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Bamboos and a new perspective on nitrogen input in tropical forests

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Background. Bamboos are typical plants in tropical forests acting as resource for different animals and influencing forest structure and dynamics, but our knowledge about their influence on ecosystem functioning remains in its infancy. Nitrogen (N) is an important macronutrient that exerts control over productivity of ecosystems. Biological Nitrogen Fixation (BNF) is one of the main N input to terrestrial systems, more specifically by free-living BNF in tropical forests. In these forests, the dominant presence of bamboo and the occurrence of free-living N-fixers in its leaf surfaces appear to play a relevant role in N cycling. Here, we explore the importance of a native bamboo to N cycle in a Neotropical forest to provide insights on bamboo's role on ecosystem functioning.

Methods. The study was conducted in a pristine montane Atlantic Forest, Brazil. We select 100 sample units (100 m² each) and counted all bamboo clumps and live culms, estimated the leaf area, the litter production and its N content. We estimated the potential N input mediated by bamboo based on available data of free-living BNF rates for this species and then we contextualized it with information about N cycling components in the study area.

Results. We counted 4000 live culms ha⁻¹ and estimated 4.3 x 10⁴ m² ha⁻¹ of bamboo leaf area for free-living N-fixers colonization. Considering the free-living BNF rates quantified for the same study area, the native bamboo may contribute up to 61.6 kg N ha⁻¹ y⁻¹ which represents a reduction in the N deficit of at least 25% in the Neotropical forest area we studied. Through its litter, the bamboo adds 9 kg N ha⁻¹ y⁻¹ to the system (15% of the total fixed on its leaf surface).

Discussion. The bamboo's contribution for N input we found may be explained by free-living community composition on its leaf as previously indicated by other studies, as well as by the bamboo overabundance, and thus habitat availability for colonization. Such N input represents a reduction in N deficit in the study area where the rates of symbiotic BNF (0.2 kg N ha⁻¹ y⁻¹) are lower than values in Amazon Forest (3 kg N ha⁻¹ y⁻¹). This native bamboo may supply N to the system probably through the decomposition of its leaves which represents a return of 15% of the total N fixed. Although it is still necessary to evaluate the characteristics of bamboo that will further elucidate its role in the functioning of the forests, our findings suggest that it closely regulates N inputs and may better explain high diversity and carbon stocks of the area.

1 **TITLE: BAMBOOS AND A NEW PERSPECTIVE ON NITROGEN INPUT IN**
2 **TROPICAL FORESTS**

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14 **Abstract**

15 **Background.** Bamboos are typical plants in tropical forests acting as resource for different
16 animals and influencing forest structure and dynamics, but our knowledge about their influence
17 on ecosystem functioning remains in its infancy. Nitrogen (N) is an important macronutrient that
18 exerts control over productivity of ecosystems. Biological Nitrogen Fixation (BNF) is one of the
19 main N input to terrestrial systems, more specifically by free-living BNF in tropical forests. In
20 these forests, the dominant presence of bamboo and the occurrence of free-living N-fixers in its
21 leaf surfaces appear to play a relevant role in N cycling. Here, we explore the importance of a
22 native bamboo to N cycle in a Neotropical forest to provide insights on bamboo's role on
23 ecosystem functioning. **Methods.** The study was conducted in a pristine montane Atlantic Forest,
24 Brazil. We select 100 sample units (100 m² each) and counted all bamboo clumps and live culms,
25 estimated the leaf area, the litter production and its N content. We estimated the potential N input
26 mediated by bamboo based on available data of free-living BNF rates for this species and then we
27 contextualized it with information about N cycling components in the study area. **Results.** We
28 counted 4000 live culms ha⁻¹ and estimated 4.3 x 10⁴ m² ha⁻¹ of bamboo leaf area for free-living
29 N-fixers colonization. Considering the free-living BNF rates quantified for the same study area,
30 the native bamboo may contribute up to 61.6 kg N ha⁻¹ y⁻¹ which represents a reduction in the N
31 deficit of at least 25% in the Neotropical forest area we studied. Through its litter, the bamboo
32 adds 9 kg N ha⁻¹ y⁻¹ to the system (15% of the total fixed on its leaf surface). **Discussion.** The
33 bamboo's contribution for N input we found may be explained by free-living community
34 composition on its leaf as previously indicated by other studies, as well as by the bamboo
35 overabundance, and thus habitat availability for colonization. Such N input represents a reduction
36 in N deficit in the study area where the rates of symbiotic BNF (0.2 kg N ha⁻¹y⁻¹) are lower than
37 values in Amazon Forest (3 kg N ha⁻¹y⁻¹). This native bamboo may supply N to the system
38 probably through the decomposition of its leaves which represents a return of 15% of the total N

39 fixed. Although it is still necessary to evaluate the characteristics of bamboo that will further
40 elucidate its role in the functioning of the forests, our findings suggest that it closely regulates N
41 inputs and may better explain high diversity and carbon stocks of the area.

42 **Keywords:** *Merostachys neesii*, Neotropical bamboo, Atlantic forest, N cycling, free-living
43 Biological Nitrogen Fixation

44 Introduction

45 Woody bamboos are typical plants in many tropical forests (Humboldt & Bonpland 1907;
46 Judziewicz et al. 1999). They have a prolonged life cycle during which the rhizomes give origin
47 to the clones (culms) that remain connected in a clump (Judziewicz et al. 1999). The clump
48 structure and the rapid colonization in a greater availability of light (Widmer 1998; Yang et al.
49 2014), soil nutrients (Cirtain et al. 2009) or root colonizing fungi (Jiang et al. 2013) make the
50 group occur at high densities inside forests (Judziewicz et al. 1999). Such density influences the
51 structure (Tabarelli & Mantovani 2000; Griscom & Ashton 2003; Lima et al. 2012) and the
52 dynamic of forest, opening an opportunity for tree regeneration after gregarious flowering
53 (Giordano et al. 2009) or limiting it during the clones' phase (Rother et al. 2009; Grombone-
54 Guaratini et al. 2014); it also acts as a resource for different animals (Reid et al. 2004; Areta et al.
55 2009; Hilário & Ferrari 2010; Cestari & Bernardi 2011). These bamboos' roles are relatively well
56 known, but do they have any influence on ecosystem functioning?

57 Nitrogen (N) exerts strong control over composition, diversity and productivity of
58 ecosystems (Townsend et al. 2011). Biological nitrogen fixation (BNF) and N deposition are the
59 two dominant pathways of N input to terrestrial ecosystems (Hedin et al. 2009, Sullivan et al.
60 2014). In mature tropical forests, the contribution of symbiotic BNF associated with legume tree
61 species do not explain the high nitrogen availability (Gehring et al. 2005; Nardoto et al. 2008;
62 Hedin et al. 2009; Cleveland et al. 2010) and may not be as important as believed (Sullivan et al.
63 2014) occurring only in cases of transient N limitation (Barron et al. 2011; Nardoto et al. 2014).

64 Conversely, free-living BNF in litter and associated with aerial parts of plants can
65 contribute to N inputs, notably in tropical forests (Bentley 1987; Benner et al. 2007; Reed et al.
66 2008) where free-living BNF often exceeds symbiotic N inputs (Reed et al. 2011). The leaf
67 surfaces (phyllosphere) of tropical tree species harbor a great diversity of bacteria, including
68 putative diazotrophs (Lambais et al. 2006; Fürnkranz et al. 2008; Lambais et al. 2014). The N

69 cycling through litter is important in the nutrition budgeting once vegetation depends on the
70 recycling of nutrients contained in plant debris (Kuruvilla et al. 2014).
71 Studies about bamboo's influences on N cycling has been increasing mostly because it
72 plays a role on the recuperation of soil fertility (Christanty et al. 1997, Singh & Singh 1999,
73 Embaye et al. 2005, Shiau et al. 2017). In an agroforestry at Indonesia, the N content in bamboo
74 litterfall varied between 28.2 and 45.2 kg ha⁻¹ (Mailly et al. 1997); in India varied from 33.2
75 (Kuruvilla et al. 2014, Kuruvilla et al. 2016) to 79 kg N ha⁻¹ (Singh & Singh 1999), but nothing
76 compared to 115 kg N ha⁻¹ added by *Yushania alpina* in Ethiopia (Embaye et al. 2005). These
77 works explicit the importance of bamboos on N cycling through litterfall, but we do not know
78 how these N enters the system. In the Brazilian Atlantic Forest, a threatened hotspot and the place
79 of the highest bamboo diversity in the Neotropics (Judziewicz et al. 1999), Gómez (2012) found
80 prominent level of bacterial diversity in the phyllosphere of *Merostachys neesii* Rupr. (Poaceae:
81 Bambusoideae), including several groups of putative free-living diazotrophs. Rigonato et al.
82 (2016) recorded the greatest abundance of cyanobacteria affiliated to the diazotrophic order
83 Nostocales on the *M. neesii*'s phyllosphere.
84 Studying in this pristine Atlantic Forest, we want to provide insights on bamboo's role in
85 neotropical forest functioning addressing the questions: how much N does the *M. neesii* may
86 contribute by free-living diazotrophs communities on its phyllosphere? How much litter and N
87 through the litter does the *M. neesii* add to the system? Is this addition stable at different seasons?
88 We calculated the *M. neesii* density, leaf area, litter production and its N content. Using available
89 data on free-living BNF rates (Gómez 2012), we estimated the potential bamboo N input and
90 contextualized it with information about N cycling components in the study area. The presence of
91 *M. neesii* with some evidence of free-living diazotrophs suggests that they have efficient
92 mechanisms to cope with potential nutrient limitations in such acidic, dystrophic soils (Martins et
93 al. 2015).

94 **Materials and Methods**

95 **Study area**

96 The study was conducted in the northeastern of São Paulo State, Brazil, in the Serra do
 97 Mar State Park (PESM in Portuguese), Santa Virginia administrative nucleus (Fig. 1). We select
 98 100 sample units (100 m² each) inside the previously established permanent plots (Joly et al.
 99 2012). The physiognomy is pristine montane Atlantic Forest (1000 meters a.s.l.) with humid
 100 subtropical climate (Cfa and Cfb), an average annual temperature of 21°C and an average annual
 101 rainfall of 2,180 mm without a dry season (Salemi et al. 2013). A dense fog covers the region
 102 almost daily, especially in the winter. The soil order is Inceptisol (United States Department of
 103 Agriculture taxonomy) with very low pH (≈ 3.8), low fertility and elevated levels of aluminum
 104 saturation (Martins et al. 2015). The aboveground biomass (283.2 Mg ha⁻¹) (Alves et al. 2010)
 105 and the floristic diversity (≈ 200 tree species/ha) (Padgurschi et al. 2011) are both high (Joly et al.
 106 2014). Arecaceae, Myrtaceae, Lauraceae and Sapotaceae are among the most abundant families
 107 (Padgurschi et al. 2011).

108 **Bamboo species: density, leaf area and litter**

109 *Merostachys neesii* Rupr. (Poaceae: Bambusoideae) is a native and endemic species of the
 110 Brazilian Atlantic Forest (Fig. 2). We estimated its total leaf area (LA_t) based on the culms'
 111 density, on previously estimated leaf biomass per culm (L_b) (551.4 ± 362.8 g, Padgurschi 2010),
 112 on the average leaf dry weight (L_w) (n=50; at 65°C until constant weight) and on the average leaf
 113 area (LA_a) (n=50) (LI-3100 area meter - LI-COR, Lincoln, Nebraska, USA).

114 We counted all clumps and live culms (culms' density) within the sample units. To
 115 contrast the number of clumps of *M. neesii*, we compared it to the highest density species in the
 116 area (*Euterpe edulis* Mart. Arecaceae - Padgurschi et al. 2011). To obtain the number of leaves
 117 per culm (L_c), we divided estimated leaf biomass per culm (L_b) by the average leaf dry weight
 118 (L_w). For the leaf area per culm (LA_c) we multiplied L_c by the average leaf area (LA_a). Finally, we
 119 estimated the total bamboo leaf area (LA_t) (m² ha⁻¹) by:

$$LA_t = \frac{LA_c * \text{culms}}{10000}$$

Equation (1)

120 Among the 100 sample units, we randomly selected 40 to install litter collectors (0.22 m²
 121 each) which were analyzed every 15 days for 20 months. The material was dried (at 65°C until
 122 constant weight) and weighted to obtain the dry mass; all bamboo leaves were separated. We
 123 calculated the production of bamboo litter from Sylvestre & Rosa (2002):

$$LP = \frac{\left(\frac{\sum MA * 10,000}{CA} \right)}{1000} \quad \text{Equation (2)}$$

124 where LP = annual litter production (kg ha⁻¹ y⁻¹); MA = month average of litter production (kg ha⁻¹);
 125 CA = collector's area (m²). For N chemical analysis, we grinded the leaves and prepared a composite
 126 sample of which we random selected 3 subsamples for each season (January, May, July and October)
 127 during the months of collection (results expressed in kg N ha⁻¹). The research was performed with
 128 permits COTEC/IF 010.323/2013, 002.766/2013 and 010.631/2013 and IBAMA/SISBIO #33217.

129 **Estimation of N input by free-living BNF rates in *M. neesii*'s phyllosphere**

130 To estimate the N input, we applied available data on free-living BNF rates in *M. neesii*'s
 131 phyllosphere (Gómez 2012) that were recorded at the same site we studied. The BNF rate is 64.25 ng
 132 N cm⁻² h⁻¹ (summer) and 34.78 ng N cm⁻² h⁻¹ (winter) (Gómez 2012). Considering 8 hours of light per
 133 day (365 days) and the mean value (BNF_m) of 49.52 ng N cm⁻² h⁻¹, we estimated the N potential

134 fixing (N_f expressed in kg N ha⁻¹y⁻¹) by:

$$N_f = \frac{(BNF_m * LA_t) * 2920}{10^{12}} \quad \text{Equation (3)}$$

135 where 2920 are the hours of light in a year.

136 **N cycling**

137 To contextualize the estimation of N input mediated by *M. neesii*, we set up a table of N
 138 cycling components in the study area. For N input, we considered the two dominant pathways in
 139 most terrestrial ecosystems (Hedin et al. 2009): symbiotic BNF (Manarin 2012) and the total
 140 atmospheric N deposition (Groppo 2010). In terms of N required by the system (demand), we
 141 considered 1.5 mm y⁻¹ of tree growth (Scaranello 2015) and the biomass of the life forms (trees,
 142 palms and ferns - Alves et al. 2010) from an Atlantic Forest database (www.forestplot.net) to

143 calculate the annual increment of biomass. We then multiplied the leaf and stem biomass by its
144 respective N concentration (leaves = 2.61%; stems = 0.52% - Vieira et al. 2011) to obtain the N
145 demand for tree growth. In the same way, we estimated the annual N for bamboo growth based
146 on the average biomass for each compartment (leaves = 0.5 kg, culms = 2.9, branches = 0.9) of
147 *M. neesii* (Padgurschi 2010), on net change of culms density (1.82% per year) of another
148 *Merostachys* species also from Atlantic Forest (*M. riedeliana* Rupr. ex Döll - Guilherme et al.
149 2004), on the number of live culms we counted and on N concentration of a native *Guadua*
150 species (leaves = 2.7%; culms and branches = 0.8% - Galvão et al. 2012). From data on litter
151 biomass (5.5 Mg ha⁻¹ y⁻¹ - Sousa Neto et al. 2011) and on N content of the litter layer (1.72% -
152 Vieira et al. 2011), we estimated the N demand (for bamboo litter please check methods above).
153 Finally, we considered as outputs the N via riverine transport and the losses to the
154 atmosphere of N₂O and NO by soil emissions (Groppo 2010; Sousa Neto et al. 2011; Ghehi et al.
155 2013). Usually, there is considerable spatial and temporal variability of NO_x emissions due to
156 environmental conditions (Ghehi et al. 2013). The N₂O emission we present here were measured at
157 the same plot we studied, but NO emission is based on models developed for Tropical Highland
158 Forest (Ghehi et al. 2013). However, both areas are similar: (i) pristine montane forest; (ii) 1000 m
159 a.s.l.; (iii) 2000 mm y⁻¹ of rainfall; (iv) presence of bamboo; and (v) pH 3.8 (Ghehi et al. 2013;
160 Martins et al. 2015). Therefore, we consider valid the use of NO emission only as a reference for
161 the cycling of N in the Atlantic Forest. All analysis and graphs were performed at R environment
162 (R Core Team 2014).

163 **Results**

164 By free-living diazotrophs on its phyllosphere, *M. neesii* may contribute up to 61.6 kg N
165 ha⁻¹y⁻¹. Its annual litter production is 540 kg ha⁻¹y⁻¹ with significantly higher values during
166 summer/spring when compared to fall/winter (p<0.001) (Fig. 3). Through its litter, *M. neesii* adds
167 9 kg N ha⁻¹ y⁻¹ to the system, which represents 15% of the total fixed on its phyllosphere, with the
168 highest value in spring (3 kg N ha⁻¹ y⁻¹). Considering the inputs, demands and outputs of N in the

169 Atlantic Forest system we studied, such bamboo contribution may represent a reduction in the
170 nutrient deficit of at least 25% (Table 1), although the final balance remains negative (-170 kg N
171 ha⁻¹ y⁻¹).
172 The bamboo density is 579 clumps ha⁻¹, a value as high as the highest density tree species
173 in the study area: *Euterpe edulis* (574 trees ha⁻¹). With an average of 7.5 (±2.5) live culms per
174 clump, we counted 4000 culms ha⁻¹. Based on this and on available data on bamboo biomass, we
175 estimated 10.66 m² of leaf area in each of these culms and 4.3 x 10⁴ m² ha⁻¹ of bamboo leaf area
176 (*LA_t*) for microbial colonization. These and other information on *M. neesii* traits are available in
177 Table 2.

178 Discussion

179 The phyllosphere of *M. neesii* growing in a pristine montane Neotropical forest harbored
180 prominent levels of BNF rates (61.6 kg N ha⁻¹ y⁻¹), which are greater than other values of our
181 knowledge. Some tropical tree species - *Spathacanthus hoffmannii* Lindau (Acanthaceae),
182 *Myriocarpa longipes* Liebm. (Urticaceae), *Chamaedorea tepejilote* Liebm. (Arecaceae) and
183 *Cyclanthus bipartitus* Poit. (Cyclanthaceae) - contribute up to 5 kg N ha⁻¹ y⁻¹ by free-living BNF
184 (Freiberg 1998). These rates are even considerably less for *Brosimum utile* (Moraceae), *Caryocar*
185 *costaricense* (Caryocaraceae), *Staminodella manilkara* (Sapotaceae), *Qualea paraensis*
186 (Vochysiaceae), *Schizolobium parahybum* (Fabaceae) and *Symphonia globulifera* (Clusiaceae)
187 which contribute with 0.035 kg N ha⁻¹ y⁻¹ (Reed et al. 2008).

188 Several factors may act and result in these rate differences: leaf age, intensity of light,
189 temperature, micro and macronutrient availability, tree species (phorophyte) and free-living
190 community composition (see Reed et al. 2011 for a review). In the same area of our study,
191 Rigonato et al. (2016) recorded the greatest abundance of cyanobacteria affiliated to the
192 diazotrophic order Nostocales on *M. neesii*'s phyllosphere. Similarly, Gómez (2012) recorded
193 prominent level of groups of putative free-living diazotrophs on bamboo leaves, even when
194 compared to *Euterpe edulis* Mart. and other species in the same area. Although we did not

195 measure these variables, here we provide evidence of the great abundance of *M. neesii* (Table 2),
196 resulting in a large habitat availability for microbial colonization which added to the high amount
197 of N fixed on its phyllosphere, closely regulate the N input in this Atlantic Forest.
198 In mature tropical forests, the contribution of symbiotic BNF associated with legume tree
199 species do not explain the nitrogen availability (Gehring et al. 2005; Nardoto et al. 2008; Hedin et
200 al. 2009; Cleveland et al. 2010). In our study site, in addition to low occurrence of tree legumes
201 (Padgurschi et al. 2011), Manarin (2012) found rates of symbiotic BNF ($0.2 \text{ kg N ha}^{-1} \text{ y}^{-1}$) lower
202 than values found in Amazon Forest ($3 \text{ kg N ha}^{-1} \text{ y}^{-1}$) (Nardoto et al. 2014) and Costa Rica (1.2 kg
203 $\text{N ha}^{-1} \text{ y}^{-1}$) (Sullivan et al. 2014). This may suggest that other forms of N input contribute to the N
204 maintenance in these pristine forests. Indeed, the *M. neesii*'s contribution increased more than 20
205 times the N input values in our study area (Table 1). This is particularly important since the
206 demand for N, such as tree and bamboos growth and litter production, is at least $127.3 \text{ kg N ha}^{-1}$
207 y^{-1} (Table 1). Therefore, the association of this bamboo species with N-fixers may play a key role
208 in the functioning of the system supplying N to other plants probably through the decomposition
209 of its leaves. Such N recycling is important in the nutrition budgeting on tropical ecosystems
210 where vegetation mainly depends on the nutrients contained in plant debris (Kuruvillea et al.
211 2014).
212 Bamboo is important in the recuperation of soil fertility (Christanty et al. 1997, Embaye et
213 al. 2005), soil physiochemical properties (Shiau et al. 2017), net primary production and soil
214 redevelopment (Singh & Singh 1999). In an agroforestry at Indonesia, the “talun-bakun” system
215 success, which includes four years of bamboo plantation, is due to the recovery of nutrients
216 leached by the pumping action exerted by the bamboos (Christanty et al. 1997). In this system,
217 the N content in bamboo litterfall varied between 28.2 and 45.2 kg ha^{-1} and the N concentration in
218 litter did not differ from live leaf (Mailly et al. 1997). In a natural forest in India, Joshi et al.
219 (1991) reported 580 kg ha^{-1} of annual bamboo litterfall of which 5.4 kg ha^{-1} were N that returned
220 to system. Other authors reported higher values ranging from 33.2 (Kuruvillea et al. 2014,

221 Kuruvilla et al. 2016) to 79 kg N ha⁻¹ (Singh & Singh 1999) and 115 kg N ha⁻¹ (Embaye et al.
222 2005). Except for Joshi et al. (1991), all these N values are higher than one we found in this
223 study. However, the N concentrations they recorded are all similar to *M. neesii* (1.6%): 1.2%
224 (Joshi et al. 1991), 1.5% (Kuruvilla et al. 2014), 1.7% (Kuruvilla et al. 2016), 1.4% (Embaye et
225 al. 2005) and 0.7% (Singh & Singh 1999). We thus attributed the differences to the amount of
226 bamboo litterfall they found that varied from 2 to 10 Mg ha⁻¹ y⁻¹ (Kuruvilla et al. 2014; Singh &
227 Singh 1999, respectively).

228 **Conclusion**

229 The development of lush tropical forests on acidic and dystrophic soils has been a puzzle
230 in tropical forest ecology for many decades (Hardy 1936) and the explanation has partially relied
231 on the nutrient cycling mechanisms of these forests (Vitousek & Sanford 1986). Our findings
232 suggest that the amount of N fixed by free-living N-fixers associated with bamboo closely
233 regulates N inputs in these montane tropical forests and may better explain high diversity
234 (Padgurschi et al. 2011) and carbon stocks (Vieira et al. 2011) even with the overabundance of
235 bamboo.

236 Woody bamboos are typical plants in many tropical forests playing a vital role on forest
237 structure, dynamics and as resource for different animals, but our knowledge about their
238 influence on ecosystem functioning remains in its infancy. This is the first time to our best
239 knowledge that a work explores free-living BNF in bamboo phyllosphere making linkages to N
240 cycling in Neotropical forest. However, it is still necessary to evaluate the characteristics of
241 bamboo that will further elucidate its role in the functioning of these forests in addition to
242 features that can better explain the relationship between bamboo and its associated free-living
243 BNF community.

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Figure 1

Location of the study area ($45^{\circ}\text{W } 04' 34''$ $23^{\circ}\text{S } 17' 24''$).

Figures (A) and (B) illustrate the geographic localization of the region; (C) indicates the position of the study region (São Paulo State, SE/Brazil) and the position of the sample units (yellow dot) compared to neighboring municipalities (São Luis do Paraitinga and Ubatuba).

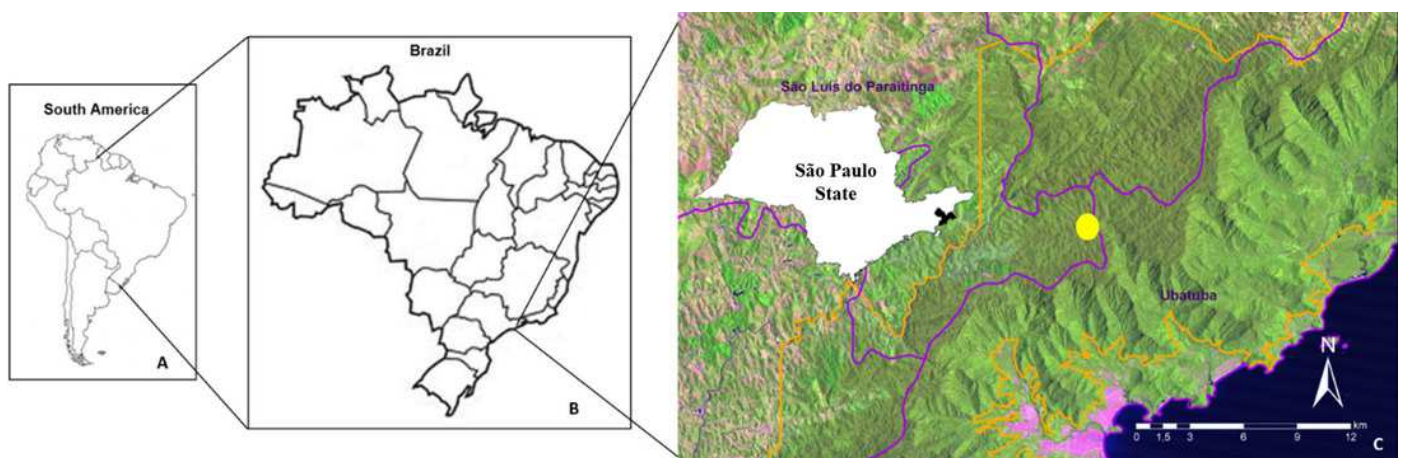


Figure 2

Merostachys neesii Rupr. (Poaceae: Bambusoideae), a native woody bamboo in a pristine montane forest (Atlantic Forest), Brazil.

(A) Flowers at anthesis; (B) Detail of a clump in the study area; (C) Detail of characteristic *M. neesii*'s leaf culm. Photos credit: MCG Padgurschi.



Figure 3

M. neesii's annual litter production ($540 \text{ kg ha}^{-1} \text{ y}^{-1}$) in the pristine montane Atlantic Forest, Brazil.

(A) Seasonal variation with significantly higher values during summer/spring when compared to fall/winter ($p < 0.001$); (B) Annual variation.

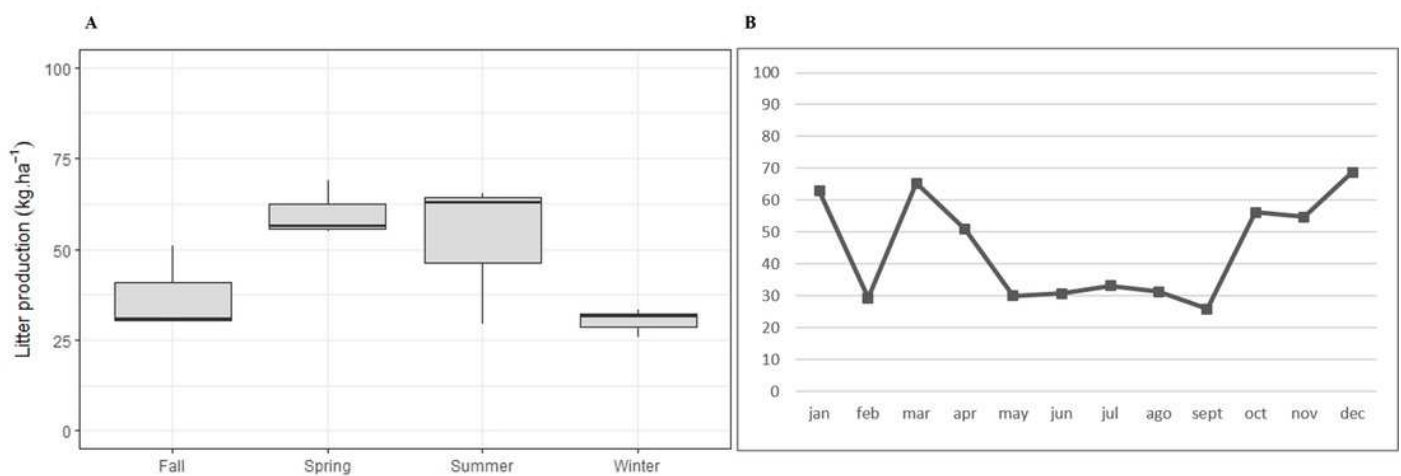


Table 1 (on next page)

Estimates of N inputs, demand and outputs in the Atlantic Forest studied.

When local data were not available, we used information from literature. * We considered the litter as an indirect measurement of N demand to leaves' production.

**TITLE: BAMBOOS AND A NEW PERSPECTIVE ON NITROGEN INPUT IN
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Table 1. Estimates of N inputs, demand and outputs in the Atlantic Forest studied. When local data were not available, we used information from literature. * We considered the litter as an indirect measurement of N demand to leaves' production.

	Reference	Biome	Compartment	Nitrogen (kg N ha ⁻¹ y ⁻¹)
Inputs	Grosso 2010	Atlantic Forest, Brazil	N _{total} (N-N _{inorg} +N-N _{org})	2.8
	Manarin 2012	Atlantic Forest, Brazil	BNF by legume trees	0.2
	Total			3.0
Demand	Scaranello 2015	Atlantic Forest, Brazil	Tree growth	20.0
	Galvão <i>et al.</i> 2012 Padgurschi 2010; Guilherme <i>et al.</i> 2004	Atlantic Forest, Brazil	Bamboo growth	3.3
	Sousa-Neto <i>et al.</i> 2011 Vieira <i>et al.</i> 2011	Atlantic Forest, Brazil	Litter (general) *	95.0
	This study	Atlantic Forest, Brazil	Litter (bamboo leaves) *	9
	Total			127.3
	Grosso 2010	Atlantic Forest, Brazil	Riverine transport	0.6

	Sousa Neto <i>et al</i> 2011	Atlantic Forest, Brazil	N ₂ O soil emission	0.8
	Ghahi <i>et al.</i> 2013	Tropical Highland Forest, Rwanda	NO soil emission	2.0
			Total	3.4
Balance			Without Bamboo inputs	-231.7
			With Bamboo inputs	-170.0

Table 2 (on next page)

Traits of *M. neesii* and its contribution to nitrogen input in a pristine montane Atlantic Forest, São Paulo State, Brazil.

Values in parenthesis are standard deviation (SD). L_w = Leaf dry weight; LA_a = Average leaf area; LA_t = Total bamboo's leaf area; N fixed = Total nitrogen fixed on bamboo's phyllosphere.

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<i>Merostachys neesii</i> Traits	
Density (clumps ha ⁻¹)	579
Culms (ha ⁻¹)	4000
Estimated leaves per culm	4595
(L_w)(g)	0.12 (±0.03)
LA_a (m ²)	0.002 (±0.004)
LA_t (m ² ha ⁻¹)	4.3 x 10 ⁴
N fixed (kg N ha ⁻¹ y ⁻¹)	61.6
N content in bamboo litterfall (%)	1.65