Ecography

ECOG-02104
Carlucci, M. B., Seger, G. D. S., Sheil, D., Amaral, I. L., Chuyong, G. B., Ferreira, L. V., Galatti, U., Hurtado, J., Kenfack, D., Leal, D. C., Lewis, S. L., Lovett, J. C., Marshall, A. R., Martin, E., Mugerwa, B., Munishi, P., Oliveira, Á. C. A., Razafimahaimodison, J. C., Rovero, F., Sainge, M. N., Thomas, D., Pillar, V. D. and Duarte, L. D. S. 2016. Phylogenetic composition and structure of tree communities shed light on historical processes influencing tropical rainforest diversity. – Ecography doi: 10.1111/ecog.02104

Supplementary material

Appendix 1. Lists of TEAM Network's sites (7), Gentry's sites (74), published studies (34 sites from 32 studies) used to compile rainforest tree species pools for Neotropics, Afrotropics and Madagascar. TEAM data sets are available at http://www.teamnetwork.org. Gentry's transect data is available at http://www.mobot.org/mobot/research/gentry/welcome.shtml.

(a) TEAM's sites used: NEOTROPICS - Volcán Barva (La Selva Biological Station and Braulio Carrillo National Park, Costa Rica), Manaus (three different field stations near the city of Manaus, Brazil) and Caxiuanã (Caxiuanã National Forest, Brazil); AFROTROPICS - Korup (Korup National Park, Cameroon), Bwindi (Bwindi Impenetrable National Park, Uganda), Udzungwa (Udzungwa Mountains National Park, Tanzania); MADAGASCAR - Ranomafana (Ranomafana National Park, Madagascar).

We selected seven sites containing information of tree composition and abundance in tropical rainforests. For each site, we used the inventory data that ranged between Aug 2010 and May 2011, available in "TEAM-DataPackage-20111206074616_1064". The TEAM Network sampling design for trees consists of tropical rainforest sites with five to seven 1-ha plots (100 x 100 m), each subdivided in 25 subplots of 400 m^2 (20 x 20 m), where trees with diameter at breast height ≥10 cm were recorded. Plots were placed in closed-canopy moist forest habitats. Each of the selected sites was composed by six plots of 1 ha, except for Korup and Volcán Barva, which were composed by five and nine plots, respectively. The data from all these plots were gathered using a defined, shared and therefore comparable method, which follows quality controls, such as including late successional forests with little anthropogenic impact. Further information can be found in TEAM Network (2010) and at http://www.teamnetwork.org.

(b) Alwyn Gentry's sites (codes in parentheses): AFROTROPICS – Banyong (Afr1), Belinga (Afr6), Makokou 1 (Afr7), Makokou 2 (Afr8), Mount Cameroun (Afr3), Ndakan (Afr4), Pande Forest Reserve (Afr17), Pugu Forest Reserve (Afr18); MADAGASCAR – Nosy Mangabe (Afr13), Perinet Forestry Station (Afr14); NEOTROPICS - Allpahuayo (SAm89), Alter de Chao (SAm20), Alto de Cuevas (SAm33), Alto de Mirador (SAm35), Alto Madidi (SAm10), Alto Madidi – Ridge Top (SAm11), Anchicayá (SAm36), Antado (SAm37), Araracuara (SAm39), Araracuara - High Campina (SAm38), Bajo Calima (SAm40), Belém-Mocambo (SAm29), Berbice River (SAm87), Bosque de la Cueva (SAm41), Bosque Nacional von Humboldt (SAm90), Cabeza de Mono (SAm91), Candamo (SAm108), Carajas (SAm23), Carara National Park (CAm6), Centinela (SAm70), Cerro de la Neblina 1 (SAm124), Cerro de la Neblina 2 (SAm125), Cerro El Picacho (CAm24), Cerro Olumo (CAm23), Cochacashu (SAm96), Constancia (SAm97),Cuangos (SAm71),Curundu (CAm25), Cuzco Amazónico (SAm99), Dureno (SAm72), Fila de Bilsa (SAm68), Huamaní (SAm75), Indiana (SAm101), Jatun Sacha (SAm76), Jenaro Herrera (SAm102), La Planada (SAm54), Madden Forest (CAm26), Maquipucuna (SAm78), Miazi (SAm79), Mishana - Tahuampa (SAm104), Mishana Old Floodplain (SAm105), Mishana White Sand (SAm106), Murrí (SAm59), Osa-Sirena (CAm8), Pampas del Heath (SAm109), Pipeline Road (CAm27), Quebrada Sucusari (SAm112), Rancho Quemado (CAm7), Río Manso (SAm61), Río Nangaritza (SAm82), Río Palenque 1 (SAm83), Río Palenque 2 (SAm84), Río Távara (SAm110), San Sebastían (SAm85), Saul (SAm86), Shiringamazú (SAm111), Tambopata Alluvial (SAm114), Tambopata Lateritic (SAm116), Tambopata Swamp Trail (SAm115), Tambopata Upland Sandy (SAm113), Tutunendo (SAm65), Yanamono 1 (SAm120), Yanamono 2 (SAm121), Yanamono Tahuampo (SAm119).

(c) Published studies:

Adekunle, V. A. J. 2006. Conservation of tree species diversity in tropical rainforest ecosystem of South-West Nigeria. – J. Trop. For. Sci. 18: 91-101.

Alarcón, J. G. S. and Peixoto, A. L. 2007. Florística e fitossociologia de um trecho de um hectare de floresta de terra firme, em Caracaraí, Roraima, Brasil. - Bol. Mus. Par. Em. Goel. 2: 33-60.

Almeida, S. S. et al. 2004. Análise florística e estrutura de florestas de Várzea no estuário Amazônico. - Acta Amaz. 34: 513-524.

Amaral, D. D. et al. 2009. Checklist da flora arbórea de remanescentes florestais da região metropolitana de Belém e valor histórico dos fragmentos, Pará, Brasil. - Bol. Mus. Par. Em. Goel. 4: 231-289.

Batista, F. J. et al. 2011. Comparação florística e estrutural de duas florestas de várzea no estuário amazônico, Pará, Brasil. - Rev. Árv. 35: 289-298.

Bongers, E. et al. 1988. Structure and floristic composition of the lowland rain forest of Los Tuxtlas, Mexico. - Vegetatio 74: 55-80.

Boubli, J. P. et al. 2004. Mesoscale transect sampling of trees in the Lomako-Yekokora interfluvium, Democratic Republic of the Congo. - Biodivers. Conserv. 13: 2399–2417.

Carim, S. et al. Riqueza de espécies, estrutura e composição florística de uma floresta secundária de 40 anos no leste da Amazônia. - Acta Bot. Brasilica, 21, 293-308.

Chapman, C. A. et al. 1997. Spatial and temporal variability in the structure of a tropical forest. - Afr. J. Ecol. 35: 287-302.

Eilu, G. et al. 2004. Density and species diversity of trees in four tropical forests of the Albertine rift, western Uganda. - Divers. Distrib. 10: 303-312.

Espírito-Santo, F. D. B. et al. 2005. Análise da composição florística e fitossociológica da floresta nacional do Tapajós com o apoio geográfico de imagens de satélites. - Acta Amaz. 35: 155-173.

Fashing, P. J. and Gathua, J. M. 2004. Spatial variability in the vegetation structure and composition of an East African rain forest. - Afr. J. Ecol. 42: 189-197.

Ihenyen, J. et al. 2009. Composition of tree species in Ehor Forest Reserve, Edo State, Nigeria. - Nature and Science 7: 8-18.

Ivanauskas, N. M. et al. 2004. Composição florística de trechos florestais na borda sul-amazônica. - Acta Amaz. 34: 399-413.

Jardim, M. A. G. and Vieira, I. C. G. 2001. Composição florística e estrutura de uma floresta de várzea do estuário Amazônico, Ilha do Combu, Estado do Pará, Brasil. - Bol. Mus. Par. Em. Goel. 17: 333-354.

Lewis, B. A. et al. 1996. A study of the botanical structure, composition, and diversity of the eastern slopes of the Reserve Naturelle Integrate d'Andringitra, Madagascar. - Fieldiana (Zoology), 85, 24-75.

Maciel, U. N. and Lisboa, P. L. B. 1989. Estudo florístico de 1 hectare de mata de terra firme no km 15 da rodovia Presidente Médici Costa Marques (RO-429), Rondônia. - Bol. Mus. Par. Em. Goel. 5: 25-37.

Malheiros, A. F. et al. 2009. Análise estrutural da floresta tropical úmida do município de Alta Floresta, Mato Grosso, Brasil. - Acta Amaz. 39: 539-548.

Montag, L. F. A. et al. 2008. Listagem de espécies. Biodiversidade na Província Petrolífera de Urucu (ed. by S.O.F. Lima et al.), pp. 157-185. Petrobras, Rio de Janeiro, Brazil.

Nadkarni, N. M. et al. 1995. Structural characteristics and floristic composition of a Neotropical cloud forest, Monteverde, Costa Rica. - J. Trop. Ecol. 11: 481-495.

Nascimento, M. T. et al. 1997. Forest structure, floristic composition and soils of an Amazonian monodominant forest on Maracá Island, Roraima, Brazil. - Edinburgh J. Bot. 54: 1-38.

Ojo, L. O. and Ola-Adams, B.A. 1996. Measurement of tree diversity in the Nigerian rainforest. - Biodivers. Conserv. 5: 1253-1270.

Queiroz, J. A. L. and Machado, S.A. 2008. Fitossociologia em floresta de várzea do estuário Amazônico no Estado do Amapá. - Pesq. Flor. Bras. 57: 5-20.

Ribeiro, R. J. et al. 1999. Estudo fitossociológico nas regiões de Carajás e Marabá- Pará, Brasil. - Acta Amaz. 29: 207-222.

Salomão, R. P. et al. 2007. As florestas de Belo Monte na grande curva do rio Xingu, Amazônia Oriental. - Bol. Mus. Par. Em. Goel. 2: 57-153.

Sheil, D., Jennings, S. and Savill, P. 2000. Long-term permanent plot observations of vegetation dynamics in Budongo, a Ugandan rain forest. - J. Trop. Ecol. 16: 765-800.

Silva, K. E. et al. 2008. Composição florística e fitossociologia de espécies arbóreas do Parque Fenológico da Embrapa Amazônia Ocidental. - Acta Amaz. 38: 213-222.

Stropp, J. et al. 2011. Tree communities of white-sand and terra-firme forests of the upper Rio Negro. - Acta Amaz. 41: 521-544.

ter Steege, H. et al. 2007. Plant diversity of the bauxite plateaus of North East Suriname. A Rapid Biological Assessment of the Lely and Nassau Plateaus, Suriname (with additional information on the Brownsberg Plateau). RAP Bulletin of Biological Assessment, 43 (ed. by L. E. Alonso and J. H. Mol), pp. 76-85. Conservation International, Arlington, VA, USA.

van Gemerden, B. S. et al. 2003. The pristine rain forest? Remnants of historical human impacts on current tree species composition and diversity. - J. Biogeogr. 30: 1381-1390.

Vicentini, A. 2004. A Vegetação ao longo de um gradiente edáfico no Parque Nacional do Jaú. Janelas para a biodiversidade no Parque Nacional do Jaú: uma estratégia para o estudo da biodiversidade na Amazônia (ed. by S.H. Borges et al.), pp. 105-131. Fundação Vitória Amazônica, WWF-Brasil, USAID, Manaus, Brazil.

Webb, E. I. and Peralta, R. 1998. Tree community diversity of lowland swamp forest in Northeast Costa Rica, and changes associated with controlled selective logging. - Biodivers. Conserv. 7: 565-583.

Table A1. Criteria of inclusion used in the different data sources.

Data source	DBH
Alarcon & Peixoto 2007	≥10 cm
Amaral et al. 2009	≥10 cm
Bongers et al. 1988	≥10 cm
Chapman et al 1997	≥10 cm
Espírito-Santo et al. 2005	≥10 cm
Fashing & Gathua 2004	≥15 cm
Gentry_Allpahua	≥5 cm
Gentry_Alterdoc	≥5 cm
Gentry_Altocuevas	≥5 cm
Gentry_Altodemi	≥5 cm
Gentry_Anchicay	≥5 cm
Gentry_Antado	≥5 cm
Gentry_Araracua	≥5 cm
Gentry_Arcating	≥5 cm
Gentry_Banyong	≥5 cm
Gentry_Belem	≥5 cm
Gentry_Belinga	≥5 cm
Gentry_Berbicer	≥5 cm
Gentry_Bilsa	≥5 cm
Gentry_Bosqcueva	≥5 cm
Gentry_Cabezade	≥5 cm
Gentry_Calima	≥5 cm
Gentry_Candamo	≥5 cm
Gentry_Carajas	≥5 cm
Gentry_Carara	≥5 cm
Gentry_Centinel	≥5 cm
Gentry_Ceroneb1	≥5 cm
Gentry_Ceroneb2	≥5 cm
Gentry_Cerroelp	≥5 cm
Gentry_Cerroolu	≥5 cm
Gentry_Cochacas	≥5 cm
Gentry_Constanc	≥5 cm
Gentry_Cuangos	≥5 cm
Gentry_Curundu	≥5 cm
Gentry_Cuzcoama	≥5 cm
Gentry_Dureno	≥5 cm
Gentry_Huamani	≥5 cm
Gentry_Humboldt	≥5 cm
Gentry_Indiana	≥5 cm
Gentry_Jatunsac	≥5 cm
Gentry_Jenarohe	≥5 cm
Gentry_Laplanad	≥5 cm

Gentry_Madden	≥5 cm
Gentry_Madidi	≥5 cm
Gentry_Madidiri	≥5 cm
Gentry_Makokou1	≥5 cm
Gentry_Makokou2	≥5 cm
Gentry_Maquipuc	≥5 cm
Gentry_Miazi	≥5 cm
Gentry_Mishnfl	≥5 cm
Gentry_Mishws	≥5 cm
Gentry_Mtcam	≥5 cm
Gentry_Murri	≥5 cm
Gentry_Nangarit	≥5 cm
Gentry_Ndakani	≥5 cm
Gentry_Nosymang	≥5 cm
Gentry_Osasiren	≥5 cm
Gentry_Pande	≥5 cm
Gentry_Perinet	≥5 cm
Gentry_Pipeline	≥5 cm
Gentry_Pugu	≥5 cm
Gentry_Ranchoqu	≥5 cm
Gentry_Rioheath	≥5 cm
Gentry_Riomanso	≥5 cm
Gentry_Riopal1	≥5 cm
Gentry_Riopal2	≥5 cm
Gentry_Riotavar	≥5 cm
Gentry_Sansebas	≥5 cm
Gentry_Saul	≥5 cm
Gentry_Shiringa	≥5 cm
Gentry_Sucusari	≥5 cm
Gentry_Tahuampa	≥5 cm
Gentry_Tamblat2	≥5 cm
Gentry_Tambo	≥5 cm
Gentry_Tamboall	≥5 cm
Gentry_Tambupl	≥5 cm
Gentry_Tutunend	≥5 cm
Gentry_Yanam1	≥5 cm
Gentry_Yanam2	≥5 cm
Gentry_Yanamtah	≥5 cm
Salomão et al. 2007	≥5cm
Sheil et al. 2000	≥10cm
Silva et al. 2008	≥20cm
Stropp et al. 2011	≥10cm
TEAM_Bwindi	≥10 cm
TEAM_Caxiuanã	≥10 cm
TEAM_Korup	≥10 cm

TEAM_Manaus	≥10 cm
TEAM_Ranomafana	≥10 cm
TEAM_Udzungwa	≥10 cm
TEAM_Volcán Barva	≥10 cm
ter Steege et al. 2007	≥10cm
van Gemergen et al. 2003	≥10cm
Webb & Peralta 1998	≥10cm

Appendix 2. Analyses of the influence of data source on phylogenetic structure patterns.

Considering that our data came from different sources with different sampling sizes and inclusion criteria (minimum stem diameter), we tested for the influence of data source on net relatedness index (NRI), our measure of phylogenetic structure. Among the data sources used, the sites sampled by Alwyn Gentry had the smallest sampling size, with each site having one transect with 0.1 ha. TEAM Network's sites in turn had 5 to 9 ha sampled, while the surveys from the literature had variable sampling effort (but mostly 1 ha). See Table A1 in Supplementary material Appendix 1. Thus, one could wonder about the effect of small sampling effort in Gentry's sites over NRI.

In order to test for this possible sampling effect, we compared NRI values between data sources. For this, we used a two-way ANOVA, in which the factors were Source (Gentry vs. TEAM vs. Literature) and Andes (sites in the Andes vs. sites in other regions). Since the design was unbalanced, we used an ANOVA with randomization tests (Pillar and Orlóci 1996) to test for the significance of contrasts between groups of each factor. Analyses were performed using the software MULTIV v. 3.1 by V. Pillar (available at http://ecoqua.ecologia.ufrgs.br/software.html).

Gentry's sites had lower NRI values than TEAM's sites and surveys from the literature (Table A2; Fig. A1). Moreover, Andes sites had lower NRI values than other sites (Table A2; Fig. A2).

Given that all data on Andean sites came from Gentry's database, we were not able to decouple the effect of data source from biogeographic causation using only the data from the Andean sites. Thus, we compared NRI values between Gentry's non-Andean sites and non-Andean sites from other data sources. If Gentry's sites are not biased toward low NRI values, then there should be no significant difference in NRI between Gentry's non-Andean sites and all other non-Andean sites.

Indeed, there were no significant differences in NRI between non-Andean sites from different data sources (Table A3; Fig. A3). Hence, Gentry's sites in general presented lower NRI values than other data sources probably because of Andes, which typically had low NRI values (see Results in the main text). Therefore, we concluded that Gentry's sites were unbiased and could be used together with TEAM Network's sites and the surveys from the literature in the analyses.

References

Pillar, V. D. and Orlóci, L. 1996. On randomization testing in vegetation science: multifactor comparisons of relevé groups. - J. Veg. Sci.: 585–592.

Table A2. Results of the two-way ANOVA with randomization tests, comparing NRI values between Andean and non-Andean sites and between sites from different data sources.

Source of variation	Sum of squares (*Q*)	$P(Qb_{null} \geq Qb)$
Factor Andes		
Andean sites vs. other sites	40.721	0.002
Factor Source		
Between groups	30.391	0.034
Contrasts:		
Gentry vs. Literature	17.188	0.048
Gentry vs. TEAM	16.656	0.036
Literature vs. TEAM	0.61308	0.672
Andes vs. Source *	-18.8	0.973
Between groups	52.312	0.001
Within groups	158.17	
Total	210.48	

*Note that the interaction between Andes and Source does not contain all the combinations of levels, because all Andean sites came from Gentry's database.

Table A3. Results of the one-way ANOVA with randomization tests, comparing NRI values between non-Andean sites from different data sources.

Source of variation	Sum of squares (*Q*)	$P(Qb_{null} \geq Qb)$
Factor Source		
Between groups	11.591	0.084
Contrasts		
Gentry vs. Literature	5.9116	0.096
Gentry vs. TEAM	7.7806	0.061
Literature vs. TEAM	0.61308	0.669
Within groups	129.01	
Total	140.6	

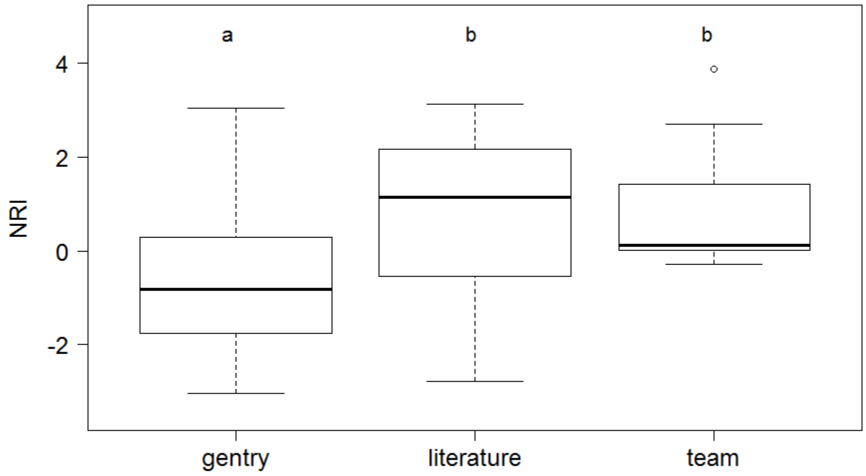

Figure A1. Comparison of NRI values between different sources of data: Gentry's transects, surveys from the literature, and TEAM Network's plots. Different letter above boxes mean significant differences between data sources ($P < 0.05$).

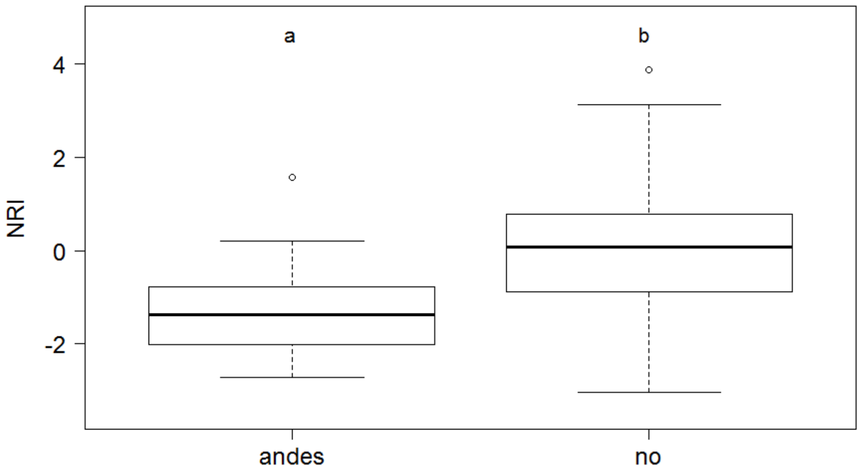

Figure A2. Comparison of NRI values between groups of sites in Andes and in other regions. Different letter above boxes mean significant differences between data sources ($P < 0.05$).

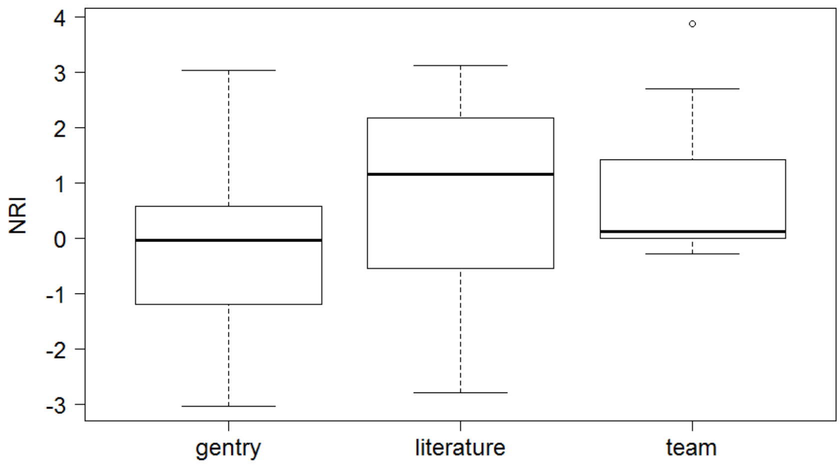

Figure A3. Comparison of NRI values between non-Andean sites from different data sources. NRI did not differ between groups.

Appendix 3. Figure of the phylogenetic tree.

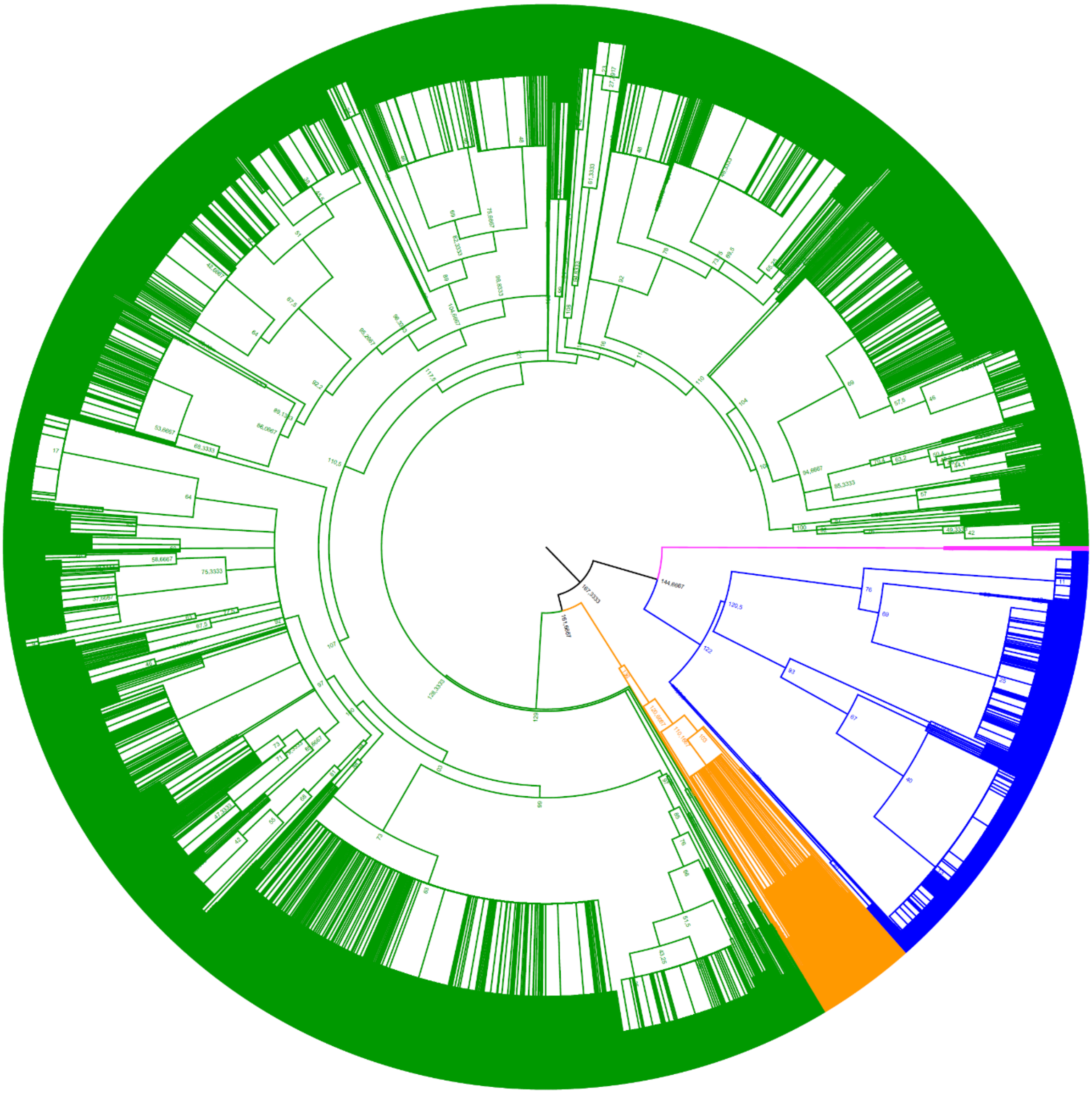

Figure A4. Phylogenetic tree for 6,056 rainforest tree species occurring in 115 Neotropical, Afrotropical and Malagasy communities (including the 94 with species abundance data and 21 with only species occurrence data). Pink, Chloranthales; Blue, magnoliids; orange, monocots; Green, eudicots.

Appendix 4. Correlation between PCPS (principal coordinates of phylogenetic structure) and NRI (net relatedness index).

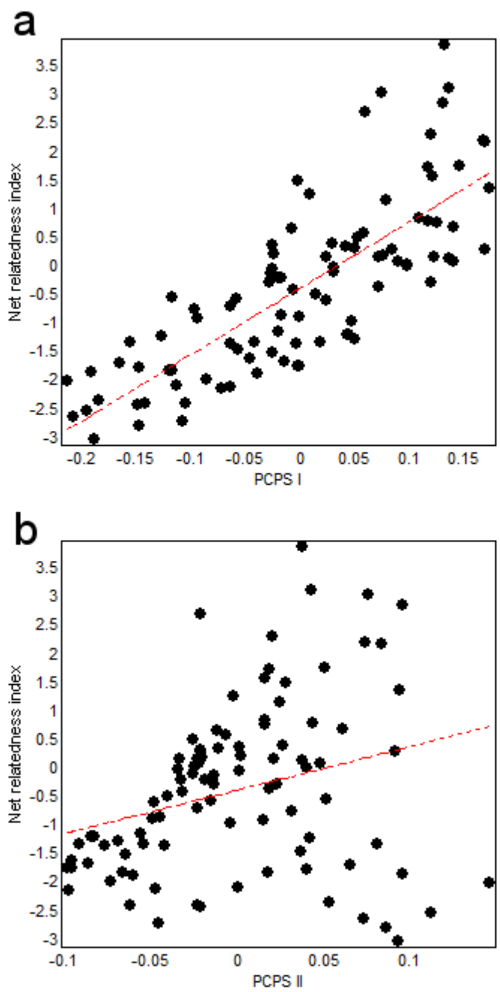

Figure A5. Scatter plot between phylogenetic composition and local phylogenetic structure of tropical rainforest tree communities (n= 94), measured using PCPS and NRI, respectively. Pearson's correlation was significant for the comparisons of NRI with both main phylogenetic composition vectors: (a) PCPS I *vs*. NRI, $r = 0.791$, $F_{30.2} = 50.35$, $P <.001$; (b) PCPS II *vs*. NRI, $r = 0.28$, $F_{52.1} = 4.42$, $P = 0.04$. Correlation statistics and significance were obtained after accounting for the influence of spatial autocorrelation on the number of degrees of freedom by using Dutilleul's correction (Dutilleul 1993).

References

Dutilleul, P. 1993. Modifying the t test for assessing the correlation between two spatial processes. - Biometrics 49: 305–314.