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Title: Carbon stock loss from deforestation through 2013 in Brazilian Amazonia

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Authors: Euler Melo Nogueira[1*], Aurora M Yanai[1], Frederico O R Fonseca[1], Philip Martin Fearnside[1*]

Author affiliation:

1. Department of Environmental Dynamics, National Institute for Research in Amazonia (INPA), Av. André Araújo nº 2936, CEP 69 067-375, Manaus, Amazonas, Brazil

Correspondence: Philip Martin Fearnside; Tel.: + 55 92 3643 1822, Fax: + 55 92 3642 3028; e-mail: pmfearn@inpa.gov.br, philip.fearnside@gmail.com
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Abstract

The largest carbon stock in tropical vegetation is in Brazilian Amazonia. In this ~5 million km^2 area, over 750,000 km^2 of forest and ~240,000 km^2 of non-forest vegetation types had been cleared through 2013. We estimate current carbon stocks and cumulative gross carbon loss from clearing of primary vegetation in Brazil's "Legal Amazonia" and "Amazonia biome" regions. Biomass of "pre-modern" vegetation (prior to major increases in disturbance beginning in the 1970s) was estimated by matching vegetation classes mapped at a scale of 1:250,000 and 29 biomass means from 41 published studies for vegetation types classified as forest (2317 1-ha plots) and as either non-forest or contact zones (1830 plots and sub-plots of varied size). Total biomass (above and below-ground, dry weight) underwent a gross reduction of 18.3% in Legal Amazonia (13.1 Pg C) and 16.7% in the Amazonia biome (11.2 Pg C) through 2013, excluding carbon loss from the effects of fragmentation, selective logging, fires, mortality induced by recent droughts and clearing of forest regrowth. In spite of the loss of carbon from clearing, large amounts of carbon were stored in stands of remaining vegetation in 2013, equivalent to around 149 Mg C ha^{-1} when weighted by the total area covered by each vegetation type in Legal Amazonia. Native vegetation in Legal Amazonia in 2013 originally contained 58.6 Pg C, while that in the Amazonia biome contained 56 Pg C. Emissions per unit area from clearing could potentially be larger in the future because previously cleared areas were mainly covered by vegetation with lower mean biomass than the remaining vegetation. Estimates of original biomass are essential for estimating losses to forest degradation. This study offers estimates of cumulative biomass loss, as well as estimates of pre-modern carbon stocks that have not been represented in recent estimates of deforestation impacts.

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Supporting information

Table S1. Details on collection sites, sampling methods, number and size of plots for each source dataset used in Tables 1 and 2.

Table S2. Notes for Tables 1 and 2.

Table S3. Total biomass and carbon stocks (dry weight in Pg) by vegetation physiognomy in the Amazonia biome.

Figure S1. Variability of total biomass shown in Figure 2.

Figure S2. Distribution of original total biomass (above- and below-ground; dry weight in Mg ha^{-1}) in areas cleared through 2013 in Brazil's "Legal Amazonia" and "Amazonia biome" regions.

Table 1. Dry above-ground biomass and carbon stock estimates (Mg ha^{-1}) for *campinaranas* (vegetation on white-sand soils), savannas and pioneer formations from 38 published studies (see Table S1 in Supplementary Material for details about collection sites, sampling method, number and size of plots for each source dataset used). Means for each vegetation type are shown in bold.

Vegetation type (Legend from Brazil, IBGE, 1992)	**Herbaceous ± SD or (±SE)**		**Trees and Shrubs ± SD or (±SE)**		**Necromass (litter) ± SD or (±SE)**		**Total live and dead biomass ± SD or (±SE)**		**Carbon ± SD or (±SE)**		**Source**	**Note**
Forested shade-loving *campinarana* (Ld)	-	-	264.35	1.63	-	-	-	-	-	-	Lima *et al.* (2012, Table 2)	[1]
	1.96	-	180.36	-	9.75	-	192.05	-	86.04	-	Bongers *et al.* (1985, Tables 3, 9 and 10) "Tall *Bana*"	[2], [3]
	3.46	-	273.48	-	13.12	9.34	289.88	-	129.86	-	Klinge & Herrera (1983, Tables 5 and 16)	[3], [4]
Mean	**2.71**	**-**	**239.40**	**-**	**11.44**	**-**	**253.54** [*a*]	**-**	**113.59**	**-**		[3]
Treed shade-loving *campinarana* (La)	0.83	-	13.70	-	1.37	-	15.90	-	7.12	-	Barbosa & Ferreira (2004, Tables 4 and 6)	[3], [5]
	-	-	-	-	-	-	38.80	-	17.38	-	Barbosa & Fearnside (1999, Table 3)	[3], [6]
	2.47	-	37.32	-	31.80	-	71.57	-	32.06	-	Bongers *et al.* (1985, Tables 3, 9 and 10) "Low *Bana*"	[2], [3]
Mean	**1.65**	**-**	**25.51**	**-**	**16.58**	**-**	**42.09**	**-**	**18.86**	**-**		
Grassy-woody shade-loving *campinarana* (Lg)	1.92	-	3.88	-	1.85	-	7.65	-	2.96	-	Bongers *et al.* (1985, Tables 3, 9 and 10) "Open *Bana*"	[2], [3]
Mean	**1.92**	**-**	**3.88**	**-**	**1.85**	**-**	**7.65**	**-**	**2.96**	**-**		
Seasonal forested savanna (Sd)	2.02	1.29	39.41	18.97	9.86	4.84	51.29	21.46	22.98	9.61	Ottmar *et al.* (2001) "*Cerrado Denso*"	[3], [7]
Mean	**2.02**	1.29	**39.41**	18.97	**9.86**	4.84	**51.29**	21.46	**22.98**	9.61		
Seasonal treed savanna (Sa)	-	-	15.10	-	9.21	-	-	-	-	-	Paiva *et al.* (2011, Table 3)	[8]
	-	-	67.64	-	6.32	12.3*	73.96	-	33.13	-	Ribeiro *et al.* (2011)	
	-	-	-	-	-	-	9.43	1.31	4.23	0.59	Brazil, MCT (2006, Table 2) "*Cerrado sensu stricto*"	[3], [9]
	1.52	0.42	9.56	1.30	0.65	-	11.73	1.12	5.22	0.52	Barbosa & Fearnside (2005, Tables 3 and 5) "Sa"	[10]
	-	-	-	-	-	-	-	-	11.60	-	Rezende (2002, p. 216)	[11]

	-	-	-	-	-	-	14.11	3.41	6.32	1.53	Santos *et al.* (2002, Table 1) "Savanna woodland"	[3], [12]
	-	-	-	-	-	-	12.40	-	5.56	-	de Araújo *et al.* (2001)	[13]
	1.35	-	19.32	-	2.06	-	22.73	-	10.18	-	Lilienfein *et al.* (2001, Tables 2 and 4)	[3], [14]
	2.50	0.61	26.15	12.45	8.41	2.93	37.06	15.56	16.60	6.97	Ottmar *et al.* (2001) "*Sensu stricto*"	[3], [7], [15], [16], [17]
	-	-	-	-	-	-	39.79	-	17.83	-	Abdala *et al.* (1998)	[3], [18]
	4.80	-	12.80	-	7.20	-	24.80	(2.50)	11.11	(1.12)	Castro & Kauffman (1998, Table 1) "*Cerrado stricto sensu, aberto*"	[3], [19]
	2.30	-	16.10	-	6.60	-	25.00	(2.90)	11.20	(1.30)	Castro & Kauffman (1998, Table 1) "*Cerrado stricto sensu, denso*"	[3], [19]
	8.11	-	-	-	1.82	0.61	-	-	-	-	Kauffman *et al.* (1994, Table 1) "*Cerrado sensu stricto*"	[20]
	-	-	-	-	-	-	27.38	6.68	12.26	2.99	Santos (1988, pp. 143-144)	[3], [21]
Mean	**3.43**	**-**	**23.81**	**-**	**5.28**	**-**	**27.13**	**-**	**12.10**	**-**		
Seasonal parkland savanna (Sp)	-	-	19.50	-	-	-	**-**	**-**	**-**	**-**	Delitti *et al.* (2006, Tables 4 and 8) "*Campo cerrado*"	-
	3.65	0.86	3.64	0.16	0.74	-	8.04	0.47	3.42	0.18	Barbosa & Fearnside (2005, Tables 3 and 5) "Sp"	[10], [22]
	-	-	-	-	-	-	7.42	1.73	3.19	0.74	Santos *et al.* (2002, Table 1) "Shrub and/or treed savanna"	[3], [12]
	3.99	2.86	13.04	7.95	5.14	2.94	22.17	8.06	9.53	3.47	Ottmar *et al.* (2001) "*Cerrado ralo*"	[3], [7], [16]
	7.27	-	-	-	1.33	0.62	-	-	-	-	Kauffman *et al.* (1994, Table 1) "*Campo cerrado*"	[20]
Mean	**4.97**	-	**12.06**	-	**2.40**	-	**12.54**	**-**	**5.38**	**-**		
Seasonal grassy-woody savanna (Sg)	4.59	-	1.06	0.68	0.66	-	6.31	0.88	2.30	-	Barbosa *et al.* (2012, Tables 1, 2 and 4) "DG-Arg"	[23]
	5.89	-	0.60	1.08	0.85	-	7.34	1.96	2.68	-	Barbosa *et al.* (2012, Tables 1, 2 and 4) "DG-Lts"	[23]
	5.34	-	2.76	1.59	0.77	-	8.87	2.43	3.42	-	Barbosa *et al.* (2012, Tables 1, 2 and 4) "GP-Lts"	[23]
	7.65	-	-	-	1.36	-	9.01	2.86	3.26	-	Barbosa *et al.* (2012, Tables 1, 2 and 4) "WG-Hyd"	[23]
	-	-	-	-	-	-	4.77	1.84	1.85	0.71	Santos *et al.* (2002, Table 1) "Grassland savanna"	[3], [12]

	-	-	-	-	-	-	7.18	1.42	2.78	0.55	Brazil, MCT (2006, Table 1) "*Campo sujo*"	[3], [7]
	2.77	0.50	0.04	0.00	0.50	-	3.31	0.45	1.19	0.16	Barbosa & Fearnside (2005, Tables 3 and 5) "Sg Clean field"(*Campo limpo)*	[10], [22]
	2.31	0.98	0.60	0.01	0.35	-	3.26	0.71	1.24	0.24	Barbosa & Fearnside (2005; Tables 3 and 5) "Sg Dirty field" (*Campo sujo*)	[10], [22]
	8.84	4.74	0.04	0.11	0.95	0.70	9.84	5.18	3.56	1.88	Ottmar *et al.* (2001) "*Campo limpo*"	[3], [7], [16]
	5.58	2.62	2.52	2.09	2.71	1.21	10.81	3.08	4.18	1.19	Ottmar *et al.* (2001) "*Campo sujo*"	[3], [7]
	2.90	-	-	-	2.60	-	-	-	-	-	Castro & Kauffman (1998, Table 1) "*Campo limpo*"	[19]
	2.20	-	1.70	(0.30)	5.30	-	9.20	(0.80)	3.56	(0.31)	Castro & Kauffman (1998, Table 1) "Campo sujo"	[3], [19]
	2.31	0.96	-	-	1.26	0.41	3.57	1.06	1.29	0.38	Cardoso *et al.* (2000, Figure 2)	[3], [24]
	7.13	-	-	-	-	-	-	-	-	-	Kauffman *et al.* (1994, Table 1) "*Campo limpo*"	-
	7.32	-	-	-	-	-	-	-	-	-	Kauffman *et al.* (1994, Table 1) "*Campo sujo*"	-
Mean	**4.99**	-	**1.16**	-	**1.57**	-	**6.95**	-	**2.61**	-		
Steppe-like seasonal treed savanna (Ta)	1.52	0.42	7.64	0.25	1.08	-	10.25	0.26	4.40	0.11	Barbosa & Fearnside (2005, Tables 4 and 6) "Ta"	[10]
Mean	**1.52**	0.42	**7.64**	0.25	**1.08**	-	**10.25**	0.26	**4.40**	0.11		
Steppe-like seasonal parkland savanna (Tp)	3.17	1.53	2.32	0.08	0.64	-	6.13	0.85	2.52	0.32	Barbosa & Fearnside (2005, Tables 4 and 6) "Tp"	[10]
Mean	**3.17**	1.53	**2.32**	0.25	**0.64**	-	**6.13**	0.85	**2.52**	0.32		
Steppe-like seasonal grassy-woody savanna (Tg)	1.38	0.49	0.09	0.01	0.16	-	1.63	0.43	0.68	0.17	Barbosa & Fearnside (2005, Tables 4 and 6) "Tg Clean field" (*Campo limpo*)	[10]
	2.28	1.00	1.32	0.21	0.45	-	4.05	0.65	1.72	0.26	Barbosa & Fearnside (2005, Table 4 and 6) "Tg Dirty field" (*Campo sujo*)	[10]
Mean	**1.83**	**-**	**0.70**	**-**	**0.30**	**-**	**2.84**	**-**	**1.20**	**-**		
Pioneer vegetation in areas with riverine	-	-	-	-	-	-	18.00	3.00	8.06	1.35	Schöngart *et al.* (2010, Table 18.10)	[25], [26]

influence (Pa)												
	-	-	-	-	-	-	21.35	-	9.56	-	Junk & Piedade (1993)	[26], [27]
Mean	**-**	**-**	**-**	**-**	**-**	**-**	**19.68**	**-**	**8.81**	**-**		
Pioneer vegetation in areas with marine influence (Pm) [b, c]	-	-	-	-	7.68	-	-	-	-	-	Assis *et al.* (2011, p. 108)	[28]
	-	-	166.30	-	-	-	-	-	-	-	Alves *et al.* (2010, Table 3 "*Restinga* forest")	[29]
	-	-	3.55	-	1.59	-	5.14	-	-	-	Dias *et al.* (2006, Table 2 "*Restinga* open woodland")	[30]
	-	-	-	-	5.54	-	-	-	-	-	Pires *et al.* (2006; p.177)	[31]
	-	-	-	-	3.93	-	-	-	-	-	de Moraes *et al.* (1999, Table 2)	[28]
Mean	**-**	**-**	**84.92**	**-**	**4.69**	**-**	**89.61** [a]	**-**	**40.14**	**-**		[26]
Pioneer vegetation in areas with riverine and marine influence (Pf) [c]	-	-	104.78	-	-	-	-	-	-	-	Medeiros & Sampaio (2008, Table 5)	-
	-	-	-	-	11.36	-	-	-	-	-	de Menezes *et al.* (2008, Table 4)	[28], [32]
	-	-	-	-	7.40	-	-	-	-	-	Fernandes *et al.* (2007)	[28]
	-	-	195.38	109.27	-	-			-	-	Proisy *et al.* (2007, Table 1)	[33]
	-	-	-	-	6.17	-	-	-	4.07	-	Ribas (2007, p. 30)	[28]
	-	-	-	-	7.29	-	-	-	-	-	Gonçalves *et al.* (2006)	[28]
	-	-	-	-	16.38	-	-	-	-	-	Nordhaus *et al.* (2006)	[28]
	-	-	201.45	-	-	-	-	-	-	-	Fromard *et al.* (1998, Table 4)	[34]
	-	-	-	-	8.69	-	-	-	-	-	Silva *et al.* (1998)	[28]
	-	-	65.37	-	-	-	-	-	-	-	Silva *et al.* (1991, Table 1)	-
Mean	**-**	**-**	**141.75**	**-**	**9.55**	**-**	**151.29** [a]	**-**	**73.03**	**-**		[35]

[a] The estimates of mean biomass can sometimes differ from the simple mean of the values listed in the table. In these cases the value was calculated so as to take advantage of the estimates that only report the biomass of some of the components of the vegetation (*e.g.,* the total biomass can be obtained from the sum of the means of the components).

[b] "Seasonally flooded coastal forest at sea level" (also known as *restinga*) refers to vegetation mosaics growing on poor sandy soil along the Brazilian coast, which include forests and open woodlands (César & Monteiro, 1995; Rizzini, 1997; Assis *et al.,* 2004).

[c] Despite estimates having been carried out in Amazonia for "pioneer vegetation in areas with riverine influence" (Pa) and in "pioneer vegetation in areas with riverine-marine influence" (Pf) (*e.g.,* Fernandes *et al.,* 2007; Proisy *et al.,* 2007; de Menezes *et al.,* 2008; Schöngart *et al.,* 2010), we used additional estimates obtained in other regions of Brazil (*e.g.,* the states of Pernambuco, São Paulo and Rio de Janeiro), especially for "pioneer vegetation in areas with marine influence" (Pm).

* Standard deviation value is express in %.

See Table S2 in Supplementary Material for notes [1] to [35].

Table 2. Dry below-ground-biomass and carbon stock estimates (Mg ha^{-1}) for *campinaranas* (vegetation on white-sand soils), savannas and pioneer formations from 17 published studies (see Table S1 in Supplementary Material for details about collection sites, sampling method, number and size of plots for each source dataset used). Means for each vegetation type are shown in bold.

Vegetation type (Legend from Brazil, IBGE, 1992)	**Root mass [a] (only ≥ 2 mm) (± SD or SE)**		**Total root mass [b] (± SD or SE)**		**Carbon (± SD or SE)**		**Max. Depth (m)**	**Source**	**Note**
Forested shade-loving *campinarana* (Ld)	33.75	1.20	-	-	-	-	2.20	Lima *et al.* (2012, Table 2)	
	-	-	127.50	-	63.75	-	0.68	Bongers *et al.* (1985, Tables 3, 9 and 10) "Tall *Bana*"	[2], [36]
	-	-	134.84	75.19	67.42	-	-	Klinge & Herrera (1983, Tables 5 and 16)	[36]
Mean	**33.75**	**-**	**131.17**	**75.19**	**65.58**	**-**	**-**		
Treed shade-loving *campinarana* (La)	-	-	23.08	-	11.54	-	-	Barbosa & Ferreira (2004, Tables 4 and 6)	[36], [5]
	-	-	21.30	-	10.65	-	-	Barbosa & Fearnside (1999, Table 3)	[36], [6]
	-	-	69.00	-	34.50	-	0.39	Bongers *et al.* (1985, Tables 3, 9 and 10) "Low *Bana*"	[2], [36]
Mean	**-**	**-**	**37.79**	**-**	**18.90**	**-**	**-**		
Grassy-woody shade-loving *campinarana* (Lg)	-	-	42.00	-	21.00	-	0.22	Bongers *et al.* (1985, Tables 3, 9 and 10) "Open *Bana*"	[2], [36]
Mean	**-**	**-**	**42.00**	**-**	**21.00**	**-**	**-**		
Seasonal forested savanna (Sd)	**-**	**-**	108.52	-	54.26	-	**-**	Ottmar *et al.* (2001) "*Cerrado Denso*"	[36], [37]
Mean	**-**	**-**	**108.52**	**-**	**54.26**	**-**	**-**		
Seasonal treed savanna (Sa)	-	-	46.63	-	22.38	-	2.00	Paiva *et al.* (2011, Table 3)	[8]
	-	-	37.50	23.0*	18.75	-	1.00	Ribeiro *et al.* (2011)	[36]
	-	-	-	-	18.60	-	-	Rezende (2002, p. 216)	[11]
	12.76	-	30.36	-	15.18	-	2.00	Lilienfein *et al.* (2001, Tables 2 and 4)	[36]
	-	-	43.10	-	21.55	-	6.00	Abdala *et al.* (1998)	[36]
	-	-	46.60	-	23.30	-	2.00	Castro & Kauffman (1998, Table 1) "*Cerrado stricto sensu, aberto*"	[36]
	-	-	52.90	-	26.45	-	2.00	Castro & Kauffman (1998, Table 1) "*Cerrado stricto sensu, denso*"	[36]
Mean	**12.76**	**-**	**42.85**	**-**	**20.89**	**-**	**-**		

Seasonal parkland savanna (Sp)	-	-	15.10	-	7.55	-	-	Barbosa & Fearnside (2005, Tables 3 and 5) "Sp"	[36], [38]
	-	-	13.95	-	6.97	-	-	Santos *et al.* (2002, Table 1) "Shrub and/or treed savanna"	[36], [12], [38]
	-	-	41.66	-	20.83	-	-	Ottmar *et al.* (2001) "*Cerrado ralo*"	[36], [38]
Mean	-	-	**23.57**	-	**11.79**	-	-		
Seasonal grassy-woody savanna (Sg)	1.14	-	21.40	2.47	6.69	0.29	1.00	Barbosa *et al.* (2012, Tables 1, 2 and 4) "DG-Arg"	
	0.47	-	22.62	2.21	6.25	1.12	1.00	Barbosa *et al.* (2012, Tables 1, 2 and 4) "DG-Lts"	
	1.65	-	22.14	4.90	7.21	1.85	1.00	Barbosa *et al.* (2012, Tables 1, 2 and 4) "GP-Lts"	
	0.00	-	29.52	7.15	7.10	1.65	1.00	Barbosa *et al.* (2012, Tables 1, 2 and 4) "WG-Hyd"	
	-	-	16.30	-	4.79	-	2.00	Castro & Kauffman (1998, Table 1) "*Campo limpo*"	[39]
	-	-	30.10	-	8.84	-	2.00	Castro & Kauffman (1998, Table 1) "*Campo sujo*"	[39]
Mean	-	-	**23.68**	-	**6.81**	-	**1.33**		
Steppe-like seasonal treed savanna (Ta)	-	-	19.26	-	9.63	-	-	Barbosa & Fearnside (2005, Tables 4 and 6) "Ta"	[36], [38]
Mean	-	-	**19.26**	-	**9.63**	-	-		
Steppe-like seasonal parkland savanna (Tp)	-	-	11.52	-	5.76	-	-	Barbosa & Fearnside (2005, Tables 4 and 6) "Tp"	[36], [38]
Mean	-	-	**11.52**	-	**5.76**	-	-		
Steppe-like seasonal grassy-woody savanna (Tg)	-	-	4.98	-	2.49	-	-	Barbosa & Fearnside (2005, Tables 4 and 6) "Tg Clean field" (*Campo limpo*)	[36], [40]
	-	-	12.38	-	6.19	-	-	Barbosa & Fearnside (2005, Table 4 and 6) "Tg Dirty field" (*Campo sujo*)	[36], [40]
Mean	-	-	**8.68**	-	**4.34**	-	-	-	-
Pioneer vegetation in areas with riverine influence (Pa)	-	-	7.56	-	3.39	-	-	Schöngart *et al.* (2010, Table 18.10)	[36], [26], [41]
	-	-	8.97	-	4.02	-	-	Junk & Piedade (1993)	[36], [26], [41]
Mean	-	-	**8.26**	-	**3.70**	-	-	-	-
Pioneer vegetation in areas with	-	-	37.64	-	16.86	-	-		[26], [41]

marine influence (Pm)									
Mean	**-**	**-**	**37.64**	**-**	**16.86**	**-**	**-**	**-**	
Pioneer vegetation in areas with riverine and marine influence (Pf)	-	-	75.65	-	36.51	-	-	-	[42], [35]
Mean	**-**	**-**	**75.65**	**-**	**36.51**	**-**	**-**	**-**	

[a] Includes only roots with diameter ≥2 mm, in accord with the recommendation of the IPCC (2006, p. 1.9) that fine roots should not be included as part of the "below-ground biomass" because it is difficult to distinguish them empirically from soil organic matter.

[b] Includes the biomass of roots of all sizes, including fine roots with diameter < 2 mm.

* Standard deviation value is express in %.

See Table S2 in Supplementary Material for notes [2] to [42].

Table 3. Dry biomass and carbon stock estimates (Mg ha^{-1}) for 29 vegetation types in Brazilian Amazonia.

Vegetation type (Legend from Brazil, IBGE, 1992)	Above-ground **biomass** (mean ± SD)	Above-ground **carbon** (mean ± SD)*	Below-ground **biomass** (mean ± SD)	Below-ground **carbon** (mean ± SD)*	Above- and below-ground **biomass** (mean ± SD)	Above- and below-ground **carbon** (mean ± SD.)*	**N° of plots**	**Source**	**Notes**
Dense-canopy rainforest, montane (Dm)	299.66 ± 61.71	145.33 ± 29.93	61.65 ± 12.69	29.90 ± 6.16	361.30 ± 74.40	175.23 ± 36.09	27	Nogueira *et al.* (2008a)	
Dense-canopy rainforest, submontane (Ds)	319.59 ± 76.72	155.00 ± 37.21	65.75 ± 15.78	31.89 ± 7.65	385.33 ± 92.50	186.89 ± 44.86	533	Nogueira *et al.* (2008a)	
Dense-canopy rainforest on non-flooding lowlands (Db)	318.90 ± 58.15	154.67 ± 28.20	65.61 ± 11.96	31.82 ± 5.80	384.50 ± 70.11	186.48 ± 34.00	517	Nogueira *et al.* (2008a)	
Dense-canopy rainforest on river floodplain (Da)	299.26 ± 63.52	145.14 ± 30.81	61.57 ± 13.07	29.86 ± 6.34	360.83 ± 76.59	175.00 ± 37.15	144	Nogueira *et al.* (2008a)	
Open-canopy rainforest, submontane (As)	280.24 ± 64.38	135.92 ± 31.22	55.78 ± 12.81	27.06 ± 6.22	336.02 ± 77.19	162.97 ± 37.44	618	Nogueira *et al.* (2008a)	
Open-canopy submontane forest dominated by bamboo in southwestern Amazonia (Asb)	175.95 ± 32.22	85.33 ± 15.62	32.00 ± 6.34	15.52 ± 3.07	207.95 ± 38.51	100.85 ± 18.68	10	Nogueira *et al.* (2008b)	(a)
Open-canopy rainforest on non-flooding lowlands (Ab)	303.10 ± 57.66	147.00 ± 27.97	60.33 ± 11.48	29.26 ± 5.57	363.43 ± 69.14	176.26 ± 33.53	265	Nogueira *et al.* (2008a)	
Open-canopy rainforest on river floodplain (Aa)	298.39 ± 60.66	144.72 ± 29.42	59.40 ± 12.08	28.81 ± 5.86	357.79 ± 72.74	173.53 ± 35.28	146	Nogueira (2008)	
Seasonal semi-deciduous submontane forest (Fs)	263.27 ± 94.29	127.69 ± 45.73	52.41 ± 18.77	25.42 ± 9.10	315.68 ± 113.06	153.10 ± 54.83	33	Nogueira *et al.* (2008a)	
Seasonal, semi-deciduous, lowland forest (Fb)	257.99 ± 77.44	125.13 ± 37.56	51.36 ± 15.41	24.91 ± 7.48	309.35 ± 92.85	150.03 ± 45.03	12	Nogueira *et al.* (2008a)	
Seasonal, semi-deciduous, alluvial forest (Fa)	236.35 ± 42.76	114.63 ± 20.74	47.05 ± 8.51	22.82 ± 4.13	283.40 ± 51.27	137.45 ± 24.87	9	This, study, unpublished	(b)
Seasonal, deciduous, submontane forest (Cs)	241.90 ± 68.16	117.32 ± 33.06	48.15 ± 13.57	23.35 ± 6.58	290.06 ± 81.72	140.68 ± 39.64	3	This, study, unpublished	(b)
Contact between rainforest and seasonal forest (ON)	259.05 ± 64.12	125.64 ± 31.10	51.57 ± 12.76	25.01 ± 6.19	310.62 ± 76.89	150.65 ± 37.29	128	Nogueira *et al.* (2008a)	
Contact between *campinarana* and rainforest (LO)	320.78 ± 64.36	155.58 ± 31.22	63.85 ± 12.81	30.97 ± 6.21	384.63 ± 77.18	186.55 ± 37.43	274	Nogueira *et al.* (2008a)	
Contact between savanna and rainforest (SO)	262.10 ± 93.73	127.12 ± 45.46	52.17 ± 18.66	25.30 ± 9.05	314.28 ± 112.39	152.42 ± 54.51	77	Nogueira *et al.* (2008a)	
Contact between savanna and seasonal forest (SN)	252.44 ± 76.76	122.43 ± 37.23	50.25 ± 15.28	24.37 ± 7.41	302.69 ± 92.04	146.81 ± 44.64	74	Nogueira *et al.* (2008a)	
Forested shade-loving *campinarana* (Ld)	253.54 ± 69.17	113.59 ± 30.99	131.17 ± 5.19	65.58 ± 2.59	384.71 ± 74.36	179.17 ± 33.58	38	This study, Tables 1 and 2	(c)

Treed shade-loving *campinarana* (La)	42.09 ± 27.98	18.86 ± 12.53	37.79 ± 27.04	18.90 ± 13.52	79.88 ± 53.60	37.75 ± 25.39	25	This study, Tables 1 and 2	(d)
Grassy-woody shade-loving *campinarana* (Lg)	7.65 ± 5.73	2.96 ± 2.22	42.00 ± 14.14	21.00 ± 7.07	49.65 ± 19.87	23.96 ± 9.29	2	This study, Tables 1 and 2	
Seasonal forested savanna (Sd)	51.29 ± 21.46	22.98 ± 9.61	108.52	54.26	159.80	77.24	4	This study, Tables 1 and 2	
Seasonal treed savanna (Sa)	27.13 ± 18.49	12.10 ± 7.90	42.85 ± 7.92	20.89 ± 3.69	69.98 ± 21.20	32.99 ± 9.10	175	This study, Tables 1 and 2	(d), (e)
Seasonal parkland savanna (Sp)	12.54 ± 8.34	5.38 ± 3.60	23.57 ± 15.68	11.79 ± 7.84	36.12 ± 24.02	17.17 ± 11.44	137	This study, Tables 1 and 2	
Seasonal grassy-woody savanna (Sg)	6.95 ± 2.70	2.61 ± 1.03	23.68 ± 5.26	6.81 ± 1.33	30.63	9.42	531	This study, Tables 1 and 2	(d)
Steppe-like seasonal treed savanna (Ta)	10.25 ± 0.26	4.40 ± 0.11	19.26	9.63	29.51	14.03	34	This study, Tables 1 and 2	
Steppe-like seasonal parkland savanna (Tp)	6.13 ± 0.85	2.52 ± 0.32	11.52 ± 1.60	5.76 ± 0.80	17.65	8.28	38	This study, Tables 1 and 2	
Steppe-like seasonal grassy-woody savanna (Tg)	2.84 ± 1.71	1.20 ± 0.74	8.68 ± 5.23	4.34 ± 2.62	11.52 ± 6.94	5.54 ± 3.36	54	This study, Tables 1 and 2	
Pioneer vegetation in areas with riverine influence (Pa)	19.68 ± 2.37	8.81 ± 1.06	8.26 ± 0.99	3.70 ± 0.45	27.94 ± 3.36	12.52 ± 1.51	21	This study, Tables 1 and 2	
Pioneer vegetation in areas with marine influence (Pm)	89.61	40.14	37.64	16.86	127.24	57.01	77	This study, Tables 1 and 2	
Pioneer vegetation in areas with riverine and marine influence (Pf)	151.29	73.03	75.65	36.51	226.94	109.54	141	This study, Tables 1 and 2	

* In forests the carbon content was considered to be 48.5% for dry biomass (da Silva, 2007, Table 6:13b). In non-forest formations these estimates vary in accord with Tables 1 and 2.

(a) The biomass of trees and palms with DBH ≥ 5 cm was obtained from Nogueira *et al.* (2008b). The biomasses of the other components, as explained in the methodology section, were added from the inventories of de Oliveira (2000).

(b) These estimates were obtained using data on wood volume from Brazil, Projeto RadamBrasil (1973-1983) using the same methodology as that used in Nogueira *et al.* (2008a).

(c) For forested shade-loving *campinarana* (Ld)the mean above-ground biomass was obtained as the sum of the means of the components ("Herbaceous", "Trees and shrubs" and "Necromass") from Table 1. The mean was calculated in this way to allow better use of estimates available in the literature. Standard deviation was calculated from the values for the components (Table 1).

(d) The number of plots is approximated and could be greater because there are studies cited in Table 1 and 2 (see also Table S1 in Supplementary Material) for which it is not clear what the total number of plots sampled was.

(e) The calculations of the standard deviation of the biomass and of the total carbon (above-ground + below-ground) only considered means from estimates that reported both above-ground and below-ground biomass.

Table 4. Total gross loss of dry biomass and carbon stocks through 2013 in Brazil's "Legal Amazonia" and "Amazonia biome" regions and in the portion of Legal Amazonia not included in the Amazonia biome.

Stock reduction by region	Dry biomass [and carbon stocks] lost*			
	in Pg (= 10^9 tons or billions of tons)		(in Mg ha^{-1} ± standard deviation)	
Legal Amazonia	27.1 ± 6.6	[13.1 ± 3.2]	280.1 ± 68.2	[135.6 ± 32.9]
Amazonia biome	23.1 ± 5.4	[11.2 ± 2.6]	343.8 ± 80.8	[166.7 ± 39.2]
Area in Legal Amazonia not included in the Amazonia biome	5.6 ± 1.5	[2.7 ± 0.7]	108.5 ± 29.3	[51.8 ± 13.7]

* Note that these uncertainty values underestimate the true variation because some vegetation types do not have measurements of uncertainties associated with the biomass and carbon estimates (see Tables 1, 2 and 3).

Table 5. Dry biomass and carbon stocks in the “pre-modern” vegetation (prior to the great increases in disturbance beginning in the 1970s), in the remaining vegetation after cumulative clearing through 2013 and the corresponding gross loss of biomass for the states in Brazil’s Legal Amazonia region.

States in Legal Amazonia	Cleared area in forest and non-forest types (km^2)*	Biomass stock in the ‘pre-modern’ vegetation	Remaining biomass stock in 2013	Biomass loss through 2013		Carbon stock in the ‘pre-modern’ vegetation	Remaining carbon stock in 2013	Carbon loss through 2013	
		in Pg (± uncertainty values)**			%	in Pg (± uncertainty values)			%
Acre [1]	20,850.62	4.79 ± 0.92	4.08 ± 0.77	0.71 ± 0.14	14.8	2.32 ± 0.44	1.98 ± 0.37	0.34 ± 0.07	14.8
Amazonas [1]	33,924.86	54.70 ± 10.97	53.49 ± 10.71	1.22 ± 0.26	2.2	26.44 ± 5.29	25.85 ± 5.16	0.59 ± 0.12	2.2
Amapá	2,951.14	4.43 ± 1.00	4.33 ± 0.98	0.10 ± 0.02	2.2	2.14 ± 0.48	2.09 ± 0.47	0.05 ± 0.01	2.2
Maranhão [2,3]	128,418.92	6.36 ± 1.51	2.42 ± 0.56	3.94 ± 0.94	61.9	3.08 ± 0.73	1.17 ± 0.27	1.91 ± 0.46	62.0
Mato Grosso [3]	338,530.22	19.05 ± 5.35	11.77 ± 3.28	7.28 ± 2.07	38.2	9.21 ± 2.57	5.69 ± 1.57	3.52 ± 0.99	38.2
Pará	254,017.13	41.81 ± 9.34	32.57 ± 7.30	9.25 ± 2.04	22.1	20.27 ± 4.53	15.79 ± 3.54	4.48 ± 0.99	22.1
Rondônia [3]	86,464.51	7.47 ± 1.71	4.56 ± 1.02	2.91 ± 0.69	39.0	3.62 ± 0.83	2.21 ± 0.49	1.41 ± 0.33	39.0
Roraima	9,844.23	6.66 ± 1.58	6.31 ± 1.49	0.34 ± 0.09	5.2	3.21 ± 0.76	3.04 ± 0.71	0.16 ± 0.04	5.2
Tocantins [3]	92,001.69	3.03 ± 0.77	1.66 ± 0.42	1.36 ± 0.35	45.0	1.44 ± 0.36	0.79 ± 0.19	0.65 ± 0.16	45.4
Total	967,003.32	148.32 ± 33.16	121.20 ± 26.55	27.11 ± 6.60	-	71.75 ± 15.99	58.62 ± 12.81	13.13 ± 3.18	-

* The value for total cleared area obtained by summing the values for all states is slightly lower that total area cleared in Legal Amazonia because there are small differences between the boundaries of Amazonia Legal and the state boundaries (*e.g.*, for the state of Tocantins).
** Uncertainty is expressed as the sum of the products of the area occupied by each vegetation type (ha) and the limits of the standard deviation of the biomass mean for the corresponding vegetation type. Some values for uncertainties can be larger than the values shown because some vegetation types do not have measurements of uncertainties associated with the biomass and carbon estimates (see Tables 1, 2 and 3).
[1] The estimates for these states were made considering the new state boundaries established by the "Cunha Gomes line."
[2] Refers only to the area of the state falling within the limits of Legal Amazonia.
[3] The total area cleared in these states includes areas deforested that are monitored by INPE/PRODES (Brazil, INPE, 2014) and the areas cleared in the *cerrado* monitored by IBAMA/PMDBBS (Brazil, IBAMA, 2013). In the case of Rondônia, only an area of ~14 km^2 of *cerrado* clearing monitored by IBAMA/PMDBBS was included.

Table 6. Total biomass and carbon stocks (dry weight in Pg) by vegetation physiognomy in Brazil's Legal Amazonia.

Status of vegetation	Vegetation types	Area (km^2)	Dry biomass estimates					
			Above-ground	Uncertainty values.*	Below-ground	Uncertainty values *	Above and below-ground	Uncertainty values*
'Pre-modern' vegetation (prior to the great increases in disturbance beginning in the 1970s)	Forest	3,634,717.94	109.164	24.149	22.162	4.903	131.317	29.052
	Campinarana	183,563.31	3.450	1.009	1.909	0.192	5.358	1.195
	Savanna	832,623.32	2.110	1.235	3.857	0.710	5.967	1.409
	Contact zones**	167,975.64	4.352	1.241	0.871	0.247	5.222	1.488
	Pioneer formations	86,931.29	0.353	0.017	0.165	0.007	0.518	0.025
	Refugium areas	3,999.93	0.0014	0.0006	0.0037	0.0018	0.0051	0.0022
	Total	4,909,811.42	119.43	27.65	28.97	6.06	148.39	33.17
Remaining vegetation in 2013 (after cumulative clearing through 2013).	Forest	3,011,029.80	90.753	19.812	18.438	4.027	109.181	23.838
	Campinarana	182,580.39	3.438	1.005	1.902	0.190	5.340	1.190
	Savanna	598,796.12	1.490	0.851	2.779	0.509	4.268	0.965
	Contact zones**	63,198.12	1.659	0.452	0.335	0.090	1.993	0.542
	Pioneer formations	81,863.06	0.324	0.016	0.151	0.007	0.475	0.023
	Refugium areas	3,812.82	0.0013	0.0006	0.0035	0.0017	0.0048	0.0021
	Total	3,941280.31	97.67	22.14	23.61	4.82	121.26	26.56

* Uncertainty values associated with large-scale estimates do not include uncertainties for those forest types reported in Table 3 without values for standard deviation associated with the mean biomass estimates.
** Includes contact zones between rainforest and seasonal forest, *campinarana* and rainforest, savanna and rainforest, savanna and seasonal forest, savanna and pioneer formations, and seasonal savanna and steppe-like savanna.

FIGURE CAPTIONS

Figure 1. Limits of Legal Amazonia, the Amazonia biome and the Brazilian states in these regions.

Figure 2. Distributions of total biomass (above- and below-ground; dry weight in Mg ha^{-1}) in the original vegetation (before extensive clearing) in two regions of Brazilian Amazonia: in the regions denominated as “Legal Amazonia” (whole map) and as the “Amazonia biome” (black line). See Table 3 for summary of biomass mean and standard deviation by vegetation type.

Figure 3. Framework showing the different stages used in this study for estimates of biomass loss in Legal Amazonia and the Amazonia biome.

SUPPLEMENTARY MATERIAL:

Carbon stock loss from deforestation through 2013 in Brazilian Amazonia

Euler Melo Nogueira[1*], Aurora M Yanai[1], Frederico O Fonseca[1], Philip Martin Fearnside[1*]

[1*] Department of Environmental Dynamics, National Institute for Research in Amazonia (INPA), Av. André Araújo nº 2936, CEP 69 067-375, Manaus, Amazonas, Brazil

Correspondence: Philip Martin Fearnside; Tel.: + 55 92 3643 1822, Fax: + 55 92 3642 3028;

e-mail: pmfearn@inpa.gov.br, philip.fearnside@gmail.com

Table S1. Details on collection sites, sampling methods, number and size of plots for each source dataset used in Tables 1 and 2.

Vegetation type (Legend from Brazil,	Source	Nº of Plots	Size of plots (m^2)	Sampling method: Direct	Collection site

IBGE, 1992)				**(D) or Indirect (I)**	
Forested shade-loving *campinarana* (Ld)	Lima *et al.* (2012, Table 2)	23	2500	(D) and (I)	State of Amazonas, Brazil.
	Bongers *et al.* (1985, Tables 3, 9 and 10) "Tall *Bana*"	2	5	(D)	San Carlos, Venezuela.
	Klinge *&* Herrera (1983, Tables 5 and 16)	13	100	(D)	San Carlos, Venezuela.
Treed shade-loving *campinarana* (La)	Barbosa *&* Ferreira (2004, Tables 4 and 6)	20	500	(D) and (I)	State of Roraima, Brazil.
	Barbosa *&* Fearnside (1999, Table 3)	-	-	-	State of Roraima, Brazil.
	Bongers *et al.* (1985, Tables 3, 9 and 10) "Low *Bana*"	5	5	(D)	San Carlos, Venezuela.
Grassy-woody shade-loving *campinarana* (Lg)	Bongers *et al.* (1985, Tables 3, 9 and 10) "Open *Bana*"	2	5	(D)	San Carlos, Venezuela.
Seasonal forested savanna (Sd)	Brazil, MCT (2006, Table 3) "*Cerradão*"	-	-	-	Distrito Federal, Brazil.
	Ottmar *et al.* (2001) "*Cerrado Denso*"	4	675*	(D) and (I)	Distrito Federal, Brazil.
Seasonal treed savanna (Sa)	Paiva *et al.* (2011, Table 3)	18	1000	(D) and (I)	Distrito Federal, Brazil.
	Ribeiro *et al.* (2011)	10	500	(D) and (I)	State of Minas Gerais, Brazil.

Brazil, MCT (2006, Table 2) "*Cerrado sensu stricto*"	-	-	-	Distrito Federal, Brazil.
Barbosa *&* Fearnside (2005, Tables 3 and 5) "Sa"	14	80	(D) and (I)	State of Roraima, Brazil.
Rezende (2002, p. 216)	10	1000	(D) and (I)	Distrito Federal, Brazil.
Santos *et al.* (2002, Table 1) "Savanna woodland"	7	500	(D)	State of Mato Grosso, Brazil.
de Araújo *et al.* (2001)	8	500	(D) and (I)	State of Mato Grosso, Brasil.
Lilienfein *et al.* (2001, Tables 2 and 4)	5	625	(D) and (I)	State of Minas Gerais, Brazil.
Ottmar *et al.* (2001) "*Sensu stricto*"	5	675*	(D) and (I)	Distrito Federal, States of Minas Gerais & Mato Grosso, Brazil.
Abdala *et al.* (1998)	2	1000	(D) and (I)	Distrito Federal, Brazil.
Castro *&* Kauffman (1998, Table 1) "*Cerrado stricto sensu, aberto*"	16 a 32	45	(D) and (I)	Distrito Federal, Brazil.
Castro *&* Kauffman (1998, Table 1) "*Cerrado stricto sensu, denso*"	16 a 32	45	(D) and (I)	Distrito Federal, Brazil.
Kauffman *et al.* (1994,	10	5	(D) and (I)	Distrito Federal,

	Table 1) "*Cerrado sensu stricto*"				Brazil.
	Santos (1988, pp. 143-144)	38	100	(D)	Distrito Federal, Brazil.
Seasonal parkland savanna (Sp)	Delitti *et al.* (2006, Tables 4 and 8) "*Campo cerrado*"	60	-	(D) and (I)	State of São Paulo, Brazil.
	Barbosa *&* Fearnside (2005, Tables 3 and 5) "Sp"	40	80	(D) and (I)	State of Roraima, Brazil.
	Santos *et al.* (2002, Table 1) "Shrub and/or treed savanna"	18	500	(D)	States of Mato Grosso & Roraima, Brazil.
	Ottmar *et al.* (2001) "*Cerrado ralo*"	9	675*	(D) and (I)	Distrito Federal & States of Minas Gerais & Goiás, Brazil.
	Kauffman *et al.* (1994, Table 1) "*Campo cerrado*"	10	5	(D) and (I)	Distrito Federal, Brazil.
Seasonal grassy-woody savanna (Sg)	Barbosa *et al.* (2012, Tables 1, 2 and 4) "DG-Arg"	4	2500	(D) and (I)	State of Roraima, Brazil.
	Barbosa *et al.* (2012, Tables 1, 2 and 4) "DG-Lts"	8	2500	(D) and (I)	State of Roraima, Brazil.
	Barbosa *et al.* (2012, Tables 1, 2 and 4) "GP-Lts"	5	2500	(D) and (I)	State of Roraima, Brazil.

Barbosa *et al.* (2012, Tables 1, 2 and 4) "WG-Hyd"	10	2500	(D) and (I)	State of Roraima, Brazil.
Santos *et al.* (2002, Table 1) "Grassland savanna"	14	500	(D)	State of Roraima, Brazil.
Brasil, MCT (2006, Table 1) "*Campo sujo*"	-	-	-	Distrito Federal, Brazil.
Barbosa *&* Fearnside (2005, Tables 3 and 5) "Sg Clean field" (*Campo limpo*)	121	80	(D) and (I)	State of Roraima, Brazil.
Barbosa *&* Fearnside (2005; Tables 3 and 5) "Sg Dirty field" (*Campo sujo*)	77	80	(D) and (I)	State of Roraima, Brazil.
Ottmar *et al.* (2001) "*Campo limpo*"	7	675*	(D) and (I)	Distrito Federal & State of Goiás, Brazil.
Ottmar *et al.* (2001) "*Campo sujo*"	7	675*	(D) and (I)	Distrito Federal & States of Minas Gerais & Goiás, Brazil.
Castro *&* Kauffman (1998, Table 1) "*Campo limpo*"	16 a 32	45	(D) and (I)	Distrito Federal, Brazil.
Castro *&* Kauffman (1998, Table 1) "Campo sujo"	16 a 32	45	(D) and (I)	Distrito Federal, Brazil.
Cardoso *et al.* (2000, Figure 2)	220	1	(D)	State of Mato Grosso do Sul, Brazil.

	Kauffman *et al.* (1994, Table 1) "*Campo limpo*"	5	5	(D)	Distrito Federal, Brazil.
	Kauffman *et al.* (1994, Table 1) "*Campo sujo*"	5	5	(D)	Distrito Federal, Brasil.
Steppe-like seasonal treed savanna (Ta)	Barbosa & Fearnside (2005, Tables 4 and 6) "Ta"	34	80	(D) and (I)	State of Roraima, Brazil.
Steppe-like seasonal parkland savanna (Tp)	Barbosa & Fearnside (2005, Tables 4 and 6) "Tp"	38	80	(D) and (I)	State of Roraima, Brazil.
Steppe-like seasonal grassy-woody savanna (Tg)	Barbosa & Fearnside (2005, Tables 4 and 6) "Tg Clean field" (*Campo limpo*)	42	80	(D) and (I)	State of Roraima, Brazil.
	Barbosa & Fearnside (2005, Table 4 and 6) "Tg Dirty field" (*Campo sujo*)	12	80	(D) and (I)	State of Roraima, Brazil.
Pioneer vegetation in areas with riverine influence (Pa)	Schöngart *et al.* (2010, Table 18.10)	1	500	(I)	State of Amazonas, Brazil.
	Junk & Piedade (1993)	20	1	(D)	State of Amazonas, Brazil.
Pioneer vegetation in areas with marine influence (Pm)	Assis *et al.* (2011, p. 108)	30	0.29	(D)	State of São Paulo, Brazil.
	Alves *et al.* (2010, Table 3 "*Restinga* forest")	1	10000	(I)	State of São Paulo, Brazil.

	Dias *et al.* (2006, Table 2 "*Restinga* open woodland")	6	10000	(D) and (I)	State of Rio de Janeiro, Brazil.
	Pires *et al.* (2006; p.177)	10	0.25	(D)	State of Paraná, Brazil.
	de Moraes *et al.* (1999, Table 2)	30	0.25	(D)	State of São Paulo, Brazil.
Pioneer vegetation in areas with riverine and marine influence (Pf)	Medeiros & Sampaio (2008, Table 5)	-	-	(D) and (I)	State of Pernambuco, Brazil.
	de Menezes *et al.* (2008, Table 4)	-	-	(D) and (I)	State of Pará, Brazil.
	Fernandes *et al.* (2007)	21	1	(D)	State of Pará, Brazil.
	Proisy *et al.* (2007, Table 1)	26	200 - 10000	(D) and (I)	French Guiana
	Ribas (2007, p. 30)	21	0.49	(D)	State of Rio de Janeiro, Brazil.
	Gonçalves *et al.* (2006)	21	1	(D)	State of Pará, Brazil.
	Nordhaus *et al.* (2006)	8	1	(D)	State of Pará, Brazil.
	Fromard *et al.* (1998, Table 4)	23	150 - 400	(D) and (I)	French Guiana
	Silva *et al.* (1998)	11	0.30	(D)	State of Rio de Janeiro, Brazil.
	Silva *et al.* (1991, Table 1)	10	100	(D) and (I)	State of Rio de Janeiro, Brazil.

* In Ottmar *et al.* (2001) the sizes of the plots were calculated summing the area used for sampling woody vegetation (12 circular plots each 0.002 ha in area) with the area used for sampling the herbaceous-bushy stratum (15 plots each 0.25 m^2 in area).

Table S2. Notes for Tables 1 and 2.

Notes	Descriptions
[1]	Above-ground biomass of 'palm trees' and 'lianas' were included in the column 'Trees and shrubs'. According to Lima *et al.* (2012, p. 164), the below-ground biomass includes most of the coarse roots (>~2 mm).
[2]	Bongers *et al.* (1985) considered as "trees" all woody individuals with DBH ≥ 1 cm. The non-woody plants and the climbers (Bongers *et al.*, 1985, Table 3) were included in this study, respectively, in the "Herbaceous" and "Trees and shrubs" columns. For the maximum depth (m) the maximum values reported in Table 6 were considered.
[3]	Carbon stock in total above-ground biomass was estimated using the carbon percentage reported by Barbosa & Fearnside (2005, Table 5) for several savanna ecosystems. In areas classified as "seasonal forested savanna" (Sd), "treed shade-loving *campinarana"* (La), and "forested shade-loving *campinarana*" (Ld), carbon was estimated considering the same percentage (44.8%) reported by Barbosa & Fearnside (2005, Table 5) for "typical *cerrado*." In areas of "grassy-woody *campinarana*" (Lg) we used the carbon percentage (38.7%) reported by Barbosa & Fearnside (2005) for "grassy-woody savanna".
[4]	Klinge & Herrera (1983, Table 5) considered as 'trees' all woody individuals with DBH ≥ 1 cm. In the present study all 'trees' < 1 cm DBH, climbers < 1 cm DBH, epiphytes, moss and ground flora were included in the "Herbaceous" column. Climbers with DBH ≥ 1 cm were included in the "Trees and shrubs" column.
[5]	Among the components of the grassy-woody stratum cited in Table 4 of Barbosa & Ferreira (2004), we included the following in the "Herbaceous" column: Bromeliaceae, sedges and other weeds (Poaceae, Cyperaceae, Eriocaulaceae, Cladonia spp.), and young seedlings of trees and bushes with circumference at the base < 5 cm or diameter < 1.6 cm). The below-ground biomass was obtained by indirect methods, weighted by the results of Barbosa & Fearnside (2002).

[6] These estimates were obtained in the southern part of the state of Roraima in an area of "*campina/campinarana*" by Cavalcanti & Higuchi (personal communication originally cited in Barbosa & Fearnside (1999, Table 3).

[7] Mean biomass and standard deviation values reported in each column were obtained considering the values reported for sites sampled in each physiognomic formation. The "Herbaceous" column includes individuals with diameter < 2 cm and the "Necromass" column includes downed woody material < 2.6 cm in diameter and standing stems ≤ 2.0 cm in diameter measured 30 cm above the soil surface.

[8] The estimated above-ground carbon does not include components with diameter < 5 cm; therefore, it does not include the biomass of the herbaceous components. The biomass of woody individuals was separated into live (the "Trees and shrubs" column) and standing dead, which were included in the "Necromass" column together with the values reported for litter. The dry biomass was obtained by multiplying the estimated carbon by 2, since the equation used by Paiva *et al.* (2011, p. 529) estimates carbon considering that it constitutes 50% of the dry biomass, after Rezende *et al.* (2006). The biomasses of roots were sampled by Paiva *et al.* (2011, p. 530) to 0.30 m depth, with the biomass of roots between 0.30 m and 2 m being estimated based on the percentages reported by Castro (1996), which apparently are the same data as those published by Castro & Kauffman (1998).

[9] Details on sampling have not been supplied for these data because they are not included in the original source (unpublished estimates by H.S. Miranda cited by Brazil, MCT, 2006).

[10] Herbaceous biomass includes all live components (diameter < 2 cm, measured approximately 1 cm above the ground) defined by Barbosa & Fearnside (2005) as "Fine-fuels" pre-burn (Poaceae, Herbs, Cyperaceae, tree seedlings). Dead "fine-fuels" and dead "trees and shrubs" were considered to be "Necromass" in the present study.

[11] Rezende (2002, p. 216) estimated the carbon stock based on the percentages originally obtained in another study carried out in the same area (Castro, 1996). We considered the dry biomass to be double the carbon estimate.

[12] Some of these data come from de Araújo *et al.* (2001).

[13] In the present study we assumed that all of the above-ground components were weighed, although it was not stated explicitly in the methodology of de Araújo *et al.* (2001) that the necromass had also been included.

[14] "Necromass" values here include 2% of the biomass of “all trees” (>0.5 m) and 4% of the biomass of “shrubs and brown grass" because these percentages refer to dead wood (Lilienfein *et al.*, 2001, p. 491). Thus, the values in the "herbaceous" and "trees and shrubs" columns differ from those found in the Table 2 of Lilienfein *et al.* (2001).

[15] The five plots defined in Ottmar *et al.* (2001) as "*cerrado stricto sensu*" were considered to be Sa savanna (open woodland) in the present study.

[16] The palm biomass values were included in the column for biomass of "Trees and Shrubs".

[17] In the sum of subtotal biomass values one of the plots in Ottmar *et al.* (2001) differs from the total biomass reported here for the plot. We considered the sum of the reported sub-total biomass values as correct values, on the assumption that the sum of these reported by Ottmar *et al.* (2001) must be in error.

[18] The estimate of the mass of litter does not include branches and trunks with circumferences ≥ 6 cm.

[19] "Herbaceous" biomass includes green graminoids + dicots, palms and bromeliads. When present, the category "Trees and shrubs" includes the total biomass of shrubs and trees; "Necromass" includes litter, dry graminoids and total woody debris.

[20] Above-ground biomass of "shrub leaves" is not considered as part of the herbaceous component in the present study (see Kauffman *et al.* 1994, Table 1).

[21] Mean biomass was calculated assuming that all of the above-ground components were included in the sampling by Santos (1988) and that the reported values for woody biomass were expressed as dry weight.

[22] These values for above-ground biomass (live and dead) were considered to be the same as those used by Barbosa & Fearnside (1999, Table 3), derived by Barbosa (1998).

[23] Herbaceous biomass was defined as "grasses" (Poaceae, Cyperaceae, seedlings, small dicots and litter) and woody individuals with diameter at the base (Db) < 2 cm, measured at 2 cm above the ground (Barbosa *et al.*, 2012).

[24] The value for biomass refers to the mean of 11 monthly values obtained from digitizing Figure 2 "without burning" from Cardoso *et al.* (2000, p. 2313). Deviations can occur from the values obtained by digitalizing the figure and the original values.

[25] Estimates refer to a 500-m^2 circular plot that was established in young pioneer vegetation (7 years age) on a recently formed sand bar in the Japurá River. The above-ground live forest biomass values were based on three models (one from Cannell, 1984 and two models from Chave *et al.*, 2005). A mean value and a standard deviation of these three estimates were calculated.

[26] The carbon content of the above-ground biomass was considered to be 44.8%, the same percentage adopted by Schöngart *et al.* (2010, p. 368) for fast-growing tree species in the initial stages of succession. This same percentage is reported by da Silva (2007, Table 6.13c) for secondary forest.

[27] The biomass mean was obtained from two mixed herbaceous plant communities, both measured in the upper Amazon floodplain about 80 km upstream of the confluence of the Amazon River and the Rio Negro. A mixed population was composed of various terrestrial Cyperaceae, *Oryza perennis*, and *Paspalum repens*, with the sum of the biomass reached 12.7 Mg ha^{-1}. Other mixed population including *Hymenachne amplexicaulis*, various gramineans, cyperaceans, *Aeschynomene sensitiva*, besides the free floating species

Salvivia sp., *Pistia* sp., *Ceratopteris* sp., and *Eichhornia* sp., with the sum of the biomass reaching 30 Mg ha^{-1}.

[28] The estimates for litter refer to the annual production per hectare, not to estimates of stock per hectare.

[29] The biomass included in the "Trees and shrubs" component refers to trees, palms and tree ferns that have stems with DBH ≥ 4.8 cm.

[30] Estimates of above-ground biomass stock were obtained from three sites with 42, 29 and 20% vegetation cover.

[31] The estimates refer to the total amount of litter accumulated per hectare during the year.

[32] The litter biomass corresponds to the mean obtained from the eight estimates cited by de Menezes *et al.* (2008, Table 4).

[33] For the estimates at the Kaw site, adjusted above-ground biomass values were used (Proisy *et al.* 2007, Table 1).

[34] Biomass based on the mean of stands IV, V, VI and VII. The biomass values reported are clearly underestimated because some species were not evaluated (Fromard *et al.*, 1998, p. 45).

[35] The concentration of carbon was considered to be 48.27% of the dry weight of the wood, obtained from the mean of three species (Ribas, 2007, p. 30).

[36] Carbon was considered to constitute 50% of the dry below-ground biomass.

[37] The below-ground biomass was considered to be 2.12 times greater than the above-ground biomass. This value was obtained from the ratio between the below-ground and above-

Table S3. Total biomass and carbon stocks (dry weight in Pg) by vegetation physiognomy in the Amazonia biome.

			Dry biomass estimate (± uncertainties values)*						Carbon estimate (± uncertainties values)*					
Status of vegetation	Vegetation types	Area (km^2)	Above-ground	Uncertainty value	Below-ground	Uncertainty value	Above and below-ground	Uncertainty value	Above-ground	Uncertainty value	Below-ground	Uncertainty value	Above and below-ground	Uncertainty value
'Pre-modern' vegetation (prior to the great increases in disturbance beginning in the 1970s)	Forest	3,525,085.30	106.329	23.327	21.597	4.740	127.917	28.066	51.566	11.314	10.475	2.299	62.040	13.612
	Campinarana	183,511.85	3.448	1.008	1.908	0.192	5.356	1.195	1.544	0.451	0.954	0.096	2.498	0.545
	Savanna	187,217.29	0.512	0.259	1.020	0.138	1.532	0.233	0.227	0.113	0.500	0.066	0.726	0.107
	Contact zones**	110,275.57	2.888	0.798	0.580	0.159	3.467	0.957	1.400	0.387	0.281	0.077	1.681	0.464
	Pioneer formations	85,275.80	0.341	0.017	0.159	0.007	0.500	0.024	0.160	0.008	0.075	0.003	0.234	0.011
	Refugium areas	3,989.95	0.0014	0.0006	0.0037	0.0018	0.0050	0.0022	0.0006	0.0003	0.0018	0.0009	0.0024	0.0011
	Total	4,095,355.76	113.52	25.41	25.27	5.24	138.78	30.48	54.90	12.27	12.29	2.54	67.18	14.74
Remaining vegetation in 2013 (after cumulative clearing through 2013)	Forest	2,948,509.98	89.157	19.361	18.120	3.937	107.268	23.298	43.238	9.390	8.788	1.910	52.025	11.299
	Campinarana	182,529.21	3.437	1.005	1.901	0.190	5.338	1.190	1.539	0.450	0.950	0.095	2.489	0.542
	Savanna	168,222.06	0.440	0.223	0.878	0.129	1.319	0.214	0.195	0.098	0.429	0.062	0.624	0.099
	Contact zones**	38,603.14	1.033	0.262	0.210	0.052	1.243	0.314	0.501	0.127	0.102	0.025	0.603	0.152
	Pioneer formations	80,493.73	0.313	0.016	0.145	0.007	0.458	0.023	0.146	0.007	0.068	0.003	0.215	0.010
	Refugium areas	3,802.84	0.0013	0.0006	0.0035	0.0017	0.0048	0.0021	0.0006	0.0002	0.0018	0.0009	0.0023	0.0010
	Total	3,422,160.97	94.38	20.87	21.26	4.32	115.63	25.04	45.62	10.07	10.34	2.10	55.96	12.10

* Uncertainties values associated with large-scale estimates do not include uncertainties for those forest types reported in Table 3 without values for the standard deviation associated with the mean biomass estimates.

**Includes contact zones between rainforest and seasonal forest, *campinarana* and rainforest, savanna and rainforest, savanna and seasonal forest, savanna and pioneer formations, and seasonal savanna and steppe-like savanna.

ground biomass reported by Castro *&* Kauffman (1998, Table 1) in dense *cerrado stricto sensu*.

[38] Below-ground biomass was estimated considering it to be 1.88 times greater than above-ground biomass. This factor was obtained from the ratio between below- and above-ground biomass reported by Castro *&* Kauffman (1998, Table 1) in open *cerrado stricto sensu*.

[39] The carbon stock in roots was estimated using the mean carbon percentage (29.36%) calculated from the four values for percent total carbon reported by Barbosa *et al.* (2012) in Table 3. The carbon percentages reported by Barbosa *et al.* (2012) were obtained from roots collected to 1 m depth, while the roots collected by Castro *&* Kauffman (1998) were collected to 2 m depth.

[40] The below-ground biomass was calculated considering the biomass of roots as 3.06 times greater than the total above-ground biomass. This value was obtained from the ratio between the biomass of roots and the total above-ground biomass reported by Barbosa *et al.* (2012, Tables 1 and 2) for four types of grassy-woody savannas in Roraima.

[41] Below-ground biomass was considered to be 42% of the above-ground biomass. This percentage is equivalent to the root/shoot ratio used by Fearnside *&* Guimarães (1996, Tables 3 and 4) for secondary forest four years after abandonment.

[42] Below-ground biomass was obtained from the ratio between above-ground biomass and below-ground biomass (2.0) estimated by Komiyama *et al.* (2008, Fig. 3) from 12 mangrove stands.

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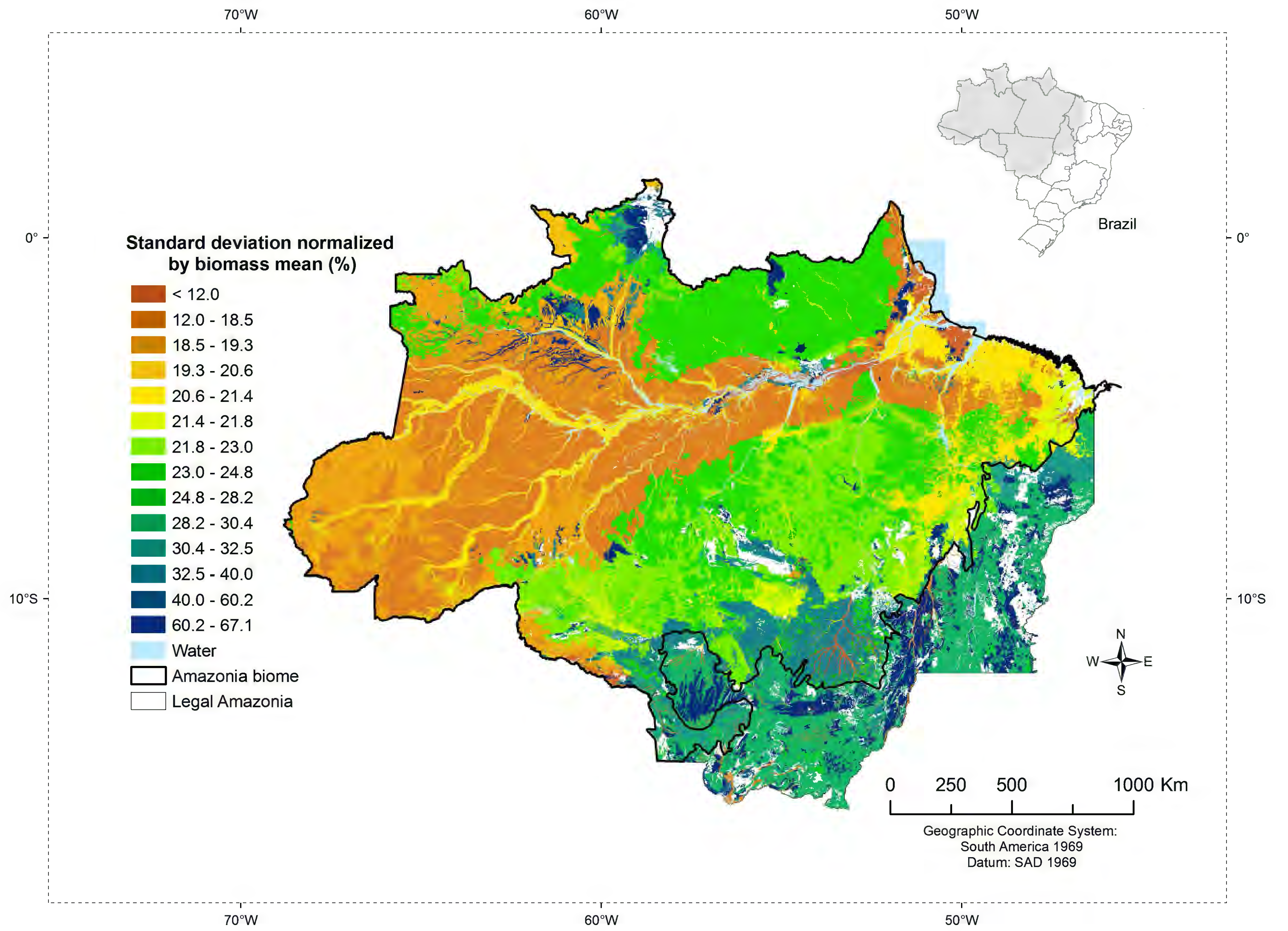
SUPPLEMENTARY MATERIAL - FIGURE CAPTIONS

Figure S1. Variability of total biomass shown in Figure 2; standard deviation values normalized by biomass mean across Legal Amazonia (whole map) and in the Amazonia biome (delimited by the black line). White areas on the map refer to vegetation types for which uncertainty estimates for the biomass values are not available (~213,485 km^2). Large variability that is shown for biomass estimates in areas covered by non-forest types could be caused by diverse methodologies employed in the studies cited in Tables 1 and 2.

Figure S2. Distribution of original total biomass (above- and below-ground; dry weight in Mg ha^{-1}) in areas cleared through 2013 in two regions of the Brazilian Amazon: "Legal Amazonia" (whole map) and the "Amazonia biome" (delimited by the black line). White areas on the map refer to total vegetation cleared through 2013 (~968,000 km^2). See Tables 6 and S3 for estimates of total biomass remaining in 2013.


70°W
60°W
50°W
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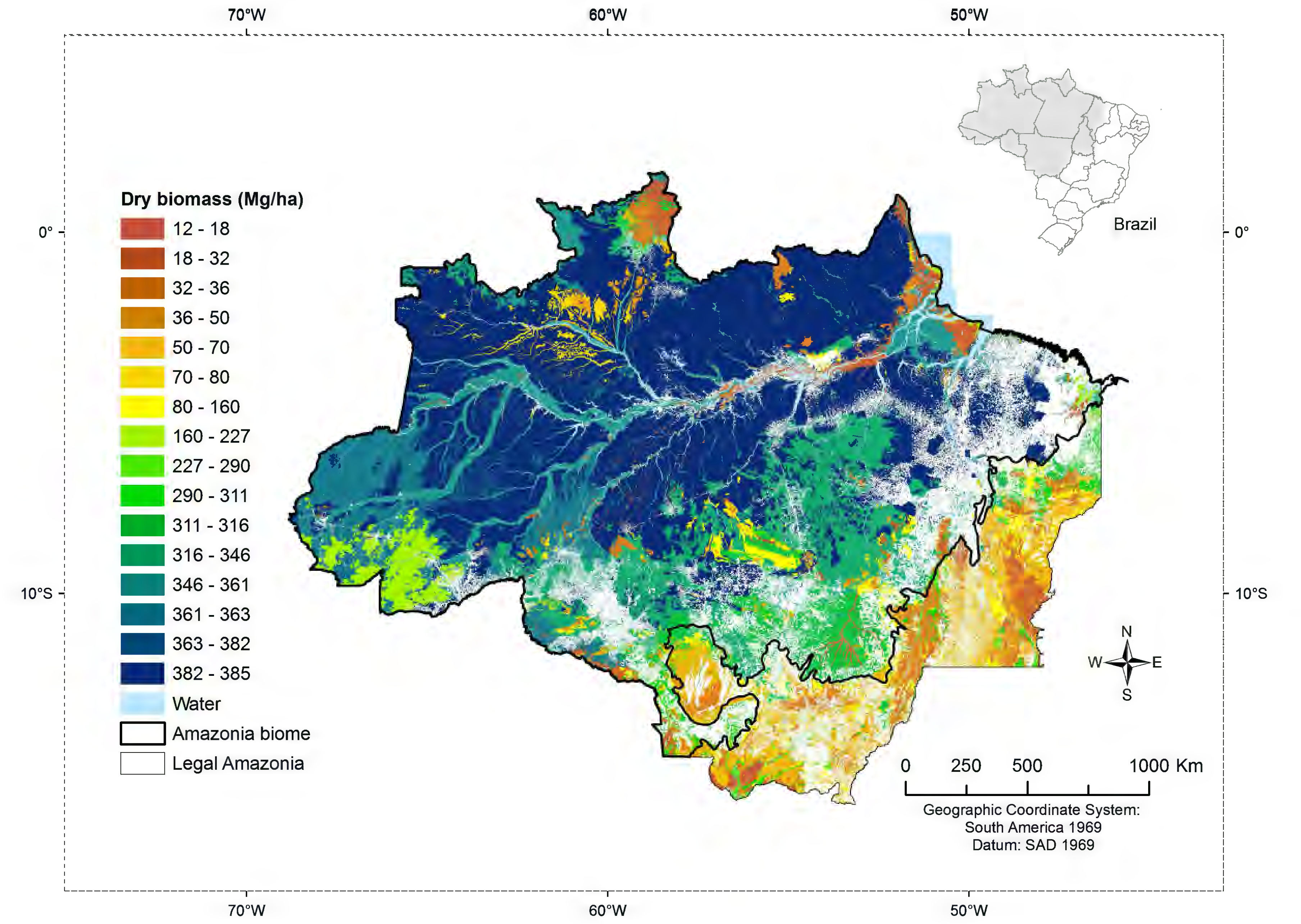
10°S
Standard deviation normalized by biomass mean (%)
< 12.0
12.0 - 18.5
18.5 - 19.3
19.3 - 20.6
20.6 - 21.4
21.4 - 21.8
21.8 - 23.0
23.0 - 24.8
24.8 - 28.2
28.2 - 30.4
30.4 - 32.5
32.5 - 40.0
40.0 - 60.2
60.2 - 67.1
Water
Amazonia biome
Legal Amazonia
Brazil
N
W
E
S
0 250 500 1000 Km
Geographic Coordinate System:
South America 1969
Datum: SAD 1969


70°W
60°W
50°W
0°
10°S
Dry biomass (Mg/ha)
12 - 18
18 - 32
32 - 36
36 - 50
50 - 70
70 - 80
80 - 160
160 - 227
227 - 290
290 - 311
311 - 316
316 - 346
346 - 361
361 - 363
363 - 382
382 - 385
Water
Amazonia biome
Legal Amazonia
Brazil
N
W
E
S
0
250
500
1000 Km
Geographic Coordinate System:
South America 1969
Datum: SAD 1969