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1 **Current Brazilian forest management guidelines are unsustainable for *Swietenia*,**
2 ***Cedrela*, *Amburana*, and *Copaifera*: A response to da Cunha and colleagues**

3
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17
18 **Paper type:** Correspondence

19
20 **A response to the following paper:**

21 da Cunha, T. A., Finger, C. A. G., Hasenauer, H. (2016) Tree basal area increment models for
22 *Cedrela*, *Amburana*, *Copaifera* and *Swietenia* growing in the Amazon rain forests. *Forest*
23 *Ecology and Management* 365: 174-183.

24
25 **Keywords:** Brazil; sustainable forest management; harvest regulations; big-leaf
26 mahogany; Spanish cedar; copaiba

27 **Current Brazilian forest management guidelines are unsustainable for *Swietenia*,**
28 ***Cedrela*, *Amburana*, and *Copaifera*: A response to da Cunha and colleagues**

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30 In their recent *Forest Ecology and Management* paper, da Cunha et al. (2016)
31 reconstruct annual basal area increments from tree cores for *Swietenia macrophylla* (big-
32 leaf mahogany), *Cedrela odorata* (Spanish cedar), *Amburana cearensis* (amburana), and
33 *Copaifera paupera* (copaiba) in the Brazilian Amazon and relate species-specific growth
34 rates to four tree size indices, two competition indices, and liana load (the study species
35 are hereafter referred to by their generic names). The reconstruction of growth histories
36 and statistical tests of relationships between growth and crown form, light environment,
37 and competition represent important contributions to the growing body of research on
38 Amazonian tree life history and management. Unfortunately, the authors attempt to use
39 this valuable but limited information to draw broad conclusions about the sustainability of
40 current Brazilian management regulations. Ultimately, they conclude that their study
41 “confirms that the current forest management guidelines and regulation [sic] applied in the
42 Amazon rain forest are conservative but correct estimates and ensure sustainable harvesting”
43 (pg. 182). We argue that da Cunha et al. provide no evidence to support this claim and
44 actually report results that coincide with more comprehensive studies demonstrating that
45 current Brazilian harvest regulations are unsustainable without longer cutting cycles,
46 higher retention rates, and extensive silviculture.

47 It is reckless to make sweeping statements regarding the sustainability of harvest
48 regulations, especially for threatened species like *Swietenia* and *Cedrela* (listed on CITES
49 Appendices II and III, respectively), without directly examining the recovery of tree
50 densities and harvest volumes under all of the relevant regulatory parameters.
51 Nevertheless, da Cunha et al. conclude that current Brazilian harvest regulations – which
52 employ a 50 cm minimum diameter cutting limit (MDCL), 25-35 year cutting cycles, and an
53 80% maximum cutting intensity – are sustainable based only on their models of the time
54 required for trees to pass from 30 cm diameter to commercial size (**Table 1**). However,
55 the meaning of this arbitrary passage time is unclear. If it is meant to show that trees reach
56 commercial size within a commercial rotation, then the time from seed to commercial size
57 is the relevant and necessary statistic. However, even this statistic is insufficient for
58 evaluating sustainability without consideration of size structure and mortality rates, both

59 of which are completely ignored by da Cunha et al.. Furthermore, da Cunha et al. fail to
60 consider cutting intensity, which is necessary in any evaluation of harvest sustainability.

61 The peer-reviewed studies that do directly and comprehensively evaluate current
62 harvest regulations demonstrate that they are unsustainable for the four study species.
63 For example, Brienen and Zuidema (2006b) use a simple population growth and yield
64 model to examine the sustainability of current Bolivian forest regulations for *Cedrela* and
65 *Amburana* over one cutting cycle (20 years) with a 50 cm MDCL and 80% cutting intensity.
66 They found that it takes ~72 years and >84 years to recuperate initial harvest volumes of
67 *Cedrela* and *Amburana*, respectively, demonstrating that Brazilian harvest regulations,
68 even with their longer cutting cycles, would be unsustainable for these species. Grogan et
69 al. (2014) use an even more detailed individual-based population model that incorporates
70 growth, mortality, fruit production, seed germination, and canopy disturbance rates to
71 evaluate the sustainability of current Brazilian harvest regulations for *Swietenia* and show
72 that current regulations lead to commercial depletion after 2-3 cutting cycles. Although
73 harvest regulations for *Copaifera* have yet to be evaluated, they are unlikely to be
74 sustainable given that *Copaifera* exhibits the slowest growth rates of the four study species.

75 These studies, unlike da Cunha et al., explicitly evaluate both population density
76 and harvest volume outcomes under current regulations while accounting for mortality
77 and size structure and simply cannot be refuted by conclusions based on a meaningless
78 passage time. In fact, the results of da Cunha et al. actually validate conclusions that
79 current Brazilian harvest standards are unsustainable. The 30-50 cm diameter passage
80 times documented by da Cunha et al. are nearly identical to those documented in studies
81 showing that current cutting cycles are too short for these slow-growing species (**Table 1**;
82 Brienen and Zuidema 2006b; Free et al. 2014; Grogan et al. 2014). da Cunha et al. also
83 demonstrate that extensive silviculture is required to promote the fast growth rates
84 necessary for sustainable and profitable logging to be achievable. They show significant
85 decreases in 30-50 cm diameter growth rates from ideal to moderate growth conditions
86 for all four species and these decreases likely compound over the more relevant 0-50 cm
87 diameter passage time. The necessity of extensive and expensive silviculture, often
88 unattractive to loggers through the lens of financial discount rates, undermines da Cunha
89 et al.'s assertion that current forest management regulations are “conservative” (pg. 182).

90 In their opening sentence, the authors assert that “*little is known about sustainable*
91 *forest management and tree growth in the Amazon forest*” (pg. 174). In reality, tropical

92 forest ecologists and managers have learned a lot about the factors contributing to the
93 success and failure of sustainable forest management in the last few decades and
94 knowledge of tree growth dynamics has been central in these developments. For example,
95 we know that: (1) harvest parameters such as the minimum diameter cutting limit, cutting
96 cycle length, and cutting intensity must be coupled to species-specific biological realities
97 (Schöngart 2008); (2) sustainable management will require extensive silvicultural
98 intervention including enrichment planting, crown liberation, liana cutting, and gap
99 creation (Wadsworth and Zweede 2006; Peña-Claros et al. 2008; Schwartz et al. 2016); (3)
100 reduced-impact logging can reduce the ecological impacts of logging (Putz et al. 2008); and
101 (4) community-based forest management, forest certification programs, and REDD+
102 subsidy programs can incentivize sustainable behavior (Gray et al. 2001; Putz et al. 2012).
103 Thus, the slow progress towards sustainable management is due, not to a lack of scientific
104 knowledge, but to a lack of political will and incentives that counterbalance the
105 opportunity costs and investments essential to truly sustainable management systems.

106 Although da Cunha et al. draw erroneous conclusions regarding the sustainability
107 of Brazilian forest management, they do provide some useful results. First, they confirm
108 that silvicultural interventions such as liana cutting and crown liberation are effective and
109 necessary tools for sustainable forest management. Second, although the growth and age-
110 size dynamics of *Swietenia* and their management implications have been well studied (e.g.,
111 Gullison et al. 1996; Grogan et al. 2003, 2005, 2008; Grogan & Landis 2009; Grogan &
112 Schulze 2012; Free et al. 2014), *Cedrela* and *Amburana*'s dynamics have been less well
113 studied (e.g., Brienens & Zuidema 2006ab; Zuidema et al. 2009), and the da Cunha et al.
114 *Copaifera* results are entirely novel and highly valuable to scientists and managers. Finally,
115 this paper contributes to the growing literature demonstrating that tropical trees can be
116 aged and that describing species-specific growth rates and age-size relationships are
117 essential to the future of sustainable forest management in the tropics (Worbes 2002).

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195 **Tables & Figures**

196

197 **Table 1. 30-50 cm and 0-50 cm diameter passage times reported by da Cunha et al.**

198 **(2016) compared to other studies.** The 30-50 cm diameter passage time (reported by da

199 Cunha et al.) is an arbitrary metric without clear management implications whereas the 0-

200 50 cm diameter passage time (not reported by da Cunha et al.) represents a first-cut

201 approximation of the sustainable cutting cycle length. 0-50 cm diameter passage times

202 reported in other studies indicate that current Brazilian harvest regulations employ

203 cutting cycles (25-35 years) too short for these slow-growing species. 30-50 cm diameter

204 passage times reported by da Cunha et al. are nearly identical to those reported in these

205 other studies, thereby indirectly validating the results and conclusions of these studies.

206

Species and source*	Mean (min-max) passage times (yr)	
	30-50 cm diam	0-50 cm diam
<i>Swietenia macrophylla</i>		
da Cunha et al. 2016 - CPI 1 trees	22 (13-105)	---
da Cunha et al. 2016 - CPI 2 trees	37 (23-103)	---
Dünisch et al. 2003 - Brazil, tree rings	30.0 (16-45)	83.7 (57-110)
Free et al. 2014 - Brazil, growth model	23.7 (7-84)	66.1 (28-159)
<i>Cedrela odorata</i>		
da Cunha et al. 2016 - CPI 1 trees	17 (13-27)	---
da Cunha et al. 2016 - CPI 2 trees	19 (15-25)	---
da Cunha et al. 2016 - CPI 3 trees	36 (25-57)	---
Brienen and Zuidema 2006b - Bolivia, tree rings	23.5 (9-71)	81.4 (37-152)
<i>Amburana cearensis</i>		
da Cunha et al. 2016 - CPI 1 trees	25 (21-34)	---
da Cunha et al. 2016 - CPI 2 trees	36 (27-52)	---
Brienen and Zuidema 2006b - Bolivia, tree rings	31.9 (25-41)	95 (61-135)
<i>Copaifera paupera</i>		
da Cunha et al. 2016 - CPI 1 trees	28 (22-40)	---
da Cunha et al. 2016 - CPI 2 trees	37 (23-103)	---
No other studies available	---	---

207

208 * CPI (crown position index) is a measure of light environment where values indicate (1)

209 direct light from above and laterally; (2) direct light from above; and (3) no direct light.