UNIVERSIDADE FEDERAL DE LAVRAS

CLÉBER RODRIGO DE SOUZA

PERFILHAMENTO COMO ESTRATÉGIA ECOLÓGICA DE ESPÉCIES ARBÓREAS: REPRESENTATIVIDADE, PADRÕES EVOLUTIVOS E IMPACTO NA COLETA DE DADOS EM FLORESTAS TROPICAIS

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Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Engenharia Florestal, área de concentração em Ecologia e Conservação, para a obtenção do título de Doutor.

Dr. Rubens Manoel Dos Santos
Orientador

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RESPROUTING AS AN ECOLOGICAL STRATEGY BY TREE SPECIES: REPRESENTATIVITY, EVOLUTIONARY PATTERNS AND IMPACT ON DATA COLLECTION IN TROPICAL FORESTS

Tese apresentada à Universidade Federal de Lavras, como parte das exigências do Programa de Pós-Graduação em Engenharia Florestal, área de concentração em Ecologia e Conservação, para a obtenção do título de Doutor.

APROVADA em 16 de abril de 2021
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“But nature is always more subtle, more intricate, more elegant than what we are able to imagine.”

Car Sagan (1934 – 1996) em “The Demon-Haunted World”

“Los niños habían de recordar por el resto de su vida la augusta solemnidad con que su padre se sentó a la cabecera de la mesa, temblando de fiebre, devastado por la prolongada vigilia y por el encono de su imaginación, y les reveló su descubrimiento:

—La tierra es redonda como una naranja.”

Gabriel Garcia Marquez (1927 – 2014) em “Cien Años de Soledad”.

“Onde eu nasci passa um rio

Que passa no igual sem fim

Igual, sem fim minha terra

Passava dentro de mim.”

Caetano Veloso (1942) em “Onde eu nasci passa um rio”

RESUMO

O perfilhamento, que consiste na emissão de fustes por árvores após distúrbios, é uma das estratégias ecológicas mais comuns em comunidades arbóreas. Através do perfilhamento, o indivíduo aumenta suas chances de sobrevivência ao potencializar a captação de recursos, à medida que conta com sistemas hidráulico e radicular já estabelecidos. Assim, o perfilhamento é entendido como uma estratégia de regeneração que se contrapõe à regeneração oriunda de sementes e plântulas. Apesar do perfilhamento estar amplamente presente nas florestas tropicais, pouco se sabe sobre sua representatividade, padrões ecológicos, quais os principais fatores determinantes e como esta estratégia pode influenciar a amostragem de comunidades arbóreas. Neste trabalho tais questões foram exploradas em dois artigos. O primeiro deles explora os padrões de representatividade ecológica do perfilhamento em florestas tropicais secas, avaliando ainda quais os seus principais determinantes (identidade taxonômica vs. ambiente) e se há uma estruturação filogenética na sua expressão em gêneros (sinal filogenético). Utilizamos duas variáveis de perfilhamento: frequência, que consiste na relação entre o número de indivíduos perfilhantes e o número de indivíduos total; e número médio de fustes por árvore. Nossos resultados apontam que espécies com frequência baixa e média de perfilhamento são as mais representativas nestas florestas, em que pode ser adotado ou não como estratégia de persistência na comunidade em função da restrição local. Além disso, observamos que as variáveis de perfilhamento são determinadas principalmente pela identidade taxonômica, de forma que o perfilhamento varia dentro de um limite determinado pelos padrões da espécie. Por fim, não encontramos sinal filogenético para as duas variáveis, o que sugere que a estruturação filogenética destas características está associada principalmente a processos de convergência evolutiva entre linhagens distantes e divergência evolutiva entre linhagens próximas. No segundo artigo, avaliamos como escolhas metodológicas (tamanho mínimo de inclusão e método de inclusão) impactam a amostragem de quatros variáveis vegetacionais (número de árvores, número de fustes, biomassa e riqueza de espécies) em três tipos de florestas tropicais (florestas ombrófilas, florestas semidecíduas e florestas decíduas). Consideramos dois métodos de inclusão: o método por fuste, em que se considera o diâmetro do fuste isolado; e o método por árvore, em que é obtido o diâmetro equivalente considerando todos os fustes do indivíduo. Assim, fustes menores que o tamanho mínimo podem ser incluídos na amostragem no método por árvore, caso o diâmetro equivalente do indivíduo atinja o tamanho mínimo. Encontramos que estas escolhas metodológicas impactam principalmente florestas decíduas e semidecíduas, em que a adoção do método por fuste e de tamanhos maiores de diâmetro mínimo implicam subamostragem dos padrões ecológicos reais de número de árvores, fustes e riqueza de espécies. Nestes tipos vegetacionais, onde o perfilhamento é importante, espécies podem nunca ser amostradas com o método por fuste, mesmo que apresentem vários fustes que juntos atingiriam o tamanho mínimo, caso o método por árvore fosse adotado. Com base nos resultados, sugerimos a adoção ampla do método por árvore e não utilização de tamanhos mínimos altos principalmente em tipos florestais onde o perfilhamento é uma estratégia importante.

Palavras-chave: Florestas tropicais sazonalmente secas. Florestas tropicais ombrófilas. Florestas tropicais semideciduais. Nicho de persistência. Amostragem. Sinal filogenético. Tamanho mínimo de inclusão. Método de inclusão.

ABSTRACT

Resprouting, which consists of the emission of stems by trees after disturbances, is one of the most common ecological strategies in tree communities. Through resprouting, the individual increases its chances of survival by improving the resources obtaining as he has already established hydraulic and root systems. Thus, resprouting is understood as a regeneration strategy that opposes regeneration from seeds and seedlings. Although resprouting is widely present in tropical forests, little is known about its representativeness, ecological patterns, which are the main determining factors and how this strategy can influence the sampling of tree communities. Here these issues were explored in two papers. The first one explores the patterns of ecological representativeness of resprouting in dry tropical forests, also evaluating which are its main determinants (taxonomic identity vs. environment) and whether there is a phylogenetic structuring in its expression in genera (phylogenetic sign). We used two resprouting variables: the frequency, which consists of the relationship between the number of resprouted trees and the total number of individuals; and the average number of stems per tree. Our results indicate that species with low and medium resprouting frequency are the most representative species in these forests, in which it can be adopted or not as a strategy of persistence in the community due to the local restriction. We also found that resprouting variables are mainly determined by taxonomic identity, so that resprouting varies within a limit determined by the species' patterns. Finally, we did not find a phylogenetic sign for the two variables, which suggests that the phylogenetic structuring of these characteristics is mainly associated with processes of evolutionary convergence between distant lineages and evolutionary divergence between close lineages. In the second, we evaluate how methodological choices (minimum size of inclusion and method of inclusion) impact the sampling of four vegetational variables (number of trees, number of stems, biomass and species richness) in three types of tropical forests (evergreen forests, semi-deciduous and deciduous forests). For the inclusion method, we considered two methods: the by-stem method, in which the diameter of the isolated stems is considered; and the by-tree method, in which the equivalent diameter is obtained considering all of the individual's stems. Thus, in the by-tree method, stems smaller than the minimum size can be included in the sampling, if the equivalent diameter of the individual reaches the minimum size. We found that these methodological choices mainly impact deciduous and semideciduous forests, in which the adoption of the by-stem method and larger sizes of minimum diameter implies undersampling of the real ecological patterns of the number of trees, stems and species richness. In these vegetation types where resprouting is important, species may never be sampled using the by-stem method, even though they have several stems that together would reach the minimum size, if the by-tree method were adopted. Based on the results, we suggest the widespread adoption of the by-tree method and not using high minimum sizes mainly in forest types where resprouting is an important strategy.

Key-words: Seasonally dry tropical forests. Tropical rainforests. Semideciduous tropical forests. Persistence niche. Sampling. Phylogenetic sign. Minimum inclusion size. Inclusion method.

SUMÁRIO

PRIMEIRA PARTE

1 INTRODUÇÃO

As plantas utilizam de diversas estratégias para sobreviver e ter sucesso frente aos diversos fatores restritivos presentes nos ecossistemas, tais como escassez ou excesso de água, altas ou baixas temperaturas, incêndios, presença de herbívoros e patógenos, competição ou distúrbios antrópicos. Cada fator restritivo (ou combinação de fatores) está associado a um conjunto de características desenvolvidas pelos organismos ao longo da história evolutiva, que permitem aos indivíduos se estabelecerem e persistirem nos ambientes, podendo assim completarem seu ciclo de vida. Neste sentido, entender os padrões e processos associados a tais estratégias é um tema central na ecologia, sendo crucial para compreender os padrões estruturais e de biodiversidade dos ecossistemas.

O processo de emissão de novos fustes por plantas após distúrbios, chamado de perfilhamento, é uma destas estratégias adotadas diante de fatores restritivos. Ela está presente nos diversos ecossistemas globais, fazendo parte da sua estrutura e funcionamento, bem como das experiências do setor florestal e dos pesquisadores no processo de coleta de dados. Não raro nos deparamos em campo com indivíduos com um número elevado de fustes ou com comunidades em que grande adoção do perfilhamento chega a dificultar as medições e a locomoção da equipe, os popularmente chamados “paliteiros”.

No entanto, embora tão prevalente nos ecossistemas, ainda é incipiente o entendimento do papel do perfilhamento na sobrevivência e sucesso de espécies, assim como de sua influência nos padrões ecológicos nestas comunidades e quais as melhores formas de avaliação desta estratégia. A necessidade de construção de conhecimento sobre o perfilhamento é ainda mais urgente, considerando-se os cenários de modificações ambientais que terão efeitos sobre o funcionamento dos ecossistemas, e dentro dos quais o perfilhamento pode ter um papel central na resposta das comunidades.

Dentro de tal contexto, este trabalho explora o perfilhamento em dois artigos independentes. O primeiro deles analisa a ocorrência da estratégia em espécies de florestas tropicais secas, além de identificar os principais determinantes da sua variação e avaliar possíveis padrões evolutivos. O segundo busca investigar o impacto de escolhas metodológicas que minimizam a importância do perfilhamento em variáveis de vegetação, trabalhando alternativas mais inclusivas para ambientes onde a estratégia é importante. A expectativa é contribuir para o conhecimento ecológico do perfilhamento em florestas tropicais, além de construir possibilidades de trabalhos futuros sobre o tema.

2 REFERENCIAL TEÓRICO

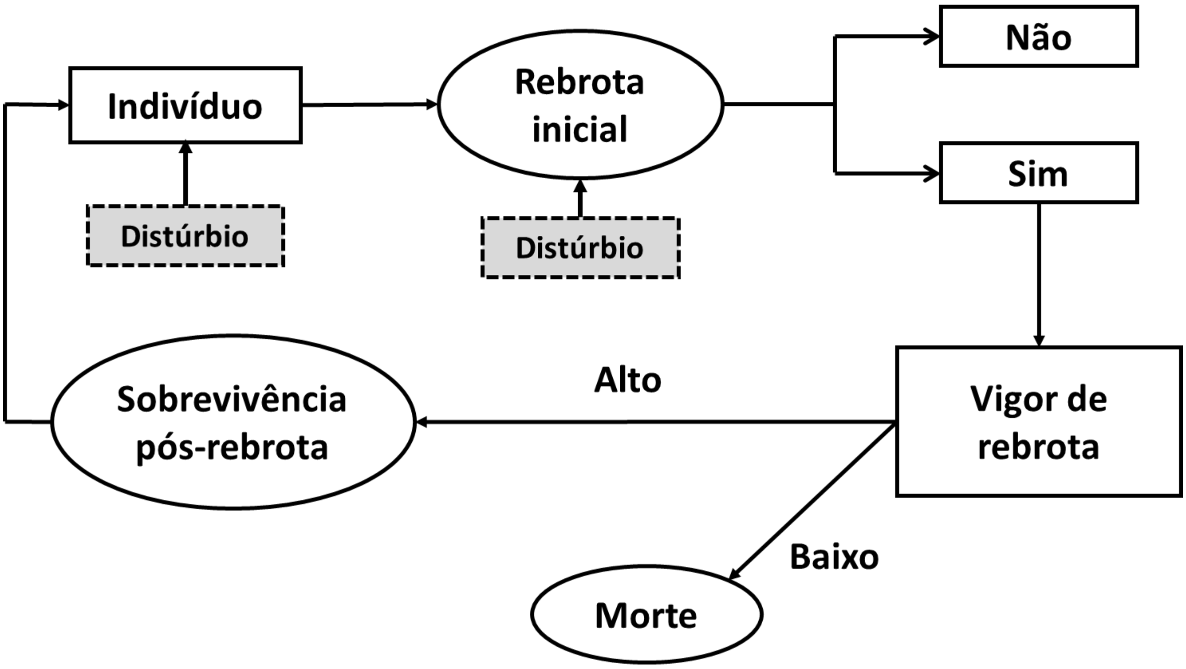
2.1 Perfilhamento por plantas: definição e mecanismo de ocorrência

As restrições ambientais têm papel fundamental nos padrões ecológicos dos diferentes ecossistemas globais, podendo atuar na forma de restrições de condições e disponibilidade de recursos, interações bióticas deletérias ou distúrbios (CADOTTE; TUCKER, 2017). Estas restrições atuam continuamente selecionando determinadas características funcionais e estratégias que possam garantir a sobrevivência das espécies e potencializar o seu sucesso nos diferentes ambientes. O perfilhamento, que consiste na emissão de novos brotos por plantas ocasionada por alguma injúria física ou fisiológica, é uma destas estratégias desenvolvidas ao longo dos processos evolutivos (BELLINGHAM; SPARROW, 2000; PAUSAS et al., 2016).

O perfilhamento está presente em diversos ecossistemas globais e ocorre em resposta a diversos fatores, tais como fogo, herbivoria, alagamentos, furacões, estresse hídrico e restrições edáficas (ARAUJO; SANTOS, 2019; BOND; MIDGLEY, 2003; CECCON; HUANTE; RINCÓN, 2006; JIMENEZ-RODRÍGUEZ et al., 2018; SOUZA et al., 2019; ZEPPEL et al., 2015). Em cada um destes casos, o perfilhamento está associado a conjuntos singulares de características funcionais que são reflexo de condições locais atuais e pretéritas, a que as espécies e linhagens estiveram submetidas (PAUSAS et al., 2016; ZEPPEL et al., 2015). Assim, embora frequentemente seja considerado uma característica binária (presença ou ausência de perfilhamento), o perfilhamento deve ser tratado como uma síndrome ecológica que reúne diversas características funcionais (BELLINGHAM; SPARROW, 2000; BOND; MIDGLEY, 2003; PAUSAS et al., 2016). Esta característica (capacidade de perfilhar) está presente em linhagens antigas de gimnospermas e angiospermas arbóreas, sendo sua presença considerada como estado ancestral e sua ausência um estado derivado nas linhagens de plantas arbóreas (BOND; MIDGLEY, 2003; PAUSAS; KEELEY, 2014).

O perfilhamento ocorre quando um indivíduo tem sua sobrevivência ameaçada por algum fator restritivo, e em resposta, aloca recurso não estrutural para a emissão de um novo broto que poderá se converter em um novo fuste (MOREIRA; TORMO; PAUSAS, 2012; SCHWILK; ACKERLY, 2005). Contudo, desde a ocorrência do distúrbio até o estabelecimento do novo fuste, existem vários processos apresentados por Moreira, Tormo e Pausas (2012) em um modelo de ocorrência do perfilhamento (FIGURA 1). De acordo com esse modelo, inicialmente há a ocorrência do distúrbio, que pode induzir ou não uma rebrota inicial pela planta em função das características da espécie e do próprio distúrbio, tais como duração e intensidade. Se emitida, essa rebrota inicial pode ter maior ou menor vigor fisiológico inicial e nos momentos posteriores, o que vai determinar sua sobrevivência. Este broto recém-emitido pode sobreviver inicialmente (sobrevivência-pós-rebrota), porém morrer em seguida em função de baixa reserva de energia do indivíduo ou por distúrbios posteriores. Caso sobreviva, esta rebrota poderá enfim se tornar um fuste estabelecido de porte adulto (MOREIRA; TORMO; PAUSAS, 2012).

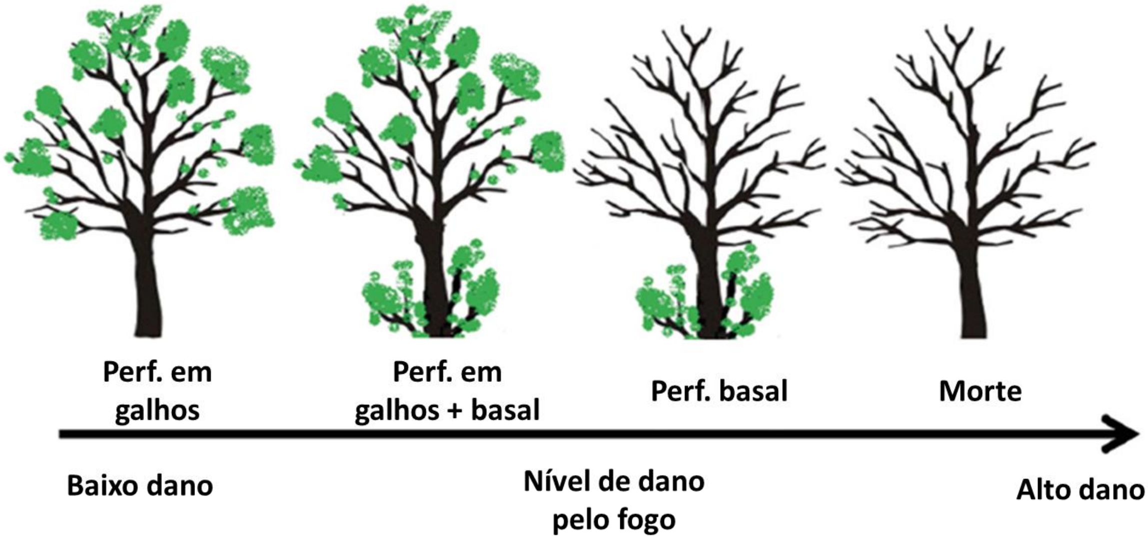
Figura 1 - Esquema ilustrativo do processo de perfilhamento em plantas.



Fonte: Adaptado de Moreira, Tormo e Pausas (2012).

O recurso não estrutural utilizado no perfilhamento normalmente está alocado nas raízes, porém recursos de outros órgãos podem ser utilizados em função de particularidades do regime de restrições ecológicas (BELLINGHAM; SPARROW, 2000; BOND; MIDGLEY, 2001; CLARKE et al., 2013). Assim, o novo broto pode ser emitido em diferentes pontos do indivíduo (galhos, caule, raízes, etc.), o que também será reflexo de qual a restrição ecológica imposta (BOND; MIDGLEY, 2001, 2003). Em ambientes suscetíveis ao fogo, por exemplo, o perfilhamento subterrâneo ocorre nas situações mais extremas, enquanto o perfilhamento em alturas superiores tende a ocorrer em situações de menor intensidade e frequência (CLARKE et al., 2013; SOUCHIE et al., 2017). Nestes ambientes, tal padrão se relaciona principalmente a altura em que as gemas são atingidas pelo fogo (FIGURA 2), assim como à altura de danos ao câmbio, de forma que gemas e as porções do câmbio localizados abaixo da altura limite de dano serão utilizadas pela planta para a emissão de novos fustes no momento posterior ao distúrbio (CLARKE et al., 2013; SOUCHIE et al., 2017). Embora já bem documentado para ambientes sujeitos a fogo, este padrão de altura de perfilhamento em resposta a outros fatores restritivos como seca, inundação ou restrição edáfica ainda não foi foco de estudos e, portanto, ainda não se sabe se a mesma relação pode ser observada em resposta a outros fatores.

Figura 2 - Tipos de resposta observados em indivíduos arbóreos em resposta a fogo.



Fonte: Adaptado de Souchie et al. (2017).

Esta emissão de fustes interage ainda com idade do indivíduo, em que esta capacidade de perfilhar tende a ser maior em indivíduos jovens e diminui com a idade (CLARKE et al., 2013; JAUREGUIBERRY et al., 2020), e também com a capacidade de armazenamento de recursos em função do regime de distúrbios, onde a ocorrência de distúrbios sucessivos que estimulem o perfilhamento pode reduzir a disponibilidade de recurso armazenado. Assim, nesse último caso o indivíduo de uma espécie capaz de perfilhar acaba não perfilhando em função da baixa quantidade de recursos (BELLINGHAM; SPARROW, 2000; BOND; MIDGLEY, 2003; MOREIRA; TORMO; PAUSAS, 2012). Além disso, o perfilhamento pode ser utilizado como uma estratégia de sobrevivência inicial e permanência na comunidade através da potencialização da exploração de recursos, sendo descartados à medida que indivíduos atingem o dossel (BELLINGHAM; SPARROW, 2000; BOND; MIDGLEY, 2003).

Em função da sua importância na sobrevivência, o perfilhamento é frequentemente considerado como a alternativa ecológica direta à reprodução sexuada, que está associada a colonização de ambientes por dispersão e estabelecimento, enquanto pelo perfilhamento a ocupação e estabelecimento ocorrerá através da emissão de novos fustes. Este novo broto será uma cópia idêntica do fuste original, de forma que este processo pode ser entendido como uma forma de clonalidade, propagação vegetativa e/ou reprodução assexuada (BOND; MIDGLEY, 2001; LASSO; ENGELBRECHT; DALLING, 2009; PAUSAS et al., 2016). Em função disso, o perfilhamento é normalmente considerado como parte do chamado “nicho de persistência” (BOND; MIDGLEY, 2001; PAUSAS et al., 2016), que inclui características funcionais associadas a permanência dos indivíduos frente a distúrbios frequentes e intensos, em contraposição ao “nicho de regeneração”, que inclui características reprodutivas como tamanho de semente e forma de dispersão (GRUBB, 1977). Tais características funcionais associadas ao perfilhamento implicam comportamentos ecológicos específicos que tem consequências ecológicas em nível de indivíduo, população e comunidade.

2.2 Consequências ecológicas do perfilhamento para indivíduos, populações e comunidades

A adoção do perfilhamento em resposta a algum fator restritivo tem uma série de consequência positivas e negativas para os indivíduos e populações em diferentes escalas espaciais e temporais. Em primeiro momento, a adoção do perfilhamento pode garantir a sobrevivência do indivíduo, em situações de morte do fuste principal; ou aumentar seu sucesso adaptativo em comparação a indivíduos não perfilhantes, já que o novo broto terá um sistema radicular e foliar já desenvolvido a disposição para auxiliar na captação de recursos e na resistência aos filtros ecológicos locais (BOND; MIDGLEY, 2003). Além disso, o novo broto não terá que passar por pressões que plântulas oriundas de sementes normalmente estão sujeitas nos estágios iniciais de desenvolvimento, o que configura uma vantagem de sobrevivência em situações em que os fatores restritivos são frequentes ou intrínsecos ao ambiente (BOND; MIDGLEY, 2003; CLARKE et al., 2013; PAUSAS et al., 2016).

O perfilhamento garante às espécies maior independência da disponibilidade de polinizadores e dispersores, assim como da existência de uma produtividade local que permita que os indivíduos sobrevivam e cresçam até a idade reprodutiva, de forma que populações podem garantir sua permanecer na comunidade por maiores períodos de tempo através do perfilhamento (BOND; MIDGLEY, 2001, 2003; NZUNDA; LAWES, 2011). Neste contexto, há ainda a ocorrência de um *trade-off* de alocação de recursos entre as duas estratégias (perfilhamento x reprodução sexuada), já que ao perfilhar os indivíduos acabam utilizando recursos que poderiam ser usados na reprodução sexuada (BOND; MIDGLEY, 2003;

LAMONT; ENRIGTH, 2011; MOREIRA; TORMO; PAUSAS, 2012; SCHWILK; ACKERLY, 2005).

Esta menor quantidade de recurso disponível para a reprodução sexuada afeta a produção e qualidade das sementes produzidas, de forma que espécies perfilhantes produzem menor quantidade de sementes e sementes de menor qualidade, que dão origem a plântulas de menor vigor e indivíduos com menor crescimento em altura (KNOX; CLARKE, 2005; NZUNDA; LAWES, 2011; VERDÚ, 2000). A adoção do perfilhamento tem consequências também para padrões genéticos das populações, em que a permanência mais longa de indivíduos na comunidade implica menor taxa temporal de modificações genéticas entre gerações em relação a espécies não perfilhantes, com consequências para a capacidade de adaptação e ao acúmulo de mutações deletérias (LEVIN, 1990; PAUSAS; KEELEY, 2014). Assim, este *trade-off* ecológico entre a adoção do perfilhamento ou da reprodução sexuada pelas espécies como estratégia está intrinsicamente relacionada a ganhos e perdas no *fitness* dos indivíduos (BOND; MIDGLEY, 2001; PAUSAS et al., 2016).

A representatividade da adoção do perfilhamento nos diferentes ambientes é uma resposta direta a características espaciais e temporais do seu regime de restrições ambientais, produtividade local e distúrbios (NZUNDA; LAWES, 2011; PAUSAS; KEELEY, 2014; VESK; WESTOBY, 2004). Assim, o perfilhamento tende a ser adotado como estratégia ecológica de persistência nos locais de menor produtividade (condições mais restritivas e menor disponibilidade de recursos) ou que ofereçam algum distúrbio severo e frequente (PAUSAS et al., 2016; VESK; WESTOBY, 2004). Embora não existam estudos amplos a respeito, a tendência é de que diferentes ambientes associados a distintos fatores restritivos (fogo, seca, inundação, etc.) apresentarão padrões específicos de representatividade em riqueza de espécies perfilhantes e abundância e biomassa de perfilhos, em função das características intrínsecas do ambiente (história evolutiva), das espécies ocorrentes e dos fatores restritivos presentes (PAUSAS; KEELEY, 2014; VESK; WESTOBY, 2004).

O perfilhamento é também parte da resposta temporal das comunidades, sendo importante para os seus padrões demográficos e de produtividade (PAUSAS et al., 2016). Em ambientes submetidos a fatores restritivos, o perfilhamento pode ser entendido como uma forma de recrutamento associada a rápida acumulação de biomassa, em contraposição ao recrutamento oriundo de plântulas (BOND; MIDGLEY, 2001; JAUREGUIBERRY et al., 2020; PAUSAS et al., 2016; SOUCHIE et al., 2017). Contudo, como os novos fustes tendem a ser menores e terem menor biomassa, a maior adoção do perfilhamento com forma de recrutamento implica diferenças nos padrões ecológicos das comunidades por condicionar seus padrões de estoque e estocagem de biomassa (PAUSAS et al., 2016; ZEPPEL et al., 2015).

Nos cenários atuais de mudanças climáticas que apontam pra aumento de aridez em grande parte dos ecossistemas globais (INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – IPCC, 2014), diversos autores têm apontado o perfilhamento como parte importante do comportamento das comunidades e ecossistemas frente a tais modificações (PAUSAS et al., 2016; PAUSAS; KEELEY, 2014; ZEPPEL et al., 2015). Esta possível resposta associada ao perfilhamento passa por dois principais aspectos que interagem entre si: a resistência ao estresse hídrico e a eficiência na utilização de carbono de plantas perfilhantes em comparação com plantas não perfilhantes. Ao perfilhar, o novo fuste emitido terá um sistema radicular desenvolvido que auxiliará a captação de água e sua sobrevivência no curto prazo (BELLINGHAM; SPARROW, 2000; MOREIRA; TORMO; PAUSAS, 2012). No médio e longo prazo, contudo, estes fustes tenderiam a apresentar uma menor resistência a cavitação induzida pelo estresse hídrico, o que implicaria maior taxa de mortalidade de perfilhantes (PAUSAS et al., 2016). Em relação ao segundo aspecto, plantas perfilhantes tendem a ter maior utilização do carbono presente na atmosfera, que seria armazenado para poder ser utilizado na emissão de novos fustes (BOND; MIDGLEY, 2003; PAUSAS et al., 2016). Assim, nos cenários atuais de aumento da concentração de CO_2 na atmosfera espécies perfilhantes teriam uma vantagem adaptativa em relação às não perfilhantes, o que poderia implicar maior representatividade da estratégia nas comunidades (PAUSAS et al., 2016; PAUSAS; KEELEY, 2014; ZEPPEL et al., 2015).

Embora o perfilhamento seja uma estratégia ecológica adotada por plantas em ecossistemas ao longo de todo o globo, os conhecimentos sobre seus padrões ainda são escassos. A maior parte dos estudos foi realizada em ambientes em que o fator restritivo é fogo, principalmente na região do Mediterrâneo, de forma que o conhecimento relacionado a sua ocorrência em resposta a outros fatores restritivos ainda é incipiente (PAUSAS et al., 2016). Neste sentido, ainda se conhece pouco sobre a estruturação filogenética da característica, quais são as principais características funcionais relacionadas em resposta a cada fator restritivo, qual a importância da estratégia nas diferentes comunidades e também ao longo de processos dinâmicos como sucessão ecológica, bem como sua participação na caracterização dos tipos vegetacionais e na sua história biogeográfica (BOND; MIDGLEY, 2001, 2003; PAUSAS et al., 2016; PAUSAS; KEELEY, 2014). Assim, há a necessidade de inclusão desta característica como um atributo ecológico a ser investigado e incluído em trabalhos e modelos vegetacionais, considerando que ela é parte importante dos padrões atuais dos ecossistemas e provavelmente também será das suas respostas futuras.

A ampla ocorrência do perfilhamento como estratégia de persistência em comunidades também oferece desafios para a caracterização fisionômica, estrutural e da biodiversidade dos diferentes tipos vegetacionais. Por ser uma estratégia comum em vários ecossistemas, autores argumentam que a metodologia de amostragem da vegetação deve considerar variáveis relacionadas ao perfilhamento como descritoras das comunidades, além de adequar protocolos de coleta à sua presença e importância (PAUSAS et al., 2016; SOUZA et al., 2019). Um exemplo é o método de inclusão por fuste, em que os fustes são as unidades básicas de inclusão e são amostrados se apresentam um determinado valor mínimo. Assim, utilizando-se tal método, fustes com diâmetro menor que o tamanho mínimo não são incluídos na amostragem, mesmo que existam fustes amostrados no mesmo indivíduo.

Este método tem sido amplamente aplicado na coleta de dados em florestas tropicais, sendo recomendado em protocolos de coletas de diversos grupos de pesquisa em florestas úmidas e secas (ANDERSON-TEIXEIRA et al., 2014; MALHI et al. 2002, 2020; MOONLIGTH et al., 2020). A problemática entre este método de inclusão e o perfilhamento se dá principalmente em tipos vegetacionais sujeitos a fatores restritivos como estresse hídrico, inundação ou fogo, em que muitos indivíduos perfilham como forma de persistência na comunidade (ARAÚJO; SANTOS, 2019; CECCON et al., 2006; PAUSAS et al., 2016). Nestes locais, a adoção do método por fuste pode implicar na não amostragem de muitos indivíduos que apresentam diversos fustes, porém todos ou grande parte deles com diâmetro que individualmente não atinge o tamanho mínimo de inclusão. Como consequência, tem-se uma distorção de variáveis de vegetação como número de árvores e fustes, biomassa e riqueza de espécies em relação à realidade de campo, que pode influenciar nas inferências realizadas e o as iniciativas de conservação e manejo derivadas. Dessa forma, são necessários esforços de construção de conhecimento sobre os impactos do perfilhamento na coleta de variáveis de vegetação, bem como sobre como as metodologias podem se adaptar a sua importância ecológica nas comunidades.

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REFERÊNCIAS

ANDERSON-TEIXEIRA, K. J. et al. CTFS-ForestGEO: A worldwide network monitoring forests in an era of global change. **Global Change Biology**, v. 21, p. 528–549, 2014. https://doi.org/10.1111/gcb.12712

ARAÚJO, F. D. C.; SANTOS, R. M. Different degrees of water-related stress affect evolutionary diversity in a seasonally dry biome. **Oecologia**, v. 189, n. 3, p. 795-802, 2019. https://doi.org/10.1007/s00442-019-04358-4

BELLINGHAM, P. J.; SPARROW, A. D. Resprouting as a life history strategy in woody plant communities. **Oikos**, v. 89, n. 2, p. 409-416, 2000. https://doi.org/10.1034/j.1600-0706.2000.890224.x

BOND, W. J.; MIDGLEY, J. J. Ecology of sprouting in woody plants: the persistence niche. **Trends in ecology & evolution**, v. 16, n. 1, p. 45-51, 2001. https://doi.org/10.1016/S0169-5347(00)02033-4

BOND, W. J.; MIDGLEY, J. J. The evolutionary ecology of sprouting in woody plants. **International Journal of Plant Sciences**, v. 164, n. S3, p. S103-S114, 2003. https://www.jstor.org/stable/10.1086/374191

CADOTTE, M. W.; TUCKER, C. M. Should environmental filtering be abandoned?. **Trends in ecology & evolution**, v. 32, n. 6, p. 429-437, 2017. https://doi.org/10.1016/j.tree.2017.03.004

CECCON, E.; HUANTE, P.; RINCÓN, E. Abiotic factors influencing tropical dry forests regeneration. **Brazilian archives of Biology and Technology**, v. 49, n. 2, p. 305-312, 2006. https://doi.org/10.1590/S1516-89132006000300016

CLARKE, P. J. et al. Resprouting as a key functional trait: how buds, protection and resources drive persistence after fire. **New phytologist**, v. 197, n. 1, p. 19-35, 2013. https://doi.org/10.1111/nph.12001

GRUBB, P. J. The maintenance of species-richness in plant communities: the importance of the regeneration niche. **Biological reviews**, v. 52, n. 1, p. 107-145, 1977. https://doi.org/10.1111/j.1469-185X.1977.tb01347.x

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE. **Climate change 2013:** the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. London: Cambridge University Press, 2014.

JAUREGUIBERRY, P. et al. Post-fire resprouting capacity of seasonally dry forest species–Two quantitative indices. **Forest Ecology and Management**, v. 473, p. 118267, 2020. https://doi.org/10.1016/j.foreco.2020.118267

JIMENEZ-RODRÍGUEZ, D. L. et al. Structural and functional traits predict short term response of tropical dry forests to a high intensity hurricane. **Forest Ecology and Management**, v. 426, p. 101-114, 2018. https://doi.org/10.1016/j.foreco.2018.04.009

KNOX, K. J. E.; CLARKE, P. J. Nutrient availability induces contrasting allocation and starch formation in resprouting and obligate seeding shrubs. **Functional Ecology**, v. 19, n. 4, p. 690-698, 2005. https://doi.org/10.1111/j.1365-2435.2005.01006.x

LAMONT, B. B.; ENRIGHT, N. J.; HE, T. Fitness and evolution of resprouters in relation to fire. **Plant Ecology**, v. 212, n. 12, p. 1945-1957, 2011. https://doi.org/10.1007/s11258-011-9982-3

LASSO, E.; ENGELBRECHT, B. M. J.; DALLING, J. W. When sex is not enough: ecological correlates of resprouting capacity in congeneric tropical forest shrubs. **Oecologia**, v. 161, n. 1, p. 43-56, 2009. https://doi.org/10.1007/s00442-009-1353-6

LEVIN, D. A. The seed bank as a source of genetic novelty in plants. **The American Naturalist**, v. 135, n. 4, p. 563-572, 1990. https://doi.org/10.1086/285062

MALHI, Y. et al. An international network to monitor the structure, composition and dynamics of Amazonian forests (RAINFOR). **Journal of Vegetation Science**, v. 13, p. 439–450, 2002. https://doi.org/10.1111/j.1654-1103.2002.tb020 68.x

MOONLIGHT, P. W et al. Expanding tropical forest monitoring into Dry Forests: The DRYFLOR protocol for permanent plots. **Plants, People, Planet**, v. 00, p. 1–6, 2002. https://doi.org/10.1002/ppp3.10112

MOREIRA, B.; TORMO, J.; PAUSAS, J. G. To resprout or not to resprout: factors driving intraspecific variability in resprouting. **Oikos**, v. 121, n. 10, p. 1577-1584, 2012. https://doi.org/10.1111/j.1600-0706.2011.20258.x

NZUNDA, E. F.; LAWES, M. J. Costs of resprouting are traded off against reproduction in subtropical coastal dune forest trees. **Plant Ecology**, v. 212, n. 12, p. 1991-2001, 2011. https://doi.org/10.1007/s11258-011-9991-2

PAUSAS, J. G. et al. Towards understanding resprouting at the global scale. **New Phytologist**, v. 209, n. 3, p. 945-954, 2016. https://doi.org/10.1111/nph.13644

PAUSAS, J. G.; KEELEY, J. E. Evolutionary ecology of resprouting and seeding in fire-prone ecosystems. **New Phytologist**, v. 204, n. 1, p. 55-65, 2014. https://doi.org/10.1111/nph.12921

SCHWILK, D. W.; ACKERLY, D. D. Is there a cost to resprouting? Seedling growth rate and drought tolerance in sprouting and nonsprouting Ceanothus (Rhamnaceae). **American Journal of Botany**, v. 92, n. 3, p. 404-410, 2005. https://doi.org/10.3732/ajb.92.3.404

SOUCHIE, F. F. et al. Post-fire resprouting strategies of woody vegetation in the Brazilian savanna. **Acta Botanica Brasilica**, v. 31, n. 2, p. 260-266, 2017. https://doi.org/10.1590/0102-33062016abb0376

SOUZA, C. R. et al. Small-scale edaphic heterogeneity as a floristic–structural complexity driver in Seasonally Dry Tropical Forests tree communities. **Journal of Forestry Research**, p. 1-11, 2019. https://doi.org/10.1007/s11676-019-01013-9

VERDÚ, M. Ecological and evolutionary differences between Mediterranean seeders and resprouters. **Journal of Vegetation Science**, v. 11, n. 2, p. 265-268, 2000. https://www.jstor.org/stable/3236806

VESK, P. A.; WESTOBY, M. Sprouting ability across diverse disturbances and vegetation types worldwide. **Journal of Ecology**, v. 92, n. 2, p. 310-320, 2004. https://doi.org/10.1111/j.0022-0477.2004.00871.x

ZEPPEL, M. J. B. et al. Drought and resprouting plants. **New Phytologist**, v. 206, n. 2, p. 583-589, 2015. https://doi.org/10.1111/nph.13205

SEGUNDA PARTE- ARTIGOS

ARTIGO 1 - BEYOND THE “RESPROUT OR NOT RESPROUT” DICHOTOMY: ON THE PREVALENCE AND EVOLUTIONARY FINGERPRINT OF RESPROUTING IN TROPICAL DRY FOREST TREES

Versão preliminar preparada de acordo com as normas do periódico *Journal of Ecology*. O conselho editorial do periódico poderá sugerir alterações para adequá-lo ao seu próprio estilo.

Beyond the "resprout or not resprout" dichotomy: on the prevalence and evolutionary fingerprint of resprouting in tropical dry forest trees

Running title: Resprouting patterns by tropical dry forests tree species

Abstract

1. Resprouting is a plant persistence strategy in communities subjected to disturbance or challenging environmental conditions. Knowledge on resprouting expression in drought-prone, yet fire free, environments is scarce, despite its potential relevance in scenarios of climate change and increased aridity. Here, we assess the importance of resprouting in tree communities of tropical dry forests (TDF) that undergo strong seasonal water stress, attempting to identify its main drivers and the evolutionary fingerprint potentially underlying patterns.

2. Based on inventories of 16 TDF fragments (12.52 ha; 313 forest subplots), we calculated two resprouting metrics (frequency of individuals that resprout and average number of stems *per* tree), classified *taxa* (genera and species) into groups according to their resprouting frequency and assessed the prevalence of these groups in the sampled fragments. We investigated the role of environment versus taxonomic and evolutionary identity for resprouting strategies.

3. Species and genera with low and medium resprouting frequencies are the most prevalent in TDF, compared to non-resprouters and high-frequency resprouters. Resprouting frequency was more explained by taxonomic identity than by environmental factors. Altogether, resprouting ability seems to be an intrinsic trait that varies in response to environmental conditions but within a range of variation previously determined by species and genus identity. However, we found no phylogenetic signal above the genus level for any of the resprouting variables, with closely related genera displaying contrasting resprouting patterns. Thus, resprouting expression in TDF lineages may have been determined by processes of divergence between closely related *taxa* and convergence between distantly related ones, reflecting the restrictive factors to which they have been subjected over the evolutionary history.

4. **Synthesis:** *Taxa* with low and intermediate resprouting strategies are dominant in TDF, which is likely directly associated with the seedling trade-off in response to water restriction, in which each regeneration strategy may be more or less important in response to local conditions. Resprouting is determined by *taxon* identity, but is not conserved more deeply into the phylogeny, suggesting that this is a labile trait shaped by the history of individual species.

Key-Words: Tillering; persistence niche; sprouting; deciduous forests; phylogenetic signal.

1 INTRODUCTION

Environmental pressures select functional traits and strategies that improve species survival and success (Cadotte & Tucker, 2017; Diaz et al., 1998). One such strategy, resprouting, can improve plant survival, fitness and persistence (Poorter et al., 2010) via the emission of new shoots as a response to physical or physiological injuries suffered by a plant (Bellingham & Sparrow, 2000; Pausas et al., 2016, Vesk & Westoby, 2004). The ability to resprout is observed in ecosystems worldwide in response to several stressors, such as fire, herbivory, floods, hurricanes, water stress and edaphic restrictions (Araujo & Santos, 2019; Bond & Midgley, 2003; Ceccon et al., 2006; Jimenez-Rodriguez et al., 2018; Souza et al., 2019; Zeppel et al. 2015). Although in all these cases the same final expression is achieved (i.e. emission of new shoots), depending on environmental peculiarities, local and past selective factors, a varying set of specific functional characteristics is involved. For example, thick bark is a resprouting-related trait important to protect buds from fire, but is not effective in flooded or drought-prone, but fire-free environments (Pausas et al., 2016; Zeppel et al., 2015). Thus, resprouting should not be understood as a simple binary trait (i.e., resprout or not resprout), but as an ecological syndrome that integrates several functional traits and is inserted in a wide spectrum of ecological variability (Bellingham & Sparrow, 2000; Bond & Midgley, 2003; Pausas et al., 2016).

Resprouting occurs when some stressful condition threatens plant survival, and the plant responds by allocating non-structural resources (carbohydrates) toward emitting a new shoot and generating a new stem (Moreira et al., 2012, Schwilk & Ackerly, 2005). Non-structural carbohydrates used to generate the resprout are normally obtained from the roots; however, resources from other plant parts can be used if resource availability is scarce (Bellingham & Sparrow, 2000; Bond & Midgley, 2001; Clarke et al., 2013). By generating identical copies of the original tree, these new shoots represent a form of asexual reproduction (Bond and Midgley, 2001; Lasso et al., 2009; Pausas et al., 2016; Souchie et al., 2017). Resprouting is therefore an occupation strategy that can be considered a direct ecological alternative to sexual reproduction. Thus, resprouting is normally considered part of a species' "persistence niche", as opposed to the classic "regeneration niche" that comprises reproductive characteristics (Bond & Midgley, 2001; Grubb, 1977; Pausas et al., 2016). In a mature organism, new shoots benefit from mature root and leaf systems, which facilitate resource acquisition and resistance to local ecological stressors, since resprouts will not face environmental pressure that is usually undergone by seedlings (Bond & Midgley, 2003; Clarke et al., 2013; Pausas et al., 2016).

The importance of the sexual reproduction versus resprouting dichotomy is further highlighted by the resource allocation trade-offs experienced by trees that employ this strategy; in some cases, resprouting may even be favored to the detriment of sexual reproduction (Bond & Midgley, 2003; Lamont et al., 2011; Moreira et al., 2012; Schwilk & Ackerly, 2005). As a consequence, resprouting species often produce fewer and lower quality seeds that give rise to low vigor seedlings and individuals with slow height growth (Knox & Clarke, 2005; Nzunda & Lawes, 2011; Verdú, 2000). Because of the association with asexual reproduction, resprouting species populations tend to have lower rates of genetic change across generations (or at least time) than non-resprouting species, which may promote an accumulation of deleterious mutations (Levin, 1990; Pausas & Keeley, 2014) (but see Fowler et al., 2018). Therefore, this strategy is intrinsically related to gains and losses in individuals' fitness, and the prevalence of resprouting and sexual reproduction strategies in different environments is a direct response to the spatial and temporal characteristics of environmental stressors, local productivity and the intensity and frequency of disturbances (Nzunda & Lawes, 2011; Pausas & Keeley, 2014; Vesk & Westoby, 2004). Finally, resprouting improves species independence from pollinators, dispersers and to some degree local environmental resources, the latter because non-resprouting individuals depend on local environmental resources to survive and grow until reproductive age (Bond & Midgley, 2001; Bond & Midgley, 2003; Nzunda & Lawes, 2011).

Beyond its prevalence in fire-prone ecosystems, resprouting is a broadly adopted tree strategy under seasonal climates with little to no precipitation during the dry season (Ceccon et al., 2006; Zeppel et al., 2015). In these dry ecosystems, the emission of new stems is a strategy to increase the chances of survival of the individuals through a new leaf and hydraulic system without the damages suffered by the main stem (Zeppel et al., 2015). However, there are many uncertainties around resprouting strategy in drought-prone, yet fire-free environments, such as: how common is the resprouting strategy across individuals; how does resprouting vary across different species and genera of trees; and whether resprouting expression is mainly determined by evolutionary or environmental factors (Pausas et al., 2016; Zeppel et al., 2015). In addition, it is not clear how labile the manifestation of resprouting is and whether in drought-prone ecosystems, individuals of the same species or closely related species tend to have more similar resprouting strategies than heterospecific or distantly related ones. Such knowledge is crucial to understand and predict the responses of trees and ecosystems to scenarios of increasing aridity worldwide (IPCC, 2014). Increasing aridity has direct consequences for community function and ecological patterns (Allen et al., 2017; IPCC, 2014; Pausas et al., 2016; Zeppel, 2015), and the way tree stands respond to increasing aridity may be associated with their resprouting ability.

Tropical dry forests (TDF) are a particularly relevant and widespread vegetation formation for understanding the links between water stress and resprouting expression across different *taxa* (Fernandes et al., 2020; Pennington et al., 2009). TDF undergo seasonal water stress, with average annual rainfall below 1800 mm and 3 to 6 months with less than 100 mm of monthly rainfall (DRYFLOR, 2016; Pennington et al., 2009). Besides this, TDF are also particularly drought-prone in South America, with high inter-annual variability in water availability (Allen et al., 2017; Pennington et al., 2009). In fact, exploring resprouting patterns in TDF is likely to provide relevant information about the ecology of seasonal communities and help to predict how other vegetation types may respond to predicted scenarios of increasing aridity (Allen et al., 2017; Bond & Midgley, 2003; Pausas et al., 2016). Moreover, assessing resprouting prevalence (i.e., beyond the presence vs. absence approach) and its manifestation across evolutionarily related *taxa* in TDF can help us understand the role of this strategy in drought-prone ecosystems elsewhere.

Here we explored resprouting expression within and across lineages in undisturbed tropical dry forests (TDF) in order to understand the importance of this ecological strategy as a means of persistence by species in drought-prone ecosystems. Specifically, we i) investigated the variability in the frequency of resprouting across species and genera of trees; ii) evaluated the influence of taxonomic identity and environmental factors on the frequency of resprouting and the number of stems per tree; and iii) investigated the evolutionary fingerprint on resprouting patterns across TDF genera by quantifying the extent of phylogenetic signal for resprouting characteristics. We addressed these questions by sampling tree communities in 16 TDF fragments (12.52 ha of total area sampled) in the southern portion of the Brazilian Caatinga. By studying variation in the number of stems produced by resprouters and in the frequency with which different *taxa* resprout, we aim to advance knowledge on resprouting expression in tropical trees beyond a traditional binary classification of *taxa* as resprouters versus non-resprouters.

2 MATERIAL AND METHODS

2.1 Study areas

We used data from 16 fragments (hereafter plots) of tropical dry forests (TDF) located in the Brazilian states of Minas Gerais and Bahia, distributed in the southern portion of the Caatinga biome and in patches within the Cerrado biome (Fig. 1; Table S1). The regional climate is classified as Köppen As/Aw (tropical with dry winters), with average monthly temperature in the sampled sites ranging from 22 to 24.6 ° C, and total annual rainfall ranging from 754 to 1060 mm, concentrated between November and March. Flatlands predominate in the region, although relief may vary in areas near watercourses or adjacent to limestone outcrops. Arboreal Caatinga, a tall upright deciduous forest vegetation, predominates in the region (Santos et al., 2012), with occasional variations in vegetation physiognomy, floristics and structure driven by microenvironmental factors such as the presence of rocky outcrops and floodplain sandbanks (Aguiar-Campos et al., 2020; Apgaua et al., 2015; Paula et al., 2018; Souza et al., 2019).

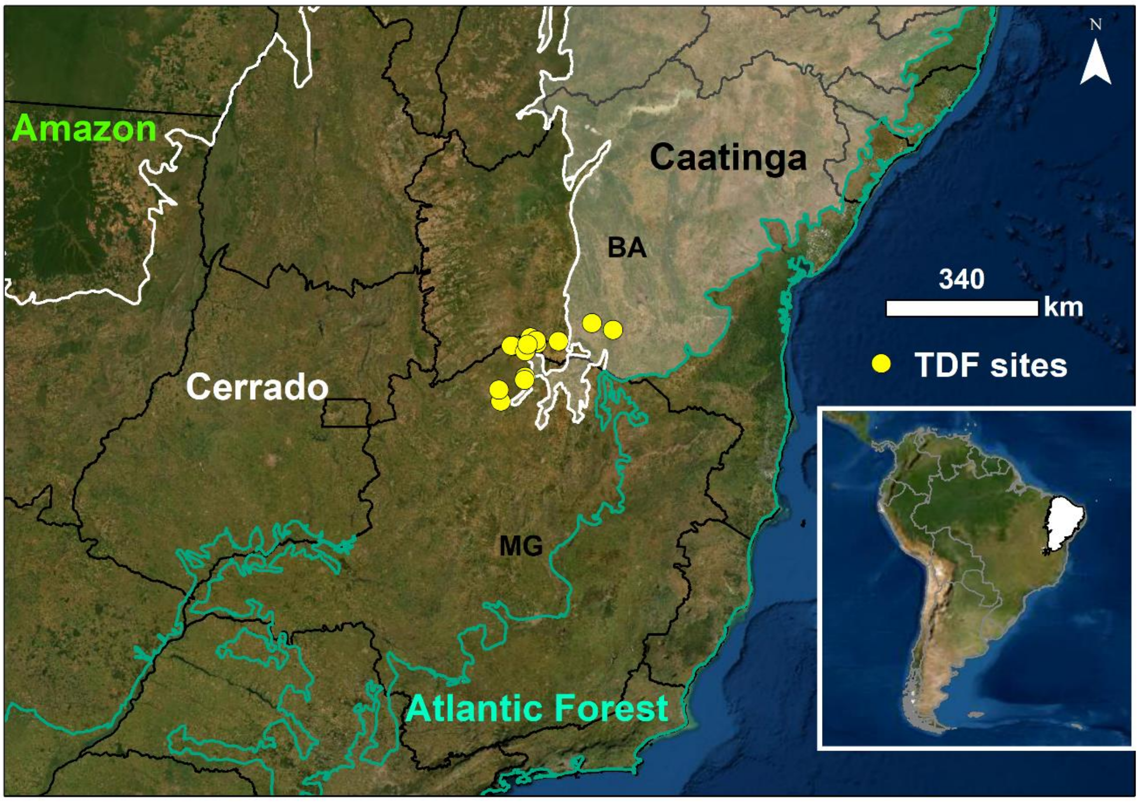

Figure 1: Location of 16 tropical dry forests (TDF) plots in the states of Minas Gerais (MG) and Bahia (BA), Brazil. Position of the sites relative to South America and Brazilian biogeographic regions (official boundaries) are also shown.

2.2 Vegetation data collection

From 2006 to 2017, we established 313 permanent sample units or subplots, each of 400 m², in the dimensions of 20 x 20 m or 10 x 40 m, depending on terrain characteristics (see Fig. S1), totaling 12.52 ha of sampled area. Sampling intensity at each plot ranged from 5 to 51 subplots, depending on plot's environmental heterogeneity, fragment size and data collection goals (see references in Table S1). In each subplot we included all tree individuals with diameter at breast height (DBH, 1.30 m above the ground) greater than or equal to 3 cm. An individual with multiple stems was included even when no individual stem surpassed 3 cm DBH if the square-root of the sum of squares of the stems' DBH was ≥ 3 cm. We identified all individuals to the species level and measured each stem diameter that met the inclusion criterion (achieving breast height, or 1.30 m above the ground). Plant identification was carried out by experts in the field or in herbaria and followed taxonomic nomenclature of the Angiosperm Phylogeny Group (APG IV, 2016). Name standardization followed REFLORA (2020), through the *flora* package (Carvalho, 2016), implemented in the software R v. 4.0.3 (2020). Forest inventory data for the 16 sites are stored in the ForestPlots.net database (https://www.forestplots.net/) (see plot codes in Table S1). We sampled 15,642 individual trees and 25,720 stems, belonging to 321 species, 171 genera and 51 plant families (Tables S4 and S5).

2.3 Analyses of resprouting

To understand general patterns of resprouting across *taxa*, we calculated two measures for each species and genus across our dataset: the average number of stems per tree and the proportion of individuals that have resprouts (hereafter, resprouting frequency). To classify species and genera into groups based on resprouting frequency, we used the k-means algorithm (Jain, 2010). To ensure sufficient sampling to quantify resprouting patterns, we set a threshold of including *taxa* (species or genus) with a minimum abundance of 10 individuals sampled in the entire dataset (167 species and 114 genera). We tested a number of k-values ranging from two to seven and selected the optimal number of groups (i.e., optimal k-value) based on within-group sum of squares through the elbow method (Kodinariya & Makwana, 2013). Aside from the non-resprouting *taxa* (not included in this partitioning), the analyses indicated the existence of three groups (optimal k-value = 3; Fig. S2), which we term low-frequency, medium-frequency and high-frequency resprouters (See Table S2 for center values for each group). We quantified the proportion of species and genera in our dataset that fell into each category, and also the proportion of each group in the total number of trees, total number of stems and total aboveground woody biomass, the latter obtained using allometric equations at the tree-level from Chave et al. (2014) (see supplementary information for more details).

In order to compare the relative influence of site-specific environmental factors versus taxonomic identity on resprouting variables, we used generalized linear mixed effects models and variance partitioning. For understanding variation in number of stems per individual, we modelled the observed stem count for each individual as a Poisson distributed variable with two sets of nested random effects as explanatory variables: the site factors, using the subplot and plot within which the individual was found to quantify the effect of environment; and taxonomic identity, using the species, genus and family of each individual. For understanding variance in frequency of resprouting, we calculated the number of individuals that had resprouts for each species in each plot versus the number of individuals in the plots that did not have resprouts. We modelled this as a binomial response (‘successes’ and ‘failures’ to resprout) with the same two sets of nested random effects.

From the models’ results, we performed a variance partitioning analysis to assess variance explanation by random effects (Fyllas et al., 2009; Oliveras et al., 2020). This aimed to quantify the contribution of taxonomic factors (family, genus and species identity) and site factors (plot and subplot; a proxy for environmental effects) on resprouting expression. We also compare the effect of each factor (Site vs Taxonomic) using the Akaike Information Criterion corrected for small sample size (AICc). For this, we compared the AICc of the global model with options without each one of the factors, in order to evaluate which has a great impact on the AICc value. We stress that this approach does not include relatedness between species, genera or families, so that the results related to the taxonomic component comes down to how much species' identity influences the variation in resprouting expression. Since seasonal water stress is a key TDF characteristic, we also considered testing the effect of climatological water-deficit (CWD; Chave et al., 2014) and mean annual precipitation (MAP obtained through WorldClim; Fick & Hijmans, 2017) on resprouting variables. However, preliminary analyses showed that correlation between CWD, MAP and resprouting variables was close to zero (Figure S3). We attributed this result to the geographic proximity and similar climate shared by our sites, and therefore excluded these variables from our models.

2.6 Evolutionary fingerprint on resprouting expression

To explore the evolutionary fingerprint on resprouting characteristics in TDF, we used data from genera with a minimum of 10 individuals in the sampled region. This threshold aimed to avoid potential errors in quantifications for undersampled genera. As a phylogenetic tree, we used the genus-level phylogenetic hypothesis for lowland tropical tree genera in South America from Neves et al. (2020).

To evaluate the evolutionary fingerprint, we measured the extent of phylogenetic signal for each resprouting variable using Pagel's λ (Freckleton et al., 2002; Pagel, 1999), which is a more robust parameter for incomplete phylogenies (Molina-Venegas & Rodríguez, 2017). To estimate whether phylogenetic signal was greater than expected by chance, we shuffled genera randomly in the phylogeny and calculated the proportion of 1000 randomizations that have λ greater than the observed. λ quantifies similarities between sister lineages and usually ranges from 0 to 1. If $\lambda = 0$, there is a lack of phylogenetic signal and no correlation between resprouting values and relatedness of *taxa*; if $\lambda = 1$, the distribution of trait values across the phylogeny reflects the evolutionary relatedness among *taxa* and fits the expectation under a null Brownian motion model of evolution (Freckleton et al., 2002); if $0 < \lambda < 1$, trait values are similar between closely related *taxa*, but influenced by evolutionary processes other than BM (Crisp & Cook, 2012).

To account for the uncertainty of the phylogenetic hypothesis used herein, we repeated our analyses with 100 trees from the posterior distribution (also available in Neves et al., 2020). From the 100 trees, we calculated the confidence interval and p-value significance for Pagel's λ values obtained with each tree for each of the resprouting variables. We also performed phylogenetic signal analyses for the resprouting categories (low-, medium- and high-frequency resprouters) using two different approaches: the *D* measure for binary comparisons between categories (Fritz & Purvis, 2005), and the δ measure by Borges et al. (2019) for discrete categories. We conducted all phylogenetic analyses using functions from the *phytools* (Revell, 2012), *ape* (Paradis et al., 2004), *geiger* (Harmon et al., 2008) and *caper* (Orme et al., 2020) packages in the R Statistical Software v.4.0.3 (R Team, 2020).

3 RESULTS

3.1 Resprouting occurrence and prevalence in TDF

The average number of stems *per* tree and resprouting frequency varied widely across genera (Figs 2 and 3; Table S2; S3, S4 and S5). Across all monitored individuals, 32.5% (5084 individuals) had multiple stems, with an average of 1.64 stems *per* tree. When considering just trees with resprouts, the average increases to 2.98 stems per tree.

Most genera and species fit the categories of low- and medium-frequency resprouters (Figs 2 and 3). Only a small proportion of the pool of genera and species in the studied TDF was classified as non-resprouters (i.e., with resprouting never observed) or as high-frequency resprouters (i.e., 70% of resprouting frequency) (Fig. 2 and 3). Most genera and species had an average number of stems *per* tree between 1 and 2 (low- and medium-frequency resprouters). Only a small proportion of the pool of genera and species never resprouted or had an average of more than three stems *per* tree (Fig. 2). In general, most genera and species recorded are considered facultative resprouters, meaning that individuals belonging to these *taxa* may or may not adopt the resprouting strategy.

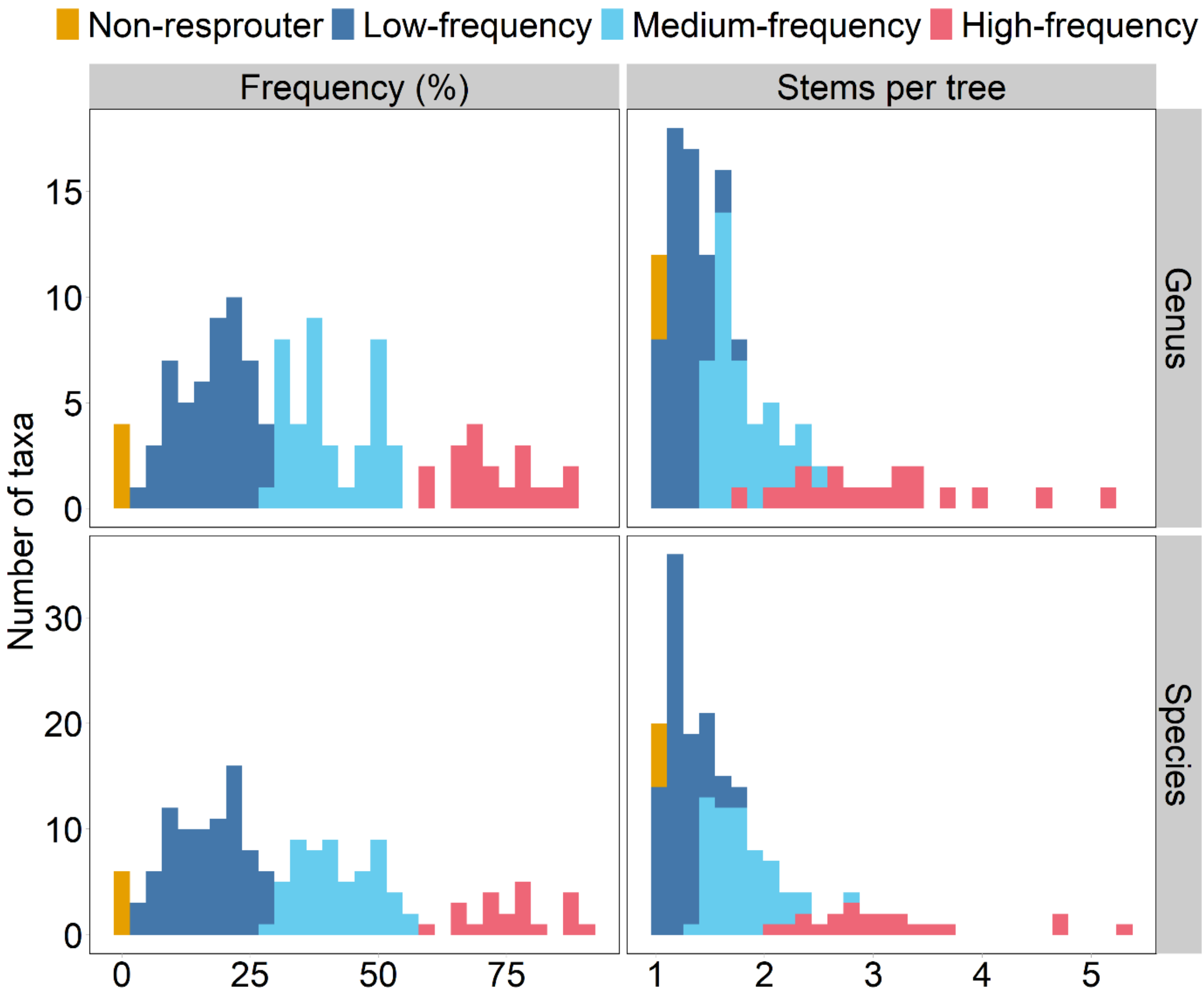

Figure 2: Histogram of resprouting frequency values and average stems per tree for species and genera evaluated in 16 tropical dry forests, with *taxa* colored according to our k-means partitioning of resprouting frequency classes.

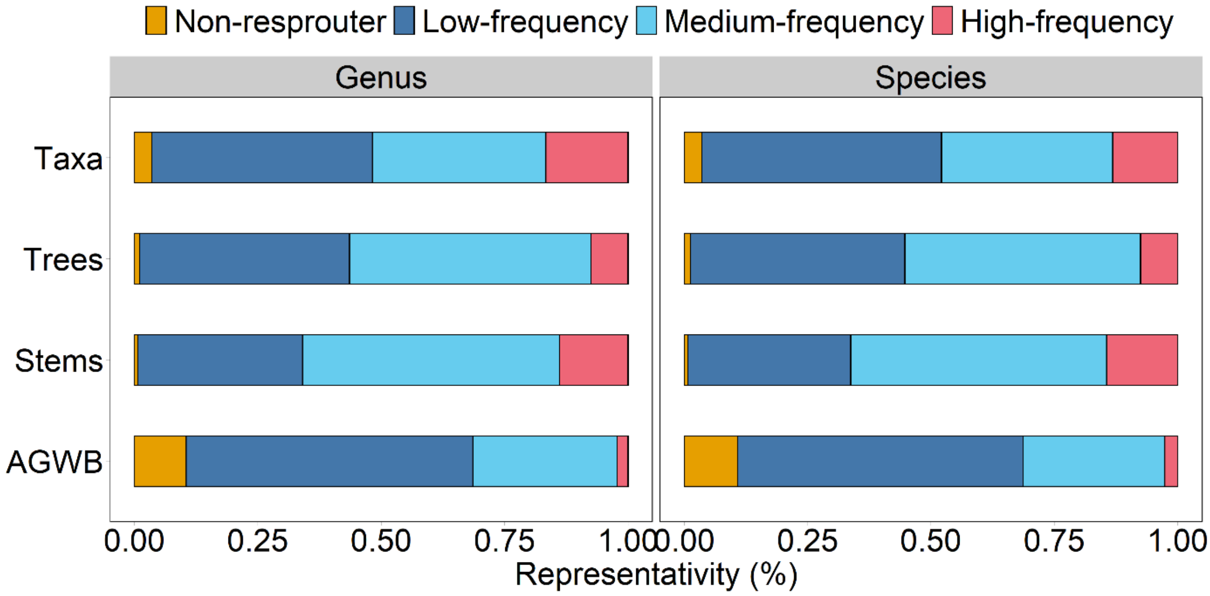

Figure 3: Proportion of resprouting frequency categories in the total number of *taxa*, trees, stems and aboveground woody biomass (AGWB) in 16 fragments of tropical dry forests, calculated for when genera are categorized (left-hand panel) or when species are categorized (right-hand panel).

3.2 Resprouting across forest plots: site and taxonomic effects

To evaluate the effects of environmental factors and taxonomic identity on resprouting measurements (i.e., resprouting frequency and average stems *per* tree), we used generalized linear mixed models, with taxonomic grouping versus site factors as random effects in our model. Variation in resprouting variables was determined to a greater degree by taxonomic identity (species, genus and family) than by the plot or site in which individuals occurred (i.e., greater variance explained by all taxonomic levels together; Fig. 4). Taxonomic effects explained 12.5 % and 28.8 % of total variance in the average number of stems *per* tree and resprouting frequency respectively, whereas site effects explained only 2.8 % and 6.4 % of the variation for the same variables (Fig. 4; Table S6). Within taxonomic levels, for both resprouting frequency and average number of stems *per* tree, genus identity was the most important taxonomic component, followed by species and family identity (Fig. 4; Table S6). The large majority of the variation in these measures of resprouting remained unexplained, 84.56 % for average stems *per* tree and 64.68 % for resprouting frequency. Greater importance of taxonomic effects is also confirmed by examining the AICc values of different models: removing taxonomic effects generated a greater increase in AICc compared to removing plot and subplot factors (Table 2).

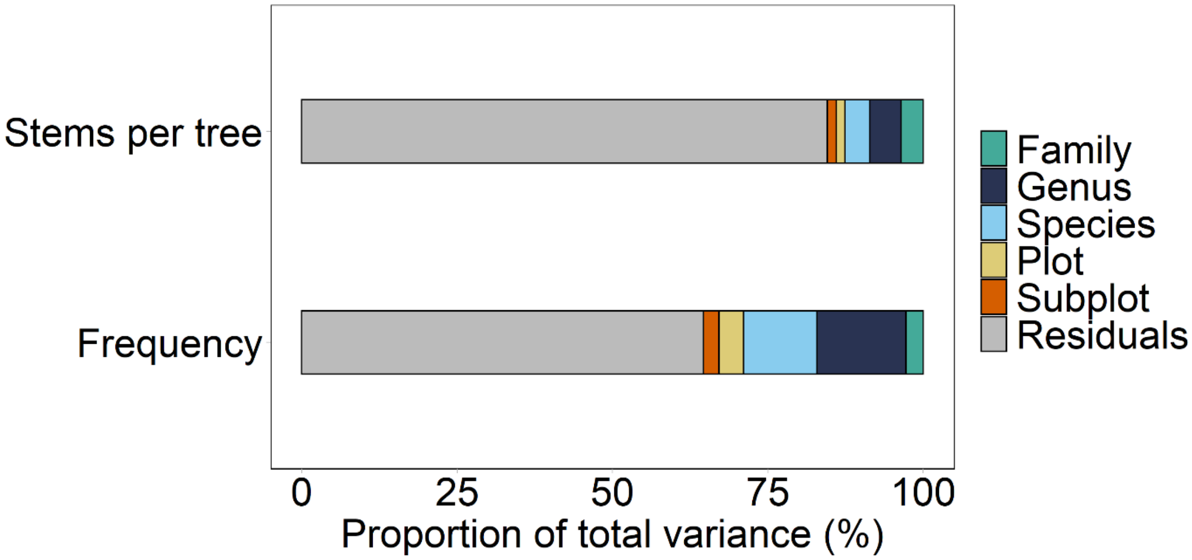

Figure 4: Variance partitioning analysis of site (plot and subplot) and taxonomy (family, genus and species) effects for number of stems *per* tree and resprouting frequency recorded in 16 fragments of tropical dry forests.

Table 2: Results for GLM models for each resprouting variable evaluated: average stems per tree and resprouting frequency. The results are for the global model, global model including site effects and global model including taxonomic effects. Delta AICc (Δ AICc) refers to the comparison between the global models and for the options accounting for relative influence of sites and taxonomic identity.

Model	**Average stems per tree**		**Frequency**	
	AICc	**Δ AICc**	**AICc**	**Δ AICc**
Global model (GM)	44200.5	-	47358.9	-
GM - Site effects	44538.2	337.62	47540.1	181.18
GM - taxonomic effects	45764.8	1564.28	48144.3	785.46

3.3 Resprouting across lineages: phylogenetic signal

We found no significant phylogenetic signal for resprouting according to estimates for Pagel’s Lambda across 100 phylogenetics genus-trees (mean of $\lambda = 0.15$ and mean $p = 0.19$ for average number of stems per tree and mean $\lambda = 0.16$ and mean $p = 0.19$ for frequency, both using the values 100 phylogenetics genus-trees) (Fig. 5; Table S8). Phylogenetic signal results for resprouting frequency categories through D (Fritz and Purvis, 2005) and δ (Borges et al., 2019) corroborate this result: an absence of phylogenetic signal for resprouting expression (see supplementary information and Fig. S4). In sum, our analyses showed that resprouting (frequency and average stems per tree) is a labile trait above the genus level, with closely related genera showing contrasting resprouting patterns: closely related *taxa* do not tend to resemble each other. These findings likely suggest that resprouting ability may have evolved repeatedly and independently over the phylogeny, rather than constrained to certain clustered clades.

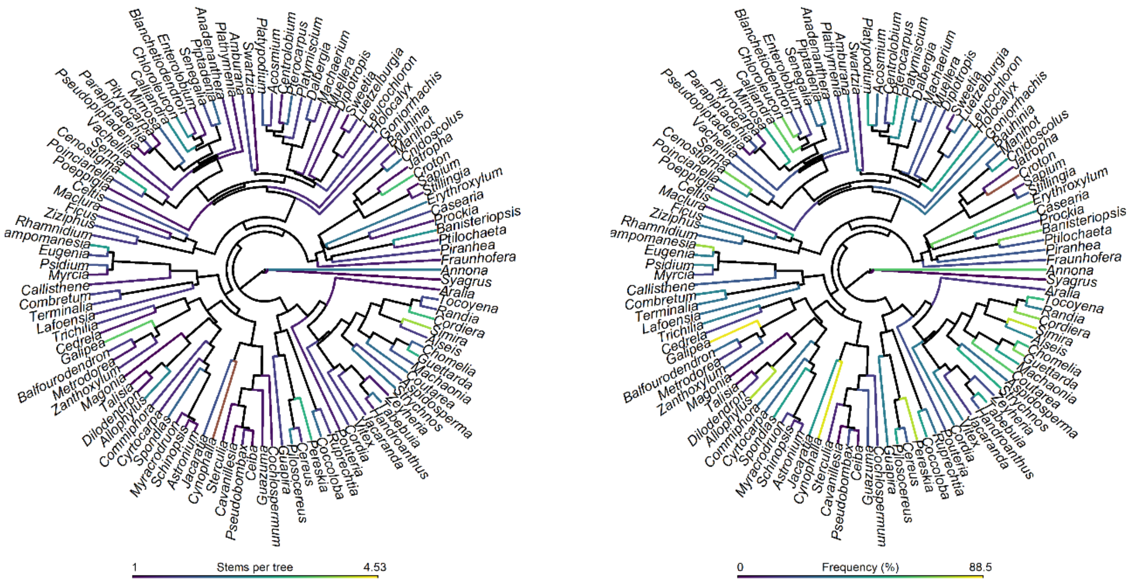

Figure 5: Phylogeny of 111 tropical dry forest tree genera with branches colored according to resprouting variables (number of stems *per* tree on the left, resprouting frequency on the right). Note that the number of genera represented here is lower than the total number used in classification, since 3 genera were not present in the phylogenetic tree.

4 DISCUSSION

Our results show that diverse resprouting strategies exist in tropical dry forests (TDF), while low- and medium-frequency were the most prevalent resprouting groups. In contrast, non-resprouters and high-frequency resprouters were less common in these dry environments. Overall, this study provides two important advances to understand resprouting strategies. First, across the TDF studied, resprouting patterns are determined more by taxonomic identity than environmental factors: both resprouting frequency and average number of stems *per* tree are intrinsic taxonomic characteristics, significantly explained by taxonomic information, mainly genus and species identity (Fig. 4). Second, there is no phylogenetic signal for resprouting strategies above the genus level (Fig. 5). These results suggest that resprouting strategies are phylogenetically labile; in other words, that sister lineages can show contrasting resprouting patterns, in these highly threatened, yet poorly understood dry ecosystems.

4.1 General resprouting patterns and environmental vs taxonomic effects

Within TDF most species are low- and medium-frequency resprouters. Although water stress is a continuous restrictive factor that we expect to promote broad resprouting (Pausas et al., 2016; Vesk & Westoby, 2004), these species of moderate-low resprouting tend to dominate in these dry environments. This finding agrees with the logic behind the resprouting vs. seedling trade-off in species persistence strategies, which is related to population growth capacity, survival and individual fitness (Bond & Midgley, 2003; Ceccon et al., 2006; Clarke et al., 2013; Pausas & Keeley, 2014). Without other influences on fitness, species would naturally tend to “opt” for seedling strategy, which is associated with greater growth capacity and, among other factors, increased genetic diversity (Bellingham & Sparrow, 2000; Nzunda & Lawes, 2011; Pausas et al., 2016) However, due to strong environmental filters in TDF, particularly strong seasonal water stress, some individuals of these species could resprout to ensure their survival by emitting a new leaf and hydraulic system to obtain resources. The prevalence of low and medium-frequency resprouters, even in relation to non-resprouters, corroborates with this strategy: high-frequency species can guarantee their local survival, but may not ensure broad ecological success within TDF communities.

Resprouting is an ecological persistence strategy adopted by tree species to endure the long dry season in TDF, which may last for up to 8 months (Pennington et al., 2009). Therefore, resprouting would be adopted as an immediate response to water deficit, and its occurrence conditioned to water stress physiological challenge that threatens individual survival (Ceccon et al., 2006; Pausas et al., 2016; Zeppel et al., 2015). In the absence of water stress, or in life stages where individuals have greater resistance to ecological filters, resprouting would probably become an obsolete strategy and therefore, may not be adopted (Bond & Midgley, 2001; Pausas & Keeley, 2014). This non-continuous need of resprouting may explain the generally low resprouting frequency and low average number of stems *per* tree we found here. In the rainy season, the water availability enables reproduction, dispersal and germination of seeds produced by resprouting individuals, however with a compromised success due to the previous use of non-structural resources in new shoots emission (Ceccon et al., 2006; Clarke et al., 2013; Moreira et al., 2012; Pausas et al., 2016).

Resprouting is an important persistence strategy that increases fitness and plant survival (Poorter et al., 2010), therefore, it should be expected that its manifestation is mainly determined by environmental conditions (i.e., high resprouting frequency and number of stems *per* tree in response to stronger environmental filter). In contrast, our results show that resprouting expression is mainly determined by species identity (taxonomic information), whilst environmental conditions (represented by sites) seem to play a minor role (Fig. 4). Thus, resprouting ability seems to be an intrinsic trait that varies in response to environmental conditions but within a limited range of variation previously determined by taxonomic identity, mainly genus and species identity. It is important to state that a large proportion of the variation remains unexplained (Fig. 4). The residual variation may be associated with communities' structure and dynamics (dominance, diversity relationships and long-term trends), population age structure, canopy dynamics, biotic interactions, intra-specific variability and other factors we did not explore here. In addition, studies on larger spatial scales that comprises longer environmental gradients may find greater importance of environmental factors such as climate and soil on resprouting variation.

Prevalence of low and medium resprouters in TDF could also reflect the absence of large herbivorous mammals in South America and consequently of their disturbance effects related by herbivory and physical injuries. For African savannas, there is clear evidence that large animals drive woody plant functional patterns, selecting traits such as i) higher wood density that confers greater mechanical resistance to stem breakage) and ii) higher number of spines and iii) lower frequency of resprouting related to the absence of fire due to higher removing of biomass (fuel) by herbivores (Dantas and Pausas., 2020). However, in South America, these large herbivorous mammals went extinct around 10,000 years ago (Doughty et al., 2017), therefore, Cerrado plant functional traits are mainly determined by the presence of fire, in these fire-driven ecosystems (Dantas & Pausas, 2020. In the absence of these large animals, resprouter species may resprout in the face of water scarcity, but not often as under the previous disturbance regime in which the higher herbivory may have promoted resprouting. In fact, if large herbivores had not been extinct, they would occur in the south, east and southeast South America regions, which overlaps our study region (Doughty et al., 2016). In comparison to the thicker leaves in Cerrado species, TDF produce more nutritious leaves due to growing in richer soils, and are also thinner and less tough, being therefore, potentially more attractive to herbivores.

4.2 Resprouting across lineages: phylogenetic signal

There is no phylogenetic signal for resprouting variables above the genus-level (Fig. 5; Table S8): evolutionary relationships of lineages do not imply an ecological similarity in terms of resprouting strategies and sister lineages can have contrasting resprouting expression (e.g. the euphorbiaceae genera *Jatropha* and *Croton*). Resprouting ability is likely a result of specific restrictive factors to which individuals of these genera and their constituent species have undergone throughout their evolutionary history (Bond & Midgley, 2003; Pausas & Keeley, 2014; Vesk & Westoby, 2004). Although heritability can be an important driver of intrinsic trait values (Coelho de Souza et al. 2016; Fyllas et al. 2009), it would appear that closely related genera may have experienced different selective pressures throughout their evolutionary history, to which they responded with different resprouting patterns. For example, some genera also occur in the Cerrado savannas, in Atlantic semideciduous forests and in the different vegetation types within the Caatinga domain, all of which have different environmental factors (Aguiar-Campos et al., 2020; Moro et al., 2014; Santos et al., 2012; Souza et al., 2019). In contrast, distantly related lineages may have been submitted to similar selective pressures and converged to similar resprouting patterns. In addition, because resprouting is controlled by a linked set of complex traits and physiological processes (such as a dispersal syndrome), variations in resprouting expression must involve a number of evolutionarily integrated changes (Bond & Midgley, 2003; Lamont et al., 2011; Pausas & Keeley, 2014; Pausas et al., 2016).

Our conclusions require a note of caution due to an incomplete phylogeny; many genera in our study have relatives that occur outside our study region and were not included. We emphasize that we only considered the final expression of resprouting, which could stem from different sets of traits according to different environmental restrictions endured by the individuals that display it (Bond & Midgley, 2003; Pausas & Keeley, 2014). Therefore, these interpretations cannot be directly extended to other resprouting-related traits, given that the final expression of this strategy may owe to several functional patterns (Bond & Midgley, 2003; Pausas et al., 2016).

4.3 General implications

The response of tropical dry forests to observed and predicted climate change scenarios of increased aridity, consecutive years of prolonged droughts and variation in annual precipitation (Allen et al., 2017; IPCC, 2014) are and will be complex. Resprouting is an important immediate strategy to avoid mortality, but carries a cost of mobilizing stored resources to grow new shoots, which could jeopardize other vital functions related to growth and reproduction (Moreira et al., 2012; Schwilk & Ackerly, 2005). However, as resprouting is repeatedly used as a persistence strategy, stored resources may become scarce and the possibility of emitting new shoots and the individual's capacity to endure water stress may be compromised (Pausas et al., 2016).

Our study begins to address the need to build knowledge on ecological resprouting patterns in fire-free environments, especially those subject to extreme dry periods. Resprouting is currently an important strategy in these drought-prone plant communities, and may have been more in the past. Investigating how it manifests beyond the "resprout or not resprout" dichotomy contributes to a better understanding of present-day ecosystem function and future responses to ongoing climate change. In addition to dry environments, other tropical ecosystems such as moist forests may experience water stress due to climate change, and our results suggest that resprouting may be an important part of their responses to such stress. Thus, resprouting may become a more common strategy in communities subjected to extreme or long-term droughts.

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DATA AVAILABILITY STATEMENT

Data used will be available upon acceptance at ForestPlots.net website https://www.forestplots.net/) as a free data package.

REFERENCES

Aguiar-Campos, N., Maia, V. A., da Silva, W. B., Souza, C. R., & Santos, R. M. (2020). Can fine-scale habitats of limestone outcrops be considered litho-refugia for dry forest tree lineages? *Biodiversity and Conservation, 29(3),* 1009–1026. https://doi.org/10.1007/s1053 1-019-01923-4

Allen, K., Dupuy, J. M., Geil, M. G., Hulshof, C., Medvigy, D., Pizzano, C., … Powers, J. (2017). Will seasonally dry tropical forests be sensitive or resistant to future changes in rainfall regimes?. *Environmental Research Letters, 12(2),* 023001. https://doi.org/10.1088/1748-9326/aa5968

Apgaua, D. M. G., Pereira, D. G. S., Santos, R. M., Menino, G. C. O., Fontes, M. A. L. & Tng, D. Y. P. (2015). Floristic variation within seasonally dry tropical forests of the Caatinga

Biogeographic Domain, Brazil, and its conservation implications. *International Forestry Review, 17(2),* 33-44. https://doi.org/10.1505/146554815815834840

APG - Angiosperm Phylogeny Group. (2016). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. *Botanical Journal of the Linnean Society, 181*, 1-20. https://doi.org/10.1111/boj.12385

Araújo, F. C., & Santos, R. M. (2019). Different degrees of water-related stress affect evolutionary diversity in a seasonally dry biome. *Oecologia, 189(3),* 795-802. https://doi.org/10.1007/s00442-019-04358-4

Bellingham, P. J., & Sparrow, A. D. (2000). Resprouting as a life history strategy in woody plant communities. *Oikos, 89(2),* 409–416. https://doi.org/10.1034/j.1600-0706.2000.890224.x

Bond, W. J., & Midgley, J. J. (2001). Ecology of sprouting in woody plants: the persistence niche. *Trends in ecology & evolution, 16(1),* 45-51. https://doi.org/10.1016/S0169-5347(00)02033-4

Bond, W. J., & Midgley, J. J. (2003). The evolutionary ecology of sprouting in woody plants. *International Journal of Plant Sciences, 164(S3),* S103-S114. https://www.jstor.org/stable/10.1086/374191

Borges, R., Machado, J. P., Gomes, C., Rocha, A. P., & Antunes, A. (2019). Measuring phylogenetic signal between categorical traits and phylogenies. *Bioinformatics, 35(11)*, 1862-1869. https://doi.org/10.1093/bioinformatics/bty800

Cadotte, M. W., & Tucker, C. (2017). Should environmental filtering be abandoned?. *Trends in ecology & evolution, 32(6)*, 429-437. https://doi.org/10.1016/j.tree.2017.03.004

Carvalho, G. (2016). flora: Tools for Interacting with the Brazilian Flora 2020. R package version 0.3.1. http://www.github.com/gustavobio/flora

Ceccon, E., Huante, P., & Rincón, E. (2006). Abiotic factors influencing tropical dry forests regeneration. *Brazilian archives of Biology and Technology, 49(2),* 305-312. https://doi.org/10.1590/S1516-89132006000300016

Chave, J., Rejou-Mechain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B. C., … Vieilledent, G. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. *Global Change Biology, 20(10),* 3177– 3190. https://doi.org/10.1111/gcb.12629

Clarke, P. J., Lawes, M. J., Midgley, J. J., Lamont, B. B., Ojeda, F., Burrows, G. E., … Knox, K. J. (2013). Resprouting as a key functional trait: how buds, protection and resources drive persistence after fire. *New Phytologist*, *197(1),* 19-35. https://doi.org/10.1111/nph.12001

Crisp, M. D., & Cook, L. G. (2012). Phylogenetic niche conservatism: What are the underlying evolutionary and ecological causes? *New Phytologist, 196(3),* 681–694. https://doi.org/10.1111/j.1469-8137.2012.04298.x

Coelho de Souza, F., Dexter, K. G., Phillips, O. L., Brienen, R. J., Chave, J., Galbraith, D. R., ... & Alexiades, M. (2016). Evolutionary heritage influences Amazon tree ecology. Proceedings of the Royal Society B: *Biological Sciences, 283(1844)*, 20161587. http://dx.doi.org/10.1098/rspb.2016.1587

Dantas, V. L., & Pausas, J. G. (2020). Megafauna biogeography explains plant functional trait variability in the tropics. *Global Ecology and Biogeography, 29(8)*, 1288-1298. https://doi.org/10.1111/geb.13111

Diaz, S., Cabido, M., Casanoves, F. (1998). Plant functional traits and environmental filters at a regional scale. *Journal of vegetation science, 9(1),* 113-122. https://doi.org/10.2307/3237229

Doughty, C. E. (2017). Herbivores increase the global availability of nutrients over millions of years. *Nature Ecology and Evolution, 1,* 1820–1827. https://doi.org/10.1038/s41559-017-0341-1

Doughty, C. E., Faurby, S., & Svenning, J. C. (2016). The impact of the megafauna extinctions on savanna woody cover in South America. *Ecography, 39(2),* 213-222. https://doi.org/10.1111/ecog.01593

DRYFLOR. (2016). Plant diversity patterns in neotropical dry forests and their conservation implications. *Science, 353(6306),* 1383-1387. https://doi.org/10.1126/science.aaf5080

Fernandes, M. F., Cardoso, D. & Queiroz, L. P. (2020). An updated plant checklist of the Brazilian Caatinga seasonally dry forests and woodlands reveals high species richness and endemism. *Journal of Arid Environments, 174*, 104079.

Fick, S. E., & Hijmans, R. J. (2017). WorldClim 2: new 1‐km spatial resolution climate surfaces for global land areas. *International journal of climatology, 37(12*), 4302-4315.. https://doi.org/10.1002/joc.5086

Flora do Brasil 2020 em construção. (2020) Jardim Botânico do Rio de Janeiro. Disponível em: < http://floradobrasil.jbrj.gov.br/ >. Acesso em: 01 Jan. 2021

Freckleton, R. P., Harvey, P. H., & Pagel, M. (2002). Phylogenetic Analysis and Comparative Data : A test and review of evidence. *The American Naturalist, 160(6)*, 712–726. https://www.jstor.org/stable/10.1086/343873

Fritz, S. A., & Purvis, A. (2010). Selectivity in mammalian extinction risk and threat types: a new measure of phylogenetic signal strength in binary traits. *Conservation Biology, 24(4),* 1042-1051. https://doi.org/10.1111/j.1523-1739.2010.01455.x

Fowler, M. W., Deng, X., Lamont, B. B., & He, T. (2018). Resprouters, assisted by somatic mutations, are as genetically diverse as nonsprouters in the world's fire-prone ecosystems. *Acta Oecologica, 92*, 1-6. https://doi.org/10.1016/j.actao.2018.07.006

Fyllas, N. M., Patiño, S., Baker, T. R., Bielefeld Nardoto, G., Martinelli, L. A., Quesada, C. A., ... & Lloyd, J. (2009). Basin-wide variations in foliar properties of Amazonian forest:

phylogeny, soils and climate. *Biogeosciences*, *6*, 2677-2708. https://doi.org/10.5194/bg-6-2677-2009

Grubb, P. (1977). The maintenance of species richness in plant communities: the importance of the regeneration niche. *Biological Reviews, 52(1),* 107–145. https://doi.org/10.1111/j.1469-185X.1977.tb01347.x

Harmon, L. J., Weir, J. T., Brock, C. D., Glor, R. E., & Challenger, W. (2008). GEIGER: Investigating evolutionary radiations. *Bioinformatics, 24(1),* 129–131. https://doi.org/10.1093/bioinformatics/btm538

IPCC. (2014). Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, London.

Jain, A. K. (2010). Data clustering: 50 years beyond K-means. *Pattern recognition letters, 31*, 651-666. https://doi.org/10.1016/j.patrec.2009.09.011

Jimenez-Rodríguez, D. L., Alvarez-Añorve, M. Y., Pineda-Cortes, M., Flores-Puerto, J. I., Benítez-Malvido, J., Oyama, K., & Avila-Cabadilla, L. D. (2018). Structural and functional traits predict short term response of tropical dry forests to a high intensity hurricane. *Forest ecology and management*, *426*, 101-114. https://doi.org/10.1016/j.foreco.2018.04.009

Knox, K. J. E., Clarke, P. J. (2005). Nutrient availability induces contrasting allocation and starch formation in resprouting and obligate seeding shrubs. *Functional Ecology, 19(4)*, 690–698. https://doi.org/10.1111/j.1365-2435.2005.01006.x

Kodinariya, T. M., Makwana, P. (2013). Review on determining number of Cluster in K-Means Clustering. *International Journal, 1*, 90-95.

Lamont, B. B., Enright, N. J., & He, T. (2011). Fitness and evolution of resprouters in relation to fire. *Plant Ecology, 212(12)*, 1945-1957. https://doi.org/10.1007/s11258-011-9982-3

Lasso, E., Engelbrecht, B. M. J., & Dalling, J. W. (2009). When sex is not enough: ecological correlates of resprouting capacity in congeneric tropical forest shrubs. *Oecologia, 161(1)*, 43-56. https://doi.org/10.1007/s00442-009-1353-6

Levin, D. A. (1990). The seed bank as a source of genetic novelty in plants. American *Naturalist, 135(4)*, 563–572. https://doi.org/10.1086/285062

Molina-Venegas, R., & Rodríguez, M. (2017). Revisiting phylogenetic signal; strong or negligible impacts of polytomies and branch length information? *BMC Evolutionary Biology, 17*, 1–10. https://doi.org/10.1186/s12862-017-0898-y

Moreira, B., Tormo, B., & Pausas, J. G. (2012). To resprout or not to resprout: factors driving intraspecific variability in resprouting. *Oikos, 121(10),* 1577-1584. https://doi.org/10.1111/j.1600-0706.2011.20258.x

Moro, M. F., Lughadha, E. N., Filer, D. L., Araujo, F. S., & Martins, F. R. (2014). A catalogue of the vascular plants of the Caatinga Phytogeographical Domain: a synthesis of floristic and phytosociological surveys. *Phytotaxa, 160(1),* 001-118. http://dx.doi.org/10.11646/phytotaxa.160.1.1

Neves, D. M., Dexter, K. G., Baker, T. R., Coelho de Souza, F., Oliveira-Filho, A. T., Queiroz, L. P., ... & Pennington, R. T. (2020). Evolutionary diversity in tropical tree communities peaks at intermediate precipitation. *Scientific Reports, 10(1),* 1-7. http://dx.doi.org/10.1038/s41598-019-55621-w

Nzunda, E. F., & Lawes, M. J. (2011). Costs of resprouting are traded off against reproduction in subtropical coastal dune forest trees. *Plant Ecology, 212(12),* 1991-2001. https://doi.org/10.1007/s11258-011-9991-2

Oliveras, I., Bentley, L., Fyllas, N. M., Gvozdevaite, A., Shenkin, A. F., Prepah, T., ... & Malhi, Y. (2020). The influence of taxonomy and environment on leaf trait variation along tropical abiotic gradients. *Frontiers in Forests and Global Change, 3,* 18. https://doi.org/10.3389/ffgc.2020.00018

Orme, D., Freckleton, F.P., Thomas, G.H., Petzoldt, T., Fritz, S., Isaac, N. & Pearse, W. (2020) The Caper package: comparative analysis of phylogenetics and evolution in R. Available at: http://cran.r-project.org/web/packages/caper.

Pagel, M. (1999). Inferring the historical patterns of biological evolution. *Nature, 401*, 877–884. https://doi.org/10.1038/44766

Paradis, E., Claude, J., & Strimmer, K. (2004). APE: Analyses of phylogenetics and evolution in R language. *Bioinformatics, 20,* 289–290. https://doi.org/10.1093/bioinformatics/btg412

Paula, G. G. P., Santos, R. M., Menino, G. C. D. O., Apgaua, D. M. G., Pereira, D. G. S., Souza, C. R., & Fontes, M. A. L. (2018). Influence of environmental variations on the formation of microhabitats within a fragment of Seasonally Dry Tropical Forest-SDTF, Brazil. *Revista Árvore, 42(2),* e420211. https://doi.org/10.1590/1806-90882018000200011

Pausas, J. G., Pratt, R. B., Keeley, J. E., Jacobsen, A. L., Ramirez, A. R., Vilagrosa, A., ... & Davis, S. D. (2016). Towards understanding resprouting at the global scale. *New Phytologist, 209(3),* 945-954. https://doi.org/10.1111/nph.13644

Pausas, J. G., & Keeley, J. E. (2014). Evolutionary ecology of resprouting and seeding in fireprone ecosystems. *New Phytologist, 204(1),* 55–65. https://doi.org/10.1111/nph.12921

Pennington, R. T., Lavin, M., & Oliveira-Filho, A. T. (2009). Woody plant diversity, evolution, and ecology in the tropics: perspectives from seasonally dry tropical forests. *Annual Review of Ecology, Evolution, and Systematics, 40,* 437-457. https://doi.org/10.1146/annurev.ecolsys.110308.120327

Poorter, L., Kitajima, K., Mercado, P., Chubina, J., Melgar, I., & Prins, H. H. (2010). Resprouting as a persistence strategy of tropical forest trees: relations with carbohydrate storage and shade tolerance. *Ecology, 91(9)*, 2613-2627. https://doi.org/10.1890/09-0862.1

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Revell, L.J. (2012) phytools: An R package for phylogenetic comparative biology (and other things). *Methods in Ecology and Evolution*, *3*, 217–223. https://doi.org/10.1111/j.2041-210X.2011.00169.x

Santos, R. M., Oliveira-Filho, A. T., Eisenlohr, P. V., Queiroz, L. P., Cardoso, D. B. O. S., & Rodal, M. J. N. (2012). Identity and relationships of the Arboreal Caatinga among other floristic units of seasonally dry tropical forests (SDTFs) of north-eastern and Central Brazil. *Ecology and Evolution, 2(2)*, 409–428. https://doi.org/10.1002/ece3.91

Schwilk, D. W., & Ackerly, D. (2005). Is there a cost to resprouting? Seedling growth rate and drought tolerance in sprouting and nonsprouting Ceanothus (Rhamnaceae). *American Journal of Botany, 92(3)*, 404-410. https://doi.org/10.3732/ajb.92.3.404

Souchie, F. F., Pinto, J. R. R., Lenza, E., Gomes, L., Maracahipes-Santos, L., & Silvério, D. V. (2017). Post-fire resprouting strategies of woody vegetation in the Brazilian savanna. *Acta Botanica Brasilica, 31(2)*, 260-266. https://doi.org/10.1590/0102-33062016abb0376

Souza, C. R., Morel, J. D., Santos, A. B. M., Silva, W. B., Maia, V. A., Coelho, P. A., ... & Santos, R. M. (2019). Small-scale edaphic heterogeneity as a floristic–structural complexity driver in Seasonally Dry Tropical Forests tree communities. *Journal of Forestry Research 2019*, 1-11. https://doi.org/10.1007/s11676-019-01013-9

Verdu´, M. (2000). Ecological and evolutionary differences between Mediterranean seeders and resprouters. *Journal of Vegetation Science, 11(2)*, 265–268. https://www.jstor.org/stable/3236806

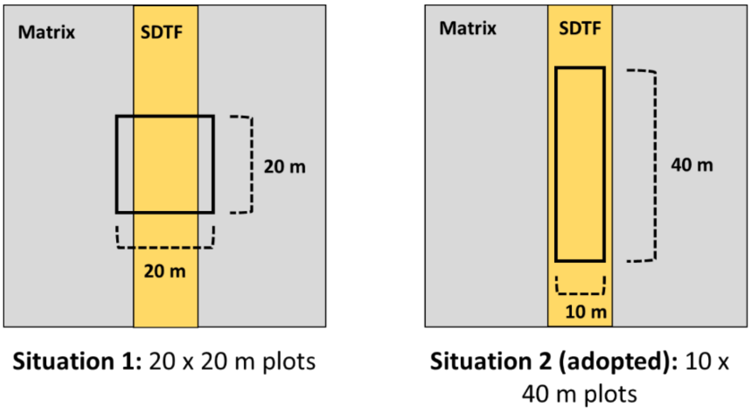
Vesk, P. A., & Westoby, M. (2004). Sprouting ability across diverse disturbances and vegetation types worldwide. *Journal of Ecology, 92 (2)*, 310-320. https://doi.org/10.1111/j.0022-0477.2004.00871.x

Zeppel, M. J. B., Harrison, S. P., Adams, H. D., Kelley, D. I., Li, G., Tissue, D. T., Palmer, A., & McDowell, N. G. (2015). Drought and resprouting plants. *New Phytologist, 206(2)*, 583–589. https://doi.org/10.1111/nph.13205

Supplementary Material
Material and Methods support information

Table S1: Basic information about the tropical dry forests sites used in this paper. Here are presented the site code in ForestPlots.net system (FP code), the internal site name considered by the authors, the spatial information of latitude (Lat), Longitude (Long) and city the site is inside, the number of plots existent in each site (N plots) and some reference about each site where more information may be found.

FP code	Site	Lat	Long	City	N plots	Reference
CTT-02	*Guanambi*	-13.9799	-42.8745	Guanambi (BA)	15	Apgaua et al. (2015)
CTT-01	*Caetité*	-14.1207	-42.4537	Caetité (BA)	15	Apgaua et al. (2015)
DEC-04	*ECM*	-14.2663	-44.1068	Juvenília (MG)	5	Santos et al. (2007)
BAH-04	*Juv Areia*	-14.3269	-43.9913	Juvenília (MG)	27	Souza et al. (2019)
IUI-01	*Iuiu*	-14.3410	-43.5461	Iuiu (BA)	15	Apgaua et al. (2015)
BAH-05	*Juv Calcário*	-14.3896	-43.9768	Juvenília (MG)	20	Aguiar-Campos et al. (2020)
DEC-01	*Vale Verde*	-14.4138	-44.1627	Juvenília (MG)	20	Santos et al. (2011)
DEC-05	*Pedra Preta*	-14.4315	-44.4911	Montalvânia (MG)	5	Santos et al. (2007)
MON-01	*Furados*	-14.4401	-44.4246	Montalvânia (MG)	25	Paula et al. (2018)
BAH-07	*Mata da Serra*	-14.4705	-44.1884	Juvenília (MG)	51	Apgua et al. (2014)
DEC-06	*Lapinha*	-14.4919	-44.1841	Juvenília (MG)	12	Santos et al. (2007)
DEC-03	*Poço da Jia*	-14.5447	-44.2105	Juvenília (MG)	10	Reis et al. (2018)
PNP-02	*Peruaçu CA*	-15.0583	-44.2069	Itacarambi (MG)	25	Apgaua et al. (2015)
PNP-01	*Peruaçu MH*	-15.1208	-44.2273	Itacarambi (MG)	23	Apgaua et al. (2015)
BON-01	*Bonito de Minas*	-15.3116	-44.7349	Bonito de Minas (MG)	15	Apgaua et al. (2015)
DEC-02	*Agropop*	-15.5502	-44.7010	Bonito de Minas (MG)	30	Reis et al. (2017)



Situation 1: 20 x 20 m plots

Situation 2 (adopted): 10 x 40 m plots

Figure S1: Scheme of how we sampled seasonally tropical dry forests (TDF). When TDF occurred in narrow patches within a matrix of another vegetation type, we opted to use the 10 x 40 m dimensions (instead of 20 x 20 m), to ensure that we collected TDF data only.

K-means clustering

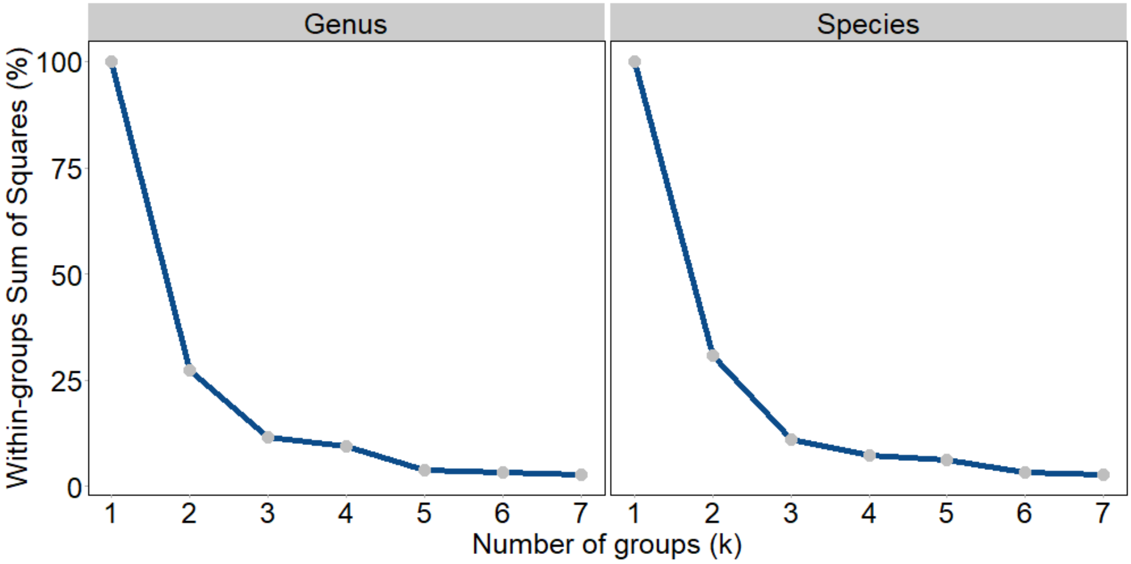


Figure S2: Within-groups Sum Squares obtained for each k-value in classification of genus and species with the K-means algorithm according to the resprouting frequency in the 16 fragments of Seasonally Dry Tropical Forest used in this study. This result was used to define the optimum k-value, according to the "Elbow method".

Table S2: Center values of resprouting frequency (%) for each group of genus and species obtained by the K-means algorithm.

Group	Genus	Species
Non-resprouters	0 %	0 %
Low-frequency resprouters	17.19 %	16.44 %
Medium-frequency resprouters	40.28 %	42.01 %
High-frequency resprouters	72.71 %	76.20 %

About the Above-Ground Woody Biomass obtaining

We obtained the Above Ground Soil Biomass (AGWB - ton) for each stem using the Chave et al. (2014) pantropical equation, modified for situations of absence of height data. We used the *computeAGB* function of the *BIOMASS* package (Rejou-Mechain et al., 2017), based on the DAP variables of each stem (cm), on the density of the wood (Global Wood density database) and the E measure of restriction to compensate the lack of height information through its relationship with climatic stress. Although its applicability in other vegetation types still presents uncertainties (it was developed for RainForest), we opted for its use due to the equation adding information to the classic approach of adopting the basal area as a measure of biomass, which considers all species in all sites as equivalent in their contribution to total biomass.

Relation between resprouting and climatic variables

The two resprouting variables did not present significant values of correlation with the variables mean annual precipitation (MAP – mm) and with climatic water deficit (CWD). Resprouting frequency presented correlation values of r = - 0.18 for MAP r = -0.16 for CWD, while average stems per tree present values of correlation of r = 0.073 for MAP and r = 0.078 for CWD (Figure S3).

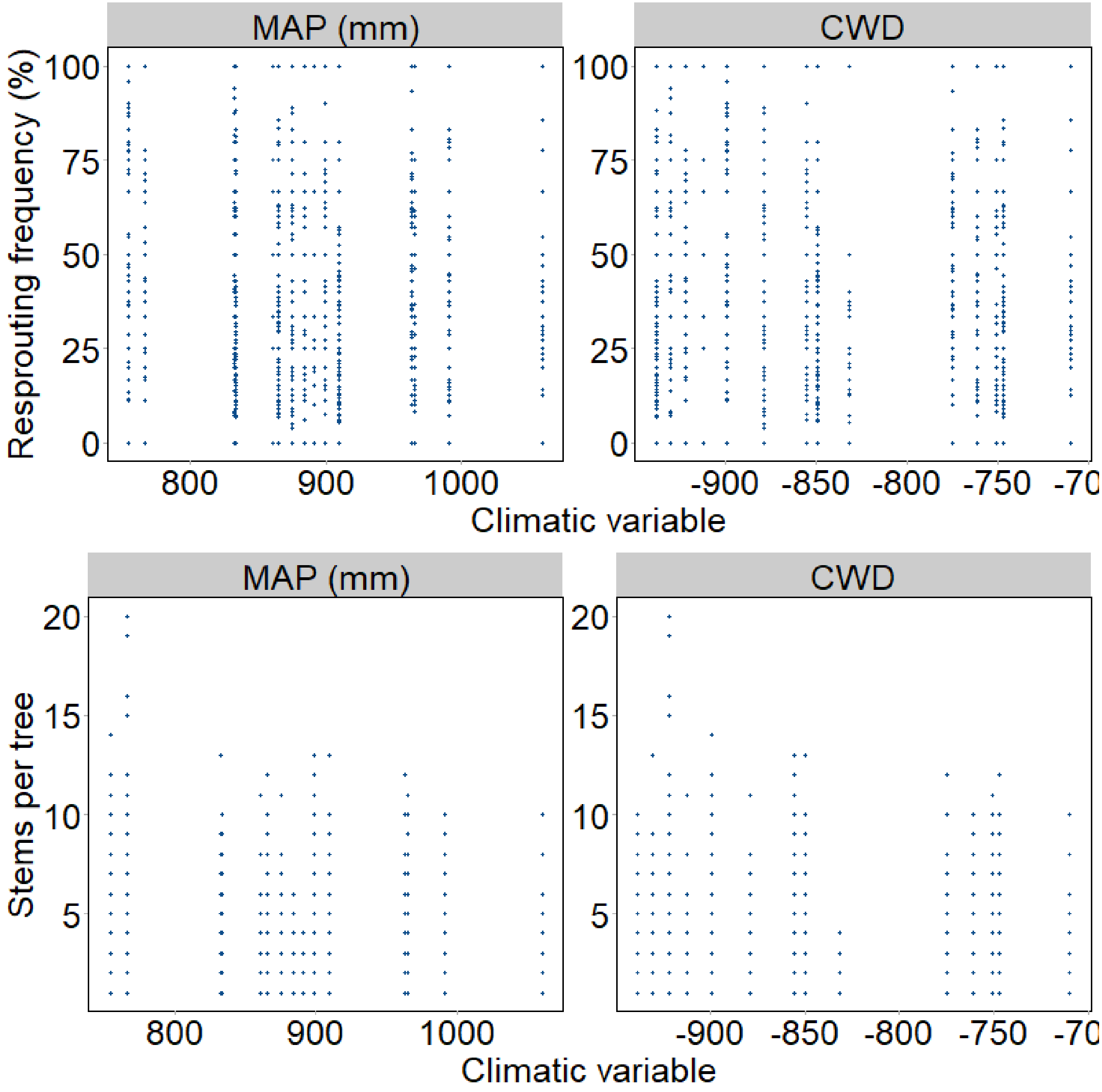


Figure S3: Scatter plot for resprouting variables (resprouting frequency and average stems per tree) in relation to climatic variables (mean annual precipitation -MAP; and climatic water deficit – CWD) for the 16 fragments of tropical dry forests used in this study.

Detailed results

Table S3: Values of representativity (%) of Resprouting categories in number of taxa, trees, stems and above-ground woody biomass (AGWB) for the 16 fragments of tropical dry forests used in this study. These values were used to obtain the Figure 3.

Level	Categories	Taxa	Trees	Stems	AGWB
Genus	Non-resprouter	3.51	1.01	0.62	10.45
	Low-frequency	44.74	42.53	33.41	58.12
	Medium-frequency	35.09	48.92	52.09	29.21
	High-frequency	16.67	7.53	13.88	2.22
Species	Non-resprouter	3.59	1.27	0.78	10.81
	Low-frequency	48.50	43.46	32.96	57.88
	Medium-frequency	34.73	47.73	51.87	28.68
	High-frequency	13.17	7.54	14.39	2.63

Table S4: Basic data of number of stems, trees, resprouted trees, above-ground woody biomass (AGWB), average stems per tree, resprouting frequency (%) and resprouting categories for the 321 species sampled in the 16 fragments of tropical dry forests.

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Anacardiaceae	*Astronium fraxinifolium* Schott	42	38	4	5.46	1.11	10.53	Low-frequency
Anacardiaceae	*Cyrtocarpa caatingae* J.D.Mitch. & Daly	93	69	19	10.25	1.35	27.54	Low-frequency
Anacardiaceae	*Myracrodruon urundeuva* Allemão	743	624	91	285.35	1.19	14.58	Low-frequency
Anacardiaceae	*Schinopsis brasiliensis* Engl.	141	130	11	35.77	1.08	8.46	Low-frequency
Anacardiaceae	*Spondias mombin* L.	12	10	2	2.05	1.20	20.00	Low-frequency
Anacardiaceae	*Spondias tuberosa* Arruda	67	23	18	5.27	2.91	78.26	High-frequency
Anacardiaceae	*Spondias venulosa* (Engl.) Engl.	11	10	1	2.58	1.10	10.00	Low-frequency
Annonaceae	*Annona leptopetala* (R.E.Fr.) H.Rainer	136	68	38	0.50	2.00	55.88	Medium-frequency
Annonaceae	*Annona vepretorum* Mart.	124	42	33	3.33	2.95	78.57	High-frequency
Annonaceae	*Duguetia reticulata* Maas	1	1	0	0.01	1.00	0.00	Not classified
Apocynaceae	*Aspidosperma cuspa* (Kunth) S.F.Blake ex Pittier	20	16	2	1.51	1.25	12.50	Low-frequency
Apocynaceae	*Aspidosperma cylindrocarpon* Müll.Arg.	4	4	0	2.77	1.00	0.00	Not classified
Apocynaceae	*Aspidosperma multiflorum* A.DC.	81	69	10	8.68	1.17	14.49	Low-frequency
Apocynaceae	*Aspidosperma polyneuron* Müll.Arg.	8	8	0	0.77	1.00	0.00	Not classified
Apocynaceae	*Aspidosperma pyrifolium* Mart.	320	160	69	7.28	2.00	43.13	Medium-frequency
Apocynaceae	*Aspidosperma subincanum* Mart. ex A.DC.	56	43	10	2.27	1.30	23.26	Low-frequency
Araliaceae	*Aralia warmingiana* (Marchal) J.Wen	65	56	7	6.38	1.16	12.50	Low-frequency
Araliaceae	*Lachesiodendron viridiflorum* (Kunth) P.G. Ribeiro, L.P. Queiroz & Luckow.	43	22	11	6.12	1.95	50.00	Medium-frequency
Arecaceae	*Syagrus oleracea* (Mart.) Becc.	63	63	0	8.83	1.00	0.00	Non-resprouter
Bignoniaceae	*Fridericia bahiensis* (Schauer) L.G.Lohmann	285	212	53	7.33	1.34	25.00	Low-frequency
Bignoniaceae	*Handroanthus chrysotrichus* (Mart. ex DC.) Mattos	31	29	2	8.30	1.07	6.90	Low-frequency
Bignoniaceae	*Handroanthus heptaphyllus* (Vell.) Mattos	32	28	3	2.52	1.14	10.71	Low-frequency
Bignoniaceae	*Handroanthus impetiginosus* (Mart. ex DC.) Mattos	240	211	22	42.86	1.14	10.43	Low-frequency
Bignoniaceae	*Handroanthus ochraceus* (Cham.) Mattos	1651	1325	237	101.95	1.25	17.89	Low-frequency
Bignoniaceae	*Handroanthus selachidentatus* (A.H.Gentry) S.O.Grose	29	24	4	0.39	1.21	16.67	Low-frequency
Bignoniaceae	*Handroanthus serratifolius* (Vahl) S.O.Grose	49	32	9	2.63	1.53	28.13	Low-frequency
Bignoniaceae	*Handroanthus spongiosus* (Rizzini) S.O.Grose	516	307	135	35.50	1.68	43.97	Medium-frequency
Bignoniaceae	*Jacaranda brasiliana* (Lam.) Pers.	21	14	2	2.83	1.50	14.29	Low-frequency
Bignoniaceae	*Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex S.Moore	3	3	0	0.92	1.00	0.00	Not classified
Bignoniaceae	*Tabebuia reticulata* A.H.Gentry	661	282	152	26.33	2.34	53.90	Medium-frequency

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Bignoniaceae	*Tabebuia roseoalba* (Ridl.) Sandwith	46	34	8	1.35	1.35	23.53	Low-frequency
Bignoniaceae	*Zeyheria tuberculosa* (Vell.) Bureau ex Verl.	26	21	4	3.50	1.24	19.05	Low-frequency
Bixaceae	*Cochlospermum vitifolium* (Willd.) Spreng.	31	27	4	0.45	1.15	14.81	Low-frequency
Boraginaceae	*Cordia glabrata* (Mart.) A.DC.	2	2	0	0.03	1.00	0.00	Not classified
Boraginaceae	*Cordia incognita* Gottschling & J.S.Mill	126	69	34	2.23	1.83	49.28	Medium-frequency
Boraginaceae	*Cordia oncocalyx* Allemão	75	52	12	2.86	1.44	23.08	Low-frequency
Boraginaceae	*Cordia trichotoma* (Vell.) Arráb. ex Steud.	9	9	0	0.20	1.00	0.00	Not classified
Burseraceae	*Commiphora leptophloeos* (Mart.) J.B.Gillett	507	335	106	94,56	1.51	31.64	Medium-frequency
Cactaceae	*Cereus albicaulis* (Britton & Rose) Luetzelb.	1	1	0	0.02	1.00	0.00	Not classified
Cactaceae	*Cereus jamacaru* DC.	60	41	10	3.75	1.46	24.39	Low-frequency
Cactaceae	*Pereskia bahiensis* Gürke	300	93	73	10.23	3.23	78.49	High-frequency
Cactaceae	*Pilosocereus gounellei (*F.A.C.Weber ex K.Schum.) Byles & G.D.Rowley	386	140	80	15.20	2.76	57.14	Medium-frequency
Cactaceae	*Pilosocereus pachycladus* F. Ritter	168	86	33	4.91	1.95	38.37	Medium-frequency
Cactaceae	*Quiabentia zehntneri* (Britton & Rose) Britton & Rose	22	8	7	0.09	2.75	87.50	Not classified
Calophyllaceae	*Kielmeyera rubriflora* Cambess.	1	1	0	0.02	1.00	0.00	Not classified
Calophyllaceae	*Kielmeyera speciosa* A. St.-Hil.	1	1	0	0.00	1.00	0.00	Not classified
Cannabaceae	*Celtis brasiliensis* (Gardner) Planch.	15	5	5	0.16	3.00	100.00	Not classified
Cannabaceae	*Celtis ehrenbergiana* (Jacq.) Sarg.	4	2	2	0.04	2.00	100.00	Not classified
Cannabaceae	*Celtis iguanaea* (Jacq.) Sarg.	12	10	2	0.10	1.20	20.00	Low-frequency
Capparaceae	*Cynophalla flexuosa* (L.) J.Presl	112	24	21	0.70	4.67	87.50	High-frequency
Capparaceae	*Cynophalla hastata* (Jacq.) J.Presl	33	8	6	0.32	4.13	75.00	Not classified
Caricaceae	*Jacaratia corumbensis* Kuntze	23	12	6	0.02	1.92	50.00	Medium-frequency
Caricaceae	*Jacaratia spinosa* (Aubl.) A.DC.	1	1	0	0.00	1.00	0.00	Not classified
Celastraceae	*Fraunhofera multiflora* Mart.	48	38	7	4.81	1.26	18.42	Low-frequency
Celastraceae	*Maytenus gonoclada* Mart.	2	1	1	0.00	2.00	100.00	Not classified
Celastraceae	*Maytenus robusta* Reissek	1	1	0	0.00	1.00	0.00	Not classified
Celastraceae	*Monteverdia quadrangulata* (Schrad.) Biral	58	11	9	0.28	5.27	81.82	High-frequency
Celastraceae	*Monteverdia rigida* (Mart.) Biral.	40	8	6	1.53	5.00	75.00	Not classified
Celastraceae	*Salacia crassifolia* (Mart. ex Schult.) G. Don	1	1	0	0.30	1.00	0.00	Not classified
Celastraceae	*Salacia elliptica* (Mart.) G.Don	6	1	1	0.03	6.00	100.00	Not classified
Celastraceae	*Salacia grandifolia* (Mart.) G. Don	25	5	5	0.44	5.00	100.00	Not classified
Combretaceae	*Buchenavia oxycarpa* (Mart.) Eichler	1	1	0	0.00	1.00	0.00	Not classified

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Combretaceae	*Buchenavia tetraphylla* (Aubl.) R.A.Howard	2	1	1	0.01	2.00	100.00	Not classified
Combretaceae	*Combretum duarteanum* Cambess.	1649	970	396	36.24	1.70	40.82	Medium-frequency
Combretaceae	*Combretum leprosum* Mart.	665	446	148	15.89	1.49	33.18	Medium-frequency
Combretaceae	*Combretum mellifluum* Eichler	14	8	3	1.32	1.75	37.50	Not classified
Combretaceae	*Terminalia argentea* Mart.	3	3	0	0.89	1.00	0.00	Not classified
Combretaceae	*Terminalia fagifolia* Mart.	66	23	18	2.15	2.87	78.26	High-frequency
Combretaceae	*Terminalia phaeocarpa Eichler*	72	60	10	3.75	1.20	16.67	Low-frequency
Dilleniaceae	*Curatella americana* L.	1	1	0	0.05	1.00	0.00	Not classified
Ebenaceae	*Diospyros lasiocalyx* (Mart.) B.Walln.	1	1	0	0.28	1.00	0.00	Not classified
Elaeocarpaceae	*Sloanea guianensis* (Aubl.) Benth.	2	1	1	0.01	2.00	100.00	Not classified
Erythroxylaceae	*Erythroxylum betulaceum* Mart.	87	38	25	0.78	2.29	65.79	High-frequency
Erythroxylaceae	*Erythroxylum caatingae* Plowman	37	16	12	0.18	2.31	75.00	High-frequency
Erythroxylaceae	*Erythroxylum nummularium* Peyr.	1	1	0	0.00	1.00	0.00	Not classified
Erythroxylaceae	*Erythroxylum revolutum* Mart.	50	20	14	0.33	2.50	70.00	High-frequency
Euphorbiaceae	*Adelia membranifolia* (Müll.Arg.) Chodat & Hassl.	3	3	0	0.03	1.00	0.00	Not classified
Euphorbiaceae	*Cnidoscolus bahianus* (Ule) Pax & K.Hoffm.	189	60	44	0.97	3.15	73.33	High-frequency
Euphorbiaceae	*Cnidoscolus oligandrus* (Müll.Arg.) Pax	199	110	34	11.59	1.81	30.91	Medium-frequency
Euphorbiaceae	*Cnidoscolus urens* (L.) Arthur	4	1	1	0.00	4.00	100.00	Not classified
Euphorbiaceae	*Croton blanchetianus* Baill.	348	97	88	0.30	3.59	90.72	High-frequency
Euphorbiaceae	*Croton tricolor* Klotzsch ex Baill.	2	2	0	0.00	1.00	0.00	Not classified
Euphorbiaceae	*Croton urticifolius* Lam.	100	31	27	0.06	3.23	87.10	High-frequency
Euphorbiaceae	*Jatropha mollissima* (Pohl) Baill.	66	59	4	0.11	1.12	6.78	Low-frequency
Euphorbiaceae	*Manihot anomala* Pohl	13	10	3	0.04	1.30	30.00	Medium-frequency
Euphorbiaceae	*Manihot brachyloba* Müll.Arg.	1	1	0	0.00	1.00	0.00	Not classified
Euphorbiaceae	*Manihot caerulescens* Pohl	61	44	9	0.28	1.39	20.45	Low-frequency
Euphorbiaceae	*Manihot dichotoma* Ule	4	3	1	0.02	1.33	33.33	Not classified
Euphorbiaceae	*Manihot tripartita* (Spreng.) Müll.Arg.	11	7	3	0.05	1.57	42.86	Not classified
Euphorbiaceae	*Sapium argutum* (Müll.Arg.) Huber	188	175	13	1.30	1.07	7.43	Low-frequency
Euphorbiaceae	*Sapium glandulosum* (L.) Morong	8	6	1	0.32	1.33	16.67	Not classified
Euphorbiaceae	*Sapium obovatum* Klotzsch ex Müll.Arg.	8	8	0	0.11	1.00	0.00	Not classified
Euphorbiaceae	*Stillingia saxatilis* Müll.Arg.	182	142	33	1.45	1.28	23.24	Low-frequency
Fabaceae	*Acosmium cardenasii* H.S.Irwin & Arroyo	18	7	6	0.22	2.57	85.71	Not classified

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Fabaceae	*Acosmium lentiscifolium* Schott	85	64	16	5.79	1.33	25.00	Low-frequency
Fabaceae	*Albizia polycephala* (Benth.)Killip	8	8	0	1.25	1.00	0.00	Not classified
Fabaceae	*Amburana cearensis* (Allemao)A.C.Sm.	83	51	20	5.52	1.63	39.22	Medium-frequency
Fabaceae	*Anadenanthera colubrina* (Vell.)Brenan	300	257	35	63.49	1.17	13.62	Low-frequency
Fabaceae	*Anadenanthera peregrina* (L.)Speg.	166	86	40	12.67	1.93	46.51	Medium-frequency
Fabaceae	*Bauhinia acuruana* Moric.	25	17	6	0.06	1.47	35.29	Medium-frequency
Fabaceae	*Bauhinia catingae* Harms	21	14	5	0.11	1.50	35.71	Medium-frequency
Fabaceae	*Bauhinia cheilantha* (Bong.)Steud.	70	56	13	1.50	1.25	23.21	Low-frequency
Fabaceae	*Bauhinia forficata* Link	81	44	21	0.42	1.84	47.73	Medium-frequency
Fabaceae	*Bauhinia rufa (*Bong.)Steud.	42	33	7	0.40	1.27	21.21	Low-frequency
Fabaceae	*Blanchetiodendron blanchetii* (Benth.)Barneby & J.W.Grimes	27	20	4	4.48	1.35	20.00	Low-frequency
Fabaceae	*Calliandra foliolosa* Benth.	614	230	154	6.11	2.67	66.96	High-frequency
Fabaceae	*Calliandra macrocalyx* Harms	3	1	1	0.01	3.00	100.00	Not classified
Fabaceae	*Cassia ferruginea* (Schrad.)DC.	8	6	1	0.90	1.33	16.67	Not classified
Fabaceae	*Cenostigma macrophyllum* Tul.	301	97	68	9.00	3.10	70.10	High-frequency
Fabaceae	*Cenostigma pluviosa* (DC.) L.P.Queiroz.	21	17	3	0.65	1.24	17.65	Low-frequency
Fabaceae	*Centrolobium sclerophyllum* H.C.Lima	6	2	2	0.01	3.00	100.00	Not classified
Fabaceae	*Chloroleucon acacioides* (Ducke)Barneby & J.W.Grimes	2	2	0	0.06	1.00	0.00	Not classified
Fabaceae	*Chloroleucon dumosum* (Benth.)G.P.Lewis	34	12	9	0.82	2.83	75.00	High-frequency
Fabaceae	*Chloroleucon foliolosum* (Benth.)G.P.Lewis	1	1	0	0.01	1.00	0.00	Not classified
Fabaceae	*Copaifera cearensis* Ducke	3	3	0	0.98	1.00	0.00	Not classified
Fabaceae	*Copaifera langsdorffii* Desf.	1	1	0	0.00	1.00	0.00	Not classified
Fabaceae	*Copaifera martii* Hayne.	7	7	0	0.07	1.00	0.00	Not classified
Fabaceae	*Coursetia rostrata* Benth.	97	77	10	1.83	1.26	12.99	Low-frequency
Fabaceae	*Dalbergia acuta* Benth.	303	146	61	8.00	2.08	41.78	Medium-frequency
Fabaceae	*Dalbergia cearensis* Ducke	98	56	21	3.37	1.75	37.50	Medium-frequency
Fabaceae	*Dalbergia foliolosa* Benth.	1	1	0	0.01	1.00	0.00	Not classified
Fabaceae	*Dalbergia frutescens (*Vell.)Britton	1	1	0	0.03	1.00	0.00	Not classified
Fabaceae	*Deguelia nitidula* (Benth.) A.M.G. Azevedo & R.A. Camargo	20	16	3	0.79	1.25	18.75	Low-frequency
Fabaceae	*Diplotropis ferruginea* Benth.	2	2	0	0.45	1.00	0.00	Not classified
Fabaceae	*Enterolobium contortisiliquum* (Vell.)Morong	15	12	2	2.77	1.25	16.67	Low-frequency
Fabaceae	*Enterolobium timbouva* Mart.	1	1	0	0.00	1.00	0.00	Not classified

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Fabaceae	*Erythrina velutina* Willd.	12	7	2	0.80	1.71	28.57	Not classified
Fabaceae	*Erythrina verna* Vell.	274	203	50	85.82	1.35	24.63	Low-frequency
Fabaceae	*Goniorrhachis marginata* Taub.	2	1	1	0.01	2.00	100.00	Not classified
Fabaceae	*Guibourtia chodatiana* (Hassl.)J.Leonard	16	10	5	3.49	1.60	50.00	Medium-frequency
Fabaceae	*Holocalyx balansae* Micheli	1	1	0	0.51	1.00	0.00	Not classified
Fabaceae	*Hymenaea courbaril* L.	2	2	0	0.03	1.00	0.00	Not classified
Fabaceae	*Hymenaea martiana* Hayne	1	1	0	0.01	1.00	0.00	Not classified
Fabaceae	*Hymenaea velutina* Ducke	8	4	2	2.82	2.00	50.00	Not classified
Fabaceae	*Inga thibaudiana* DC.	1	1	0	0.27	1.00	0.00	Not classified
Fabaceae	*Leptolobium dasycarpum* (Vogel)Yakovlev	1	1	0	0.01	1.00	0.00	Not classified
Fabaceae	*Leucochloron incuriale* (Vell.)Barneby & J.W.Grimes	114	87	20	10.44	1.31	22.99	Low-frequency
Fabaceae	*Leucochloron limae* Barneby & J.W.Grimes	2	1	1	0.04	2.00	100.00	Not classified
Fabaceae	*Libidibia ferrea* (Mart. ex Tul.) L.P.Queiroz.	3	2	1	0.03	1.50	50.00	Not classified
Fabaceae	*Lonchocarpus sericeus* (Poir.)DC.	183	124	38	6.13	1.48	30.65	Medium-frequency
Fabaceae	*Luetzelburgia andrade-limae* H.C.Lima	17	12	5	0.30	1.42	41.67	Medium-frequency
Fabaceae	*Luetzelburgia auriculata* (Allemao)Ducke	4	2	1	0.01	2.00	50.00	Not classified
Fabaceae	*Luetzelburgia bahiensis* Yakovlev	359	307	40	11.21	1.17	13.03	Low-frequency
Fabaceae	*Machaerium acutifolium* Vogel	5	5	0	0.03	1.00	0.00	Not classified
Fabaceae	*Machaerium brasiliense* Vogel	1	1	0	0.01	1.00	0.00	Not classified
Fabaceae	*Machaerium debile (Vell.)Stellfeld*	24	13	7	0.54	1.85	53.85	Medium-frequency
Fabaceae	*Machaerium floridum (Mart. ex Benth.) Ducke.*	13	11	1	3.22	1.18	9.09	Low-frequency
Fabaceae	*Machaerium hirtum (E.Mey.)Standl.*	1	1	0	0.10	1.00	0.00	Not classified
Fabaceae	*Machaerium isadelphum (E.Mey.)Standl.*	107	23	20	2.40	4.65	86.96	High-frequency
Fabaceae	*Machaerium leucopterum Vogel*	62	30	14	15.01	2.07	46.67	Medium-frequency
Fabaceae	*Machaerium punctatum Pers.*	38	22	6	7.99	1.73	27.27	Low-frequency
Fabaceae	*Machaerium scleroxylon Tul.*	24	24	0	4.09	1.00	0.00	Non-resprouter
Fabaceae	*Machaerium villosum* Vogel	7	1	1	0.31	7.00	100.00	Not classified
Fabaceae	*Mimosa hortensis* Barneby	240	121	63	2.56	1.98	52.07	Medium-frequency
Fabaceae	*Mimosa tenuiflora* (Willd.)Poir.	26	17	6	0.57	1.53	35.29	Medium-frequency
Fabaceae	*Muellera campestris* (Mart. ex Benth.) M.J. Silva & A.M.G. Azevedo	17	16	1	1.61	1.06	6.25	Low-frequency
Fabaceae	*Muellera montana* (M.J. Silva & A.M.G. Azevedo) M.J. Silva & A.M.G. Azevedo	44	27	6	0.74	1.63	22.22	Low-frequency
Fabaceae	*Parapiptadenia rigida* (Benth.)Brenan	1	1	0	0.00	1.00	0.00	Not classified

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Fabaceae	*Peltogyne confertiflora (*Hayne)Benth.	3	2	1	1.57	1.50	50.00	Not classified
Fabaceae	*Peltophorum dubium* (Spreng.) Taub.	58	27	11	0.28	2.15	40.74	Medium-frequency
Fabaceae	*Piptadenia gonoacantha* (Mart.)J.F.Macbr.	5	5	0	3.17	1.00	0.00	Not classified
Fabaceae	*Piptadenia paniculata* Benth.	9	2	2	0.05	4.50	100.00	Not classified
Fabaceae	*Piptadenia stipulacea* (Benth.)Ducke	13	12	1	0.46	1.08	8.33	Low-frequency
Fabaceae	*Pityrocarpa moniliformis* (Benth.) Luckow & R. W. Jobson	42	35	5	9.58	1.20	14.29	Low-frequency
Fabaceae	*Plathymenia reticulata* Benth.	49	31	13	1.80	1.58	41.94	Medium-frequency
Fabaceae	*Platymiscium floribundum* Vogel.	1	1	0	0.02	1.00	0.00	Not classified
Fabaceae	*Platymiscium pubescens* Micheli.	53	28	14	1.01	1.89	50.00	Medium-frequency
Fabaceae	*Platypodium elegans* Vog.	1	1	0	0.00	1.00	0.00	Not classified
Fabaceae	*Poecilanthe falcata* (Vell.)Heringer	13	5	4	0.08	2.60	80.00	Not classified
Fabaceae	*Poecilanthe ulei* (Harms)Arroyo & Rudd	25	22	3	1.88	1.14	13.64	Low-frequency
Fabaceae	*Poeppigia procera* C.Presl.	2219	1307	517	67.77	1.70	39.56	Medium-frequency
Fabaceae	*Pseudopiptadenia contorta* (DC.)G.P.Lewis & M.P.Lima	100	98	2	7.55	1.02	2.04	Low-frequency
Fabaceae	*Pseudopiptadenia leptostachya* (Benth.)Rauschert	141	134	7	6.45	1.05	5.22	Low-frequency
Fabaceae	*Pseudopiptadenia warmingii* (Benth.)G.P.Lewis & M.P.Lima	36	32	4	0.60	1.13	12.50	Low-frequency
Fabaceae	*Pterocarpus villosus* (Benth.)Benth.	7	3	2	0.05	2.33	66.67	Not classified
Fabaceae	*Pterocarpus zehntneri* Harms	136	66	32	8.71	2.06	48.48	Medium-frequency
Fabaceae	*Pterodon emarginatus* Vogel	24	7	2	0.42	3.43	28.57	Not classified
Fabaceae	*Pterogyne nitens* Tul.	13	6	2	5.96	2.17	33.33	Not classified
Fabaceae	*Senegalia bahiensis (*Benth.) Seigler & Ebinger	9	6	1	0.11	1.50	16.67	Not classified
Fabaceae	*Senegalia langsdorffii (*Benth.) Seigler & Ebinger	23	14	3	0.21	1.64	21.43	Low-frequency
Fabaceae	*Senegalia martii* (Benth.) Seigler & Ebinger	83	46	16	0.70	1.80	34.78	Medium-frequency
Fabaceae	*Senegalia piauhiensis* (Benth.) Seigler & Ebinger	1	1	0	0.00	1.00	0.00	Not classified
Fabaceae	*Senegalia polyphylla* (DC.) Britton	76	43	11	13.55	1.77	25.58	Low-frequency
Fabaceae	*Senna acuruensis* (Benth.)H.S.Irwin & Barneby	1	1	0	0.01	1.00	0.00	Not classified
Fabaceae	*Senna multijuga* (L. C. Rich.) H. S. Irwin & Barneby	3	2	1	0.01	1.50	50.00	Not classified
Fabaceae	*Senna spectabilis* (DC.)H.S.Irwin & Barneby	30	24	5	0.61	1.25	20.83	Low-frequency
Fabaceae	*Swartzia flaemingii* Raddi.	12	11	1	0.37	1.09	9.09	Low-frequency
Fabaceae	*Sweetia fruticosa* Spreng.	84	76	6	5.49	1.11	7.89	Low-frequency
Fabaceae	*Vachellia farnesiana* (L.) Wight & Arn.	200	151	32	1.26	1.32	21.19	Low-frequency
Fabaceae	*Vatairea macrocarpa* (Benth.)Ducke	1	1	0	0.01	1.00	0.00	Not classified

Family	Species	Stems	Trees	Resprouted Trees	AG WB	Stems per tree	Frequency	Category
Fabaceae	*Zollernia ilicifolia* (Brongn.)Vogel	2	2	0	0.22	1.00	0.00	Not classified
Lamiaceae	*Aegiphila integrifolia* (Jacq.) B.D.Jacks.	7	6	1	0.43	1.17	16.67	Not classified
Lamiaceae	*Vitex megapotamica* (Spreng.) Moldenke	1	1	0	0.06	1.00	0.00	Not classified
Lamiaceae	*Vitex polygama* Cham.	48	28	13	1.51	1.71	46.43	Medium-frequency
Lamiaceae	*Vitex schaueriana* Moldenke	57	40	12	0.41	1.43	30.00	Medium-frequency
Loganiaceae	*Strychnos parviflora* Spruce ex Benth.	30	13	7	0.28	2.31	53.85	Medium-frequency
Lythraceae	*Lafoensia glyptocarpa* Koehne	4	3	1	0.01	1.33	33.33	Not classified
Lythraceae	*Lafoensia pacari* A. St.-Hil.	8	5	2	0.19	1.60	40.00	Not classified
Lythraceae	*Lafoensia vandelliana* Cham. & Schltdl.	23	15	4	0.22	1.53	26.67	Low-frequency
Malpighiaceae	*Banisteriopsis latifolia* (A.Juss.) B.Gates	47	17	12	0.24	2.76	70.59	High-frequency
Malpighiaceae	*Byrsonima correifolia* A.Juss.	3	1	1	0.01	3.00	100.00	Not classified
Malpighiaceae	*Heteropterys byrsonimifolia* A.Juss.	2	2	0	0.01	1.00	0.00	Not classified
Malpighiaceae	*Ptilochaeta bahiensis* Turcz.	229	174	36	2.31	1.32	20.69	Low-frequency
Malpighiaceae	*Ptilochaeta glabra* Nied.	89	68	17	0.76	1.31	25.00	Low-frequency
Malvaceae	*Cavanillesia umbellata* Ruiz & Pav.	73	73	0	179.07	1.00	0.00	Non-resprouter
Malvaceae	*Ceiba pubiflora* (A.St.-Hil.) K.Schum.	33	32	1	13.22	1.03	3.13	Low-frequency
Malvaceae	*Ceiba rubriflora* Carv.-Sobr. & L.P.Queiroz	35	34	1	28.37	1.03	2.94	Low-frequency
Malvaceae	*Guazuma ulmifolia* Lam.	29	24	5	1.19	1.21	20.83	Low-frequency
Malvaceae	*Helicteres baruensis* Jacq.	8	3	3	0.00	2.67	100.00	Not classified
Malvaceae	*Helicteres brevispira* A.Juss.	1	1	0	0.00	1.00	0.00	Not classified
Malvaceae	*Luehea divaricata* Mart.	7	2	2	0.12	3.50	100.00	Not classified
Malvaceae	*Luehea paniculata* Mart.	12	4	3	0.06	3.00	75.00	Not classified
Malvaceae	*Pseudobombax longiflorum* (Mart. & Zucc.) A.Robyns	1	1	0	0.07	1.00	0.00	Not classified
Malvaceae	*Pseudobombax marginatum* (A.St.-Hil.) A.Robyns	40	38	2	7.71	1.05	5.26	Low-frequency
Malvaceae	*Pseudobombax simplicifolium* A. Robyns	87	57	17	8.89	1.53	29.82	Medium-frequency
Malvaceae	*Pseudobombax tomentosum* (Mart. & Zucc.) A.Robyns	3	3	0	0.57	1.00	0.00	Not classified
Malvaceae	*Sterculia excelsa* Mart.	13	12	1	1.39	1.08	8.33	Low-frequency
Malvaceae	*Sterculia striata* A. St.-Hil. & Naudin	51	46	4	10.17	1.11	8.70	Low-frequency
Melastomataceae	*Mouriri pusa Gardner* ex Gardner	30	5	5	0.07	6.00	100.00	Not classified
Meliaceae	*Cedrela fissilis* Vell.	80	68	10	18.74	1.18	14.71	Low-frequency
Meliaceae	*Trichilia casaretti* C. DC.	277	163	69	6.73	1.70	42.33	Medium-frequency
Meliaceae	*Trichilia catigua* A.Juss.	8	5	2	0.04	1.60	40.00	Not classified

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Meliaceae	*Trichilia clausseni* C. DC.	1	1	0	0.00	1.00	0.00	Not classified
Meliaceae	*Trichilia hirta* L.	82	63	14	3.74	1.30	22.22	Low-frequency
Meliaceae	*Trichilia pallens* C.DC.	1	1	0	0.01	1.00	0.00	Not classified
Moraceae	*Brosimum gaudichaudii* Trécul	9	9	0	0.04	1.00	0.00	Not classified
Moraceae	*Ficus adhatodifolia* Schott	1	1	0	0.00	1.00	0.00	Not classified
Moraceae	*Ficus bonijesulapensis* R.M.Castro	18	11	4	77.68	1.64	36.36	Medium-frequency
Moraceae	*Ficus calyptroceras* (Miq.) Miq.	1	1	0	0.01	1.00	0.00	Not classified
Moraceae	*Ficus enormis* (Miq.) Miq.	1	1	0	0.38	1.00	0.00	Not classified
Moraceae	*Ficus goiana* C.C.Berg, Carauta & A.F.P.Machado	6	4	2	0.10	1.50	50.00	Not classified
Moraceae	*Ficus nymphaeifolia* Mill.	5	2	1	0.23	2.50	50.00	Not classified
Moraceae	*Maclura tinctoria* (L.) D.Don ex Steud.	12	11	1	1.29	1.09	9.09	Low-frequency
Myrtaceae	*Campomanesia velutina* (Cambess.) O.Berg	30	9	7	0.42	3.33	77.78	Not classified
Myrtaceae	*Campomanesia xanthocarpa* (Mart.) O.Berg	5	3	2	0.11	1.67	66.67	Not classified
Myrtaceae	*Eugenia dysenterica* DC.	14	10	4	0.25	1.40	40.00	Medium-frequency
Myrtaceae	*Eugenia florida* DC.	40	19	9	0.45	2.11	47.37	Medium-frequency
Myrtaceae	*Eugenia hiemalis* Cambess.	1	1	0	0.00	1.00	0.00	Not classified
Myrtaceae	*Eugenia ligustrina* (Sw.) Willd.	167	78	39	1.18	2.14	50.00	Medium-frequency
Myrtaceae	*Eugenia sonderiana* O.Berg	3	3	0	0.03	1.00	0.00	Not classified
Myrtaceae	*Eugenia uniflora* L.	942	567	195	16.49	1.66	34.39	Medium-frequency
Myrtaceae	*Myrcia guianensis* (Aubl.) DC.	3	3	0	0.01	1.00	0.00	Not classified
Myrtaceae	*Myrcia tomentosa* (Aubl.) DC.	25	20	4	0.31	1.25	20.00	Low-frequency
Myrtaceae	*Myrciaria floribunda* (H.West ex Willd.) O.Berg	4	2	2	0.01	2.00	100.00	Not classified
Myrtaceae	*Myrciaria tenella* (DC.) O.Berg	21	4	3	0.07	5.25	75.00	Not classified
Myrtaceae	*Plinia cauliflora* (Mart.) Kausel	1	1	0	0.00	1.00	0.00	Not classified
Myrtaceae	*Psidium salutare* (Kunth) O.Berg	166	90	35	1.43	1.84	38.89	Medium-frequency
Nyctaginaceae	*Bougainvillea glabra* Choisy	3	3	0	0.02	1.00	0.00	Not classified
Nyctaginaceae	*Bougainvillea stipitata* Griseb.	1	1	0	0.01	1.00	0.00	Not classified
Nyctaginaceae	*Guapira hirsuta* (Choisy) Lundell	3	2	1	0.02	1.50	50.00	Not classified
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	12	8	2	0.44	1.50	25.00	Not classified
Nyctaginaceae	*Guapira tomentosa* (Casar.) Lundell	55	33	12	0.62	1.67	36.36	Medium-frequency
Nyctaginaceae	*Guapira venosa* (Choisy) Lundell	15	9	4	0.16	1.67	44.44	Not classified
Olacaceae	*Heisteria citrifolia* Engl.	14	5	4	0.14	2.80	80.00	Not classified

Family	**Species**	**Stems**	**Trees**	**Resprouted Trees**	**AG WB**	**Stems per tree**	**Frequency**	**Category**
Olacaceae	*Ximenia americana* L.	10	4	3	2.83	2.50	75.00	Not classified
Olacaceae	*Ximenia coriacea* Engl.	14	4	4	0.03	3.50	100.00	Not classified
Opiliaceae	*Agonandra brasiliensis* Miers ex Benth.	6	2	1	0.19	3.00	50.00	Not classified
Phyllanthaceae	*Savia dictyocarpa* Müll.Arg.	3	2	1	0.01	1.50	50.00	Not classified
Picrodendraceae	*Piranhea securinega* Radcl.-Sm. & Ratter	182	115	27	105.41	1.58	23.48	Low-frequency
Piperaceae	*Piper amalago* L.	43	4	4	0.07	10.75	100.00	Not classified
Polygonaceae	*Coccoloba brasiliensis* Nees & Mart.	15	10	2	1.01	1.50	20.00	Low-frequency
Polygonaceae	*Coccoloba declinata* (Vell.) Mart.	1	1	0	0.01	1.00	0.00	Not classified
Polygonaceae	*Coccoloba schwackeana* Nees & Mart.	326	146	74	8.54	2.23	50.68	Medium-frequency
Polygonaceae	*Ruprechtia apetala* Wedd.	69	48	11	3.17	1.44	22.92	Low-frequency
Polygonaceae	*Ruprechtia laxiflora* Meisn.	107	64	24	5.95	1.67	37.50	Medium-frequency
Polygonaceae	*Triplaris gardneriana* Wedd.	12	4	4	0.38	3.00	100.00	Not classified
Primulaceae	*Cybianthus amplus* (Mez) G.Agostini	2	2	0	0.01	1.00	0.00	Not classified
Primulaceae	*Stylogyne warmingii* Mez	3	3	0	0.09	1.00	0.00	Not classified
Rhamnaceae	*Rhamnidium molle* Reissek	17	11	3	0.32	1.55	27.27	Low-frequency
Rhamnaceae	*Ziziphus cotinifolia* Reissek	1	1	0	0.00	1.00	0.00	Not classified
Rhamnaceae	*Ziziphus joazeiro* Mart.	25	14	5	2.18	1.79	35.71	Medium-frequency
Rubiaceae	*Alseis pickelii* Pilg. & Schmale	94	60	23	2.51	1.57	38.33	Medium-frequency
Rubiaceae	*Chomelia pohliana* Müll.Arg.	32	15	9	0.59	2.13	60.00	High-frequency
Rubiaceae	*Chomelia sericea* Müll.Arg.	6	4	2	0.04	1.50	50.00	Not classified
Rubiaceae	*Cordiera sessilis* (Vell.) Kuntze	145	43	31	0.87	3.37	72.09	High-frequency
Rubiaceae	*Coutarea hexandra* (Jacq.) K.Schum.	134	60	39	0.69	2.23	65.00	High-frequency
Rubiaceae	*Guettarda angelica* Mart. ex Müll.Arg.	11	3	2	0.03	3.67	66.67	Not classified
Rubiaceae	*Guettarda pohliana* Müll.Arg.	21	7	5	0.04	3.00	71.43	Not classified
Rubiaceae	*Machaonia acuminata* Humb. & Bonpl.	157	86	42	1.18	1.83	48.84	Medium-frequency
Rubiaceae	*Randia armata* (Sw.) DC.	318	189	69	2.04	1.68	36.51	Medium-frequency
Rubiaceae	*Randia calycina* Cham.	1	1	0	0.04	1.00	0.00	Not classified
Rubiaceae	*Simira gardneriana* M.R.V.Barbosa & Peixoto	1	1	0	0.00	1.00	0.00	Not classified
Rubiaceae	*Simira sampaioana* (Standl.) Steyerm.	39	9	8	0.25	4.33	88.89	Not classified
Rubiaceae	*Tocoyena bullata* (Vell.) Mart.	5	2	2	0.01	2.50	100.00	Not classified
Rubiaceae	*Tocoyena formosa* (Cham. & Schltdl.) K.Schum.	16	10	5	0.33	1.60	50.00	Medium-frequency
Rubiaceae	*Warszewiczia coccinea* (Vahl) Klotzsch	28	9	5	0.51	3.11	55.56	Not classified

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Rutaceae	*Balfourodendron molle* (Miq.) Pirani	68	44	13	1.71	1.55	29.55	Medium-frequency
Rutaceae	*Galipea ciliata* Taub.	569	156	135	1.89	3.65	86.54	High-frequency
Rutaceae	*Galipea jasminiflora* (A.St.-Hil.) Engl.	5	2	1	0.15	2.50	50.00	Not classified
Rutaceae	*Metrodorea mollis* Taub.	137	118	15	1.64	1.16	12.71	Low-frequency
Rutaceae	*Zanthoxylum hamadryadicum* Pirani	5	3	1	0.02	1.67	33.33	Not classified
Rutaceae	*Zanthoxylum monogynum* A. St.-Hil.	18	9	5	0.33	2.00	55.56	Not classified
Rutaceae	*Zanthoxylum petiolare* A.St.-Hil. & Tul.	12	12	0	0.32	1.00	0.00	Non-resprouter
Rutaceae	*Zanthoxylum riedelianum* Engl.	5	3	2	0.08	1.67	66.67	Not classified
Rutaceae	*Zanthoxylum stelligerum* Turcz.	4	4	0	0.02	1.00	0.00	Not classified
Salicaceae	*Casearia commersoniana* Cambess.	41	27	9	1.43	1.52	33.33	Medium-frequency
Salicaceae	*Casearia decandra* Jacq.	1	1	0	0.14	1.00	0.00	Not classified
Salicaceae	*Casearia grandiflora* Cambess.	159	105	46	2.62	1.51	43.81	Medium-frequency
Salicaceae	*Casearia rupestris* Eichler	10	9	1	0.19	1.11	11.11	Not classified
Salicaceae	*Casearia selloana* Eichler	302	168	75	3.64	1.80	44.64	Medium-frequency
Salicaceae	*Casearia sylvestris* Sw.	5	2	2	0.01	2.50	100.00	Not classified
Salicaceae	*Prockia crucis* P.Browne ex L.	21	17	2	0.18	1.24	11.76	Low-frequency
Sapindaceae	*Allophylus edulis* (A.St.-Hil., A.Juss. & Cambess.) Radlk.	9	4	3	0.02	2.25	75.00	Not classified
Sapindaceae	*Allophylus puberulus* (A.St.-Hil., A.Juss. & Cambess.) Radlk.	2	1	1	0.00	2.00	100.00	Not classified
Sapindaceae	*Allophylus racemosus* Sw.	35	13	10	0.30	2.69	76.92	High-frequency
Sapindaceae	*Diatenopteryx grazielae* Vaz & Andreata	2	2	0	0.20	1.00	0.00	Not classified
Sapindaceae	*Dilodendron bipinnatum* Radlk.	49	43	5	10.52	1.14	11.63	Low-frequency
Sapindaceae	*Magonia pubescens* A. St.-Hil.	10	10	0	2.02	1.00	0.00	Non-resprouter
Sapindaceae	*Talisia esculenta* (A. St.-Hil.) Radlk.	10	10	0	0.88	1.00	0.00	Non-resprouter
Sapotaceae	*Chrysophyllum gonocarpum* (Mart. & Eichler ex Miq.) Engl.	4	3	1	0.11	1.33	33.33	Not classified
Sapotaceae	*Pouteria gardneri* (Mart. & Eichler ex Miq.) Baehni	18	14	3	0.28	1.29	21.43	Low-frequency
Sapotaceae	*Pouteria gardneriana* (A.DC.) Radlk.	1	1	0	0.00	1.00	0.00	Not classified
Schoepfiaceae	*Schoepfia brasiliensis* A.DC.	9	5	2	0.29	1.80	40.00	Not classified
Simaroubaceae	*Simarouba versicolor* A. St.-Hil.	1	1	0	0.03	1.00	0.00	Not classified
Solanaceae	*Capsicum parvifolium* Sendtn.	22	9	3	0.06	2.44	33.33	Not classified
Urticaceae	*Cecropia saxatilis* Snethl.	1	1	0	0.02	1.00	0.00	Not classified
Verbenaceae	*Aloysia virgata* (Ruiz & Pav.) Juss.	5	4	1	0.03	1.25	25.00	Not classified
Verbenaceae	*Lantana fucata* Lindl.	18	4	3	0.03	4.50	75.00	Not classified

Family	Species	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Vochysiaceae	*Callisthene fasciculata* Mart.	25	21	3	4.67	1.19	14.29	Low-frequency
Vochysiaceae	*Callisthene microphylla* Warm.	18	12	5	0.12	1.50	41.67	Medium-frequency
Vochysiaceae	*Qualea grandiflora* Mart.	1	1	0	0.02	1.00	0.00	Not classified

Table S5: Basic data of number of stems, trees, resprouted trees, above-ground woody biomass (AGWB), average stems per tree, resprouting frequency (%) and resprouting categories for the 171 genus sampled in the 16 fragments of tropical dry forests.

Family	Genus	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Fabaceae	*Acosmium*	103	71	22	6.01	1.45	30.98	Medium-frequency
Euphorbiaceae	*Adelia*	3	3	0	0.026	1	0	Not classified
Lamiaceae	*Aegiphila*	7	6	1	0.48	1.16	16.66	Not classified
Opiliaceae	*Agonandra*	6	2	1	0.19	3	50	Not classified
Fabaceae	*Albizia*	8	8	0	1.25	1	0	Not classified
Sapindaceae	*Allophylus*	46	18	14	0.32	2.55	77.778	High-frequency
Verbenaceae	*Aloysia*	5	4	1	0.03	1.25	25	Not classified
Rubiaceae	*Alseis*	94	60	23	2.51	1.56	38.33	Medium-frequency
Fabaceae	*Amburana*	83	51	20	5.51	1.62	39.21	Medium-frequency
Fabaceae	*Anadenanthera*	466	343	75	76.16	1.35	21.86	Low-frequency
Annonaceae	*Annona*	260	110	71	3.82	2.36	64.54	High-frequency
Araliaceae	*Aralia*	65	56	7	6.37	1.16	12.5	Low-frequency
Apocynaceae	*Aspidosperma*	489	300	91	23.29	1.63	30.33	Medium-frequency
Anacardiaceae	*Astronium*	42	38	4	5.45	1.10	10.52	Low-frequency
Rutaceae	*Balfourodendron*	68	44	13	1.70	1.54	29.54	Medium-frequency
Malpighiaceae	*Banisteriopsis*	47	17	12	0.23	2.76	70.58	High-frequency
Fabaceae	*Bauhinia*	239	164	52	2.48	1.46	31.70	Medium-frequency
Fabaceae	*Blanchetiodendron*	27	20	4	4.48	1.35	20	Low-frequency
Nyctaginaceae	*Bougainvillea*	4	4	0	0.02	1	0	Not classified
Moraceae	*Brosimum*	9	9	0	0.03	1	0	Not classified
Combretaceae	*Buchenavia*	3	2	1	0.01	1.5	50	Not classified
Malpighiaceae	*Byrsonima*	3	1	1	0.01	3	100	Not classified
Fabaceae	*Calliandra*	617	231	155	6.11	2.67	67.09	High-frequency
Vochysiaceae	*Callisthene*	43	33	8	4.79	1.30	24.24	Low-frequency
Myrtaceae	*Campomanesia*	35	12	9	0.53	2.91	75	High-frequency
Solanaceae	*Capsicum*	22	9	3	0.06	2.44	33.33	Not classified
Salicaceae	*Casearia*	518	312	133	8.02	1.66	42.62	Medium-frequency
Fabaceae	*Cassia*	8	6	1	0.89	1.33	16.67	Not classified
Malvaceae	*Cavanillesia*	73	73	0	179.06	1	0	Non-resprouter
Urticaceae	*Cecropia*	1	1	0	0.017	1	0	Not classified
Meliaceae	*Cedrela*	80	68	10	18.74	1.17	14.71	Low-frequency
Malvaceae	*Ceiba*	68	66	2	41.59	1.03	3.03	Low-frequency

Family	Genus	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Cannabaceae	*Celtis*	31	17	9	0.30	1.82	52.94	Medium-frequency
Fabaceae	*Cenostigma*	301	97	68	9.01	3.10	70.10	High-frequency
Fabaceae	*Centrolobium*	21	17	3	0.65	1.23	17.64	Low-frequency
Cactaceae	*Cereus*	61	42	10	3.77	1.45	23.80	Low-frequency
Fabaceae	*Chloroleucon*	42	16	11	0.88	2.62	68.75	High-frequency
Rubiaceae	*Chomelia*	38	19	11	0.63	2	57.89	High-frequency
Sapotaceae	*Chrysophyllum*	4	3	1	0.11	1.33	33.33	Not classified
Euphorbiaceae	*Cnidoscolus*	392	171	79	12.5	2.29	46.19	Medium-frequency
Polygonaceae	*Coccoloba*	342	157	76	9.56	2.17	48.41	Medium-frequency
Bixaceae	*Cochlospermum*	31	27	4	0.45	1.15	14.81	Low-frequency
Combretaceae	*Combretum*	2328	1424	547	53.45	1.63	38.41	Medium-frequency
Burseraceae	*Commiphora*	507	335	106	94.56	1.51	31.64	Medium-frequency
Fabaceae	*Copaifera*	5	5	0	0.98	1	0	Not classified
Boraginaceae	*Cordia*	212	132	46	5.31	1.61	34.85	Medium-frequency
Rubiaceae	*Cordiera*	145	43	31	0.86	3.37	72.09	High-frequency
Fabaceae	*Coursetia*	7	7	0	0.06	1	0	Not classified
Rubiaceae	*Coutarea*	134	60	39	0.69	2.23	65	High-frequency
Euphorbiaceae	*Croton*	450	130	115	0.36	3.46	88.46	High-frequency
Dilleniaceae	*Curatella*	1	1	0	0.05	1	0	Not classified
Primulaceae	*Cybianthus*	2	2	0	0.01	1	0	Not classified
Capparaceae	*Cynophalla*	145	32	27	1.02	4.53	84.37	High-frequency
Anacardiaceae	*Cyrtocarpa*	93	69	19	10.25	1.35	27.54	Low-frequency
Fabaceae	*Dalbergia*	499	280	92	13.20	1.78	32.85	Medium-frequency
Fabaceae	*Deguelia*	1	1	0	0.02	1	0	Not classified
Sapindaceae	*Diatenopteryx*	2	2	0	0.19	1	0	Not classified
Sapindaceae	*Dilodendron*	49	43	5	10.51	1.14	11.62	Low-frequency
Ebenaceae	*Diospyros*	1	1	0	0.28	1	0	Not classified
Fabaceae	*Diplotropis*	20	16	3	0.79	1.25	18.75	Low-frequency
Annonaceae	*Duguetia*	1	1	0	0.01	1	0	Not classified
Fabaceae	*Enterolobium*	17	14	2	3.22	1.21	14.28	Low-frequency
Fabaceae	*Erythrina*	13	8	2	0.81	1.62	25	Not classified
Erythroxylaceae	*Erythroxylum*	175	75	51	1.28	2.33	68	High-frequency
Myrtaceae	*Eugenia*	1167	678	247	18.40	1.72	36.43	Medium-frequency
Moraceae	*Ficus*	32	20	7	78.40	1.6	35	Medium-frequency
Celastraceae	*Fraunhofera*	48	38	7	4.81	1.26	18.42	Low-frequency
Bignoniaceae	*Fridericia*	285	212	53	7.32	1.34	25	Low-frequency
Rutaceae	*Galipea*	574	158	136	2.05	3.63	86.07	High-frequency
Fabaceae	*Goniorrhachis*	274	203	50	85.82	1.35	24.63	Low-frequency
Nyctaginaceae	*Guapira*	85	52	19	1.24	1.64	36.54	Medium-frequency
Malvaceae	*Guazuma*	29	24	5	1.182	1.21	20.83	Low-frequency
Rubiaceae	*Guettarda*	32	10	7	0.06	3.2	70	High-frequency

Family	Genus	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Fabaceae	*Guibourtia*	2	1	1	0.01	2	100	Not classified
Bignoniaceae	*Handroanthus*	2548	1956	412	194.15	1.31	21.06	Low-frequency
Olacaceae	*Heisteria*	14	5	4	0.14	2.8	80	Not classified
Malvaceae	*Helicteres*	9	4	3	0.01	2.25	75	Not classified
Malpighiaceae	*Heteropterys*	2	2	0	0.01	1	0	Not classified
Fabaceae	*Holocalyx*	16	10	5	3.49	1.6	50	Medium-frequency
Fabaceae	*Hymenaea*	4	4	0	0.54	1	0	Not classified
Fabaceae	*Inga*	8	4	2	2.81	2	50	Not classified
Bignoniaceae	*Jacaranda*	21	14	2	2.82	1.5	14.28	Low-frequency
Caricaceae	*Jacaratia*	24	13	6	0.02	1.84	46.15	Medium-frequency
Euphorbiaceae	*Jatropha*	66	59	4	0.11	1.12	6.77	Low-frequency
Calophyllaceae	*Kielmeyera*	2	2	0	0.02	1	0	Not classified
Araliaceae	*Lachesiodendron*	43	22	11	6.12	1.95	50	Medium-frequency
Lythraceae	*Lafoensia*	35	23	7	0.42	1.52	30.43	Medium-frequency
Verbenaceae	*Lantana*	18	4	3	0.03	4.5	75	Not classified
Fabaceae	*Leptolobium*	1	1	0	0.27	1	0	Not classified
Fabaceae	*Leucochloron*	115	88	20	10.45	1.31	22.72	Low-frequency
Fabaceae	*Libidibia*	2	1	1	0.03	2	100	Not classified
Fabaceae	*Lonchocarpus*	3	2	1	0.03	1.5	50	Not classified
Malvaceae	*Luehea*	19	6	5	0.17	3.17	83.33	Not classified
Fabaceae	*Luetzelburgia*	204	138	44	6.43	1.47	31.88	Medium-frequency
Fabaceae	*Machaerium*	634	437	88	44.59	1.45	20.13	Low-frequency
Rubiaceae	*Machaonia*	157	86	42	1.18	1.82	48.84	Medium-frequency
Moraceae	*Maclura*	12	11	1	1.29	1.09	9.09	Low-frequency
Sapindaceae	*Magonia*	10	10	0	2.02	1	0	Non-resprouter
Euphorbiaceae	*Manihot*	90	65	16	0.39	1.38	24.61	Low-frequency
Celastraceae	*Maytenus*	3	2	1	0.01	1.5	50	Not classified
Rutaceae	*Metrodorea*	137	118	15	1.641	1.16	12.71	Low-frequency
Fabaceae	*Mimosa*	247	122	64	2.86	2.02	52.45	Medium-frequency
Celastraceae	*Monteverdia*	98	19	15	1.81	5.15	78.94	High-frequency
Melastomataceae	*Mouriri*	30	5	5	0.06	6	100	Not classified
Fabaceae	*Muellera*	43	33	7	2.18	1.30	21.21	Low-frequency
Anacardiaceae	*Myracrodruon*	743	624	91	285.35	1.19	14.58	Low-frequency
Myrtaceae	*Myrcia*	28	23	4	0.32	1.22	17.39	Low-frequency
Myrtaceae	*Myrciaria*	25	6	5	0.08	4.17	83.33	Not classified
Fabaceae	*Parapiptadenia*	44	27	6	0.74	1.63	22.22	Low-frequency
Fabaceae	*Peltogyne*	1	1	0	0.01	1	0	Not classified
Fabaceae	*Peltophorum*	3	2	1	1.56	1.5	50	Not classified
Cactaceae	*Pereskia*	300	93	73	10.23	3.22	78.49	High-frequency
Cactaceae	*Pilosocereus*	554	226	113	20.11	2.45	50	Medium-frequency
Piperaceae	*Piper*	43	4	4	0.06	10.75	100	Not classified

Family	Genus	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Fabaceae	*Piptadenia*	72	34	13	3.51	2.12	38.23	Medium-frequency
Picrodendraceae	*Piranhea*	182	115	27	105.41	1.58	23.47	Low-frequency
Fabaceae	*Pityrocarpa*	13	12	1	0.46	1.08	8.33	Low-frequency
Fabaceae	*Plathymenia*	42	35	5	9.57	1.2	14.28	Low-frequency
Fabaceae	*Platymiscium*	50	32	13	1.82	1.56	40.62	Medium-frequency
Fabaceae	*Platypodium*	53	28	14	1.01	1.89	50	Medium-frequency
Myrtaceae	*Plinia*	1	1	0	0.01	1	0	Not classified
Fabaceae	*Poecilanthe*	14	6	4	0.07	2.33	66.66	Not classified
Fabaceae	*Poeppigia*	25	22	3	1.87	1.13	13.63	Low-frequency
Fabaceae	*Poincianella*	2219	1307	517	67.76	1.69	39.554	Medium-frequency
Sapotaceae	*Pouteria*	19	15	3	0.28	1.26	20	Low-frequency
Salicaceae	*Prockia*	21	17	2	0.17	1.23	11.76	Low-frequency
Malvaceae	*Pseudobombax*	131	99	19	17.23	1.32	19.19	Low-frequency
Fabaceae	*Pseudopiptadenia*	277	264	13	14.61	1.05	4.92	Low-frequency
Myrtaceae	*Psidium*	166	90	35	1.43	1.84	38.88	Medium-frequency
Fabaceae	*Pterocarpus*	143	69	34	8.76	2.07	49.27	Medium-frequency
Fabaceae	*Pterodon*	24	7	2	0.41	3.42	28.57	Not classified
Fabaceae	*Pterogyne*	13	6	2	5.95	2.16	33.33	Not classified
Malpighiaceae	*Ptilochaeta*	318	242	53	3.06	1.31	21.90	Low-frequency
Vochysiaceae	*Qualea*	1	1	0	0.01	1	0	Not classified
Cactaceae	*Quiabentia*	22	8	7	0.09	2.75	87.5	Not classified
Rubiaceae	*Randia*	319	190	69	2.07	1.67	36.31	Medium-frequency
Rhamnaceae	*Rhamnidium*	17	11	3	0.32	1.54	27.27	Low-frequency
Polygonaceae	*Ruprechtia*	176	112	35	9.11	1.577	31.25	Medium-frequency
Celastraceae	*Salacia*	32	7	6	0.77	4.57	85.71	Not classified
Euphorbiaceae	*Sapium*	204	189	14	1.72	1.07	7.40	Low-frequency
Phyllanthaceae	*Savia*	3	2	1	0.01	1.5	50	Not classified
Anacardiaceae	*Schinopsis*	141	130	11	35.76	1.08	8.46	Low-frequency
Schoepfiaceae	*Schoepfia*	9	5	2	0.28	1.8	40	Not classified
Fabaceae	*Senegalia*	192	110	31	14.58	1.74	28.18	Low-frequency
Fabaceae	*Senna*	34	27	6	0.63	1.25	22.22	Low-frequency
Simaroubaceae	*Simarouba*	1	1	0	0.03	1	0	Not classified
Rubiaceae	*Simira*	40	10	8	0.25	4	80	High-frequency
Elaeocarpaceae	*Sloanea*	2	1	1	0.01	2	100	Not classified
Anacardiaceae	*Spondias*	90	43	21	9.89	2.09	48.83	Medium-frequency
Malvaceae	*Sterculia*	64	58	5	11.55	1.10	8.62	Low-frequency
Euphorbiaceae	*Stillingia*	182	142	33	1.45	1.28	23.23	Low-frequency
Loganiaceae	*Strychnos*	30	13	7	0.27	2.30	53.84	Medium-frequency
Primulaceae	*Stylogyne*	3	3	0	0.09	1	0	Not classified
Fabaceae	*Swartzia*	12	11	1	0.37	1.09	9.09	Low-frequency

Family	Genus	Stems	Trees	Resprouted Trees	AGWB	Stems per tree	Frequency	Category
Fabaceae	*Sweetia*	84	76	6	5.49	1.10	7.89	Low-frequency
Arecaceae	*Syagrus*	63	63	0	8.82	1	0	Non-resprouter
Bignoniaceae	*Tabebuia*	710	319	160	28.60	2.22	50.15	Medium-frequency
Sapindaceae	*Talisia*	10	10	0	0.87	1	0	Non-resprouter
Combretaceae	*Terminalia*	141	86	28	6.79	1.63	32.55	Medium-frequency
Rubiaceae	*Tocoyena*	21	12	7	0.33	1.75	58.33	High-frequency
Meliaceae	*Trichilia*	369	233	85	10.52	1.58	36.48	Medium-frequency
Polygonaceae	*Triplaris*	12	4	4	0.38	3	100	Not classified
Fabaceae	*Vachellia*	200	151	32	1.25	1.32	21.19	Low-frequency
Fabaceae	*Vatairea*	1	1	0	0.01	1	0	Not classified
Lamiaceae	*Vitex*	106	69	25	1.98	1.53	36.23	Medium-frequency
Rubiaceae	*Warszewiczia*	28	9	5	0.51	3.11	55.55	Not classified
Olacaceae	*Ximenia*	24	8	7	2.85	3	87.5	Not classified
Rutaceae	*Zanthoxylum*	44	31	8	0.77	1.41	25.80	Low-frequency
Bignoniaceae	*Zeyheria*	26	21	4	3.49	1.23	19.04	Low-frequency
Rhamnaceae	*Ziziphus*	26	15	5	2.18	1.73	33.33	Medium-frequency
Fabaceae	*Zollernia*	2	2	0	0.21	1	0	Not classified

Table S6: Detailed values of variance partitioning of Site (Plot and Subplot) and Taxonomy (Family, Genus and Species) effects for the two Resprouting variables evaluated for the 16 fragments of tropical dry forest used in this study. These values were used to obtain the Figure 4

Random factor	% of variance – Stem per tree	% of variance - Frequency
Family	3.56	2.78
Genus	5.05	14.33
Species	3.94	11.79
Site (Plot + Subplot)	2.88	6.43
Residuals	84.56	64.68

Phylogenetic sign with 100 trees

Table S8: Summarized Pagel's λ results for the two resprouting variables using the 100 other phylogenetic hypotheses present in Neves et al. (2020). Note that CI refers to Confidence Interval considering 95 % of confidence, λ to the phylogenetic signal and p-value for the significance value obtained.

	Stems per tree		Frequency	
	λ	p-value	λ	p-value
CI-Upper limit	0.063	0.696	0.166	0.231
Average	0.058	0.666	0.162	0.220
CI-Lower limit	0.053	0.636	0.157	0.210
Maximum	0.112	1.000	0.235	0.361
Minimum	0.001	0.405	0.108	0.131

Phylogenetic signal for resprouting categories

We evaluated the presence of phylogenetic signal for the resprouting frequency categories obtained for genus (as a categorical functional trait) in two ways: the first through D measure of Frits and Purvis (2005) and the second through the δ measure of Borges et al. (2019). Here we worked only in genus level because the genus phylogenetic tree is a molecular tree and therefore more reliable for phylogenetic signal estimates. We also used just genus with at least 10 individuals, that were classified in categories by K-means algorithm.

The D measure quantifies the phylogenetic signal for a binary trait and tests the probability of a trait value distribution in a phylogeny irrespective of a random phylogenetic structure (absence of phylogenetic signal) and also from a Brownian Motion phylogenetic structure (presence of phylogenetic signal). Since we had four resprouting frequency categories (Non-resprouters, Low-frequency, Medium-frequency and High-frequency resprouters), we adopted combinations of categories in order to do the test. We adopt the double combination Non-resprouters + Low-frequency (0) vs Medium-frequency + High-frequency (1). We did not compare isolated pairs of categories due to the lower number of genus in some of them. We found absence of phylogenetic signal, since the value of $D=0.81$ has probability 0 of being resulted from a Brownian phylogenetic structure and probability 0.14 of being resulted from a random phylogenetic structure.

The δ of Borges et al. (2019) is a measure of the entropy evaluation in ancestral nodes based on the category's distribution in phylogenetic tree, based on the Shannon measure for information theory. The lower the entropy in ancestral nodes, the greater the value of δ and the greater the chance that the structuring of categories in genus is associated with phylogenetic relationships. The analysis does not offer a measure of significance, and so we can simply summarize by comparing the value of δ obtained with the values presented in the paper (Borges et al. 2019) for situations of presence and absence of phylogenetic signal. The analysis made on the resprouting categories resulted in a $\delta=1.008$, presenting a situation of high entropy in ancestral nodes. For example, the situation presented in Borges et al. (2019) for absence of phylogenetic signal had a $\delta=0.5$, while the situation of presence of phylogenetic signal had a value of $\delta=5.1$. See the Figure S3 for the resprouting categories distribution in the phylogenetic tree.

Figure S4: Phylogenetic tree of tropical dry forests trees and palm genera with number of individuals ≥ 10 in plots with branches colored according to the resprouting frequency categories.

Supplementary material references

Aguiar-Campos, N., Maia, V. A., Silva, W. B., GUIAR-CAMPOS, Souza, C. R. & Santos, R. M. (2020). Can fine-scale habitats of limestone outcrops be considered litho-refugia for dry forest tree lineages?. Biodiversity and Conservation, 29 (3), 1009-1026. https://doi.org/10.1007/s10531-019-01923-4

Apgaua, D. M. G., Coelho, P. A., Santos, R. M. D., Santos, P. F., & Oliveira-Filho, A. T. (2014). Tree community structure in a seasonally dry tropical forest remnant, Brazil. Cerne, 20(2), 173-182. https://doi.org/10.1590/01047760.201420021540

Apgaua, D. M. G., Pereira, D. G. S., Santos, R. M., Menino, G. C. O., Fontes, M. A. L. & Tng, D. Y. P. (2015). Floristic variation within seasonally dry tropical forests of the Caatinga Biogeographic Domain, Brazil, and its conservation implications. International Forestry Review, 17(2), 33-44. https://doi.org/10.1505/146554815815834840

Borges, R., Machado, J. P., Gomes, C., Rocha, A. P., & Antunes, A. (2019). Measuring phylogenetic signal between categorical traits and phylogenies. Bioinformatics, 35(11), 1862-1869. https://doi.org/10.1093/bioinformatics/bty800

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B., ... & Vieilledent, G. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. Global change biology, 20(10), 3177-3190. https://doi.org/10.1111/gcb.12629

Fritz, S. A., & Purvis, A. (2010). Selectivity in mammalian extinction risk and threat types: a new measure of phylogenetic signal strength in binary traits. Conservation Biology, 24(4), 1042-1051. https://doi.org/10.1111/j.1523-1739.2010.01455.x

Neves, D. M., Dexter, K. G., Baker, T. R., Coelho de Souza, F., Oliveira-Filho, A. T., Queiroz, L. P., ... & Pennington, R. T. (2020). Evolutionary diversity in tropical tree communities peaks at intermediate precipitation. Scientific Reports, 10(1), 1-7. http://dx.doi.org/10.1038/s41598-019-55621-w

Paula, G. G. P., Santos, R. M., Menino, G. C. D. O., Apgaua, D. M. G., Pereira, D. G. S., Souza, C. R., & Fontes, M. A. L. (2018). Influence of environmental variations on the formation of microhabitats within a fragment of Seasonally Dry Tropical Forest-SDTF, Brazil. Revista Árvore, 42(2), e420211. https://doi.org/10.1590/1806-90882018000200011

Reis, G. H., Terra, M. C. N. S., Tng, D. Y. P., Apgaua, D. M. G., Coelho, P. A., Santos, R. M., & Nunes, Y. R. F. (2017). Temporal vegetation changes in a seasonally dry tropical forest enclave in an ecotonal region between savanna and semiarid zones of Brazil. Australian journal of botany, 65(1), 85-93. https://doi.org/10.1071/BT16188

Reis, G. H., Santos, R. M. D., Pereira, D. G. S., Morel, J. D., & Santos, P. F. (2018). Tree community dynamics of a northern Minas Gerais seasonally dry forest. Revista Ceres, 65(3), 234-242. https://doi.org/10.1590/0034-737x201865030003

Réjou-Méchain, M., Tanguy, A., Piponiot, C., Chave, J., & Hérault, B. (2017). biomass: An r package for estimating above-ground biomass and its uncertainty in tropical forests. Methods in Ecology and Evolution, 8(9), 1163-1167. https://doi.org/10.1111/2041-210X.12753

Santos, R. M., Vieira, F. A., Fagundes, M., Nunes, Y. R. F., & Gusmão, E. (2007). Riqueza e similaridade florística de oito remanescentes florestais no norte de Minas Gerais, Brasil. Revista Árvore, 31(1), 135-144. https://doi.org/10.1590/S0100-67622007000100015

Santos, R. M., Barbosa, A. C. M. C., Almeida, H. S., Vieira, F. A., Santos, P. F., Carvalho, D. A., & Oliveira-Filho, A. T. (2011). Estrutura e florística de um remanescente de caatinga arbórea em Juvenília, norte de Minas Gerais, Brasil. Cerne, 17(2), 247-258. https://doi.org/10.1590/S0104-77602011000200013

Souza, C. R., Morel, J. D., Santos, A. B. M., Silva, W. B., Maia, V. A., Coelho, P. A., ... & Santos, R. M. (2019). Small-scale edaphic heterogeneity as a floristic–structural complexity driver in Seasonally Dry Tropical Forests tree communities. Journal of Forestry Research 2019, 1-11. https://doi.org/10.1007/s11676-019-01013-9

Zanne, A. E., Lopez-Gonzalez, G., Coomes, D. A., Ilic, J., Jansen, S., Lewis, S. L., ... & Chave, J. (2009). Global wood density database. Dryad Digital repository. https://doi.org/10.5061/dryad.234

ARTIGO 2 - TROPICAL FORESTS STRUCTURE AND DIVERSITY: A COMPARISON OF METHODOLOGICAL CHOICES

Versão preliminar preparada de acordo com as normas do periódico *Methods in Ecology and Evolution*. O conselho editorial do periódico poderá sugerir alterações para adequá-lo ao seu próprio estilo.

Tropical forests structure and diversity: a comparison of methodological choices

Running title: Field methods for sampling dry tropical forests

Abstract

1. Large-scale data compilation is increasing steadily in tropical forest research, but the lack of standardized methods for data collection limits drawing inferences from large datasets and cross biome analyses. Different inclusion methods and minimum tree diameter threshold are among these varying factors. To tackle this issue, we evaluated how different approaches to sample a tree affect our understanding of diversity and functioning in different tropical vegetation types.

2. We used a unique dataset of 44 inventory plots (43.54 ha) encompassing an aridity gradient: evergreen moist forests, semideciduous and deciduous tropical forests. Data were collected using the by-tree inclusion method, in which all stems are measured if the equivalent diameter of the tree reaches the minimum threshold. We simulated the impact of adopting different inclusion methods (by-stem and by-tree) and different minimum diameter thresholds on the number of trees and stems, biomass and species richness. We investigated the impact of different approaches by modeling the relationships between our response vegetation variables and the continuous variation in minimum diameter threshold for each inclusion method and also evaluating the species chances to be sampled under different minimum inclusion criterion.

3. Inclusion method and minimum diameter threshold had greater impact on the number of trees and stems and species richness, especially in deciduous and semideciduous forests, where resprouting is a common strategy. In these forests, many trees have several stems that individually do not reach the minimum size when adopting the by-stem method, but when all stems are considered together, it has an equivalent size that can be sampled with the by-tree method. For these environments under water stress, our analysis showed that using large minimum sizes, such as 10 cm used in rainforests, implies large sampling losses, especially when used together with the by-stem inclusion method.

4. We show the by-tree inclusion method represents an alternative that offers a more realistic sampling of different vegetation types, particularly in those highly threatened habitats where resprouting is a widely encountered strategy. We demonstrate the infeasibility of adopting broad and standard minimum thresholds for different tropical vegetation types, particularly considering their wide different ecological strategies.

Keywords: inclusion criterion; resprouting; tropical dry forests; forest inventory; tropical wet forest.

1. Introduction

Tropical forests are among the most diverse ecosystems on Earth and play a crucial role on the global carbon cycle (Pan et al., 2011; Gibson et al., 2011; Lewis, Edwards & Galbraith 2015; Mitchard, 2018). In recent decades, several studies have attempted to better understand tropical forests spatial and temporal ecological patterns, and also to predict their responses to land-use and climate changes (Feldpausch et al., 2016; Qie et al., 2017; Van de Perre et al., 2018; Hubau et al., 2020; Sullivan et al., 2020). Studies in tropical forests had been initially conducted at local-scale to answer specific scientific questions, though, more recently, they have been incorporating a number of datasets to allow regional and global analyses by compiling data from different tropical biomes (Malhi et al., 2002; Lopez-Gonzalez Lewis, Burkitt & Phillips 2011; Anderson-Teixeira et al., 2014; Maia et al., 2020). A number of problems emerge from the extensive sharing and increased availability of open-access ecological data (Bello et al. 2020). Forest structure and diversity are greatly impacted by survey techniques and data from different sources are rarely collected following the same protocol. Lack of standardization prevents large-scale cross-biome analyses, mainly because differences among data sources are often related to biomes vegetation particularities, which require a specific data collection protocol (Pennington, Lavin & Oliveira-Filho 2009; Moro & Martins 2011; Neves et al., 2017; Moonlight et al., 2020).

Working with different vegetation types generally includes inconsistency in tree minimum size threshold. Minimum size corresponds to the minimum diameter and/or height required for a tree to be included in the inventory (Caiafa & Martins, 2007). Within Amazon, Africa and Asia rainforests (Malhi et al., 2002; Lewis et al., 2009; Qie et al., 2017), the most common inclusion criterion is sampling each stem with diameter at the breast height equal or greater than 10 cm (DBH – 1.30 m from the ground ≥ 10 cm). For Brazilian Atlantic Forest types (e.g., semideciduous and evergreen forests), minimum diameter threshold usually ranges from 4.8 to 5 cm, referring to either stems or (equivalent diameter of) trees. This is the case regardless of structural similarities between Atlantic evergreen forests and rainforests elsewhere (Caiafa & Martins 2007; Souza et al., 2020; Mariano et al., 2020; Matos et al., 2020). For tropical dry forests, a recently released sampling protocol established a minimum diameter threshold of 5 cm for each stem (Moonlight, 2020). However, in the literature, not only minimum size threshold is inconsistent (varying from 2.5 cm, 3 cm, 4.8 and 5 cm), but inclusion method employed: by-stem or by-tree, also varies widely (Moro & Martins, 2011; Rodal et al., 2013; Huamantupa-Chuquimaco, Luza-Victorio, Linares-Palomino & Molleapaza-Arispe 2017; Arruda et al., 2012; Prado-Jr. et al., 2017; Souza et al., 2019; Maia et al., 2020).

Wide range of minimum size thresholds is motivated by differences in vegetation structural attributes, such as tree size in diameter and height, growth rhythm, age structure and resprouting patterns (Vesk & Westoby, 2004; Moro & Martins, 2011). Generally, in semideciduous and deciduous tropical forests that are strongly associated with seasonal climates and water deficit, smaller trees and lower growth rates are prevalent in comparison to rainforests (Pennington et al., 2009; Neves et al., 2017. Maia et al., 2020). Within these dry forests, a given vegetation stratum may encompass trees of different ages than the same stratum in rainforests (Moro & Martins 2011). Therefore, using rainforest minimum threshold in seasonal forest types is likely to underestimates their carbon stocks, productivity, abundance and diversity. On the other hand, adopting lower minimum thresholds in rainforests implies greater sampling effort that may hinder data collection (Gentry & Dodson, 1987; Caiafa & Martins, 2007; Moro & Martins, 2011; Duque et al., 2017).

Surveys across different forest types do not often follow the same protocol; therefore, data aggregation and broad-scale inferences often use the most restrictive and less inclusive minimum sizes. Although some studies have explored the role of minimum size on forests structure and diversity in specific tropical forests types, selection criterions are mostly driven by historical approaches than by quantitative analyses (Caiafa & Martins, 2007; Moro & Martins, 2011). These studies are either limited to small spatial scale or low sampling intensity that do not allow broad-scale inferences and extrapolations to other regions (Gentry & Dodson, 1987; Arruda et al., 2012; Duque et al., 2017). However, only now is it possible to address these issues within tropical forests due to the rapid and recent increase in collaborative research efforts worldwide for a range of forest types. Integrating this data and understanding the impacts of minimum size thresholds on different vegetation types is essential to enable consistent large-scale analyses and to produce reliable inferences on forest structure and functioning.

Another methodological choice rarely explored is the inclusion method, which can consider either the stem or the tree as a basic sampling unit (Fig. 1). The most common method in tropical forests is based on stem size (i.e., by-stem method), which only includes stems that reach the minimum size threshold (Moro & Martins, 2011; Phillips et al., 2018; Moonlight et al., 2020). In the by-stem method, multi-stemmed trees are not included if neither of their stems meet the minimum size threshold (Fig. 1). Another approach in semideciduous and deciduous forests, where multi-stemmed trees are common, is to consider a single measurement (i.e., equivalent diameter) for the whole tree, combining measurements from all living stems (i.e., by-tree method) (Scolforo & Mello, 1997; Souza et al., 2019; Souza et al., 2020; Maia et al., 2020; Mariano et al., 2020). In the by-tree method, a tree is sampled when its equivalent diameter (commonly the quadratic diameter) meets the minimum diameter threshold, meaning that all stems are included in the sampling rather than individual ones that meet the threshold (Fig. 1). Although this method is not widely used and recommended in most data collection protocols within tropical forests (Moro & Martins, 2011; Rodal et al., 2013; Phillips et al., 2018; Moonlight et al., 2020), it is a reliable alternative to sample the ecological structure of forests where resprouting is a common persistence strategy (Bond & Midgley 2001; Vesk & Westoby, 2004; Pausas et al., 2016). To our knowledge, no experimental comparison between different methodological choices is available from which to draw consistent inferences, neither is it known the impact of these methodological choices in the estimates of forest structure, diversity and functioning.

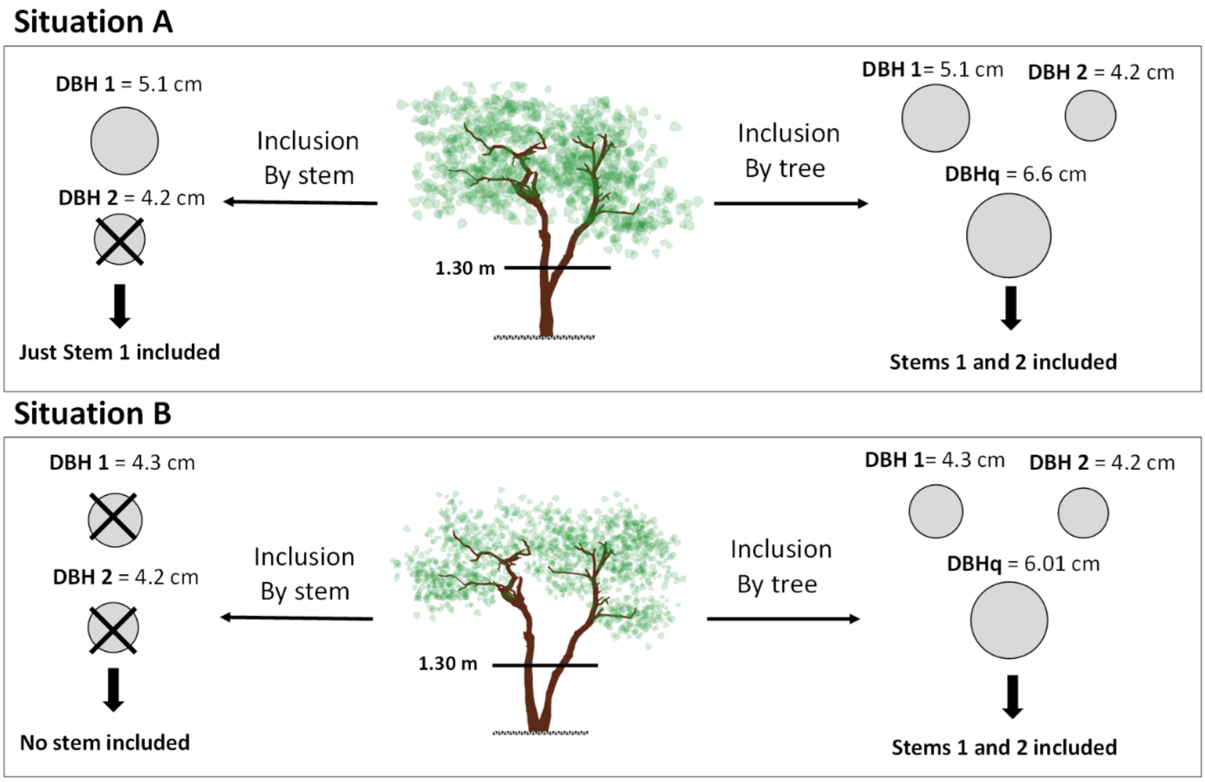


Figure 1: Conceptual framework for inclusion methods: by-stem *vs*. by-tree. In these examples, minimum diameter threshold is 5 cm at breast height (DBH). In the by-tree method, we used quadratic diameter (DBHq) as the equivalent diameter for the whole tree (since both stems reach the minimum criteria at 1.30 m from the ground). For multi-stemmed trees, by-stem is more restrictive than by-tree inclusion method.

To tackle these issues within different tropical forest types, we investigated the role of different methodological choices, minimum diameter threshold and inclusion method (by-stem *vs*. by-tree), on the number of trees, number of stems, biomass and species richness. Using a unique forest inventory dataset, including 44 sites that encompass three forest types (evergreen moist forests, deciduous and semideciduous tropical forest), for each vegetation type we specifically: i) modeled the relationship between our vegetation response variables and minimum size threshold in each inclusion method, ii) compared sampled patterns of each vegetation response variables in reference-values of minimum size threshold in each inclusion method; and also iii) investigated the probability of sampling a species increasing diameter thresholds.

2. Material and methods

2.1 Study sites and data collection

We used forest inventory data from 44 sites widely distributed across Minas Gerais and Bahia states, Brazil (43.54 ha of total sample, 1217 subplots; Fig. S1). From our 44 sampled sites, 22 are deciduous tropical forest (16.76 ha, 419 subplots), 17 semideciduous tropical forest (22.2 ha, 627 subplots) and 5 evergreen moist forest (4.6 ha, 139 subplots) (Table S1). A pronounced water deficit gradient largely summarizes environmental and forest physiognomic differences from the dry deciduous to the moist evergreen forests (Santos et al., 2012; Neves et al., 2017). Plot areas varied widely from 0.1 ha to 5.04 ha across sites, depending on environmental features and specific goals that data collection aimed to meet in each project. In each site we sampled a number of randomly distributed subplots (between 5 and 127, Table S1).

In each subplot, we identified all individual trees at the species level and measured their diameter at breast height (DBH; 1.30 m from the ground) following minimum size thresholds: DBH ≥ 3 cm in deciduous and DBH ≥ 5 cm in semideciduous and evergreen forests. For multi-stemmed trees, the inclusion method was based on quadratic diameter, considering all stems at 1.30 m from the ground (independent of the bifurcation point), or DBHq: $DBHq = \sqrt{(d1^2} + d2^3 + \cdots dn^2)$. When DBHq met the minimum inclusion threshold, diameter of each individual stem was recorded, even if below the DBH threshold. Stems that do not reach 1.30 m from the ground or that bifurcate above this height were not measured. Specific cases that we were unsure whether it represented a multi-stemmed individual or a single tree, we dug up roughly 5 cm in depth to try to identify whether resprouting occurred belowground. If bifurcation point was not found, stems were considered as different trees. Plant identification followed APG IV (2016) and name standardization followed REFLORA (2020). Forest inventory data for all sites are stored in ForestPlots.net (site codes in Table S1). We sampled 56,482 individual trees and 82,663 stems, belonging to 90 plant families, 344 genera and 913 species.

2.2 Vegetation structure and richness

To investigate the impact of different sampling methods on forest structure and richness, we simulated different datasets based on distinct methodological choices: inclusion methods (by-stem *vs*. by-tree) and different minimum diameter thresholds. By-stem inclusion method only includes individual stems with diameter higher than or equal to the minimum DBH threshold; stems from the same multi-stemmed tree may or may not be sampled based on their individual sizes (Fig. 1). In contrast, by-tree inclusion method considers a single measure for each tree, regardless of stem number, including all individual stems below the minimum diameter threshold: the quadratic DBH (Fig. 1).

For each method (by-stem and by-tree), we adopted minimum diameter thresholds varying in continuous intervals of 0.1 cm: in deciduous forests, the threshold ranging between 3 and 30 cm, whereas in semideciduous and evergreen forests, between 5 and 30 cm. We assembled 1546 different scenarios (542 for deciduous, 502 for semideciduous and 502 for evergreen forests). For each DBH value × inclusion method combination, we calculated for each site: number of trees per ha, number of stems per ha, aboveground woody biomass per ha obtained through the pantropical equation of Chave et al. (2014) and corrected species richness. Hereafter aboveground woody biomass will be treated as “biomass” (see supplementary information for details).

Because plot size varied widely, number of trees, stems and biomass were converted to hectare in order to obtain standardized measures per site. However, because species richness does not vary linearly with area, we used rarefaction to standardize the uneven number of stems per site, enabling comparison of species richness between sites. Richness per *n* stems was estimated using individual based rarefaction, considering the minimum number of individual trees sampled in one site in each dataset from the combination: vegetation type - method of inclusion – minimum diameter. Therefore, the number of individuals sampled in one site used as reference for rarefaction differed along continuous diameter values and may also be different between distinct inclusion methods and vegetation types.

2.3 Data analysis

2.3.1 Evaluating the relationship between vegetation variables and minimum DBH for different inclusion methods

The relationship between vegetation variables and minimum DBH for the different inclusion methods was accessed by modeling each vegetation variable of interest as a function of minimum diameter in interaction with the inclusion method in a mixed modeling framework where inclusion method was a factor with two levels (Table 1). Because measures from the same site along the range of diameter and in different inclusion methods are not independent, site was included as a random effect in our models. Number of trees/ha and stems/ha were assessed through non-linear mixed effects models (parameters were allowed to vary randomly among sites), while biomass and corrected species richness (*ln* transformed) were assessed through linear mixed effects models (Table 1). For number of trees/ha and stems/ha we applied three different non-linear models (Table 1), to be later selected through Akaike Information Criterium (AIC). The 'non-linear model 3' (Continuous exponential decay 2) was chosen because they showed the lowest AIC values for all combinations of vegetation variables *vs* vegetation types (table S2). All variables were analysed with the *Gaussian* family, meeting the criteria of homoscedasticity and residuals normality (Figure S2 and S3).

Table 1: Models to estimate vegetation variables (y) including minimum diameter in each inclusion method for the three vegetation types.

Model	Description	Applied for
Non-linear 1: Discrete exponential decay	y ~ a * (1 - b) ^ DBH	Trees and Stems
Non-linear 2: Continuous exponential decay 1	y ~ a * exp (-k * DBH)	Trees and Stems
Non-linear 3: Continuous exponential decay 2	y ~ a * exp (-k * DBH) + c	Trees and Stems
Linear 1	y ~ a + b * DBH	Biomass
Linear 2	ln (y) ~ a + b * DBH	Species richness (corrected)

We investigated the sensibility of vegetation variables to variations in minimum diameter for each inclusion method through the coefficients obtained in the final equations. For ‘non-linear’ and ‘Linear 2’ (with ln transformation) models, coefficients related to minimum diameter corresponds to a constant variation rate (%) as you increase 1 cm in minimum DBH and these values directly reflect minimum DBH impact. For ‘Linear 1’ model, the coefficient related to the minimum diameter corresponds to a constant value of variation in biomass per cm in comparison to the estimated biomass for the reference diameter (3 cm for deciduous forest and 5 cm for semideciduous and evergreen forest). Therefore, in order to obtain a variation rate (%) per cm, we divided the constant value (DBH coefficient) by biomass estimates in the minimum DBH reference of each condition.

To investigated the role of different reference diameter thresholds and the two different inclusion methods on each response variable, we compared their values at different reference values. For deciduous forest we adopted the 3 cm criteria used in our data collection; 5 cm, proposed by DRYFLOR (2020); and 10 cm, which is broadly used in tropical rainforests (Phillips et al., 2018). For semideciduous and evergreen forests, we used the 5 cm criteria, widely used in data collection in Brazilian Atlantic Forest (Caiafa & Martins, 2007); and 10 cm largely used in tropical rainforests. We thus obtained relative values of variation between different minimum thresholds and inclusion methods, always using the least restrictive option as reference. Further details are available in the supplementary information.

2.3.3 Species chance to be sampled in reference minimum DBH and inclusion methods

We investigated the chance of sampling each tree species in each vegetation type, considering the reference values of minimum DBH. For each species, in each vegetation type, we quantified potential tree size for isolated stems and for the individual as a whole (multi-stemmed tree). For species with at least 20 individuals, potential tree size was estimated as the 95th percentile of the size distribution, while for species with less than 20 we used the maximum DBHq, considering the stability of the average diameter value for both tree and stem levels (Fig. S4). Similar approach was used to obtain maximum DBH value of species stem. For each vegetation type we investigated whether there are species that have their maximum tree DBHq (relative to the by-tree inclusion method) and/or their maximum stem DBH (relative to the by-stem inclusion method) lower than the diameter reference values. All analyses were performed in software R v. 3.6.1 (2020), using the packages *nlme* (Pinheiro et al., 2020) and *lme4* (Bates, Maechler & Bolker 2015).

3. Results

3.1 Impact of minimum DBH and inclusion methods on vegetation variables

Variation in minimum diameter thresholds play a major role in the number of trees and stems per hectare, with losses greater than 10% per cm increase in diameter threshold (Figures 2 and 3, Table S3), followed by corrected species richness (Figure 3; losses ranging from -6 to -9% per cm increase in minimum diameter). In contrast, because biomass stocks are mainly driven by large trees, variation in minimum diameter had little effect on biomass (Figure 3; -2% per cm increase in diameter thresholds).

Increasing diameter threshold, we found considerable variation in number of stems and species richness between inclusion methods and among vegetation types Number of stems/ha varied more widely (+10% in deciduous tropical forests and +7% in evergreen moist forest using the by-stem inclusion method). Overall, species richness varied little between vegetation types and inclusion methods, thought semideciduous forests showed up to 1.65 % increase in the number of species when using the by-tree inclusion method (Figure 3). In contrast, number of trees per hectare and biomass were similar between inclusion methods and vegetation types (Figures 2 and 3, Table S3).

Using diameter reference values and the by-stem inclusion method widely used in the literature, we found greater losses in number of stems and to a lesser extent, in the number of trees: basic inclusion unities in forest inventories. For a given diameter, losses were particularly higher in deciduous tropical forests (-15% in the number of stems/ha for 3 cm, -34% for 5 cm and -51% for 10 cm diameter threshold), followed by evergreen (-16% and -22% for 5 and 10 cm, respectively) and compared semideciduous forests (-8% for 5 cm and -19% for 10 cm; Table S4). These results show that coupling 5 cm threshold with the by-tree method yields more representative results for stems/ha, even when comparing to the more inclusive 3 cm diameter associated with the by-stem method. Results for species richness and biomass are shown in table S4.

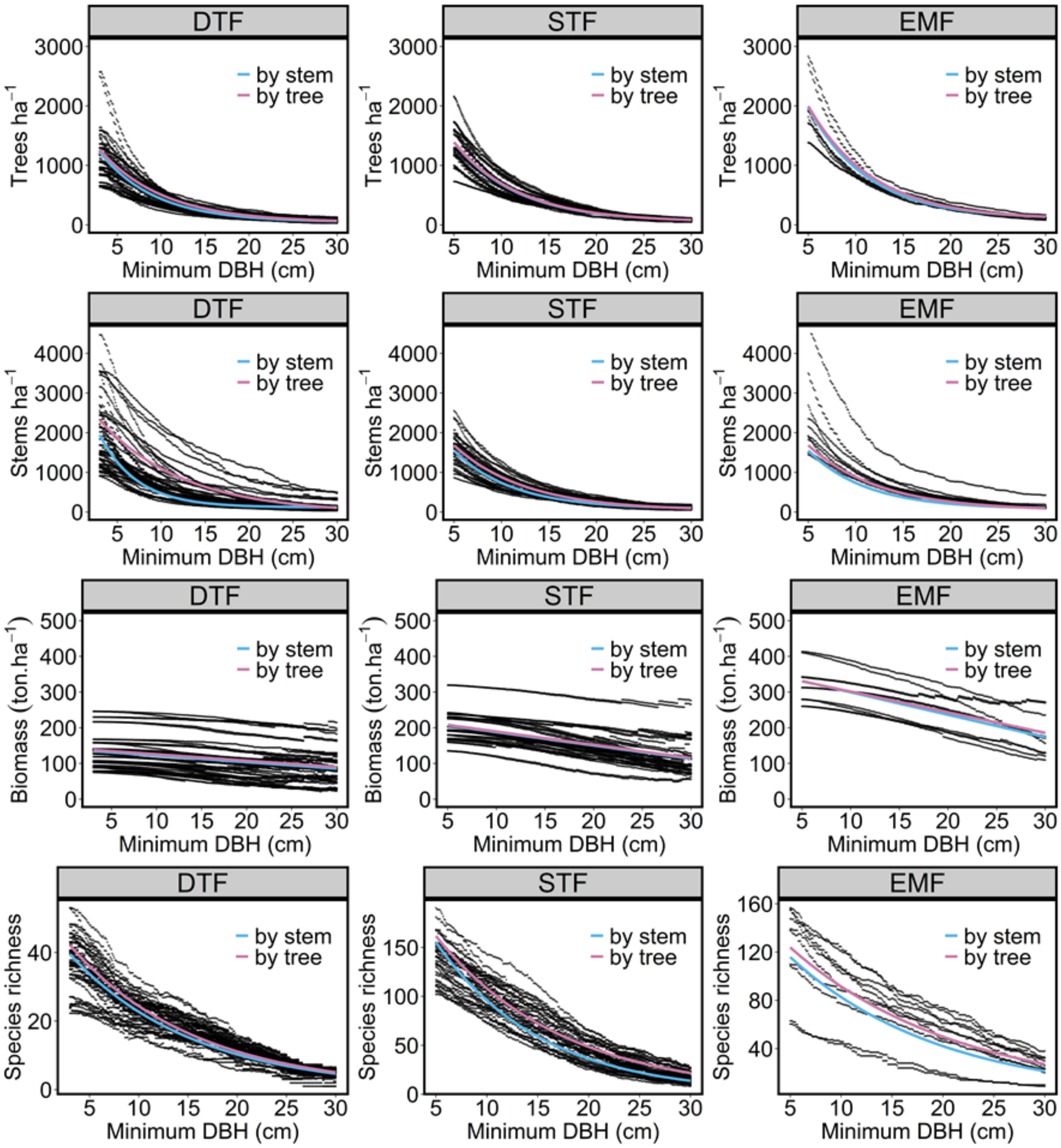


Figure 2: Variation in vegetation variables in response to increase in diameter thresholds, according to different inclusion methods (by-stem and by-tree) and distinct vegetation types (deciduous tropical forest – DTF; semideciduous tropical forest – STF; evergreen moist forest – EMF). Observed values are shown in black and predicted curves were obtained from the best fitted-model.

Figure 3: Rates of variation (%) per cm, for each vegetation variable in the different inclusion methods (by-stems and by-tree) and distinct in vegetation types (deciduous tropical forest – DTF; semideciduous tropical forest – STF; evergreen moist forest – EMF). Values were obtained from coefficients of final equations.

3.2 Species chance to be sampled in reference minimum DBH and inclusion methods

Investigating the probability of sampling any given species according to methodological choices, we show that minimum diameter threshold (especially 10 cm) and inclusion methods affect species sampling (Fig. 4). In deciduous forest 3 species did not reach the minimum of 5-cm diameter and tended not to be sampled when using the by-stem inclusion method, however, using the by-tree inclusion method increases the chances of sampling these species (Fig. 4). Impact was way stronger when using the 10 cm DBH criterion in these deciduous forests: losses of up to 56 species (26%) with the by-stem and 15 species (7%) in the by-tree inclusion method.

Semideciduous and evergreen forests are less sensitive to the 10 cm DBH threshold, showing differences of 14 (5%) and 15 (9.6%) species when using the by-stem inclusion method and 7 (2.6%) in semideciduous and 10 (6.4%) in evergreen forests when considering the by-tree inclusion method (Fig. 4).

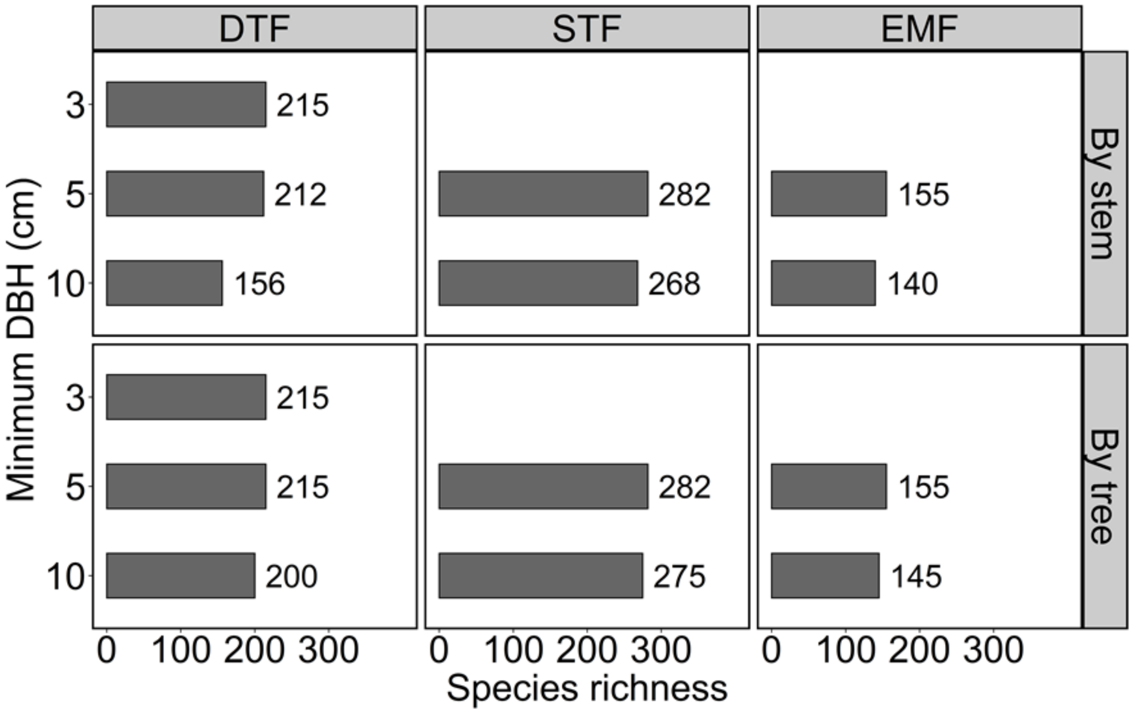


Figure 4: Number of species sampled with different minimum diameter threshold, across different vegetation types (deciduous tropical forest – DTF; semideciduous tropical forest – STF; evergreen moist forest – EMF) and considering different inclusion methods (by-stem and by-tree). Values were obtained by the maximum diameter calculated for each species.

4. Discussion

4.1 Vegetation variations in response to different inclusion methods

Our results show that different inclusion methods strongly affect the number of trees, number of stems and species richness, particularly in deciduous and semideciduous tropical forests. In these dry environments associated with climatic seasonality and long dry periods, many species adopt resprouting as a survival strategy in response to restrictive conditions: due to physiological injury caused by water stress, resprouting tends to be more frequent and intense under these harsh condition (Ceccon, Huante & Rincón et al. 2006; Zeppel et al., 2015; Pausas et al., 2016; Souza et al. 2019). Therefore, under strong environmental filter imposed, trees tend to have two or more separate stems that often do not individually meets the minimum size criteria adopted.

Using the by-stem inclusion method, most trees are not sampled for individually not meeting the minimum size and a number of species are not included because they are obligatorily associated with resprouting strategy. However, when considering the equivalent diameter of the tree as a whole (i.e., all living stems), these individuals and species are sampled for having a joint diameter that reaches this minimum size (Fig. 1). In fact, while in a moist forest a tree may have only one stem with 10 cm diameter, individuals in deciduous and semideciduous tropical forests may have this equivalent diameter as a result of all their isolated stems. For example, using the by-stem inclusion method and 5 cm threshold, from two individual trees that have 28 and 10 living stems (Fig. 5), only 2 stems in each tree would be sampled and all information about the plant's occurrence and its strategy would be lost. Therefore, because excluding these small-stemmed individuals largely undermines forest structure (number of trees) and their extraordinary biodiversity (i.e., excludes a number of tree species that rarely or never achieve the minimum threshold), we highlight the importance of resprouting strategy as essential in the assessment of vegetation patterns in these dry environments.

Inclusion methods did not impact biomass estimates (Figure 3; Table S4). Biomass stocks are largely driven by large and high statured trees (Gentry and Dodson 1987; Arruda et al. 2012; Duque et al. 2017) and individual stems in the inclusion range are small and tend to contribute little to community's biomass. In fact, in these dry environments, trees with up to 10 cm diameter, represent roughly 58 to 63 % of the number of individuals (depending on the inclusion method), thought contribute solely with nearly 4 to 8 % in terms of biomass (Table S4). In contrast, larger trees with more than 10 cm, plays a major role in the global carbon cycle, contributing to more than the 90 % of total biomass.

Figure 5: Trees sampled in two deciduous tropical forest sites. Tree on the left has 28 living stems and the tree on the right 10 living stems, with an even greater number of dead stems. In both cases, just 2 of them have diameter at the breast height equal or greater than 5 cm. Note that both trees have additional dead stems that were not included in our sampling.

Inclusion method choice plays an important role for consistently estimate the number of stems, trees and species richness and more importantly, to correctly represent resprouting ecological strategy. We show that using the widely recommended by-stem inclusion method (Moro & Martins, 2011; Rodal et al., 2013; Philips et al., 2018; DRYFLOR, 2020) is likely to underestimates this strategy and undersample species strongly related to it (Figures 3 and 4). Because sampling effort will considerably increase when adopting by-tree inclusion method, it is expected that there will be an increase in financial costs and time effort. In terms of time, small stems are the quickest component to sample, as they are easier to taxonomically identify and measure. In fact, even in these dry forests, a large number of trees have at least one stem that meets the criterion alone, which already automatically qualifies all of its stems for measurement and reduces the number of cases where after measuring all small stems and assessing their equivalent diameter, a tree is not included in the sample. Therefore, despite increase in sampling time and effort, we strongly recommend the adoption of the by-tree inclusion method for both deciduous and semideciduous tropical forests, environments where the by-stems inclusion method represents a less realistic sampling of forest structure and diversity.

By-tree method may also be preferable in evergreen and rainforest, although their forest structure and diversity are not directly impacted by this methodological choice. In these wet environments, the huge majority of individuals are represented by a single or few stems that meet the minimum size threshold (Moro & Martins, 2011; Philips et al., 2018). Therefore, adopting this method does not increase operational effort and promotes methodological standardization between different forest types, which is particularly relevant for macroscale studies.

4.2 Impacts of minimum DBH on vegetation patterns

Diameter threshold have a direct impact on forest structure, diversity and to a lesser extent, vital ecosystem functions such as the amount of carbon stored in the living biomass in all vegetation types, but mainly in dry forests (deciduous and semideciduous). In these dry ecosystems, the use of use large minimum sizes yields greater information losses due to trees being generally smaller than the ones found in rainforests. These findings point out the problem of standardizing methodological choices delineated for rainforests (i.e., that has been more widely and longest studied) for dry forests, such as adopting a common 10 cm threshold (Phillips et al., 2018; Gaui et al., 2019; D'Andrea et al., 2020).

Minimum 10 cm threshold has also been used for deciduous and semideciduous forest (Caiafa & Martins, 2007; Becknell & Powers, 2014), including great efforts such as the Brazilian National Forest Inventory that most intensively sampled large individuals (≥10 cm; SFB, 2019). Because 10 cm threshold may largely undermines forest structure and diversity in these dry environments (Fig. 3), studies adopting this criterion may not adequately provide reliable inferences on broad scales such as biogeographic region or biome. Although impacts could potentially be small (e.g., in studies focused on biomass), this may be particularly problematic for conservation decisions, such as areas priority conservation areas for vegetation. For example, *Psidium acutangulum* DC and *Peltogyne confertiflora* (Mart. ex Hayne) Benth will be hardly sampled in deciduous forests and *Myrcia pubipetala* Miq. and *Byrsonima coccolobifolia* Kunth. in semideciduous forests. In fact, although the 5 cm threshold recently proposed by DRYFLOR (2020) protocol also promotes losses when compared to the 3 cm threshold and the by-stem inclusion method, losses are reduced whilst adopting the by-tree method, particularly for the number of stems. Therefore, the 5 cm minimum threshold and the by-tree inclusion method may be preferred in these dry, undersampled and threatened ecosystems. In turn, although in broad-scale studies within different forest types adopting a less inclusive threshold may be inevitable for protocol standardization, we understand that research initiatives that aim to consistently understand these dry environments must well reflect their important ecological strategies, reducing the risks of undersample their functioning and diversity.

5. Final remarks

Inclusion method and minimum diameter threshold affect consistently estimates of important ecological patterns, particularly in dry and highly threatened ecosystems. Data collection in these dry forests worldwide must be based on their main broad ecological characteristics, which will allow future analyses at biogeographic region and biome scales. In deciduous and semideciduous tropical forests many species adopt resprouting as an occupation strategy, having several stems that alone do not reach the minimum size, but that at the tree level, attains a minimum diameter that should be included. Therefore, considering the wide occurrence of resprouting strategy in these neglected dry ecosystems, we recommend adopting 5-cm threshold and the by-tree inclusion method in different tropical dry vegetation types.

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Data availability statement

Data used will be available at Dryad (https://datadryad.org/stash/).

References

Anderson-Teixeira, K. J., Davies, S. J., Bennett, A. C., Gonzalez-Akre, E. B., Muller-Landau, H. C., Joseph Wright, S., … Zimmerman, J. (2014). CTFS-ForestGEO: A worldwide network monitoring forests in an era of global change. Global Change Biology, 21, 528–549. https://doi.org/10.1111/gcb.12712

APG - Angiosperm Phylogeny Group. (2016). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Botanical Journal of the Linnean Society, 181, 1-20. https://doi.org/10.1111/boj.12385

Arruda, D. M., Batista, M. L., Simão, M. D. C., Duque-Brasil, R., Ferreira-Júnior, W. G., & Schaefer, C. E. G. R. (2012). Different sizes of the smallest individual sampled and their interpretations: case study in the seasonally dry forest. Pesquisa Florestal Brasileira, 32(72), 471-476. https://doi.org/10.4336/2012.pfb.32.72.471

Bates, D., Maechler, M., & Bolker, B. (2015). Walker., S. Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67(1), 1-48. https://doi.org/10.18637/jss.v067.i01

Becknell, J. M., & Powers, J. S. (2014). Stand age and soils as drivers of plant functional traits and aboveground biomass in secondary tropical dry forest. Canadian Journal of Forest Research, 44(6), 604-613. https://doi.org/10.1139/cjfr-2013-0331

Bello, F., Valencia, E., Ward, D., & Hallett, L. (2020) Why we still need permanent plots for vegetation science. Journal of Vegetation Science, 31 (5). https://doi.org/10.1111/jvs.12928

Bond, W. J., & Midgley, J. J. (2001). Ecology of sprouting in woody plants: the persistence niche. Trends in ecology & evolution, 16(1), 45-51. https://doi.org/10.1016/S0169-5347(00)02033-4

Caiafa, A.N., & Martins, F.R. (2007). Taxonomic identification, sampling methods, and minimum size of the tree sampled: implications and perspectives for studies in the Brazilian Atlantic Rainforest. Functional Ecosystems and Communities, 1(2), 95-104.

Cairns, M. A., Olmsted, I., Granados, J., & Argaez, J. (2003). Composition and aboveground tree biomass of a dry semi-evergreen forest on Mexico’s Yucatan Peninsula. Forest ecology and Management, 186(1-3), 125-132. https://doi.org/10.1016/S0378-1127(03)00229-9

Carvalho, G. (2016). flora: Tools for Interacting with the Brazilian Flora 2020. R package version 0.3.1. http://www.github.com/gustavobio/flora

Ceccon, E., Huante, P., & Rincón, E. (2006). Abiotic factors influencing tropical dry forests regeneration. Brazilian archives of Biology and Technology, 49(2), 305-312. https://doi.org/10.1590/S1516-89132006000300016

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B., ... & Vieilledent, G. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. Global change biology, 20(10), 3177-3190. https://doi.org/10.1111/gcb.12629

D’Andrea, R., Guittar, J., O’Dwyer, J. P., Figueroa, H., Wright, S. J., Condit, R., & Ostling, A. (2020). Counting niches: Abundance-by-trait patterns reveal niche partitioning in a Neotropical forest. Ecology, 101(6), e03019. https://doi.org/10.1002/ecy.3019

DRYFLOR, (2020). DRYFLOR Field Manual for Plot Establishment and Remeasurement. (Latin American Seasonally Dry Tropical Forest Floristic Network, 2020, 29 p.)

Duque, A., Muller-Landau, H.C., Valencia, R., Cardenas, D., Davies, S., Oliveira, A., ... & Vicentini, A. (2017). Insights into regional patterns of Amazonian forest structure, diversity, and dominance from three large terra-firme forest dynamics plots. Biodiversity and Conservation, 26(3), 669-686. https://doi.org/10.1007/s10531-016-1265-9

Feldpausch, T. R., Phillips, O. L., Brienen, R. J. W., Gloor, E., Lloyd, J., Lopez-Gonzalez, G., … Vos, V. A. (2016). Amazon forest response to repeated droughts. Global Biogeochemical Cycles, 30, 964–982. https://doi.org/10.1002/2015G B005133

Flora do Brasil 2020 em construção. (2020) Jardim Botânico do Rio de Janeiro. Available in: http://floradobrasil.jbrj.gov.br/

Gaui, T. D., Costa, F. R. C., Souza, F. C., Amaral, M. R. M., Carvalho, D. C., Reis, F. Q., & Higuchi, N. (2019). Long-term effect of selective logging on floristic composition: A 25 year experiment in the Brazilian Amazon. Forest Ecology and Management, 440, 258-266. https://doi.org/10.1016/j.foreco.2019.02.033

Gentry, A.A., & Dodson, C., (1987) Contribution of nontrees to species richness of a tropical rain forest. Biotropica, 19(2), 149-156. https://doi.org/10.2307/2388737

Gibson, L., Lee, T.M., Koh, L.P., Brook, B.W., Gardner, T.A., Barlow, J., ... & Sodhi, N.S. (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. Nature, 478(7369), 378-381. https://doi.org/10.1038/nature10425

Huamantupa-Chuquimaco, I., Luza-Victorio, M.A., Linares-Palomino, R., & Molleapaza-Arispe, E. (2017). Woody plant diversity in seasonally dry tropical forests of Urubamba basin, a threatened biodiversity hotspot in southern Peru. Tropical Ecology, 58(3), 555-571.

Hubau, W., Lewis, S.L., Phillips, O.L., Affum-Baffoe, K., Beeckman, H., Cuní-Sanchez, A., ... & Sheil, D. (2020). Asynchronous carbon sink saturation in African and

Amazonian tropical forests. Nature, 579(7797), 80-87. https://doi.org/10.1038/s41586-020-2035-0

Lewis, S.L., Lopez-Gonzalez, G., Sonké, B., Affum-Baffoe, K., Baker, T.R., Ojo, L.O., … Wöll, H. (2009). Increasing carbon storage in intact African tropical forests. Nature, 457, 1003–1006. https://doi.org/10.1038/nature07771

Lewis, S. L., Edwards, D. P. & Galbraith, D. Increasing human dominance of tropical forests. Science 349, 827–832 (2015). https://doi.org/10.1126/science.aaa9932

Lopez-Gonzalez, G., Lewis, S. L., Burkitt, M., & Phillips, O. L. (2011). ForestPlots. net: a web application and research tool to manage and analyse tropical forest plot data. Journal of Vegetation Science, 22(4), 610-613. https://doi.org/10.1111/j.1654-1103.2011.01312.x

Maia, V.A., Souza, C.R., de Aguiar-Campos, N., Fagundes, N.C.A., Santos, A.B.M., Paula, G. G.P., ... & Santos, R.M. (2020). Interactions between climate and soil shape tree community assembly and above-ground woody biomass of tropical dry forests. Forest Ecology and Management, 474, 118348. https://doi.org/10.1016/j.foreco.2020.118348

Malhi, Y., Phillips, O. L., Lloyd, J., Baker, T., Wright, J., Almeida, S., … Vinceti, B. (2002). An international network to monitor the structure, composition and dynamics of Amazonian forests (RAINFOR). Journal of Vegetation Science, 13, 439–450. https://doi.org/10.1111/j.1654-1103.2002.tb020 68.x

Mariano, R. F., Rezende, V. L., Mendes, C. N., Santos, R. M. D., Souza, C. R. D., Moura, A. S. D., ... & Fontes, M. A. L. Phylogenetic beta diversity in an upper montane Atlantic Forest along an altitudinal gradient. Plant Ecology, 1-12. https://doi.org/10.1007/s11258-020-01041-0

Moonlight, P. W., Banda-R, K., Phillips, O. L., Dexter, K. G., Pennington, R. T., Baker, T. R., ... & Lloyd, J. (2020). Expanding tropical forest monitoring into Dry Forests: The DRYFLOR protocol for permanent plots. Plants, People, Planet, 00, 1–6. https://doi.org/10.1002/ppp3.10112

Matos, F. A., Magnago, L. F., Aquila Chan Miranda, C., de Menezes, L. F., Gastauer, M., Safar, N. V., ... & Martins, S. V. (2020). Secondary forest fragments offer important carbon and biodiversity cobenefits. Global Change Biology, 26(2), 509-522. https://doi.org/10.1111/gcb.14824

Mitchard, E.T.A. (2018). The tropical forest carbon cycle and climate change. Nature, 559(7715), 527-534. https://doi.org/10.1038/s41586-018-0300-2

Moro, M.F., & Martins, F.R. (2011). Métodos de levantamento do componente arbóreo-arbustivo. In: Felfili, J.M.m Eisenlohr, P.V., Melo, M.M.F., Andrade, L.A., & Meira-Neto, J.A.A. (Eds.). *Fitossociologia no Brasil: métodos e estudos de casos*. (pp. 174-212). Viçosa, MG: Ed. da UFV.

Neves, D.M., Dexter, K.G., Pennington, R.T., Valente, A.S., Bueno, M.L., Eisenlohr, P.V., ... & Saiter, F.Z. (2017). Dissecting a biodiversity hotspot: The importance of environmentally marginal habitats in the Atlantic Forest Domain of South America. Diversity and Distributions, 23(8), 898-909. https://doi.org/10.1111/ddi.12581

Pan, Y., Birdsey, R.A., Fang, J., Houghton, R., Kauppi, P.E., Kurz, W.A., ... & Ciais, P. (2011). A large and persistent carbon sink in the world's forests. Science, 333(6045), 988-993. https://doi.org/10.1126/science.1201609

Pausas, J.G., Pratt, R.B., Keeley, J.E., Jacobsen, A.L., Ramirez, A.R., Vilagrosa, A., ... & Davis, S.D. (2016). Towards understanding resprouting at the global scale. New Phytologist, 209(3), 945-954. https://doi.org/10.1111/nph.13644

Pennington, R. T., Lavin, M., & Oliveira-Filho, A. T. (2009). Woody plant diversity, evolution, and ecology in the tropics: perspectives from seasonally dry tropical forests. Annual Review of Ecology, Evolution, and Systematics, 40, 437-457. https://doi.org/10.1146/annurev.ecolsys.110308.120327

Pinheiro, J, Bates, D., DebRoy, D., Sarkar, D. nlme: Linear and nonlinear mixed effects. R package version 3.1-144 (2020). https://CRAN.R-project.org/package=nlme

Prado-Junior, J.A., Schiavini, I., Vale, V.S., Raymundo, D., Lopes, S.F., & Poorter, L. (2017). Functional traits shape size-dependent growth and mortality rates of dry forest tree species. Journal of Plant Ecology, 10(6), 895-906. https://doi.org/10.1093/jpe/rtw103

Phillips, O.L., Baker, T.R., Feldpausch, T.R., & Brienen, R.J.W. (2018). RAINFOR field manual for plot establishment and remeasurement. Amazon Forest Inventory Network.

Qie, L., Lewis, S.L., Sullivan, M.J.P., Lopez-Gonzalez, G., Pickavance, G.C., … Phillips, O.L. (2017). Long term sink in Borneo's forests halted by drought and vulnerable to edge effects. Nature Communications, 8, 1966. https://doi.org/10.1038/s41467-017-01997-0

R Core Team (2020). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. ISBN 3-900051-07-0. URL http://www.R-project.org

Rodal, M.J.N., Sampaio, E.V.S.B., & Figueiredo, M.A. (2013). Manual sobre métodos de estudo florístico e fitossociológico: ecossistema caatinga (1st ed.). Brasília: Sociedade Botânica do Brasil.

Santos, R.M., Oliveira-Filho, A.T., Eisenlohr, P.V., Queiroz, L. P., Cardoso, D. B. O. S., & Rodal, M. J. N. (2012). Identity and relationships of the Arboreal Caatinga among other floristic units of seasonally dry tropical forests (SDTFs) of north-eastern and Central Brazil. Ecology and Evolution, 2(2), 409–428. https://doi.org/10.1002/ece3.91

Scolforo, J.R.S, & Mello, J.M. (1997). Inventário florestal. Lavras: UFLA/FAEPE.

Serviço Florestal Brasileiro (2019). Manual de campo: procedimentos para coleta de dados biofísicos e socioambientais. Brasília: Serviço Florestal Brasileiro.

Souza, C.R., Morel, J.D., Santos, A.B.M., Silva, W.B., Maia, V.A., Coelho, P.A., ... & Santos, R.M. (2019). Small-scale edaphic heterogeneity as a floristic–structural complexity driver in Seasonally Dry Tropical Forests tree communities. Journal of Forestry Research, 2019, 1-11. https://doi.org/10.1007/s11676-019-01013-9

Souza, C.R., Paula, G.G., Mendes, C.N., Maia, V.A., Aguiar-Campos, N., Araújo, F.C., ... & Santos, R.M. (2020). Local-scale tree community ecotones are distinct vegetation types instead of mixed ones: a case study from the Cerrado–Atlantic forest ecotonal region in Brazil. Australian Journal of Botany, 68(2), 153-164. https://doi.org/10.1071/BT19108

Sullivan, M.J., Lewis, S.L., Affum-Baffoe, K., Castilho, C., Costa, F., Sanchez, A.C., ... & Qie, L. (2020). Long-term thermal sensitivity of Earth’s tropical forests. Science, 368(6493), 869-874. https://doi.org/10.1126/science.aaw7578

Van de Perre, F., Willig, M.R., Presley, S.J., Andemwana, F.B., Beeckman, H., Boeckx, P., ... & Grootaert, P. (2018). Reconciling biodiversity and carbon stock conservation in an Afrotropical forest landscape. Science advances, 4(3), eaar6603. https://doi.org/10.1126/sciadv.aar6603

Vesk, P.A., & Westoby, M. (2004). Sprouting ability across diverse disturbances and vegetation types worldwide. Journal of Ecology, 92 (2), 310-320. https://doi.org/10.1111/j.0022-0477.2004.00871.x

Zeppel, M. J. B., Harrison, S. P., Adams, H. D., Kelley, D. I., Li, G., Tissue, D. T., Palmer, A., & McDowell, N. G. (2015). Drought and resprouting plants. New Phytologist, 206(2), 583–589. https://doi.org/10.1111/nph.13205

Supplementary information

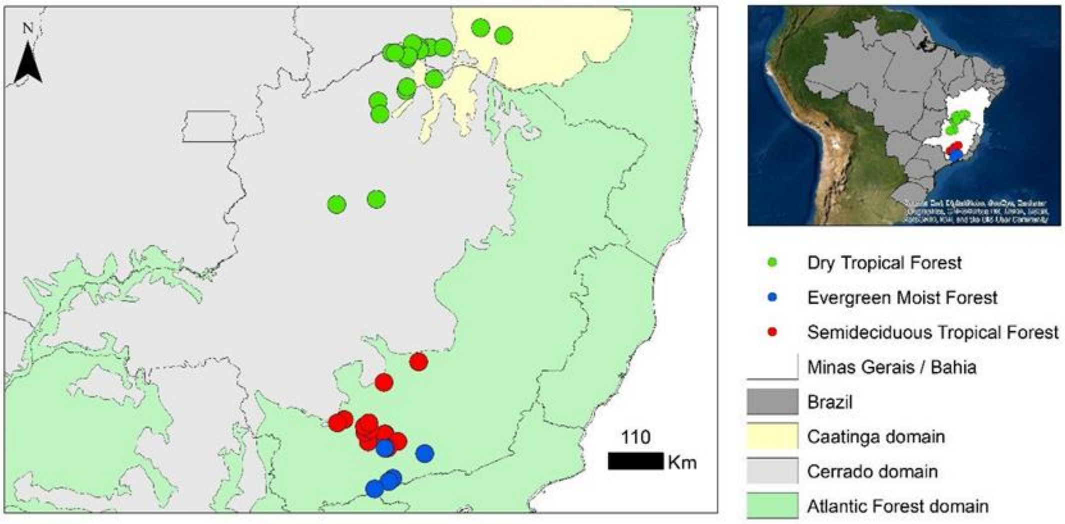

Figure S1: Location of the 44 sites of collection used in this study in relation to Brazil and biogeographic domains.

Table S1: Basic information of the 44 sites of collection used in this study. The codes for sites presented are the respective codes on ForestPlot system (https://www.forestplots.net/).

Sites	Vegetation type	Latitude	Longitude	Subplots	Sample (ha)
BAH-01	Deciduous tropical forest	-14.910683	-43.714810	30	1.2
BAH-02	Deciduous tropical forest	-14.334986	-43.801181	15	0.6
BAH-03	Deciduous tropical forest	-14.337406	-43.803228	15	0.6
BAH-04	Deciduous tropical forest	-14.326850	-43.991317	27	1.08
BAH-05	Deciduous tropical forest	-14.389583	-43.976750	20	0.8
BAH-06	Deciduous tropical forest	-14.481812	-44.205564	5	0.2
BAH-07	Deciduous tropical forest	-14.470483	-44.188433	51	2.04
BON-01	Deciduous tropical forest	-15.311600	-44.734900	15	0.6
CTT-01	Deciduous tropical forest	-14.120734	-42.453691	15	0.6
CTT-02	Deciduous tropical forest	-13.979940	-42.874492	15	0.6
DEC-01	Deciduous tropical forest	-14.413800	-44.162700	20	0.8
DEC-02	Deciduous tropical forest	-15.550200	-44.701000	30	1.2
DEC-03	Deciduous tropical forest	-14.544700	-44.210500	10	0.4
DEC-04	Deciduous tropical forest	-14.266300	-44.106800	5	0.2
DEC-05	Deciduous tropical forest	-14.431500	-44.491100	5	0.2
DEC-06	Deciduous tropical forest	-14.491900	-44.184100	12	0.48
IUI-01	Deciduous tropical forest	-14.340986	-43.546122	15	0.6
JEQ-01	Deciduous tropical forest	-17.094028	-44.765028	30	1.2
MON-01	Deciduous tropical forest	-14.440100	-44.424600	25	1.0

PAR-01	Deciduous tropical forest	-17.188193	-45.484999	30	1.2
PNP-01	Deciduous tropical forest	-15.120799	-44.227304	5	0.2
PNP-02	Deciduous tropical forest	-15.058333	-44.206944	24	0.96
CLI-01	Semideciduous tropical forest	-20.418409	-44.628740	20	0.8
COQ-01	Semideciduous tropical forest	-21.094633	-45.348231	20	0.8
COQ-02	Semideciduous tropical forest	-21.155300	-45.471400	25	1.0
ING-01	Semideciduous tropical forest	-21.409800	-44.892900	25	1.0
ITT-01	Semideciduous tropical forest	-21.352550	-44.608960	42	0.945
ITT-02	Semideciduous tropical forest	-21.355614	-44.615533	28	0.84
LUM-01	Semideciduous tropical forest	-21.497700	-44.913400	32	1.28
MDD-01	Semideciduous tropical forest	-21.488500	-44.376200	70	1.575
MTR-01	Semideciduous tropical forest	-21.606900	-44.556900	30	1.2
POC-01	Semideciduous tropical forest	-21.329200	-44.971700	26	0.78
POC-03	Semideciduous tropical forest	-21.329200	-44.971700	38	1.14
RMP-01	Semideciduous tropical forest	-20.043419	-43.998581	25	1.0
SUB-01	Semideciduous tropical forest	-21.221400	-44.963100	48	1.92
SUB-02	Semideciduous tropical forest	-21.227800	-44.963900	126	5.04
SUB-03	Semideciduous tropical forest	-21.273700	-44.882000	28	1.12
SUB-04	Semideciduous tropical forest	-21.216667	-44.980278	29	1.16
SUB-05	Semideciduous tropical forest	-21.150000	-44.900000	15	0.6
BOC-01	Evergreen moist forest	-22.161732	-44.465836	10	0.4
BOC-02	Evergreen moist forest	-22.217500	-44.538900	26	1.04
CRR-01	Evergreen moist forest	-21.612100	-44.612000	30	1.2
IBI-01	Evergreen moist forest	-21.710300	-43.885500	48	0.96
ITM-01	Evergreen moist forest	-22.350050	-44.794617	25	1.0

Above-ground woody biomass obtaining and species richness correction

AGWB for each stem was obtained through pantropical equation of Chave et al. (2014) modified for absence of height data, using the *BIOMASS* package (Rejou-Mechaine et al. 2017) in R Statistical Software (R Core Team 2020). This equation uses the stems DBH, the species average wood density in the region (tropical South America) obtained in a global database (Zanne 2009), and the *E* measure of restriction to compensate the lack of height information through its relationship with climatic stress in broad scale. When species woody density values are not available, we use the genus average, the family average (when genus information is not available) or the average of values from other species in the site when there is no information for taxonomic levels.

Modeling the relationship between vegetation variables and minimum DBH for different inclusion methods

Table S2: Akaike Information Criterion (AIC) for the three non-linear models tested for the variables "Trees/ha" and "Stems/ha" in each vegetation type. These results were considered to define the final model to be adopted for each variable in each vegetation type.

Variable	Vegetation type	Model	AIC
Trees	Dry Tropical Forest	Non-linear 1	116689
		Non-linear 2	116806
		Non-linear 3	110369
	Semideciduous Tropical Forest	Non-linear 1	80396
		Non-linear 2	80412
		Non-linear 3	70710
	Evergreen Moist Forest	Non-linear 1	26806
		Non-linear 2	26814
		Non-linear 3	23816
Stems	Dry Tropical Forest	Non-linear 1	143253
		Non-linear 2	143062
		Non-linear 3	134934
	Semideciduous Tropical Forest	Non-linear 1	92724
		Non-linear 2	89630
		Non-linear 3	85680
	Evergreen Moist Forest	Non-linear 1	28651
		Non-linear 2	30474
		Non-linear 3	26806

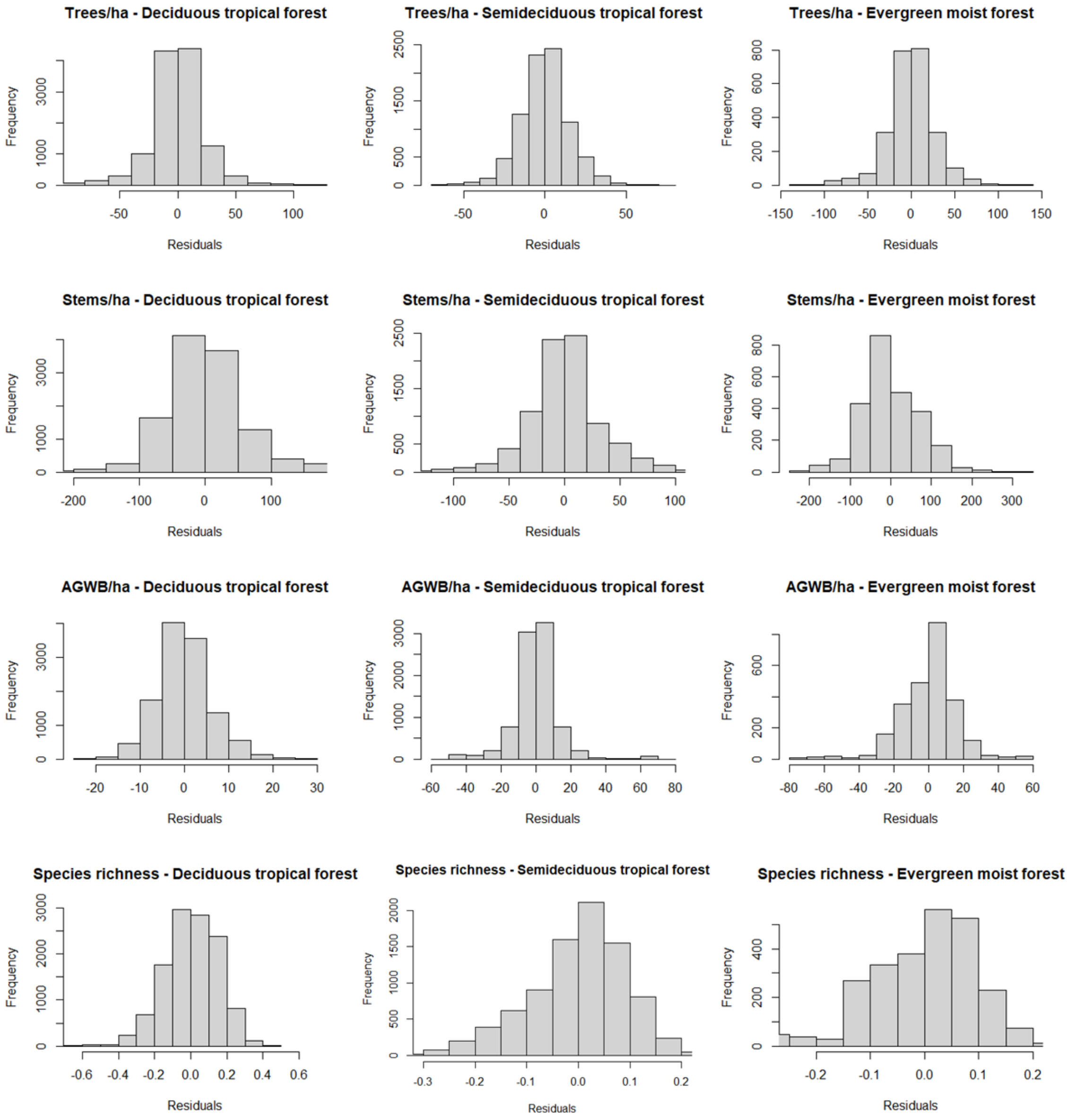

Figure S2: Residuals histograms of the selected models for the four vegetation variables sampled in its relationship with the minimum DBH and the inclusion method for the three vegetation types. **Note:** AGWB: above-ground woody biomass.

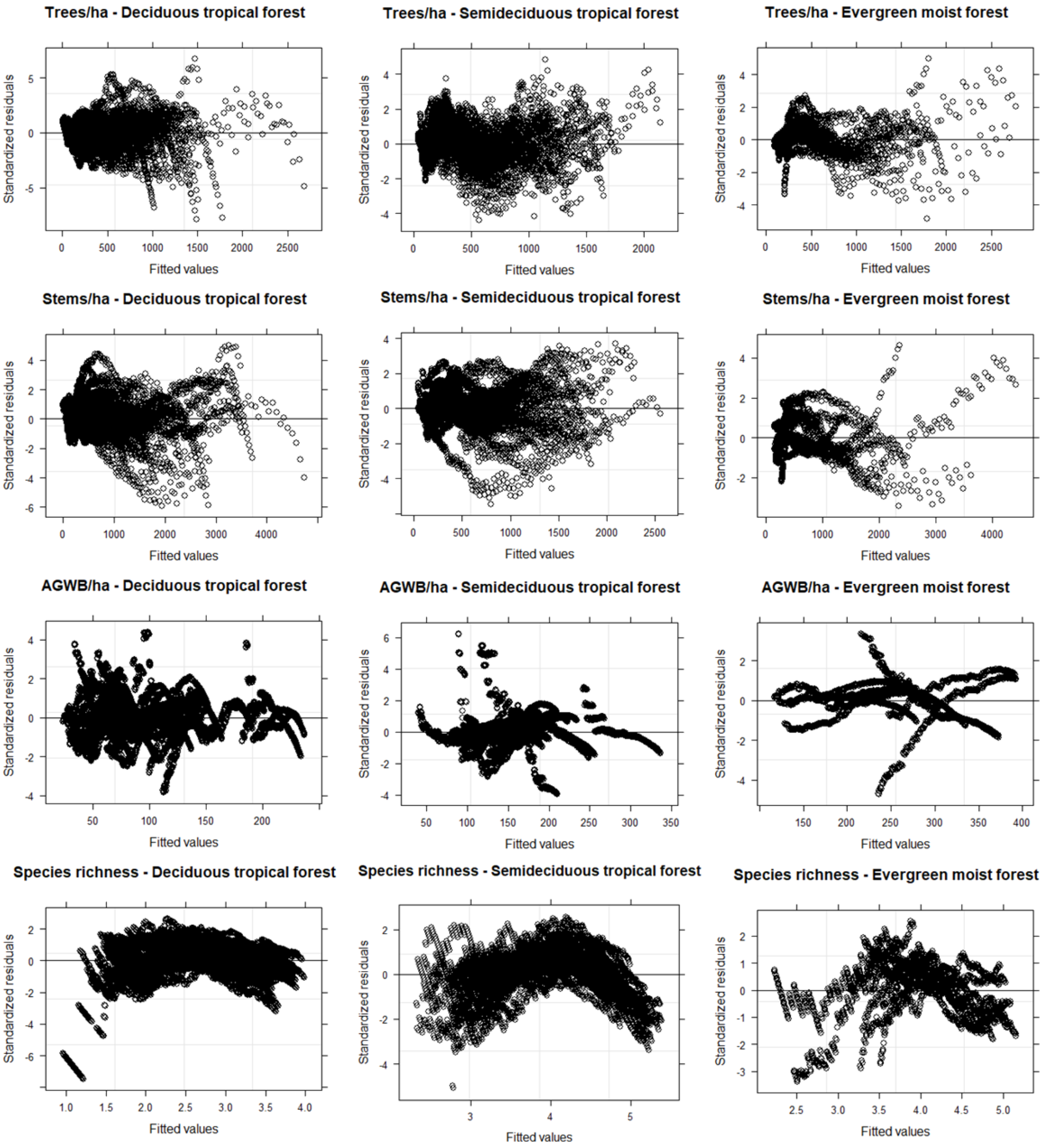

Figure S3: Plots of residuals against fitted values of the selected models for the four vegetation variables sampled in its relationship with the minimum DBH and the inclusion method for the three vegetation types. **Note:** AGWB: above-ground woody biomass.

Table S3: Final equations for each vegetation variable in function of the diameter at the breast height (DBH) in each inclusion method (by stem / by tree) for the three vegetation types (deciduous tropical forest – DTF; semideciduous tropical forest – STF; evergreen moist forest – EMF). For "Trees" and "Stems" variables the equations presented here were obtained in the non-linear model 3, after selection by Akaike Information Criterion (AIC). **Note:** AGWB: above-ground woody biomass.

Variable	Vegetation Type	Method	Equation
Trees	DTF	By stem	y ~ 1892.6367 * exp (-0.1579 * DBH) + 46.8125
		By tree	y ~ 1856.223 * exp (-0.1383 * DBH) + 40.5992
	STF	By stem	y ~ 2818.0696 * exp (-0.1498 * DBH) + 54.3502
		By tree	y ~ 2784.874 * exp (-0.1458 * DBH) + 49.253
	EMF	By stem	y ~ 4149.341 * exp (-0.159 * DBH) + 104.458
		By tree	y ~ 3962.812 * exp (-0.146 * DBH) + 86.516
Stems	DTF	By stem	y ~ 3685.940 * exp (-0.234 * DBH) + 117.045
		By tree	y ~ 3220.485 * exp (-0.105 * DBH) - 31.664
	STF	By stem	y ~ 3287.586 * exp (-0.161 * DBH) + 77.494
		By tree	y ~ 3202.95 * exp (-0.133 * DBH) + 66.759
	EMF	By stem	y ~ 5934.518 * exp (-0.205 * DBH) + 199.611
		By tree	y ~ 4795.073 * exp (-0.133 * DBH) + 96.823
AGWB	DTF	By stem	y ~ 140.17295 - 1.82333* DBH
		By tree	y ~ 143.6904 - 1.78967* DBH
	STF	By stem	y ~ 225.05666 - 3.73678 * DBH
		By tree	y ~ 226.7104 - 3.7169 * DBH
	EMF	By stem	y ~ 362.5453 - 6.3023 * DBH
		By tree	y ~ 359.2653 - 5.7912 * DBH
Species	DTF	By stem	y ~ exp (3.913057 - 0.079026 * DBH)
		By tree	y ~ exp (3.97461 - 0.078146 * DBH)
	STF	By stem	y ~exp (5.530286 - 0.096870 * DBH)
		By tree	y ~exp (5.487171 - 0.08033 * DBH)
	EMF	By stem	y ~exp (5.089744 - 0.067440 * DBH)
		By tree	y ~exp (5.121742 - -0.060551 * DBH)

Comparisons between vegetation variables in the reference values

From the all scenarios for minimum DBH x inclusion method obtained before, we assigned minimum DBH thresholds in reference values used in the literature. For deciduous forest we worked with 3, 5 and 10 cm, according to the used in this data collection, to the proposed by DRYFLOR (2020), and also to the broad use of 10 cm in tropical Rainforests (Phillips et al., 2018). For semideciduous and evergreen forests we used 5 and 10 cm criteria according to the use of 5 in Brazilian Atlantic Forest (Caiafa & Martins, 2007); and 10 cm used in tropical Rainforests. We did not use 3 cm for semideciduous and evergreen forests, since data was collected with a minimum 5 cm DBHq.

For each scenario we obtained the same vegetation variables described before: number of trees and stems per ha, biomass per ha (ton) and corrected species richness. Thus, we evaluated the impacts of inclusion method and minimum DBH on vegetation variables of each vegetation type considering DBH reference values described above (3, 5 and 10 cm for deciduous forests; and 5 and 10 cm for semideciduous and evergreen forests). We thus obtained the average values of vegetation variables in each combination (minimum DBH×inclusion method) and for each vegetation type (see Table S2), we evaluated the relative differences (Δ - %) between inclusion methods (by-tree minus by-stems) and minimum DBH (as categories). For deciduous tropical forests that have an additional category of minimum DBH (3 cm), we compared all possible combinations between them. This allowed us to evaluate the impact of different methodological approaches on the response vegetation variables of each vegetation type and to discuss the importance of standardizing methods among different vegetation types.

Forest structure and species richness varied markedly between inclusion methods, with more pronounced differences in deciduous forests, especially for the variables trees/ha and stems/ha. Within deciduous forests, these differences in the number of stems/ha using the by-stem inclusion method led to reduction of more than one third for the 5 cm criteria, and of more than half of the number of stems when considering the 10 cm minimum DBH (Table S4). In semideciduous, there were losses in stems/ha when adopting the by-stem method and the 5 cm threshold (~ 9 %), reaching almost 19 % for 10 cm of minimum DBH (Table S4). For the evergreen forests this difference between methods for stems/ha was lower than the observed for deciduous, but high than the presented by semideciduous. For the variable trees/ha, the higher loss when use by-stem method were observed in deciduous forests, with values more than ten times greater than the observed for the other vegetation types (Table S4). In turn, these results show that in these different vegetation types, particularly deciduous forests, a large part of stems is only sampled when the inclusion criterion considers the individual as a whole (inclusion method by-tree), especially at greater minimum DBH.

The use of by-stem inclusion method resulted in losses in the number of species sampled for all vegetation types, reach 8 % in deciduous forests when use the 10 cm minimum DBH and more than 10 % for semideciduous and evergreen forests (Table S4). For minimum DBH of 5 cm, deciduous and semideciduous presented markedly higher values of loss in comparison to the observed by evergreen forests. We observed inexpressive values of biomass loss when adopting the by-stem inclusion method, with the higher values of biomass loss observed for deciduous forest with 10 cm diameter criterion (3.5 %) and other not higher than 1 % (Table S4).

Deciduous forests presented the greater differences when using different minimum diameter (Table S4). Using the 5 cm criterion and the by-stem inclusion method, we observed losses of up to 23.4% in the number of trees/ha, 33.2% in the number of stem/ha, 12% decrease in the number of species and reduction of nearly 1% of biomass. Losses were smaller when applying the by-tree inclusion method, especially for stems/ha when the use of by-tree inclusion method lead to a loss value two times lower for 3-5 cm comparison than the observed for by-stem inclusion method (Table S4). In comparison to 3 cm inclusion diameter, we observed greater losses in all vegetation variables when using the 10 cm criterion: roughly 2 thirds in the number of trees/ha, more than 70% in the number of stems/ha, underestimation of more than 8% in biomass estimates and 1 third decrease in the number of species (Table S4). In the by-tree inclusion method, losses are generally lower, but still relatively high, with losses of more than 50% for both number of trees and stems per hectare (Table S4). Comparing with 5 cm criterion when using both methods, 10 cm inclusion diameter in the by-stem inclusion method underestimates in more than 40 % the number of trees and stems per hectare, greater than 30 % in species richness and up to 6.83% for biomass (Table S4). In turn, the use of larger minimum DBH has important impacts on vegetation variables in deciduous forests, particularly stronger in the number of trees and stems per hectare, when using the 10 cm DBH criteria and the by-stem inclusion method.

Semideciduous and evergreen forests are also strongly affected by minimum diameter and inclusion methods (Table S2). Using the 10 cm DBH criterion yielded differences in variables values applying the two inclusion methods, with losses close to 50 % or more for both the number of trees and stems per hectare. In terms of biomass, losses are within 5.9 % to 6.5 %, whereas species richness is largely underestimated, with values ranging between 20 % and 30 %.

Table S4: Average values obtained for vegetation variables of the three vegetation types (deciduous tropical forest – DTF; semideciduous tropical forest – STF; evergreen moist forest – EMF) in the different minimum diameter at the breast height (DBH) and inclusion methods (by stem and by tree), and the difference between them (Δ %). The values represented by Δ correspond to the percentual difference between two categories in each factor (minimum DBH or inclusion method), always considering the lower value of DBH and the inclusion "By tree" as reference. This table was used as base for the Figures 2, 3 and 4. **Note**: AGWB: above-ground woody biomass; Δ methods: percentual difference between by-trees and by-stem inclusion methods.

Trees/ha

	DBH	**By stem**	**By tree**	**Δ methods (%)**
DTF	3 cm	1145.28	1163.43	-1.56
	5 cm	877.44	952.73	-7.90
	10 cm	417.87	484.41	-13.74
	Δ 3-5 cm (%)	23.39	18.11	
	Δ 3-10 cm (%)	63.51	58.36	
	Δ 5-10 cm (%)	52.38	49.16	
STF	5 cm	1357.98	1368.13	-0.74
	10 cm	656.18	682.12	-3.80
	Δ 5-10 cm (%)	51.68	50.14	
EMF	5 cm	1903.39	1956.81	-2.73
	10 cm	903.59	941.80	-4.06
	Δ 5-10 cm (%)	52.53	51.87	

Stems/ha

	DBH	**By stem**	**By tree**	**Δ methods (%)**
DTF	3 cm	1840.12	2168.98	-15.16
	5 cm	1229.28	1865.43	-34.10
	10 cm	511.16	1044.79	-51.08
	Δ 3-5 cm (%)	33.20	14.00	
	Δ 3-10 cm (%)	72.22	51.83	
	Δ 5-10 cm (%)	58.42	43.99	
STF	5 cm	1531.16	1682.09	-8.97
	10 cm	723.11	891.59	-18.90
	Δ 5-10 cm (%)	52.77	47.00	
EMF	5 cm	2170.09	2609.8	-16.85

	10 cm	995.16	1278.34	-22.15
	Δ 5-10 cm (%)	54.14	51.02	
		AGWB (ton/ha)		
	DBH	**By stem**	**By tree**	**Δ methods (%)**
DTF	3 cm	134.00	134.19	-0.14
	5 cm	132.39	133.59	-0.90
	10 cm	123.34	127.87	-3.54
	Δ 3-5 cm (%)	1.20	0.44	
	Δ 3-10 cm (%)	7.95	4.71	
	Δ 5-10 cm (%)	6.83	4.29	
STF	5 cm	202.52	202.88	-0.18
	10 cm	189.37	190.81	-0.75
	Δ 5-10 cm (%)	6.49	5.95	
EMF	5 cm	320.86	321.88	-0.32
	10 cm	300.94	302.77	-0.60
	Δ 5-10 cm (%)	6.21	5.94	
		Species richness		
	DBH	**By stem**	**By tree**	**Δ methods (%)**
DTF	3 cm	37.78	37.6	0.44
	5 cm	33.01126	34.85417	-5.29
	10 cm	22.24026	24.17945	-8.02
	Δ 3-5 cm (%)	12.62	7.34	
	Δ 3-10 cm (%)	41.13	35.72	
	Δ 5-10 cm (%)	32.63	30.63	
STF	5 cm	133.9782	144.7578	-7.45
	10 cm	97.50774	108.9824	-10.53
	Δ 5-10 cm (%)	27.22	24.71	
EMF	5 cm	123.8224	122.6993	0.92
	10 cm	85.11269	96.56132	-11.86
	Δ 5-10 cm (%)	31.26	21.30	

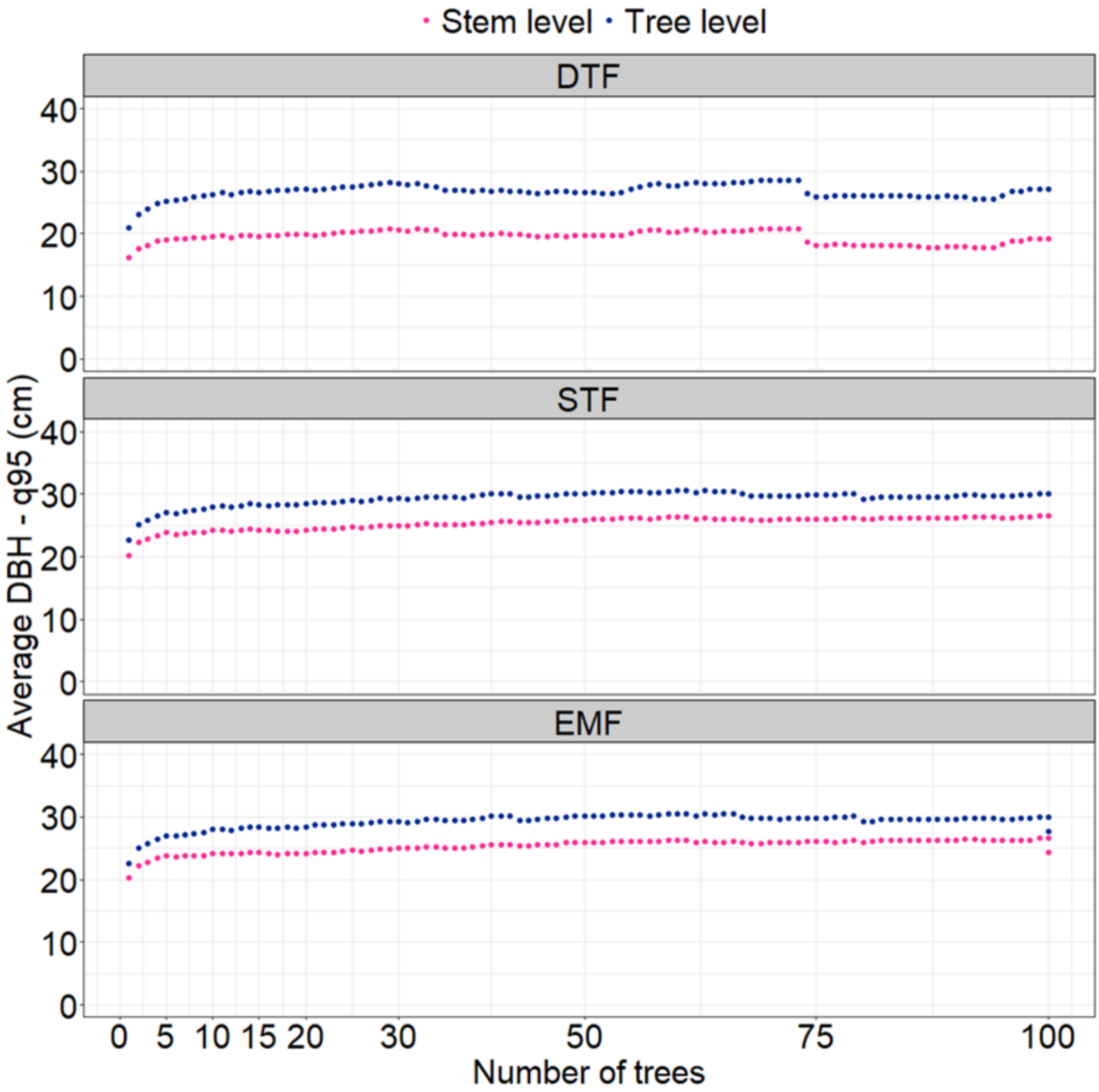

Figure S4: Average values of Diameter at the Breast height (DBH) 95 quartile (DBH – q95) per species (stem and tree level) for the data of species in the three vegetation types (DTF - deciduous tropical forests, STF - semideciduous tropical forests, EMF – evergreen moist forest) along different cut levels according to the number of trees per species sampled. Each point represents the average value for the pool as a whole considering that number of trees as cut level. These figures were used to set a threshold for select species in the section 2.3.3 of the paper.

Supplementary information references

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B., ... & Vieilledent, G. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. Global change biology, 20(10), 3177-3190. https://doi.org/10.1111/gcb.12629

Réjou-Méchain, M., Tanguy, A., Piponiot, C., Chave, J., & Hérault, B. (2017). biomass: An r package for estimating above-ground biomass and its uncertainty in tropical forests. Methods in Ecology and Evolution, 8(9), 1163-1167. https://doi.org/10.1111/2041-210X.12753

R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Zanne, A. E., Lopez-Gonzalez, G., Coomes, D. A., Ilic, J., Jansen, S., Lewis, S. L., ... & Chave, J. (2009). Global wood density database. Dryad Digital repository. https://doi.org/10.5061/dryad.234