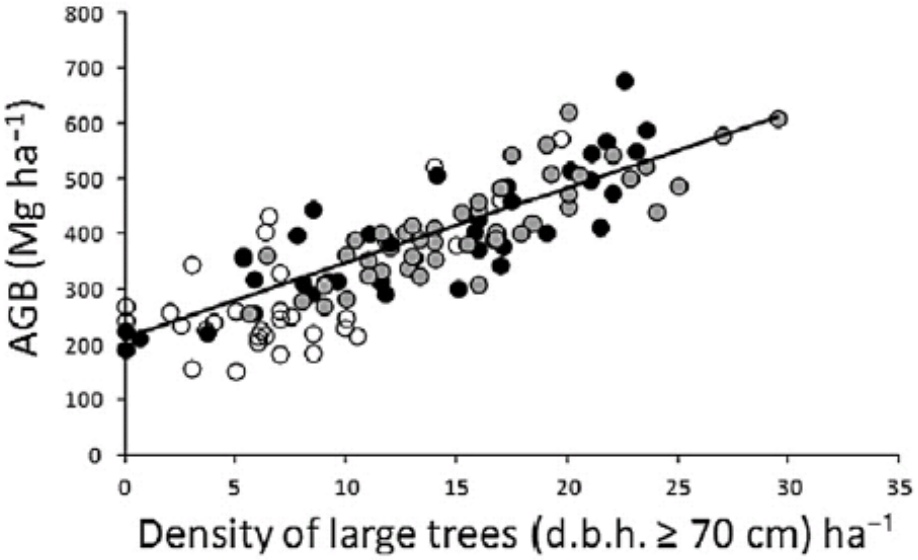
Large trees
a key structural characteristic of complex forests

Large trees are scare but their abundance drives stand biomass and carbon stocks

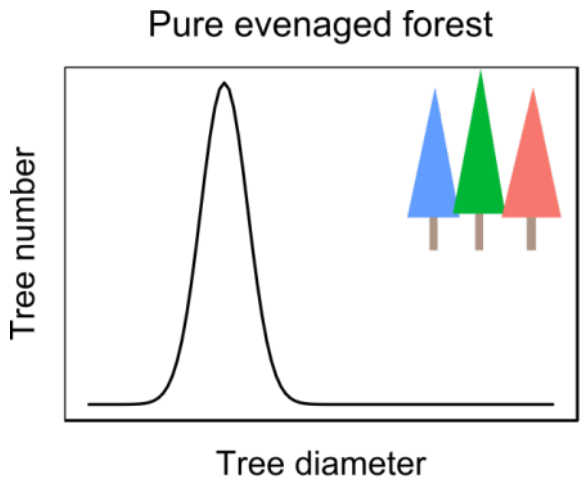
Density of large trees explains 70% of above-ground biomass (AGB) variation across the tropics



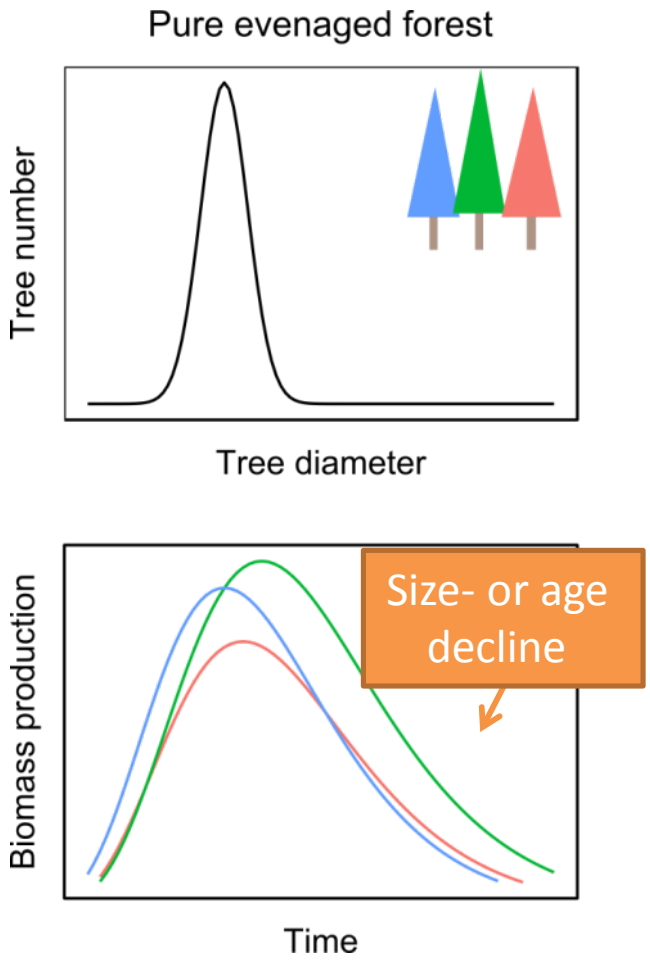
Neotropics	Africa	Asia
287 Mg.ha^{-1}	418 Mg.ha^{-1}	393 Mg.ha^{-1}

Slik *et al.* 2013 GEB

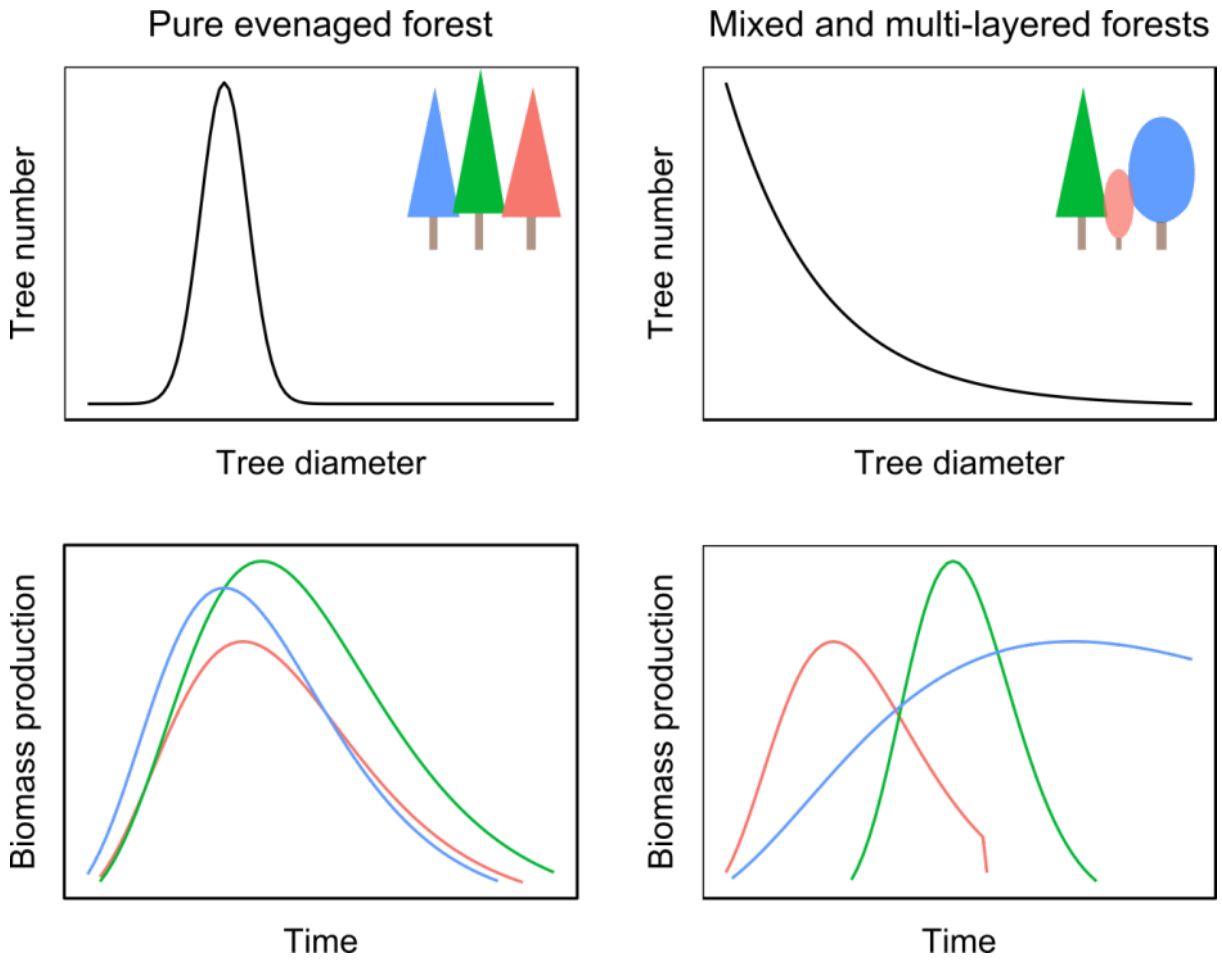
The role of large trees to annual biomass production



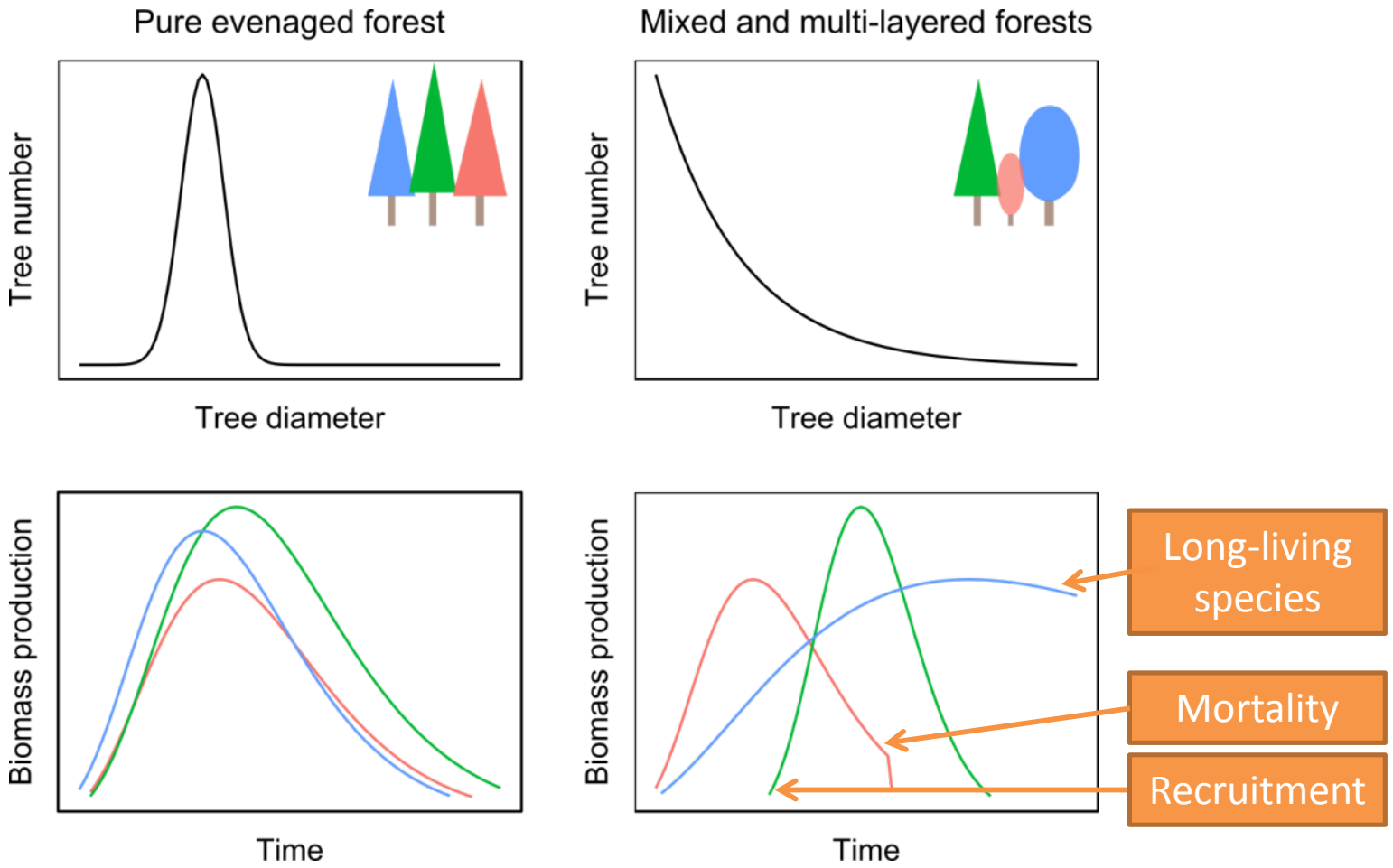
The role of large trees to annual biomass production



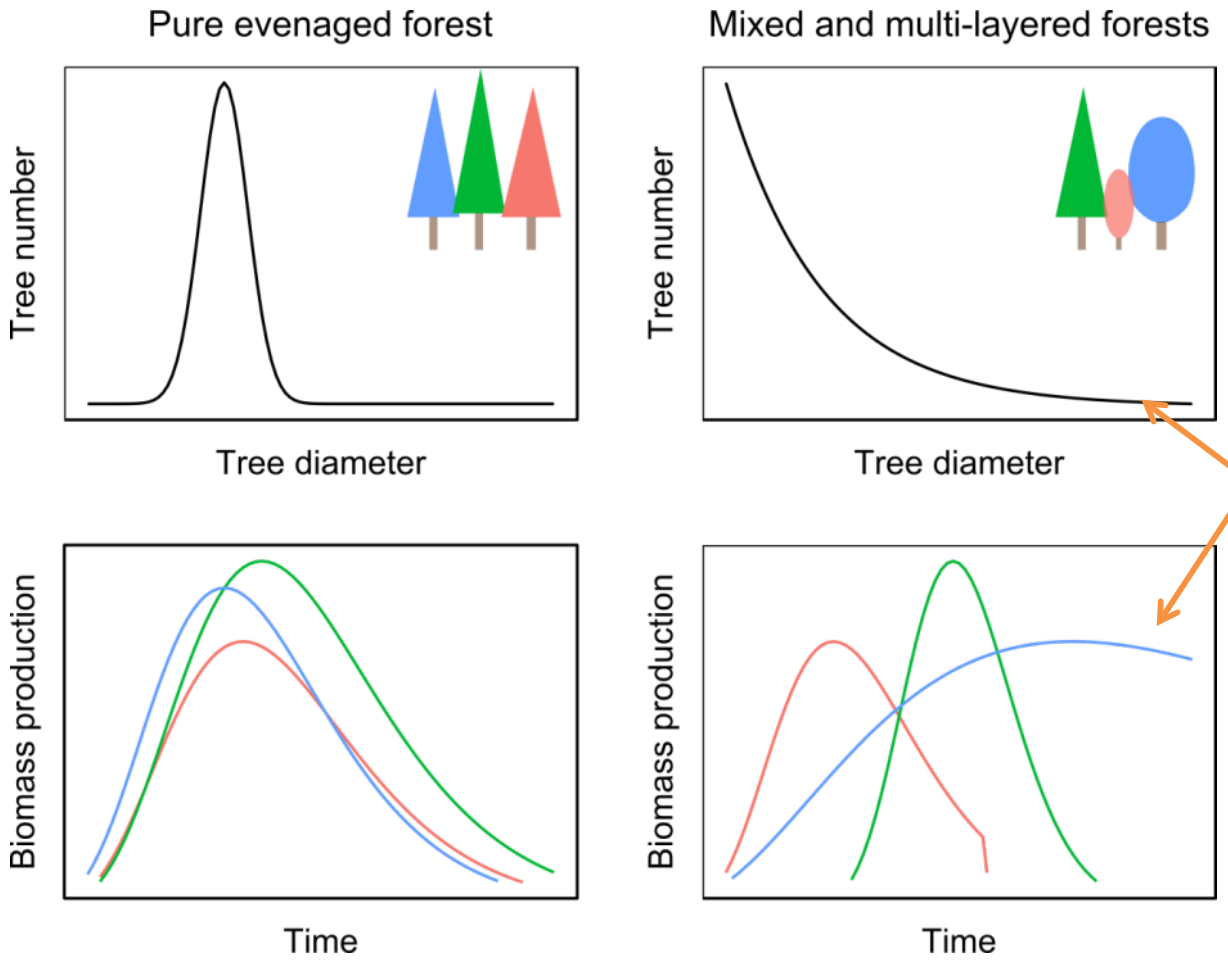
The role of large trees to annual biomass production



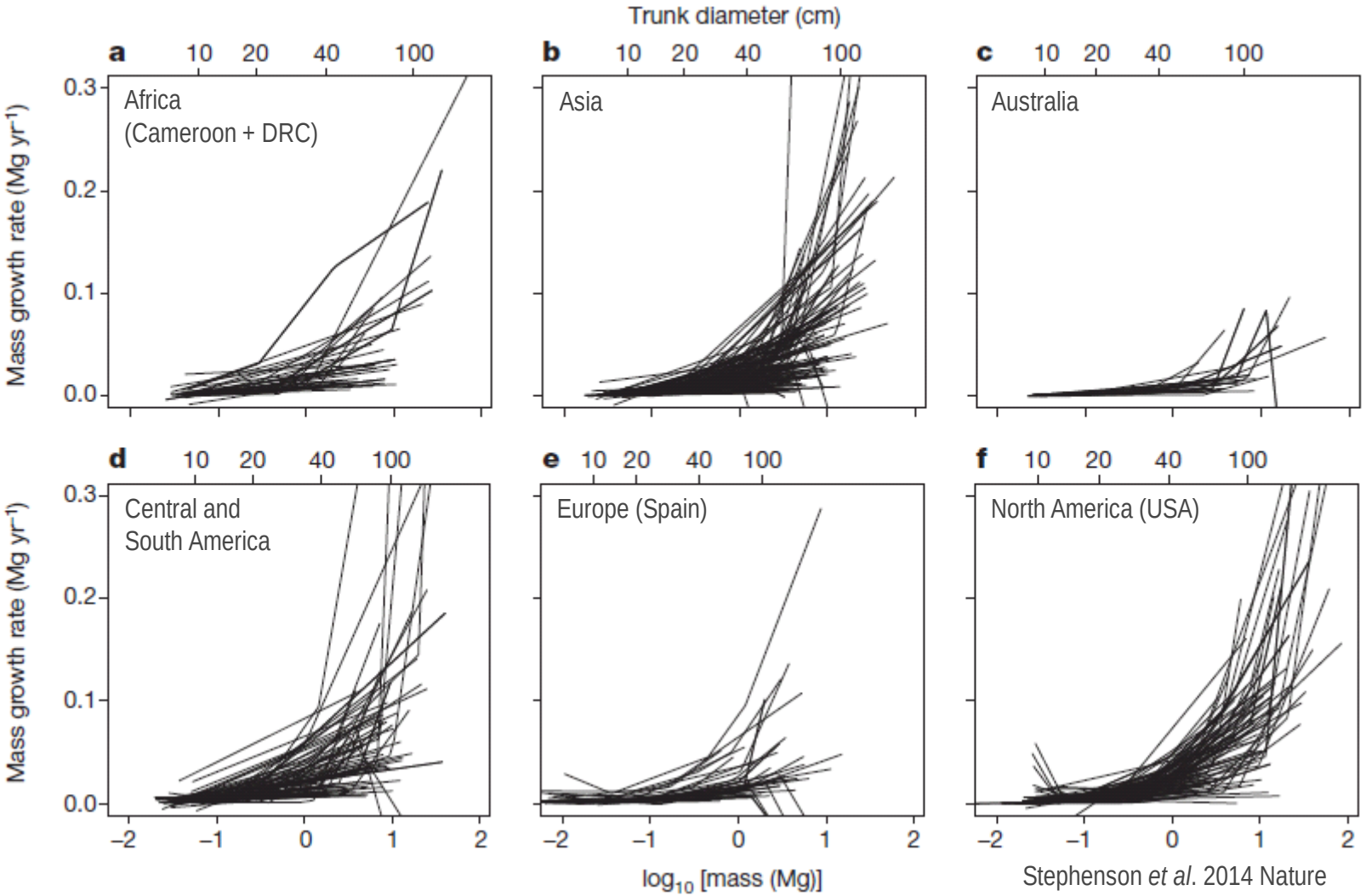
The role of large trees to annual biomass production



The role of large trees to annual biomass production

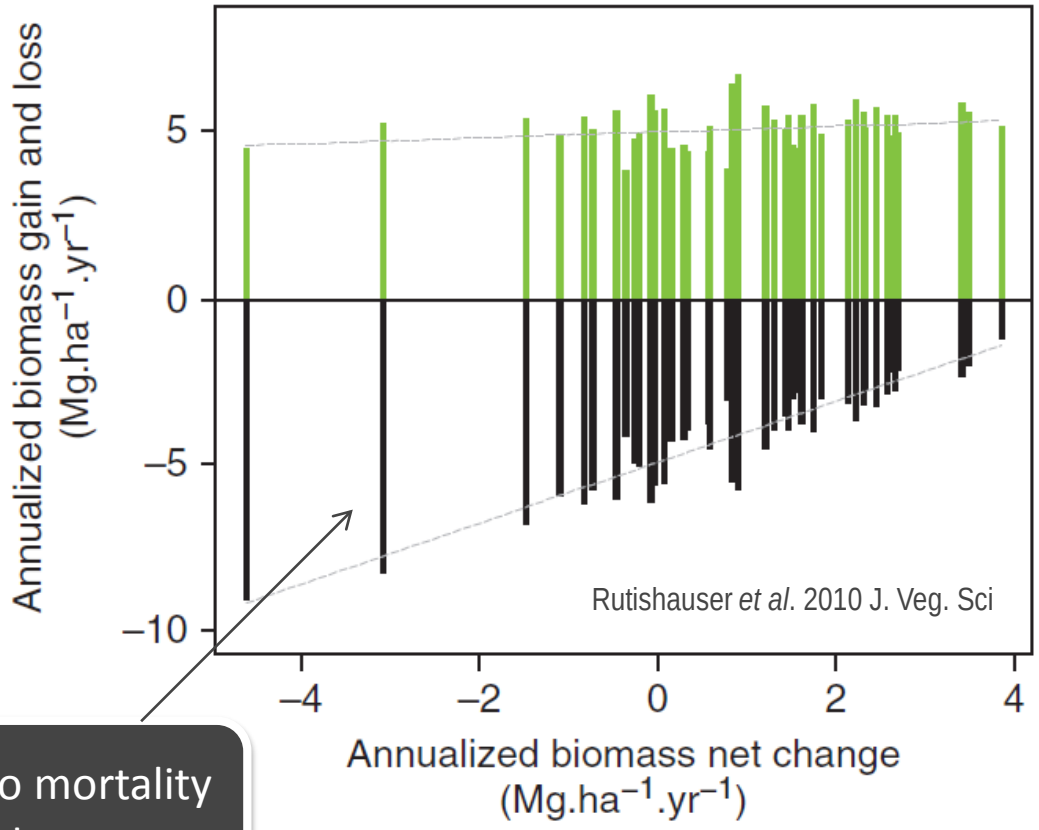


Large trees ≠ senescent biomass stock



Stephenson *et al*. 2014 Nature

Large trees mortality could drive net biomass change



Biomass gains
Tree growth, recruitment

Biomass losses
Tree mortality

Mainly due to mortality in large trees

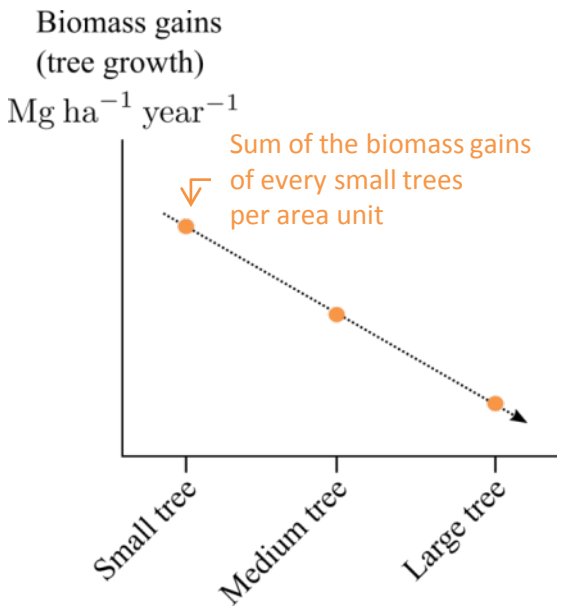
The productive role of large trees at the forest scale

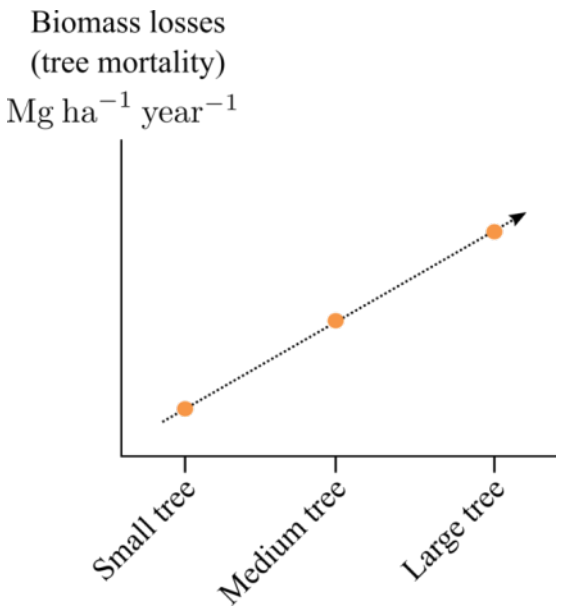
- A crucial question
  - Carbon cycle and climate mitigation
  - Forest management
  - Conservation
- A large variety of point of views
  - Observation scale
  - Ecology and Forest Sciences
- Interactions of processes operating at tree and stand levels

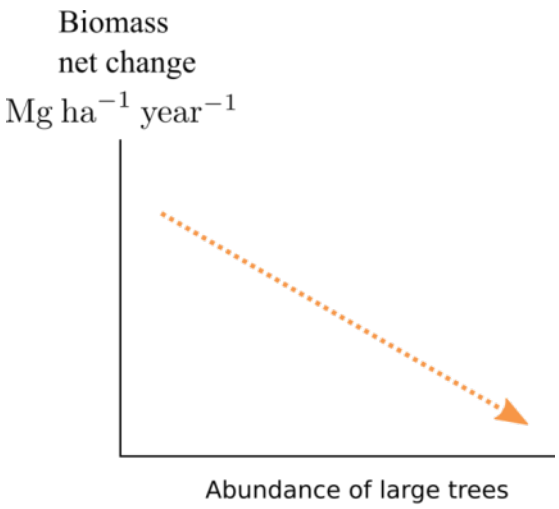



Research question and hypotheses

Clarify the relative role of large trees in biomass production at the stand level in complex forest







The M’baïki long-term silvicultural experiment
Study species and plots
Computing biomass gains and losses at the 4-ha plot scale

MATERIAL & METHODS

The M’baïki site

Location : Central African Republic

Permanent sampling plots

10 plots (4-ha) established in 1982

All trees (dbh≥10cm) marked, geo-referenced and identified

Silvicultural treatments

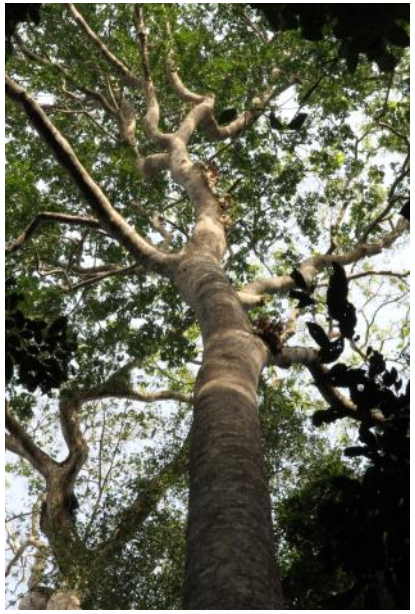
Control plots (3×4 ha)

logged plots (3×4 ha) between 1984 and 1985

Logged and thinned plots (4×4 ha) between 1984 and 1987

Data selection

- 1992 – 2012 period
- A total of 29,729 trees of 225 taxa including 200 species, 151 genera and 54 families
- Eg. *Entandophragma cylindricum* (12.4 % of AGB in large trees in 1992), *Triplochiton scleroxylon* (9.4%), *Terminalia superba* (7.3%), *Manilkara mabokeensis* (7.2%) and *Petersianthus macrocarpus* (5.0%).



Entandophragma cylindricum (Meliaceae)

Triplochiton scleroxylon (Sterculiaceae)

Terminalia superba (Combretaceae)

Khaya anthoteca (Meliaceae)

Biomass computation

Allometric relationship for moist tropical forests

(BIOMASS R Package)

$AGB_i =$

$WD_s \times \exp[-1.499 + 2.148 \times \ln(DBH) + 0.207 \times \ln(DBH)^2 - 0.0281 \times \ln(DBH)^3]$

Chave *et al*. 2005 Oecologia

biomass gain = the sum of the biomass growth of all surviving trees

recruitment = Biomass recruited is the sum of the biomass of all trees that attained 10-cm DBH

biomass loss = the sum of the biomass of all trees that died

Statistical analyses

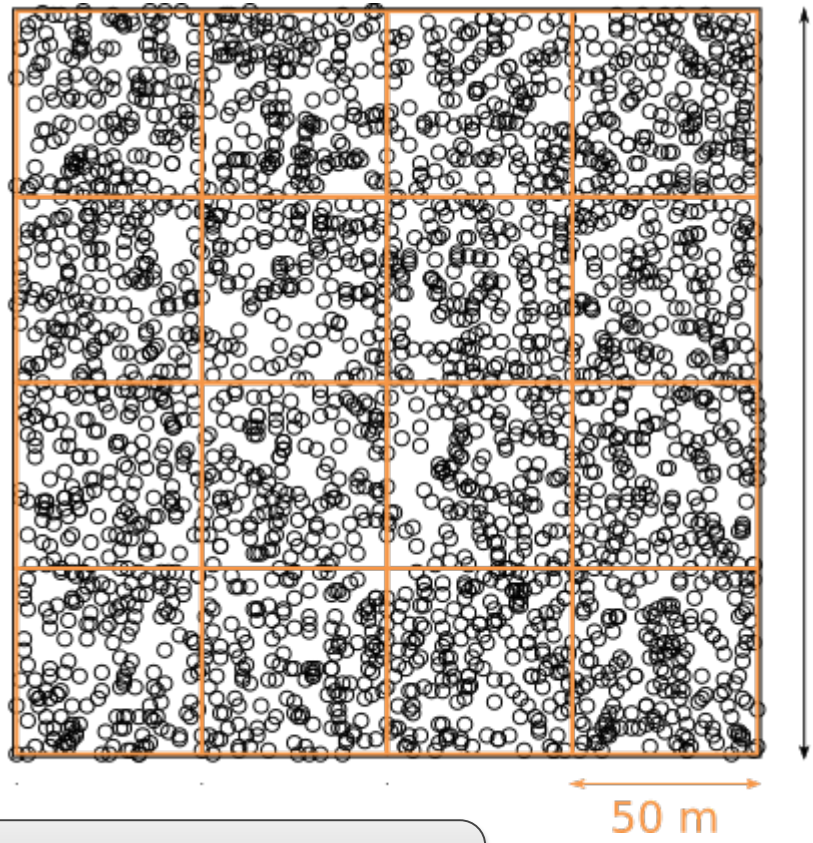
8 DBH classes of ≥ 20 cm

3 DBH classes:

- small : 10-30 cm
- medium : 30-70 cm
- large trees : >70 cm

Compute biomass gains and losses for each plot, subplot and size class

Compute confidence intervals of 4-ha plot
Biomass estimates bootstrapping over 0.25-ha subplots



10 plots of 4 ha

160 subplots of ¼ ha





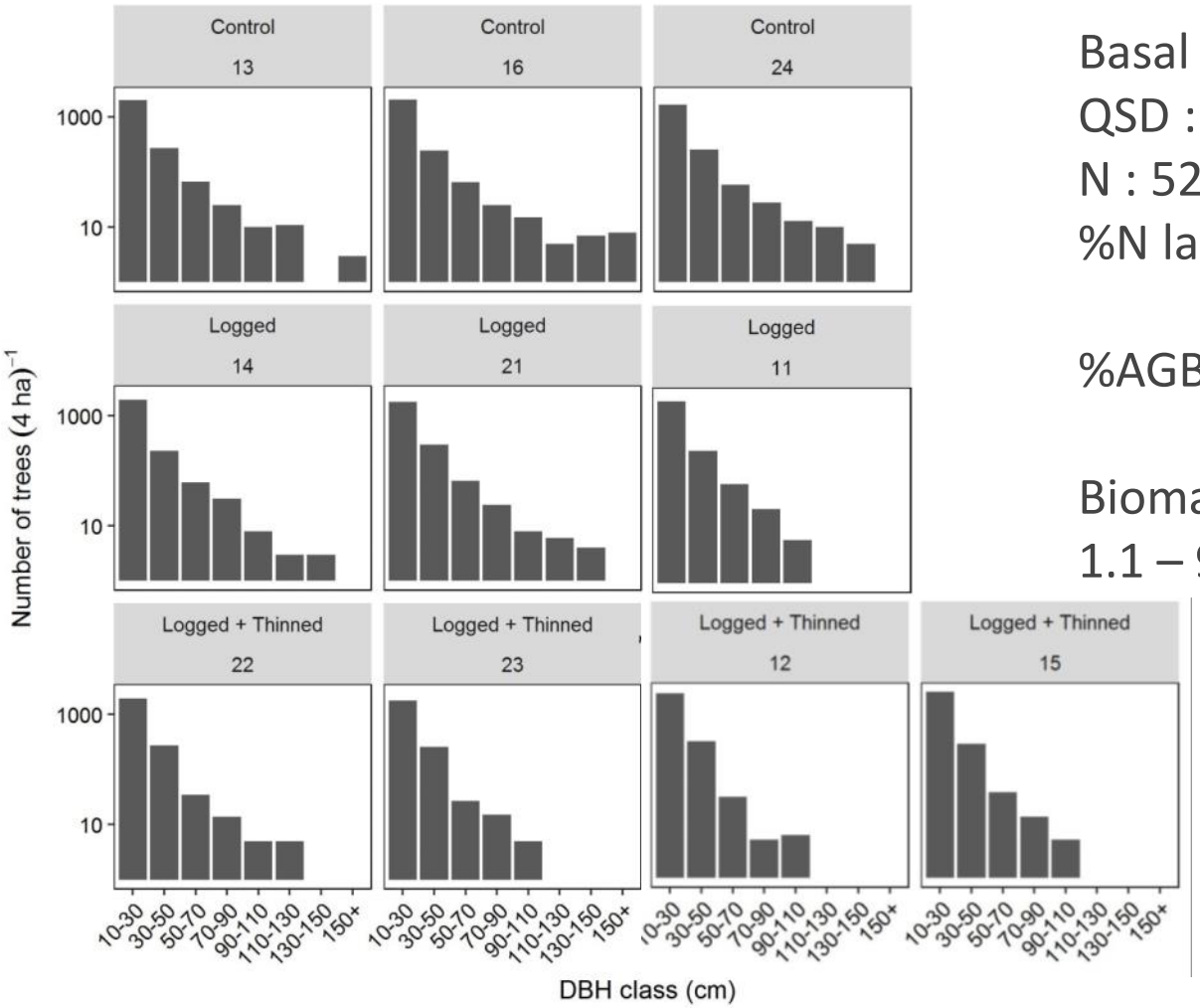
Biomass stock of large trees

Biomass gains and losses of large trees

Biomass net change versus abundance of large trees

RESULTS & DISCUSSION

Stand structures along a gradient of forest perturbation

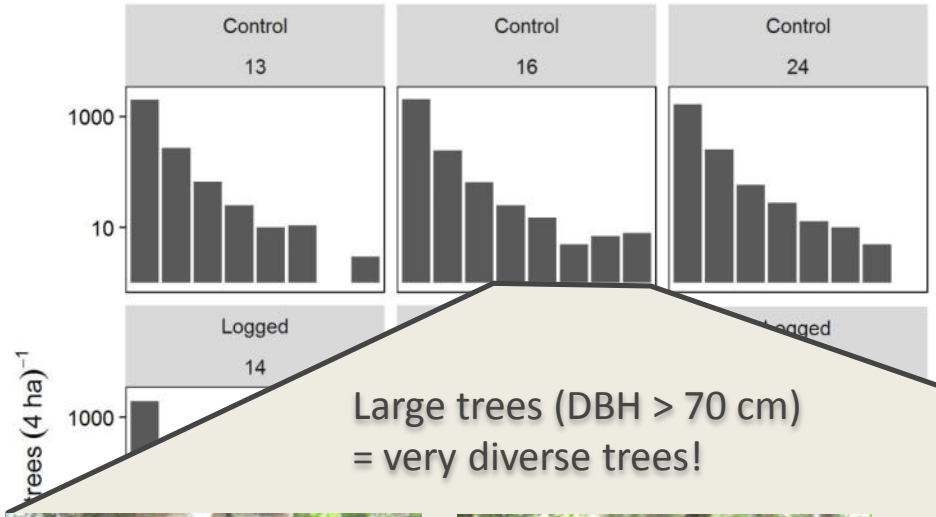


Basal area : 23 – 36 m²/ha
QSD : 24 – 28 cm
N : 523 – 603 trees/ha
%N large trees : 0.5 - 2.8%

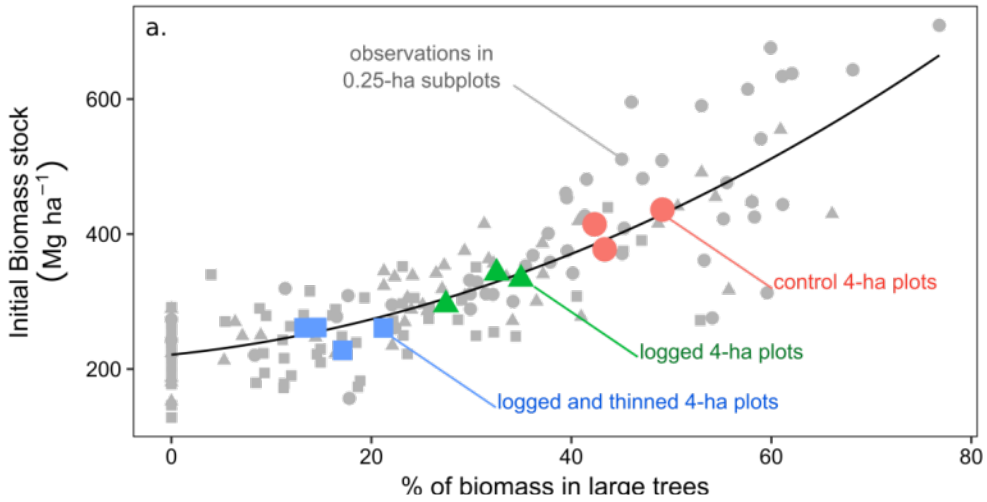
%AGB large trees : 17 – 49%

Biomass net change :
1.1 – 9.2 Mg ha^{-1} year^{-1}

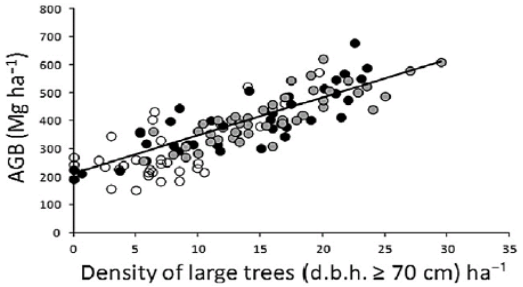
Stand structures along a gradient of forest perturbation



Biomass stock increased with the abundance of large trees



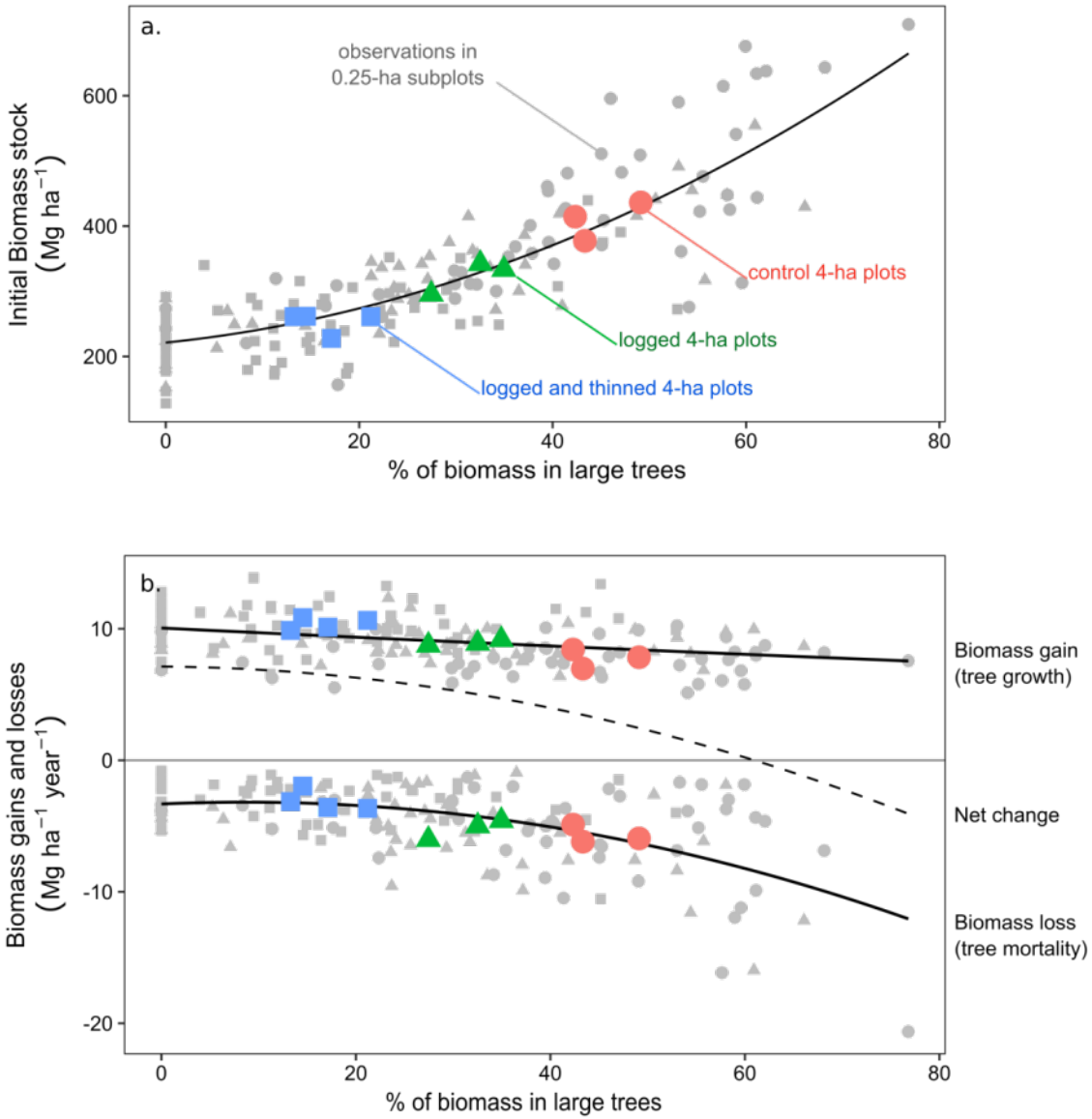
Abundance of large trees well predict total biomass stock (r=0.984, n=160)
Even at a very local scale



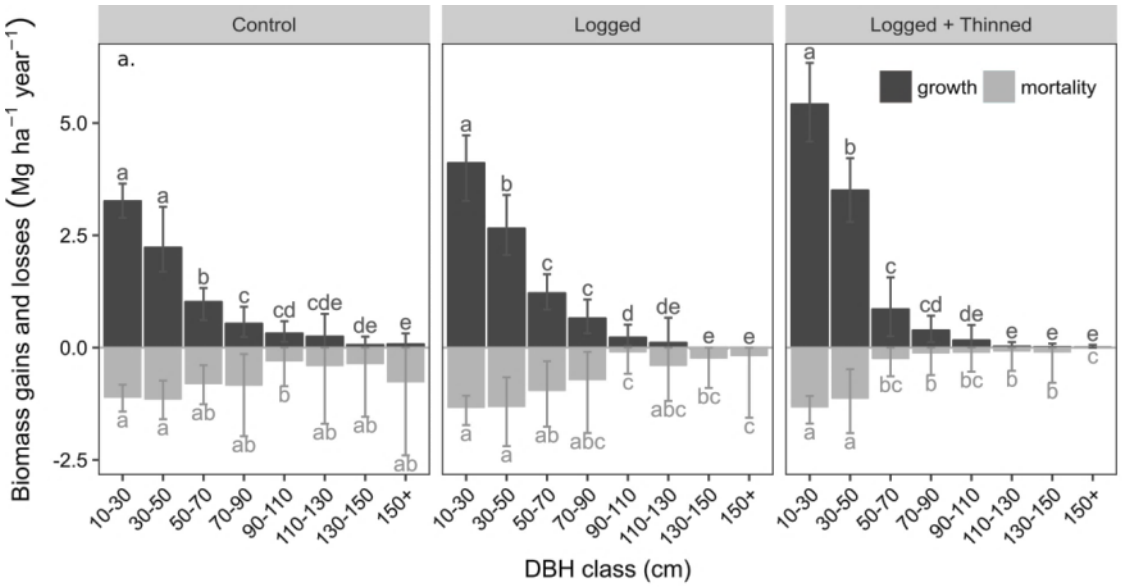
Neotr | Africa | Asia

Slik *et al.* 2013 GEB

Biomass net change decreased with the abundance of large trees



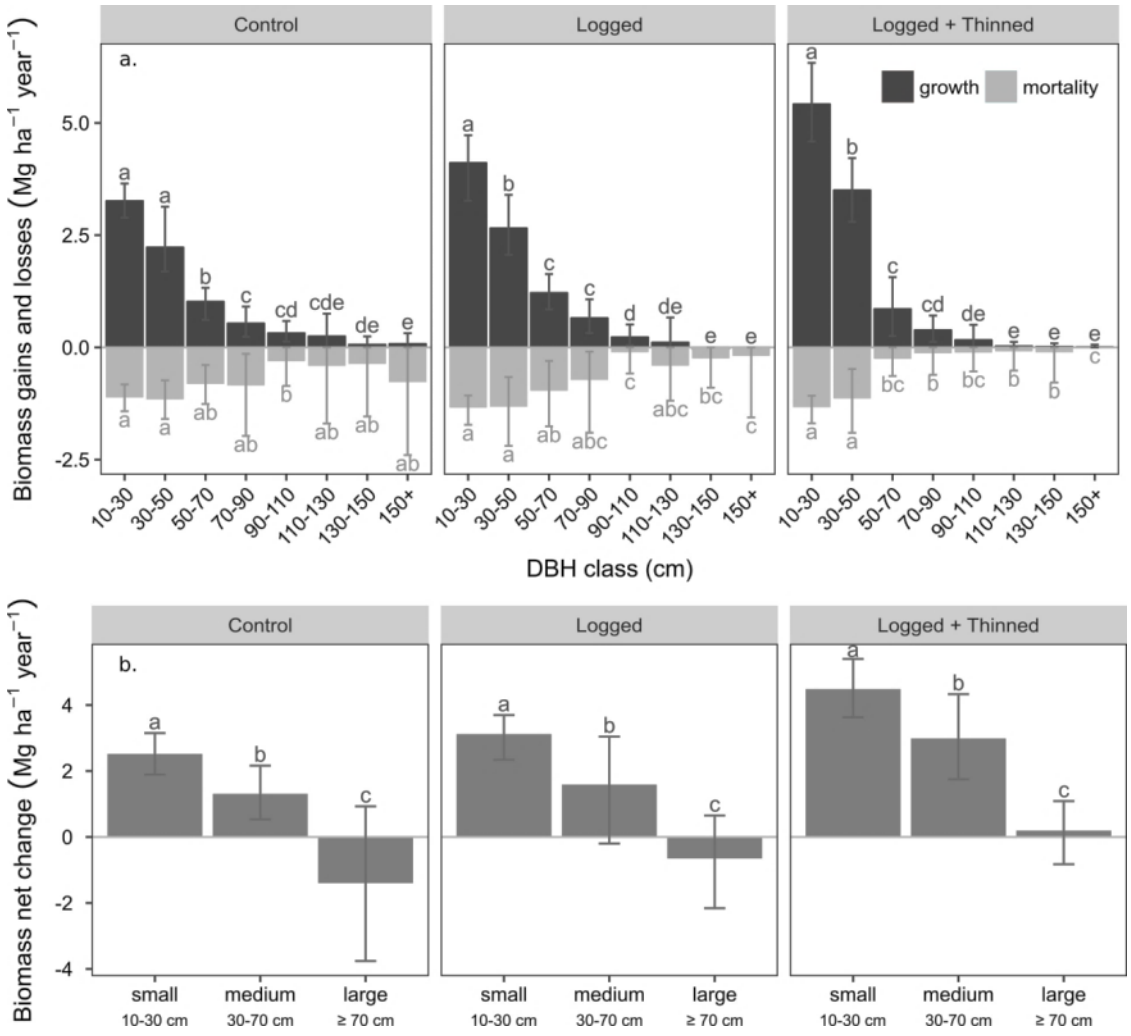
Contribution to plot biomass gains and losses



The few large trees produced substantially less biomass then the numerous small trees

Loss of biomass of large trees could be as important as that of small trees

Contribution to plot biomass gains and losses



The few large trees produced substantially less biomass then the numerous small trees

Loss of biomass of large trees could be as important as that of small trees

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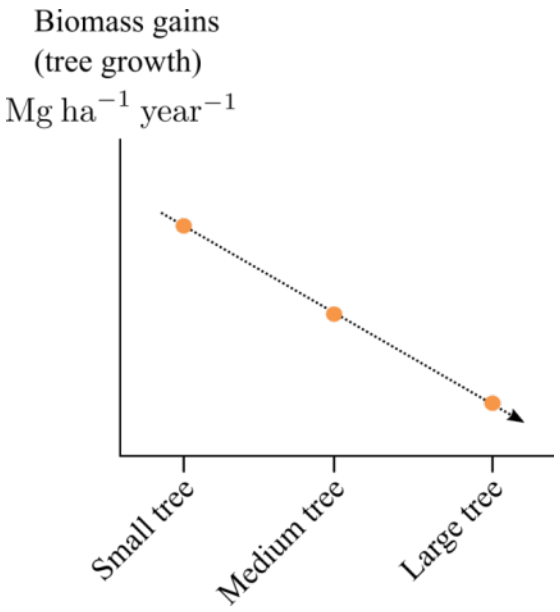
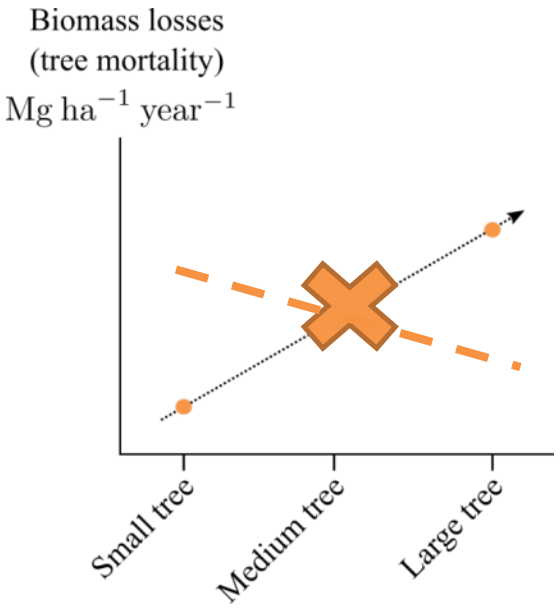
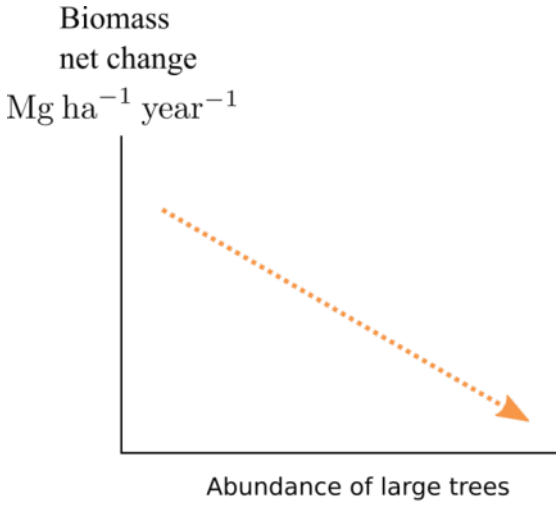
Contribution to plot biomass net change decreased with tree size and that of large trees ≈ 0

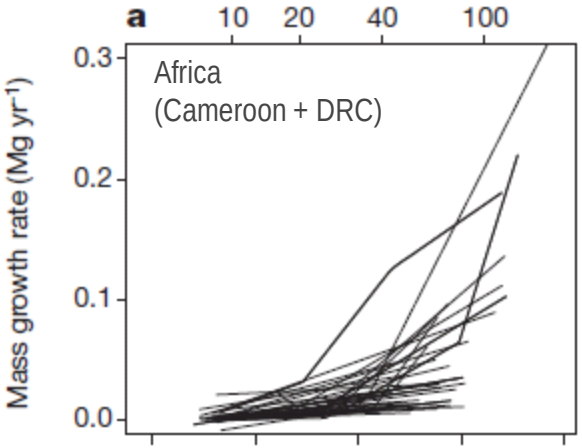
Conclusions



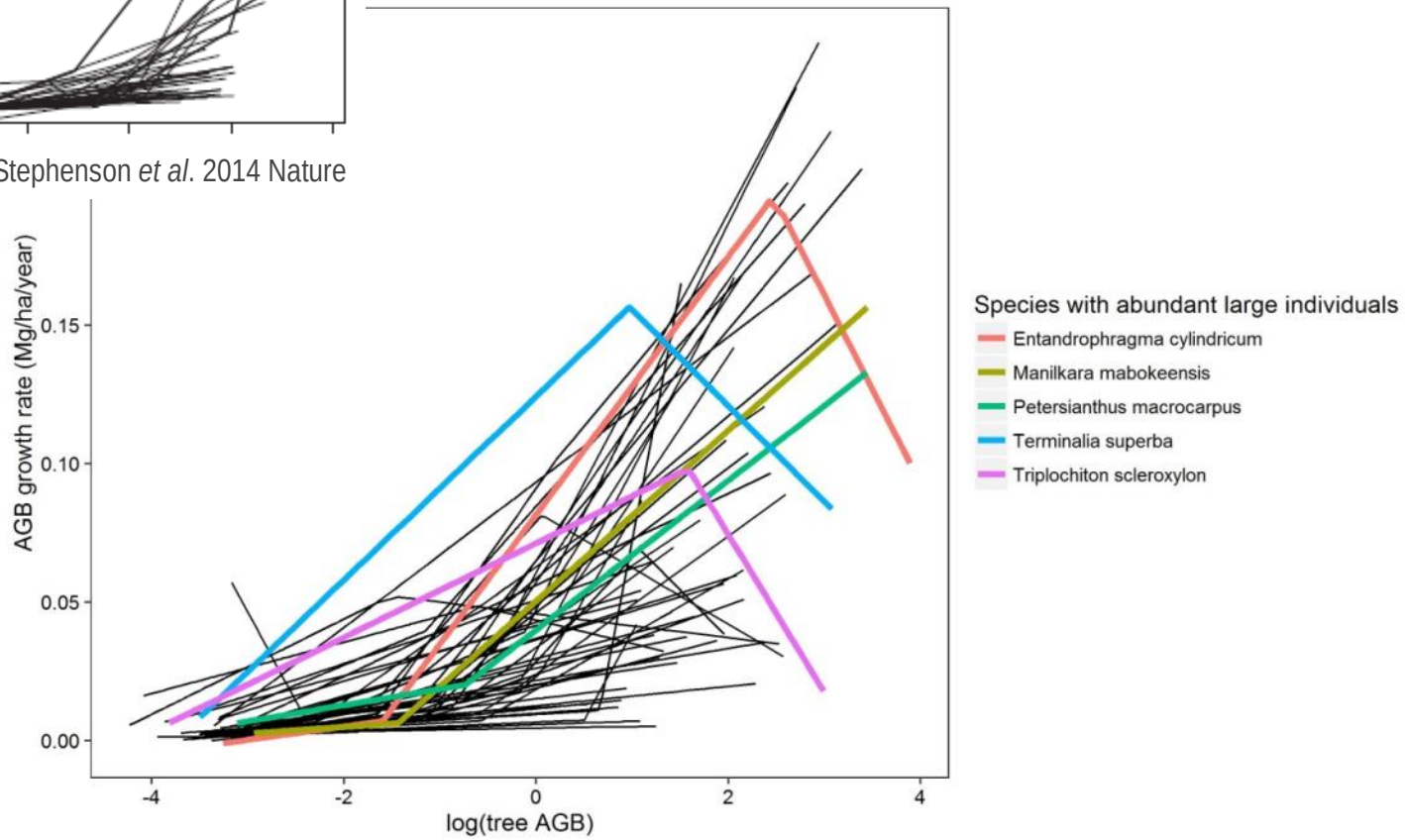




Not in contradiction with the results observed at the tree level



Stephenson *et al*. 2014 Nature



In terms of biomass or carbon only …

Forest with abundant large trees

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high capital investment

high risk level

low profitability rates

Photo credit :
© Jean-Louis Doucet, Jean-Yves de Vleeschouwer, Dakis-Yaoba Ouédraogo , Adeline Fayolle, Sebastien Bauwens

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Stand structure

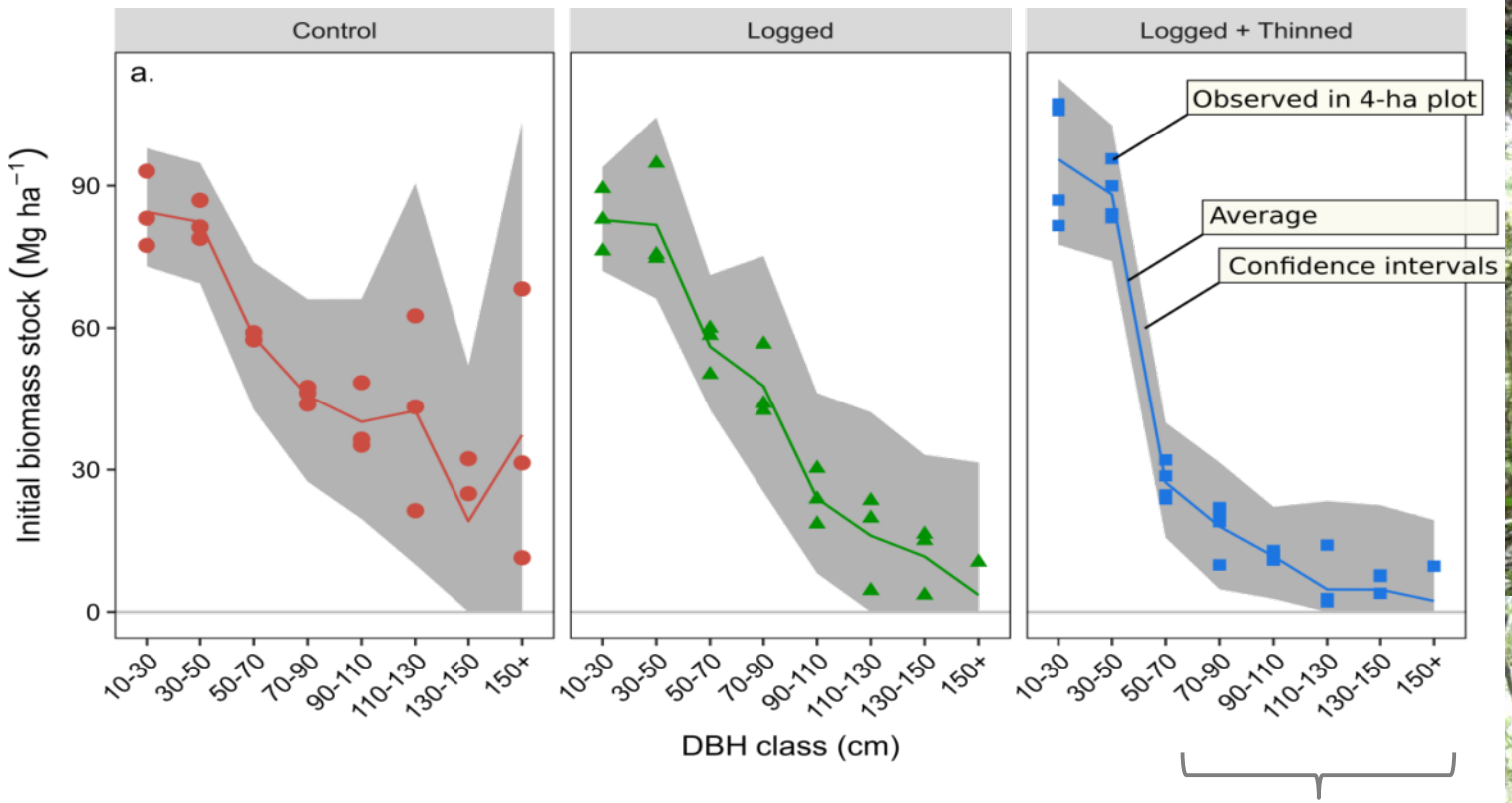
Plot	Treatment	Tree density		Quadratic mean DBH	Basal area	Aboveground Biomass		basal area 1984-1987
		(ha^{-1})	%large trees	(cm)	(m^2 ha^{-1})	(Mg ha^{-1})	% large trees	(m^2 ha^{-1})
16	Control	603.25	2.49	27.75	36.49	436.22	49.11	1.11
24	Control	506.50	2.81	28.41	32.12	377.35	43.33	0.47
13	Control	597.25	2.05	26.87	33.86	414.42	42.32	0.33
12	Logged + Thinned	649.75	0.50	22.55	25.95	261.05	13.28	-2.86
11	Logged	584.50	1.33	24.59	27.76	295.30	27.45	-3.12
21	Logged	548.50	1.91	26.73	30.79	342.23	32.53	-3.88
15	Logged + Thinned	677.00	0.70	22.29	26.41	261.53	14.54	-5.25
14	Logged	571.50	1.97	25.54	29.28	333.35	34.95	-5.58
22	Logged + Thinned	574.50	1.09	23.97	25.93	260.94	21.20	-6.44
23	Logged + Thinned	523.75	1.05	23.82	23.34	227.64	17.12	-6.87

Biomass gains, losses and net changes

Id	traitement	site	Growth		Mortality		Recruitment		Net change	
24	Control	La Lolé	6.97	(6.44;7.48)	-6.19	(-7.9;-4.77)	0.34	(0.3;0.38)	1.13	(-0.6;2.59)
16	Control	Boukoko 2	7.83	(7.27;8.44)	-5.94	(-8.47;-3.96)	0.46	(0.42;0.52)	2.36	(-0.24;4.4)
11	Logged	Boukoko 1	8.74	(8.22;9.31)	-6.03	(-7.36;-4.81)	0.35	(0.31;0.4)	3.06	(1.64;4.35)
13	Control	Boukoko 1	8.42	(7.9;8.96)	-4.89	(-6.5;-3.51)	0.27	(0.24;0.31)	3.80	(2.31;5.11)
21	Logged	La Lolé	8.89	(8.34;9.43)	-5.00	(-6.95;-3.62)	0.32	(0.28;0.37)	4.22	(2.47;5.69)
14	Logged	Boukoko 2	9.16	(8.45;9.88)	-4.59	(-6.27;-3.23)	0.35	(0.29;0.4)	4.91	(3.14;6.56)
23	Logged + T.	La Lolé	9.88	(9.11;10.54)	-3.15	(-3.85;-2.44)	0.30	(0.27;0.34)	7.03	(5.97;7.96)
12	Logged + T.	Boukoko 1	10.12	(9.35;10.79)	-3.59	(-4.34;-2.85)	0.53	(0.46;0.6)	7.06	(5.9;8.1)
22	Logged + T.	La Lolé	10.64	(9.77;11.49)	-3.66	(-4.75;-2.78)	0.43	(0.38;0.47)	7.41	(6.38;8.35)
15	Logged + T.	Boukoko 2	10.84	(10.3;11.46)	-1.96	(-2.22;-1.72)	0.32	(0.28;0.37)	9.20	(8.63;9.79)

Importance of large trees along a gradient of forest perturbation

%AGB large trees : 17 – 49%



Large trees (DBH > 70 cm)
= very diverse trees!