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INSTITUTO DE CIÊNCIAS BIOLÓGICAS E DA SAÚDE

Programa de Pós-Graduação em Diversidade Biológica e Conservação nos Trópicos

PAULO HENRIQUE SANTOS GONÇALVES

ALTERAÇÕES ANTROPOGÊNICAS CRÔNICAS DA PAISAGEM: ABORDAGEM BIBLIOMÉTRICA E *IN SITU*

Tese apresentada ao Programa de Pós-Graduação em Diversidade Biológica e Conservação nos Trópicos do Instituto de Ciências Biológicas e da Saúde, Universidade Federal de Alagoas, como requisito para obtenção do título de doutor em CIÊNCIAS BIOLÓGICAS, na área da Biodiversidade.

MACEIÓ – ALAGOAS

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Orientação: Prof. Dr. Ulysses Paulino de Albuquerque

Prof. (a) Dra. Patrícia Muniz de Medeiros

Prof. Dr. Felipe Pimentel Lopes de Melo

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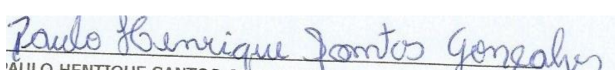

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Tese aprovada em 26 de maio de 2020.

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“Sem jamais completar o seu projeto, o bricoleur sempre coloca nele algo de si”

Claude Lévi-Strauss

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RESUMO

Esta tese é estruturada em três capítulos, os quais versam sobre distúrbios antropogênicos crônicos. No primeiro capítulo, nós usamos a bibliometria como uma ferramenta para compreender a conjuntura atual do campo de conhecimento científico sobre distúrbios antropogênicos crônicos. Nós constatamos que a maior parte do estudos sobre distúrbios crônicos versam sobre os efeitos da pecuária extensiva ou da coleta de produtos florestais sobre comunidades vegetais. Ademais, nós encontramos que publicar em jornais de elevado CiteScore é um dos principais determinantes da taxa de citação dos artigos, seguido de escrever estudos de revisão, e ter coautores pesquisadores de elevado índice H. A taxa de autocitações dos artigos é, por sua vez, influenciada positivamente pela presença de autores de elevado índice H, de autores que estão construindo sua linha de pesquisa sobre distúrbios crônicos, e pela presença de autores de países com baixos valores de índice de desenvolvimento humano. No segundo capítulo, nós fizemos um estudo de campo para entender como a coleta de produtos florestais madeireiros (uma atividade considerada como perturbação crônica) afeta a estrutura de comunidades vegetais de uma floresta tropical sazonalmente seca. Para isso, nós estimamos o uso de madeira para combustível e construção de cercas em seis comunidades rurais, no Parque Nacional do Catimbau, no Nordeste do Brasil. Nós estimamos descritores das comunidades vegetais, incluindo índices de diversidade, a densidade total, e a densidade das espécies mais frequentes na paisagem. Nossos achados demonstram que a coleta de madeira, para fins de subsistência, pode reduzir a riqueza de espécies e a densidade total das comunidades, e aumentar a equabilidade. Contudo, não encontramos evidências de que as densidades das espécies mais frequentes na paisagem são afetadas por tal atividade. Finalmente, no terceiro capítulo, nós usamos o mesmo cenário socioambiental do capítulo anterior, para testar como fatores socioeconômicos (renda, número de residentes por núcleo familiar, sexo, grau de escolaridade e idade) afetam a dependência das pessoas por recursos naturais em diferentes domínios utilitários (recursos vegetais para uso medicinal, alimentício, combustível e construção). Pessoas mais velhas e homens são os que possuem maior conhecimento sobre plantas medicinais da região, ao passo que pessoas de família com menor renda são as que possuem maior conhecimento sobre plantas alimentícias nativas. A renda e o número de residentes não afetaram a demanda por produtos madeireiros. No geral, nós verificamos que a região estudada possui baixo dinamismo socioeconômico, o que implica em forte dependência por recursos florestais. Por meio desta tese, demonstramos que os distúrbios crônicos não são apenas um problema ambiental, mas também social e político. Portanto, conciliar atividades humanas e a conservação da biodiversidade requer esforços para a adoção de medidas que garantam o usos sustentáveis dos recursos naturais.

ABSTRACT

ALTERAÇÕES ANTROPOGÊNICAS CRÔNICAS DA PAISAGEM: ABORDAGEM BIBLIOMÉTRICA E *IN SITU*

This thesis has three chapters about chronic anthropogenic disturbances. In the first one, we have used the bibliometrics as a tool to understand the current status of the field of scientific knowledge about chronic anthropogenic disturbances. We have identified that most of the papers about chronic disturbances are about the effects of livestock rearing or the collection of forest products on plant communities. Also, we have found that publishing in high CiteScore journals is one of the main drivers of the papers rate citation, followed by writing reviews studies, and having high h-index author(s). The papers' self-citation rate was influenced by the presence of authors with the following characteristics: high h-index, publish many papers about chronic disturbance, and are from low human development index countries. In the second chapter, we have performed a field study to understand how the low scale wood collection (a kind of chronic disturbance) affect plant communities structure in a dry tropical seasonal forest. To do this, we estimated the wood use for fuelwood and for building fences in six rural communities, in the Catimbau National Park, Northeastern Brazil. Moreover, we estimated the ecological descriptors of the plant communities, such as diversity indexes, the total density, and density of the most frequent species. Our findings demonstrated that the low scale wood collection may decrease plant species richness, and the total density of the communities, but may increase community evenness. Nevertheless, we have not found evidence that the most frequent species are affected by the wood collection. In the third chapter, we used the same socio-environmental setting of the second chapter to access how socioeconomic predictors (including income, number of residents in each household, sex, education level and age) may affect people dependence on forest resources in different use categories (medicinal, food, fuelwood and construction).Older people and the men are the one who have more knowledge about native medicinal plants. People from low income families are the one who have more knowledge about native food plants. Family income and number of residents did not affect the demand for wood products. In general, we have found that the studied are has a low socioeconomic dynamism. Accordingly, the local people have a high dependence on forest products. Through this thesis, we have demonstrated that chronic disturbances are not just an environmental, but also a social and political matter. Therefore, reconciling human activities and biodiversity conservation needs efforts to adopt strategies that ensure the sustainable use of natural resources.

1. APRESENTAÇÃO

Após os avanços teóricos e práticos do estudo sobre ecologia de paisagem, incluindo os fenômenos de fragmentação e perda de hábitats, ecólogos têm começado a preocupar-se em compreender as consequências de atividades humanas que não resultam em mudanças imediatas nos ecossistemas. Dentre essas atividades, destacam-se a pecuária extensiva, a coleta de produtos florestais, e a atividade pesqueira. Apesar do baixo impacto imediato, essas ações humanas podem ter sérias consequências para a biodiversidade e para os ecossistemas, a longo prazo. Consequentemente, cunhou-se o termo distúrbios antropogênicos crônicos ou perturbação crônica para referir-se a esses impactos.

Esta tese é dividida em três capítulos. O primeiro destes é um estudo sobre os padrões bibliométricos na literatura ecológica sobre distúrbios antropogênicos crônicos. O primeiro objetivo deste capítulo foi identificar quais os principais interesses dos estudiosos sobre perturbação crônica, incluindo os tipos de ambientes estudados (terrestres, marinhos ou dulciaquícolas), tipos de biomas (terrestres e marinhos) onde os estudos foram realizados, os tipos de organismos estudados, e os tipos de perturbação crônica mais estudados. O segundo objetivo do estudo foi acessar os determinantes do comportamento de citações dos artigos sobre distúrbios crônicos a fim de compreender se existem fatores que norteiam o grau de visibilidade desses estudos perante a comunidade científica. Finalmente, nosso último objetivo foi testar se características relacionadas aos perfis dos pesquisadores afetam o comportamento de autocitações dos artigos. Com base nesse panorama, buscamos explicar como os estudos sobre distúrbios crônicos têm avançado e ganhado visibilidade. Além disso, indicamos caminhos futuros para esse tópico de pesquisa, indicando quais tipos de ambientes e de organismos precisam ser mais estudados.

O segundo capítulo é um estudo de caso, no qual estudamos os padrões de uso de recursos florestais madeireiros (nosso *proxy* para acessar distúrbios antropogênicos crônicos) no Parque Nacional do Catimbau, uma unidade de preservação que se localiza em uma área de floresta tropical sazonalmente seca, no nordeste do Brasil. Nesse estudo, nós buscamos entender como a pressão de uso decorrente da coleta de madeira afeta a diversidade da flora arbustivo-arbórea, e a densidade das espécies mais frequentes na paisagem. Até o momento, declaramos que este é o primeiro estudo no qual pesquisadores acessaram diretamente o uso de madeira por comunidades rurais e tentaram predizer os efeitos sobre a estrutura das comunidades vegetais.

No terceiro capítulo, nós buscamos entender quais fatores socioeconômicos afetam a demanda por recursos florestais no Parque Nacional do Catimbau. Nós testamos se a renda e o tamanho das famílias afetam a demanda por recursos florestais madeireiros (lenha e madeira para construção de cercas). Ademais, testamos como a renda familiar, o grau de escolaridade, o número de residentes por grupo familiar, a idade e o gênero afetam o conhecimento sobre plantas medicinais e alimentícias nativas da região. Finalmente, nós testamos se a cobertura vegetal (nosso *proxy* para o grau de conservação de diferentes áreas de floresta) afeta a ocorrência de espécies úteis na paisagem. Portanto, este capítulo, versa, principalmente, sobre fatores sociais e econômicos que, em última instância, estão associados à perturbação crônica dos ambientes.

Desse modo, por meio desta tese, pretendemos avançar no conhecimento sobre os efeitos dos distúrbios antropogênicos crônicos na paisagem. No segundo capítulo, nós discutimos nossos achados usando um cenário ecológico-evolutivo (a Teoria da Construção de Nicho), que pensamos ser um cenário mais robusto do que a perspectiva dos distúrbios crônicos. Por fim, discutimos, como a conservação da biodiversidade precisa levar em consideração ações de manejo que possam conciliar o uso da paisagem e a conservação da biodiversidade local.

2. REVISÃO BIBLIOGRÁFICA

2.1 Distúrbios antropogênicos crônicos: um tópico emergente em ecologia

A ecologia tem feito grandes avanços teóricos com respeito aos efeitos da ação humana sobre a estruturação da paisagem. O longo período de estudos sistemáticos sobre fenômenos como fragmentação, perda de hábitat, efeitos de borda e efeitos dos tipos de matrizes antrópicas tem resultado na elucidação de padrões e na proposição de hipóteses e teorias em ecologia de paisagem (ver, por exemplo, FAHRIG, 2013; HILL *et al.*, 2011; KUPFER; MALANSON; FRANKLIN, 2006; LARRIVÉE; DRAPEAU; FAHRIG, 2008; THORNTON; BRANCH, 2011). Uma dessas proposições teóricas é a hipótese da quantidade de hábitat, segundo a qual a quantidade de hábitat adequado disponível é mais importante em determinar a riqueza de espécies em uma paisagem fragmentada do que o grau de isolamento dos fragmentos (FAHRIG, 2013). No entanto, as consequências de ações humanas mais brandas, principalmente aquelas decorrentes de atividades de subsistência de populações que vivem no entorno de ecossistemas florestais ainda estão começando a ser compreendidas.

No final da década de 1990, SINGH (1998) propôs o termo distúrbios antropogênicos crônicos para referir-se aos efeitos de ações humanas que não resultam em mudanças imediatas nos ecossistemas, diferentemente do que ocorre com a fragmentação e a perda de hábitat. Populações humanas que vivem próximo a áreas de paisagens naturais desempenham uma série de atividades de subsistência, tais como a coleta de recursos madeireiros, o extrativismo de produtos florestais não madeireiros, e a pecuária extensiva, as quais podem apresentar diferentes efeitos deletérios a longo prazo. O caráter frequente dessas atividades pode fazer com que populações vegetais ou animais afetadas não consigam se restabelecer porque as taxas de uso dos recursos podem superar as taxas de recrutamento ou crescimento das populações (SINGH, 1998). Nesse sentido, a lógica subjacente ao conceito de distúrbios antropogênicos crônicos é que as atividades humanas exercem efeitos negativos sobre os ecossistemas apenas a partir do momento no qual a taxa de uso de recursos supera a taxa de produção desses pelo ecossistema.

Após esse estudo inicial, o escopo de atividades consideradas como distúrbios antropogênicos crônicos expandiu-se, havendo estudos em ambientes terrestres e marinhos. A maioria dos estudos em ambientes marinhos versa sobre os efeitos da pesca de arrasto no fundo dos oceanos (em inglês, denominada de *bottom trawling fishing*) sobre comunidades de organismos bentônicos, incluindo corais, poliquetas, equinodermos, bivalves, nemátodes e crustáceos (HINZ; PRIETO; KAISER, 2009; HINZ *et al.*, 2008; KAISER *et al.*, 2002; SCHRATZBERGER; JENNINGS, 2002). Ao comparar-se áreas com diferentes frequências de pesca de arrasto, tem-se observado que essa atividade resulta em diminuição na produtividade secundária de comunidades bentônicas, além de mudanças na composição dessas comunidades (KAISER *et al.*, 2002). Assim, é possível que, a longo prazo, a pesca de arrasto possa afetar a estrutura das teias alimentares marinhas, o que pode alterar os fluxos de energia nesses ecossistemas, de maneira ainda pouco compreendidas (HINZ *et al.*, 2008)

Contudo, diferentes taxa podem apresentar respostas distintas à pesca de arrasto de fundo. No Mar do Norte (localizado entre a Europa ocidental e setentrional), e no Mar da Irlanda, essa atividade afetou negativamente a comunidade de nemátodes, em termos de abundância, produtividade secundária e riqueza de gêneros (HINZ *et al.*, 2008). A abundância da maioria dos gêneros de nemátodes foi negativamente afetada pela frequência de pesca de arrasto de fundo, mas os gêneros *Aponema* e *Sabatieria* possuem maior abundância em áreas com maior frequência dessa atividade (HINZ *et al.*, 2008). Assim, apesar desse tipo de pesca consistir em uma atividade que, fisicamente, afeta toda a comunidade bentônica, as espécies respondem de maneiras diferentes a essas perturbações.

Em ambientes terrestres, a maioria dos estudos sobre distúrbios antropogênicos crônicos têm empregado uma combinação de métricas como uma estimativa aproximada das intensidades de atividades humanas sobre populações, comunidades ou ecossistemas. Provavelmente, um dos primeiros estudos a utilizar essa abordagem foi o de Martorell & Peters (2005), que aferiram 15 métricas distintas para acessar os efeitos de distúrbios crônicos sobre populações do cacto *Mammillaria pectinifera* F.A.C. Weber. O emprego dessas métricas é considerado como uma alternativa prática, visto que se considera muito difícil medir todas as ações humanas que podem resultar nesses tipos de distúrbios.

Ainda com respeito a esse estudo, os autores utilizaram três conjuntos diferentes de métricas de distúrbios crônicos. As métricas de intensidade de pastejo dos rebanhos domésticos incluem frequência de fezes de bovinos e caprinos, densidade de trilhas dos rebanhos domésticos, e número de plantas com indícios de terem sido consumidas por animais domésticos. As métricas de intensidade de atividades humanas foram o número de árvores com ramos cortados, densidade de trilhas que as pessoas usam para percorrer as áreas da paisagem, distâncias de áreas naturais até as habitações humanas, e número de áreas com indícios de incêndios. E, por fim, as métricas de degradação do solo consistiram no registro de áreas com indícios de erosão, e a presença de superfícies terrestres modificadas pelas pessoas, como áreas pavimentadas ou canais de irrigação (MARTORELL; PETERS, 2005). Ao final, os autores combinaram as métricas por meio de uma análise de componentes principais (PCA) a fim de gerar um único índice de perturbação crônica. Essa mesma abordagem, com métricas muito semelhantes tem sido usada em vários outros estudos discutidos neste tópico.

Nesse estudo inicial relativo ao uso de métricas indiretas para estimar distúrbios antropogênicos crônicos, verificou-se que a degradação do solo é o processo mais deletério para as populações de *M. pectinifera*. Além disso, essa espécie apresenta maior densidade em áreas com intensidades intermediária de distúrbios relacionados a atividades humanas e ao pastejo dos rebanhos domésticos (MARTORELL; PETERS, 2005). *M. pectinifera* foi considerada como uma espécie aproximadamente ruderal, tanto por seu grau intermediário de tolerância a perturbações crônicas, quanto por apresentar um ciclo de vida curto, se comparada a outras Cactaceae.

Posteriormente, outros estudos foram realizados para acessar os efeitos de distúrbios antropogênicos crônicos sobre populações de Cactaceae em ambientes semiáridos, especialmente com espécies do gênero *Mammillaria*. Uma vez que esse gênero possui elevada diversidade beta (mudança substancial na composição de espécies ao longo da paisagem), em florestas secas no México, o estabelecimento de áreas de preservação não é suficiente para proteger as diferentes espécies (MARTORELL; PETERS, 2009). Contudo, a evidência acumulada indica que a maioria das espécies de *Mammillaria* possuem densidades mais altas em áreas de grau intermediário de perturbação crônica (MARTORELL; PETERS, 2009; URETA; MARTORELL, 2009; VILLARREAL-BARAJAS; MARTORELL, 2009). Desse modo, provavelmente, a conservação dessas espécies pode ser conciliada com as atividades de subsistência de populações rurais, desde que haja um certo controle da intensidade dessas atividades.

No entanto, nem sempre espécies de Cactaceae alcançam maiores densidades em áreas com níveis intermediários de distúrbios crônicos. Por exemplo, o aumento no grau de perturbação crônica reduz a taxa de crescimento populacional de *Coryphantha wedermannii* Boed (PORTILLA-ALONSO; MARTORELL, 2011), enquanto *Echinocereus lindsayii* Meyrán aumenta monotonicamente sua densidade com o aumento no nível de perturbação, ao menos nos níveis estudados (MARTORELL; GARCILLÁN; CASILLAS, 2012). Isso pode indicar que a conservação de diferentes espécies pode requerer distintos ajustes nas atividades antrópicas que podem afetá-las.

Após esses estudos sobre a estrutura populacional de Cactaceae, foram publicados uma série de estudos a fim de compreender como comunidades vegetais e animais da Caatinga (um tipo de floresta tropical sazonalmente seca que existe apenas no Brasil) são afetadas por distúrbios antropogênicos crônicos. A Caatinga localiza-se em uma região geopolítica, o semiárido, a qual possui um cenário socioambiental que torna os ecossistemas locais especialmente vulneráveis, visto que as populações locais possuem um histórico de pobreza e vulnerabilidade social. Consequentemente, as populações dessa região possuem maior dependência dos recursos naturais locais para combustível, construção, alimentação e uso medicinal. Além disso, a pecuária extensiva é uma das práticas de subsistência mais comuns nessa região, desde o início da colonização europeia. Portanto, esses estudos são essenciais para indicar como as populações locais têm transformado a paisagem de Caatinga.

Os efeitos dos distúrbios antropogênicos crônicos sobre a composição da flora da Caatinga ainda estão começando a ser compreendidos. Embora um estudo não tenha encontrado alterações na composição de espécies em decorrência desses distúrbios (RITO *et al.*, 2016), outros estudos mostram que tais transformações ocorrem, podendo haver proliferação de espécies tolerantes a distúrbios, principalmente espécies da família Euphorbiaceae, incluindo aquelas pertencentes aos gêneros *Croton*, *Jatropha* e *Cnidoscolus* (RIBEIRO *et al.*, 2019; RIBEIRO *et al.*, 2015; RITO; TABARELLI; LEAL, 2017). Essas espécies dispersam suas sementes no período chuvoso, principalmente, por meio de uma estratégia denominada de balística, a qual permite a dispersão a longas distâncias (GRIZ; MACHADO, 2001). Além disso, seus diásporos também são dispersos por formigas, cujas ocorrências nem sempre são afetadas por perturbações crônica (OLIVEIRA *et al.*, 2019). Assim, essas espécies parecem possuir capacidade de rápida colonização de hábitats, o que pode permitir que elas proliferem em ambientes perturbados.

Com respeito às espécies que são negativamente afetadas por distúrbios antropogênicos crônicos, aparentemente, é possível reconhecer dois grupos. Há um grupo que inclui espécies tipicamente utilizadas pelas populações locais, como *Piptadenia stipulacea*, *Myracrodruon urundeuva*, *Bauhinia cheilanta, Poincianella pyramidalis, Pityrocarpa moniliformis* (LEAL; ANDERSEN; LEAL, 2015; RIBEIRO *et al.*, 2015; SFAIR; BELLO; FRANC, 2018), o que indica que a menor ocorrência dessas espécies em áreas mais perturbadas pode ser uma consequência direta do uso. Entretanto, há outras espécies afetadas que não são de grande importância para as populações locais, como *Fraunhofera multiflora*, *Varronia leucocephala* e *Manihot pseudoglaziovii* (RIBEIRO *et al.*, 2015), que são negativamente afetadas por distúrbios crônicos, o que indica que modificações ambientais decorrentes das atividades humanas podem ter efeitos em cascata sobre outras espécies.

Em termos de estrutura de comunidades, os efeitos dos distúrbios crônicos parecem ser bastante complexos. Em uma área com variação em níveis de pluviosidade, o aumento no grau de perturbação crônica reduz a diversidade de espécies em áreas com menor pluviosidade, mas aumenta a diversidade de espécies nas áreas com maior pluviosidade (RITO *et al.*, 2016). Em áreas sem tais variações ambientais, o aumento no grau de perturbação crônica reduz a diversidade de espécies, a equabilidade e a densidade total de indivíduos (RIBEIRO *et al.*, 2015). Mas algumas das métricas indicadoras de distúrbios associaram-se positivamente a esses parâmetros, por exemplo, a densidade de habitantes e dos rebanhos domésticos associaram-se positivamente à riqueza de espécies (RIBEIRO *et al.*, 2015). Isso parece indicar que as diferentes ações antrópicas podem afetar as comunidades vegetais de maneiras distintas.

Em uma escala mais fina, estudos recentes têm mostrado que distúrbios antropogênicos crônicos afetam traços funcionais das comunidades e populações vegetais da região. Áreas com maiores níveis de perturbação possuem menor diversidade de traços funcionais (RIBEIRO *et al.*, 2019; ZORGER *et al.*, 2019), o que indica que condições ambientais adversas podem estar favorecendo o desenvolvimento de estratégias fisiológicas semelhantes para lidar com estresse ambiental. Além disso, as espécies respondem de maneiras distintas ao aumento no grau de perturbação crônica. Por exemplo, o aumento no grau de perturbação crônica diminui a densidade da madeira de *Cenostigma microphyllum* (Mart. ex G.Don) Gagnon & G.P.Lewis, diminui o número de ramos de *Pityrocarpa moniliformis* (Benth.) Luckow & R.W.Jobson, aumenta a altura máxima de *Peltogyne pauciflora Benth.*, e reduz os níveis de matéria seca nas folhas de *Jatropha mutabilis* (Pohl) Baill. e *Piptadenia stipulacea* (Benth.) Ducke (SFAIR; BELLO; FRANC, 2018). Essas mudanças parecem ser uma combinação dos efeitos diretos do uso das espécies, e de efeitos indiretos decorrentes de mudanças ambientais, como a redução da cobertura vegetal e o maior grau de exposição do solo, que pode reduzir a capacidade de retenção hídrica (SFAIR; BELLO; FRANC, 2018).

Ainda com respeito a estudos realizados na Caatinga, as formigas também têm sido utilizadas como bioindicadores para acessar os efeitos dos distúrbios antropogênicos crônicos. A comunidade de formigas parece responder aos distúrbios, principalmente, por meio de mudanças na composição de espécies (LEAL; ANDERSEN; LEAL, 2015; OLIVEIRA *et al.*, 2019; SILVA *et al.*, 2019). As espécies de formigas que são frequentes ao longo de gradientes de distúrbios apresentam plasticidade comportamental de uso de hábitats, forrageando tanto de dia quanto à noite, e frequentando hábitats sombreados e ensolarados (SILVA *et al.*, 2019). Em ambientes mais perturbados, há maior abundância de espécies de hábito diurno e que frequentam microhábitats ensolarados, como *Camponotus atriceps* (Smith, F., 1858), *Camponotus cingulatus* Mayr, 1862 e *Dorymyrmex thoracicus* Gallardo, 1916. Algumas espécies dos gêneros *Solenopsis*, *Pheidole* e *Camponotus fastigatus* Rogers, 1863 possuem suas ocorrências mais restritas a áreas menos perturbadas (SILVA *et al.*, 2019). Esses achados parecem confirmar que as formigas são bons indicadores de mudanças ambientais causadas por distúrbios crônicos.

É possível que essas modificações em termos de composição de espécies afetem os serviços ecossistêmicos prestados pelas formigas. Um estudo mostrou que o aumento no grau de perturbação crônica reduziu a taxa de remoção de diásporos de *J. mutabilis*, mas não afetou a taxa de remoção de diásporos de *Croton sonderianus* Müll. Arg. Porém, a distância de remoção de diásporos de ambas as espécies diminuiu com o aumento nos níveis de distúrbios (LEAL.; ANDERSEN; LEAL, 2014). No entanto, em outro estudo, a dispersão de diásporos por formigas foi pouco afetada por distúrbios crônicos (CÂMARA *et al.*, 2019). A única exceção diz respeito à espécie *J. mutabilis*, cuja dispersão de diásporos aumenta levemente em áreas mais perturbadas (CÂMARA *et al.*, 2019).

Com respeito à pecuária caprina (uma das atividades de subsistência mais comuns na Caatinga), estudos experimentais recentes têm demonstrado seus possíveis efeitos deletérios. Aparentemente, o pastejo dos caprinos não afeta a composição de espécies vegetais em paisagens da Caatinga (SCHULZ et al. 2019; MENEZES et al. 2020). Contudo, áreas com altas densidades de rebanhos caprinos apresentam menor diversidade de espécies arbustivas e arbóreas (Schulz et al. 2019). Ademais, Menezes et al. (2020) constataram que a interrupção do pastejo por dois anos já foi suficiente para que seja observado um aumento na biomassa do estrato herbáceo, demonstrando que a pecuária afeta a produtividade primária na região. Esse achado corrobora estudo prévio que revelou que pecuária caprina resulta em declínio nos níveis de carbono em solos de Caatinga (SCHULZ et al. 2016). Dessa forma, preliminarmente, é possível identificar que as práticas atuais de pecuária caprina representam uma ameaça à biodiversidade e ao funcionamento dos ecossistemas de Caatinga.

Por tratar-se de um tema de estudo relativamente novo, é normal que poucas proposições teóricas tenham sido feitas sobre os efeitos dos distúrbios antropogênicos crônicos. Alguns desses estudos discutem seus achados baseando-se no paradigma "*few winners and many losers*" (TABARELLI; PERES; MELO, 2012) para explicar o fenômeno de proliferação de algumas poucas espécies nativas tolerantes a distúrbios em detrimento do declínio de várias outras espécies sensíveis. De acordo com esses autores, as mudanças ambientais decorrentes de distúrbios crônicos atuam como filtros que induzem a proliferação de espécies arbustivas típicas de comunidades em início de sucessão ecológica. Ao final desse processo, forma-se uma floresta secundária, cuja conservação possui pouco valor em termos de proteção da biodiversidade.

Finalmente, outra proposição teórica frequentemente discutida nos estudos sobre distúrbios antropogênicos crônicos é a hipótese do distúrbio intermediário. Segundo essa hipótese, a diversidade de espécies é maior em áreas de intensidades e frequência de distúrbios intermediárias (CONNELL, 1978). Em ambientais nos quais os distúrbios ocorrem muito frequentemente, a diversidade será baixa porque as comunidades serão compostas apenas por espécies de rápido potencial de colonização e de crescimento rápido (CONNELL, 1978). Mas em outro extremo, em ambientais nos quais os distúrbios são raros, a diversidade também será baixa porque as espécies com maiores habilidades competitivas podem eliminar outras espécies (CONNELL, 1978).

Cerca de 20 anos após a proposição dessa hipótese, uma meta-análise indica que parece não haver um padrão geral nas relações entre diversidade e distúrbios (MACKEY; CURRIE, 2001). Além disso, os autores propõem que situações de maior diversidade sob frequência intermediária de distúrbios são mais comuns em estudos cujos distúrbios estudados são naturais (MACKEY; CURRIE, 2001). Contudo, Miller et al. (2011) apresentaram um novo modelo propondo que há certos níveis de frequência e de intensidade de distúrbios que favoreceriam a co-ocorrência de espécies com traços distintos, e consequentemente, apresentariam maior diversidade de espécies. Mas esse modelo ainda não tem sido apropriado pelos estudiosos dos distúrbios crônicos.

De maneira geral, ainda não é possível reconhecer um cenário teórico ubíquo nos estudos sobre distúrbios antropogênicos crônicos, com diferentes estudos baseando-se em diferentes teses para seus achados.

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4. Chronic anthropogenic disturbances in ecology: a bibliometric approach

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Abstract

Chronic anthropogenic disturbances is a research topic of increasing interest for ecologists. We conducted a bibliometric assesssment about the literature on this subject in oder to identify some gaps concerning the ecological approaches, the kinds of organisms, disturbances, environments, and ecological zones studied, and to understand the factors influencing the citations and self-citations behaviours in this field. We examined the additive effect of the auhors-related variables (the hightest h-index among the authors, authors'country human development indice, and the hightest number of papers about chronic disturbances published by the authors), Journal CitiScore and the kind of the papers (original or review) on the citation rate of the papers. The additive effect of the same authors-related variables also was tested on self-citation rate. Most of the papers about chronic disturbances are about the effects of livestock grazing or forest products collect activities over plant communities, or the effects of pollution or fishery related activities over benthic invertebrates. The most important determinant of citation rate of the papers about chronic disturbances is the Journal CiteScore, followed by writing reviews papers. The authors who are building this research line are who most use self-citations, and the h-index also affected positively the self-citation rate. Authors from low human development indice countries undertake more self-citations Latin American researches are builindg a research line about chornic disturbance, but it seems they face dificulty in get acknowledege through citations. Therefore we propoused some ways to overcome it, such as to publish in high impact journals or expand their research lines.

Keywords: Scientometrics, Conservation Bias, Latin American Researchers.

Introduction

Humans have altered ecosystems on a large scale, mainly through forest fragmentation in order to establish urban or agricultural areas. Therefore, ecologists have constructed relatively solid theoretical frameworks to explain how these human actions may alter biodiversity patterns and ecological processes on a landscape scale (see, for example, Fahrig 2013; Haila 2002; Kulkarni et al. 2015; Stanley and Maxted 2018; Standish et al. 2014).. Some of these theoretical propositions are the “habitat amount hypothesis” (Fahrig 2013), the effects of the matrix’ features over the phenomena of colonization and extinction of populations (Kennedy et al. 2011), and the edge effects related-phenomena (Potts et al. 2016). These theoretical advances may be a consequence of many well-structured field studies performed with different kinds of organisms and in many different environments.

In the last decades, ecologists have tried to understand how milder human actions may affect the biodiversity. Singh (1998) have stated that, in contrast to acute forest disturbance (such as logging or clear-cutting), there are chronic forms of antropogenic disturbances (henceforward designated as CAD), that has been a much less-recognized matter. Some kinds of these disturbances are the small-scale collect of forest biomass (such as firewood, fodder and non-timber forest products). According this author, chronic disturbances can cause adverse changes in forests because the human onslaught never stops, and consequently populations or ecosystems often do not get time to recover adequately (Singh 1998).

After this paper, seemingly, the number os researches about CAD have been increased, and some evidences of this kind of disturbance have begun to be elucited. For example, in dry tropical forests, chronic disturbances (estimated by proxies of the collect of forest biomass) reduces the biodiversity of plant communities, and drives them to be dominated by disturbance-tolerant species (Martorell et al. 2012; Ribeiro et al. 2015; Rito et al. 2017). In marine environments, chronic disturbances (estimated mainly by the effects of bottom trawling fishing) leads to a reduction of the benthic fauna biodiversity, reducing the biomass of the infauna and the epifauna communties (Kaiser et al. 2000; Schratzberger and Jennings 2002). Therefore, CAD seems to be a new chalenge to biodiversity conservation.

Since CAD seems to be a matter of greater concern in developing countries (as stated by Singh 1998), it is expected that most of the studies performed in terrestrial environments have been undertaken in ecosystems located in these regions, such as the rainforests or the dry tropical forests and deserts. As for the studies performed in marine environments, since bottom trawling fishing footprint is greater in marine regions of the Europe (Amoroso et al. 2018), it is expected that most of the marine studies concentrate in this region. Identify this kind of gap in the studies, and another related the ecological approaches used in the researches (such as population, community or ecosystem ecology) or the kind of organisms studied may be useful to indicate directions for future studies.

Another approach that may be useful to understand the development of a recent research area is accessing the determinants factors of the citation and self-citation behaviors. Authors' citation decisions are a multifatorial phenomenon, since there are many reasons to cite a paper, such as persuading the readers about the ideias or propositions in the text, criticizing another previous studies, referencing methodological protocols, or giving credit to the ideas of other authors (Tahamtan and Bornmann 2019). Despite this, in general, it is assumed that the number of citations is related to the importance or the quality of a research (from a theoretical perspective) (Abut 2000; Bornmann et al. 2012).

Nevertheless, the scientometrics literature indicates that there are many factors that influence the authors' decision of citing a paper (Tahamtan et al. 2016). For example, papers whose authors are North American or European receive more citations than Latin American authors even if these last one publish in high impact journals (Meneghini et al. 2008). It is assumed that the sovereignty of the United States and the Europe in the science is related to the greater investments in education and research (King 2004). Therefore, in spite of the greater concerns of CAD to developing countries, it is likely that most of the citation are related to nations'author characteristics.

Regarding the self-citation behavior, it is recognized as to indicate a continous research process of one author or a group, being a natural and inevitable phenomenon if they intend to improve previous ideias or hypothesis (Pichappan and Sarasvady, 2002). The scientometrics literature shows that self-citations are the *hallmark* of highly productive authors (Mishra et al. 2018) and that researchers use them to reinforce their authority in a given line of research or to continue their research lines (Hyland 2003). Thus, we expect that researchers with the highest h-index (measure based on the number of papers and the number of citations that an author has) and those who are constructing an explicit line of research about CAD are those that use self-citations the most.

Therefore, the mains of this study are to answer the following questions about the ecological literature on chronic anthropogenic disturbances. 1. What are the gaps in the literature about CAD related to the ecological approach, the kinds of environments, organisms and disturbances studied? 2. Are there biases related to the ecological zones where studies about CAD have been carried out? 3. Are the citation rates affected by the Journal CiteScore, kind of the publication (original or review), and author-related variables, such as human development index from the authors 'countries, the presence of one author with high h-index, and the presence of one author who is building a research line about this subject? And 4. Are the self-citation rates affected by these authors-related variables aforementioned?

Methods

Data collect

Our eligibility criteria consisted of the papers in which chronic anthropogenic disturbances is one of the central subjects. An essential element of this criterion is that the disturbances addressed in the study have to be from anthropic origin. If the disturbances studied are an indirect outcome from human action, there must be information in the paper about how human actions influence such ecological changes. For example, we included in our data studies in which the disturbances studied are physical-chemical changes in the water of marine environments due to glacial sedimentation, which, according to the authors, are explicitly due to human agency (see Wlodarska-Kowalczuk et al. 2005). Thus, articles included in this bibliometric study are: 1. They have explicitly tested the effects of CAD on variables from the populations, communities or ecosystems; 2. Studies that have undertaken floristic, faunistic or microbiota surveys in areas subjected to CAD; and 3. Reviews or editorial studies in which CAD consist of one of the central subjects of the paper.

In order to select the studies, we undertook a search in the Scopus database, using as a search key the term "*chronic w/2 disturbance*" in abstracts, titles or keywords of the papers. Since this search has resulted in a large number of biomedical studies, we have restricted it to the "Agricultural and Biological Sciences" and "Environmental Science" fields. This new search resulted in 260 articles, of which 176 attained our eligibility criterion.

Then we collected the following data from each paper: kind of ecological approach, environment, organisms and disturbances studied, year of publication, number of citations, number of self-citation (from any one authors of the papers), 2018 Journal CiteScore, the kind of the paper (original or review), the highest h-index (after removing the effects of self-citations in this score) among all the authors of each paper (from now on, designate as H Max), the nationality of each author (country where the author works), the number of papers that each author has published about CAD (in order to visualize which authors are building a research line about this subject). We categorized as original any paper with primary data, while all the papers with theoretical discussion about CAD as review.

In order to estimate the mean human development index (from now on designated as Mean HDI) from authors 'countries, we collected HDI data from the Human Development Reports from the United Nations Development Programme (http://hdr.undp.org/en/countries). We choose to use mean HDI instead of the authors' nationality because we believe that this variable is related to investment degree that each country makes in education and research, and because, in general, socioeconomic descriptors are related to the countries' research investment level (see King 2004; Parker et al. 2010; Shelton 2008,).

. Regarding the data about the number of papers that each author has published about CAD, we replace them by the highest number of papers that of one of the authors of each paper have been published (from now on, designate as N Max). For example, in the reference Martorell and Peters (2005), Martorell has published 10 papers about CAD, and Petters just 2, therefore the N Max from this paper is 10.

Despite of their quantitative aspect, the variables Mean HDI and N Max showed a distribution very similar to categorical variables, then we choose to categorize them in three levels. We considered low N Max values between 1 to 4, medium 5 to 9, and high 10 to 15. We considered as low Mean HDI values < 0.8, medium from 0.8 to 0.9, and high > 0.9.

Regarding the ecological zones of interest, the studies carried out in terrestrial environments were categorized into terrestrial biomes according to the classification presented by Olson et al. (2001), while those conducted in marine environments were categorized into marine ecological zones according to the classification of Spalding et al. (2007). Concerning the studies in freshwater environments, we have chosen not to discuss their locations in different ecological zones because they consisted of only four studies in our database.

Data analysis

In order to identify the mains gaps in the literature about CAD, at first, we categorized some data got from the papers. The data from the kind of environment studied were classified in terrestrial, marine (including studies in estuaries) and freshwater. The approach of the study was classified in population, community and ecosystem ecology. The data of kind of organisms studied were classified in plants (including macroalgae and marine angiosperms), animals and microorganisms (including lichens). The kind of animals studied were classified in corals, benthic invertebrates (in order to incorporate a group of studies dealing with polychaetas, bivalves and echinoderms), fishes, mammals, birds and terrestrial arthropods (including ants and spiders). In some cases, there are other category (such as amphibians and crustacea in kind of animals), but they did not attain a minimal frequency of 5 and were excluded from the analysis.

The data about the kind of disturbance studied were classified in agriculture, forest product collect-related activities (including all the kinds of extractivism), pollution, livestock grazing, fishery related activities (including bottom trawling fishing and small-scale fishing), and human intrusion (including all activities related to the presence of humans, such as trampling and touristic visits). These categories were identified after reading the methodology section of the papers.If a study was about more than one of these categories, it scored one time to each category.

In all the aforementioned classifications, in order to test if the observed frequency of each category differs from the expected frequency (admitting that all categories would have similar frequency), we used a Chi-Square test.

Regarding the bibliometric patterns, we have restricted our analysis data to the papers published until 2018, because some of the papers from 2019 do not have citations yet. Therefore, this analysis was restricted to 162 references. At first, we estimated the citation rates by the ration between external citation (all the citations minus the self-citations) and paper age (regarding 2018 as the age 1). Similarly, we estimated the self-citation rate by the ration between the number of self-citation and paper age. We considered as a self-citation any citation performed by anyone authors of the paper cited. . In order to access the independence between our quantitative predictor variables, we performed a Farrar-Glauber test (F-G test), using the package *mctest* (Imdad and Aslam 2018; Imdadullah et al. 2016) for R. Since the variance inflation factor (VIF) was smaller than 2 (2018 Journal CiteScore and H Max = 1.19), we assured there is no collinearity between them. After that, since the covariates have different numerical scales, we have performed a data standardization using the function *scale*.

We have built two different GLM models (one for citation rate and another for self-citation rate), both of them using a Gaussian distribution with the identity function. In the citation rate model, the covariates were 2018 Journal CiteScore + kind of the paper + N Max + H Max + Mean HDI. In the self-citation model, the covariates were N Max + H Max + Mean HDI. In both of these models, the data from citation rate and self-citation rate were transformed to a log scale in order to the best model fit. The variables with no significative effect (assuming a significance level as $p < 0.05$), were dropped from the models. After that, we performed an analysis of variance (Anova) of the models to understand the effect size of each variable. The graphics were made by using the *ggplot2* package (Wickham 2016). We conduced all the analysis in the R environment 3.6.1 version (R Core Team 2019).

Results

The number of papers published per year about CAD is relatively low, although there appears to be a gradual increase, especially in recent years (**Figure 1**). The first papers were published in the late 1980s, and the greatest number of papers published per year was in 2018 and 2017. Of the 176 papers, 24 are review studies (13.64%), while the remainder consists of original articles. However, of these review studies, only one relates exclusively about CAD (Singh 1998). In all other review studies, this subject is discussed along with other topics such as ecological succession, bioindicators, or general anthropogenic disturbances (including acute and chronic disturbances).

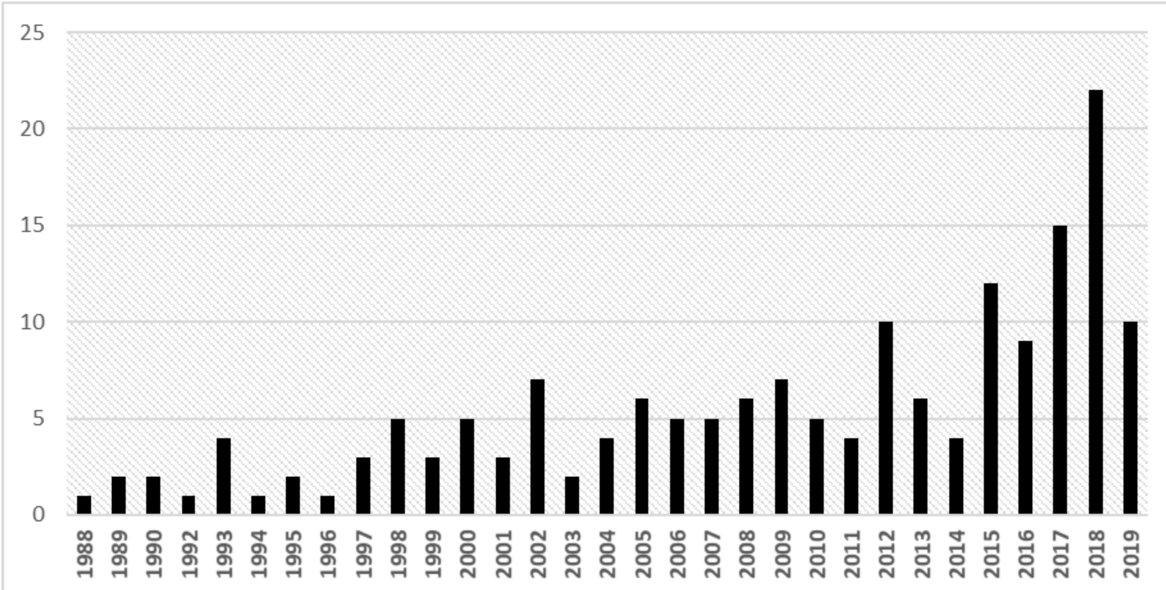

Fig 1 Temporal evolution of the number of papers published about chronic anthropogenic disturbances found in the Scopus database

There are some biases in the content of the literature about CAD concerning the ecological approaches, the environments, the organisms and the disturbances studied. Terrestrial and marine environments have been extensively studied, with 60% and 37% of the studies, respectively, but freshwater environments are overlooked (3%) (χ^2= 81.31, df = 2, p = 2.2e-16). Concerning the studies performed in terrestrial environments, most of them were undertaken in areas located in Deserts and Xeric Shrublands biomes, followed by Temperate Broadleaf and Mixed Forests, and Tropical and Subtropical Dry Broadleaf Forests (**Table 1**). Most of the studies about marine environments were undertaken within the Temperate Northern Atlantic, and Central Indo-Pacific ecoregions (**Table 2**).

Table 1. Percentage distribution of the studies about chronic anthropogenic disturbances performed in terrestrial environments in relation to the biome where they were performed.

Terrestrial biomes	Percentage of studies
Deserts and Xeric Shrublands	28.41%
Temperate Broadleaf and Mixed Forests	21.59%
Tropical and Subtropical Dry Broadleaf Forests	15.91%
Temperate Grasslands Savannas and Scrubs	9.09%
Temperate Coniferous Forests	6.81%
Tropical and Subtropical Moist Broadleaf Forests	5.68%
Tropical and Subtropical Grasslands, Savannas and Scrubs	3.41%
Mediterranean Forests, Shrublands And Scrubs	2.27%
Taiga	1.14%
Tundra	1.13%

Table 2. Percentage distribution of studies about chronic anthropogenic disturbances performed in marine environments, regarding the marine ecoregions where they were performed.

Marine ecoregions	Percentage of studies
Temperate Northern Atlantic	50.90%
Central Indo-Pacific	16.36%
Artic	10.90%
Temperate Northern Pacific	10.90%

Tropical Atlantic	10.90%
Southern Ocean	5.45%
Temperate Australasia	1.81%

Regarding the kind of approach, most of the studies are about community ecology (67.44%) followed by population (23.83%), and ecosystem ecology (8.72%) (χ^2 = 81.31, df = 2, p = 2.2e-16). The organisms most studied are the plants (51.28% of the studies) and animals (48.07%), but microorganisms (7.05%) are neglected (χ^2 = 53.50, df = 2, p = 2.40e-12). The group of animals most studied are the benthic invertebrates (33.33%), followed by the corals (19.44%) and the terrestrial arthropods (16.66%) (χ^2 = 21.52, df = 5, p = 0.0006). The kind of disturbance most studied are livestock grazing (36.02%), collect of forest products (29.19%), pollution (24.22%) and fishery-related activities (16.15%) (χ^2 = 70.76, df = 5, p = 7.09e-14).

Concerning the factors influencing the citation rate, our final model with the variables 2018 Journal CiteScore, kind of the paper, N Max and H Max, explained about 54% of the data variance (Adjusted R^2 = 0.54, df = 155, p < 2.2e-16) (see in the **Table 3**, the equation parameters of this model). The Mean HDI from the countries of the authors of the papers did not have a significant effect on citation rate, and because of this, it was dropped from the final model. Some important ways that the authors publishing about CAD may get citations are publishing in journals with a high CiteScore (F = 126.54, **Figure 2**), writing reviews papers (F = 29.66, **Figure 3**) and including senior authors (F = 8.25, **Figure 4**). Interestingly, the authors who publish an intermediate number of papers about this topic are the most having obtaining citations (F = 13.22, **Figure 5**).

Table 3. Estimated regression parameters, standard errors, t-values and p-values for the Gaussian GLM to estimate the factors influencing citation rate of the papers about chronic anthropogenic disturbances.

	Estimate	Std.error	t value	p-value
Intercept	0.074	0.133	0.560	0.576
2018 Journal CiteScore	0.179	0.021	8.202	8.46e-14
KindReview	0.500	0.110	4.526	1.19e-05
N_max_medium	0.702	0.202	3.473	0.0006
H_max	0.006	0.002	2.873	0.004

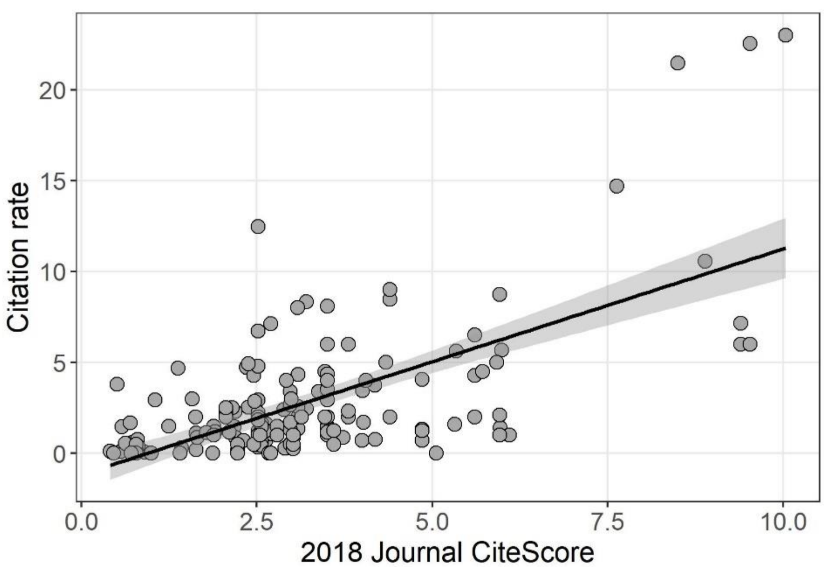

Fig 2. Effect of the 2018 Journal CiteScore on rate citation of the papers about chronic anthropogenic disturbances

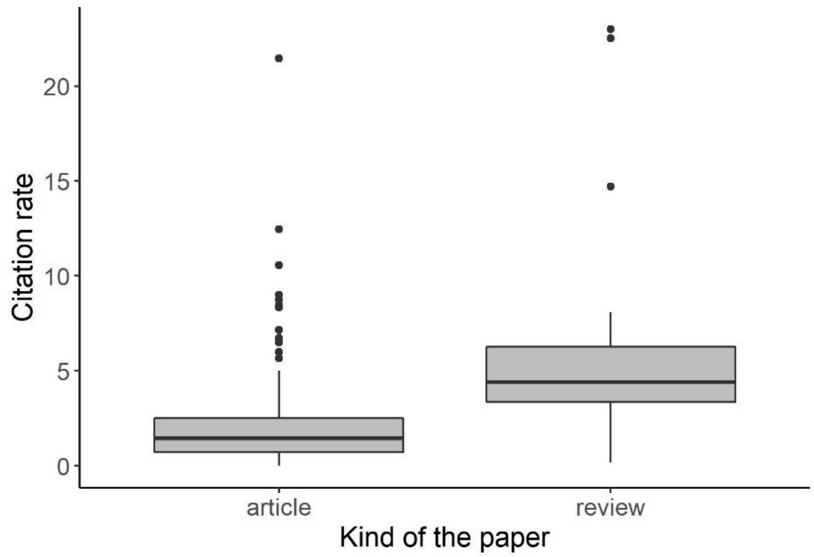

Fig 3 Differences on the rate citation of the papers about chronic anthropogenic disturbances between original and review papers

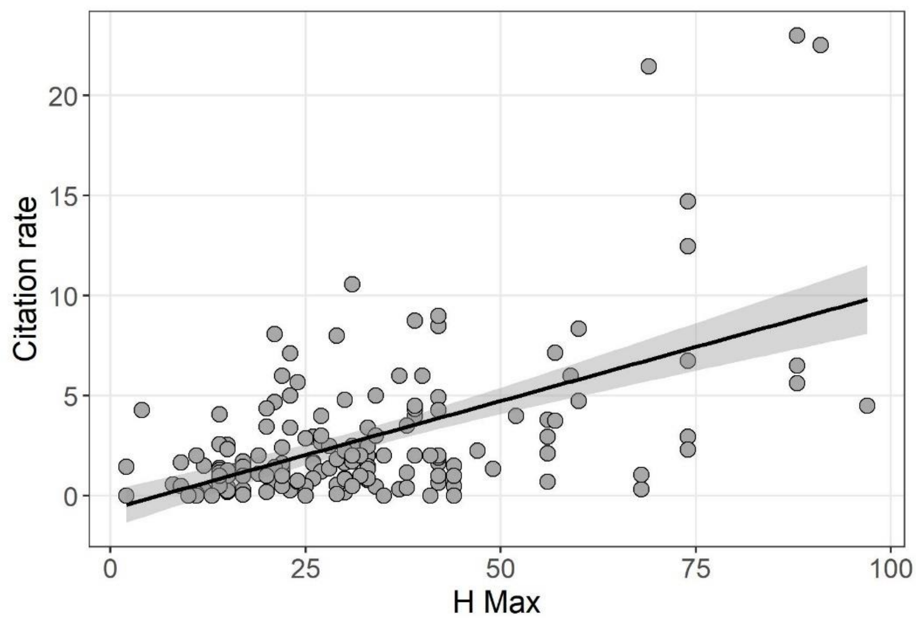

Fig 4 Effect of the highest h-index among the authors of the papers on rate citation of the papers about chronic anthropogenic disturbances

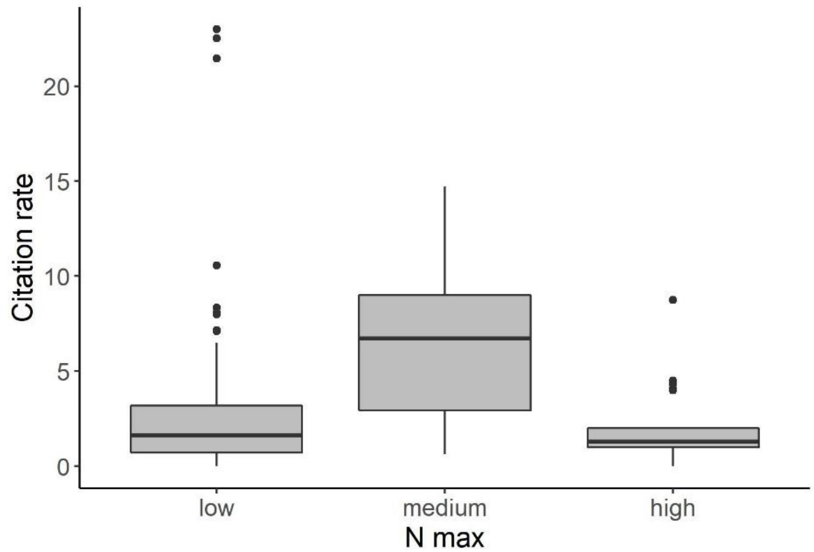

Fig 5 Differences on citation rate on the papers about chronic anthropogenic disturbance between papers whose authors have published few (low), intermediate (medium) and many (high) papers about this topic

Concerning the factors influencing the self-citation rate, our model explained about 33% of the data variance (Adjusted $R^2 = 0.33$, df = 155, $p < 2.11e-13$) (see in the **Table 4**, the equation parameters of this model). In the literature about CAD, the self-citation seems to be a behavior present in a more important way in the papers with the presence of authors with high h-index (F = 27.59, **Figure 6**), authors who publish many papers about this subject (F = 25.56, **Figure 7**), and authors from low HDI countries (F = 3.21, **Figure 8**).

Table 4. Estimated regression parameters, standard errors, t-values and p-values for the Gaussian GLM to estimate the factors influencing self-citation rate of the papers about chronic anthropogenic disturbances.

	Estimate	Std.error	t value	p-value
Intercept	0.532	0.153	3.459	0.0007

N max_low	-0.551	0.120	-4.561	1.03e-05
N max_medium	-0.575	0.193	-2.973	0.003
H Max	0.011	0.002	5.599	9.58e-08
Mean HDI Low	0.251	0.106	2.360	0.019

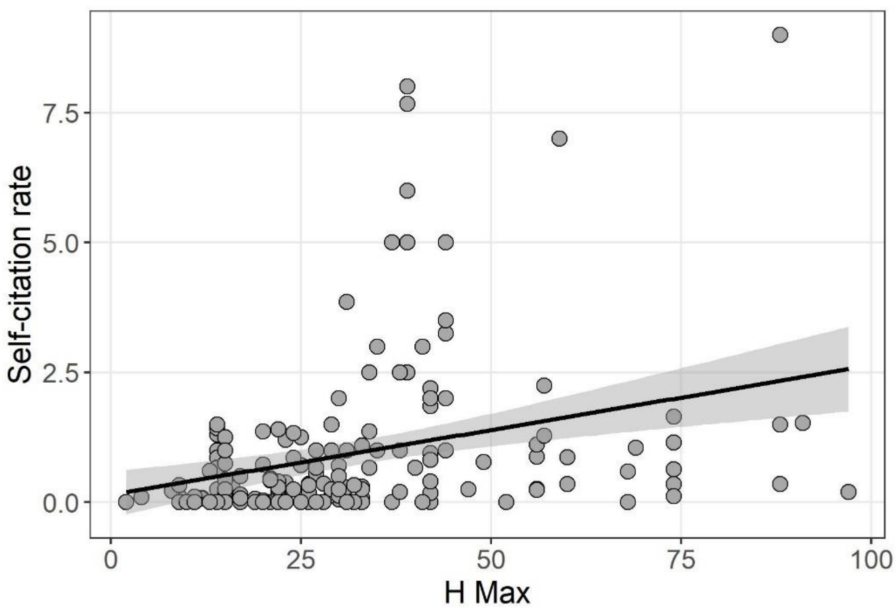

Fig 6 Effect of the highest h-index among the authors of the papers on self-citation rate of the papers about chronic anthropogenic disturbances

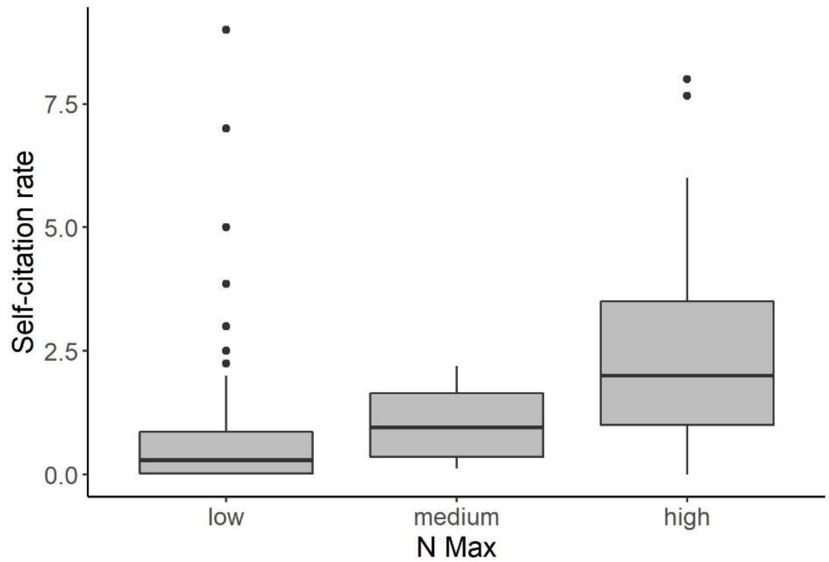

Fig 7 Differences on self-citation rate on the papers about chronic anthropogenic disturbances between papers whose authors have published few (low), intermediate (medium) and many (high) papers about this topic

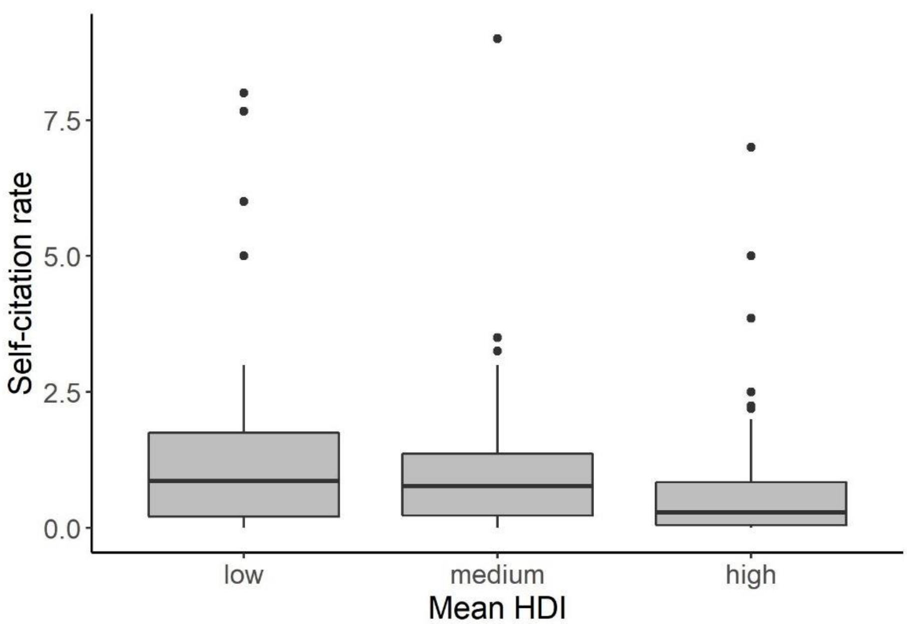

Fig 8 Differences on self-citation rate on the papers about chronic anthropogenic disturbances between papers whose authors are from countries with a low, medium or high mean of Human Development Index

Discussion

Some gaps and the future directions of the research about chronic anthropogenic disturbances

The literature about CAD seems to be divided in two axes, one of them focused in understanding the chronic effects of the livestock grazing and the collect of forest products over plant communities, and the other focused in understanding the chronic effects of the pollution and fishery activities (mainly bottom trawling fishing) over benthic invertebrates (including polychaetas, echinoderms and bivalves) and corals communities in marine environments. Therefore, from the authors' perspective, these seems to be the most important chronic disturbances affecting the biodiversity. Moreover, since plants and benthic animals are sessile, they may be perceived as good indicators of low impact human actions.

There are some clear gaps which may guide some future research on CAD. In freshwater environments, for example, it could be studied the effects of low-scale fishing over benthic invertebrates, or the effects of shipping over fishes' behavior. From an ecosystem perspective, it could be studied the effects of livestock grazing on soil nutrients cycle, or the effects of bottom trawling fishing on marine productivity. About organisms less studied, we know so little about the effects of CAD over soil fauna, or how birds and mammals may be affected by touristic-related activities, for example. Filling these gaps may gives us a wider perspective of the effects of CAD over the biodiversity.

Almost half of the studies about chronic anthropogenic disturbances in terrestrial environments were carried out in areas of dry environments (such as deserts, xeric shrublands and tropical dry forests). This is completely unlike from most of the ecological literature. In general, ecologists have been criticized themselves for undertaking most of their fieldworks in temperate forest areas or in biodiversity hotspots, such as the tropical rainforests (Martin et al. 2012; Trimble and Van Aarde 2012; Watson et al. 2017). Maybe our findings are a consequence of a change of this paradigm because of recent claims for dry forests and arid environments to be further studied, and for ecological processes in these environments to be better understood, since these ecosystems also face serious conservation pressures (Banda et al. 2016). Moreover, dry ecosystems may be more vulnerable to climatic change, another subject of increasing interest by ecologists (Neff and Corley 2009).

There are some biases in the research about CAD undertaken in marine environments too, since about half of them were performed in Temperate Northern Atlantic region. Since bottom trawling fishing is a great matter in this region (Amoroso et al. 2018) it would be expected. Nevertheless, this shows there is a clear gap to be more studied the effects of CAD on corals (an animal group especially vulnerable to climatic change and overfishing) in another ecoregions, mainly in the Central Indo-Pacific region, where are most of the corals reef in the world (Teh et al. 2013).

Citation behavior in the ecological literature about chronic anthropogenic disturbances

The most important driver of citation rate of the papers about chronic anthropogenic disturbances is the 2018 Journal CiteScore. The importance of publishing in high impact journals to obtain more citations is one of the most acknowledged patterns in scientometric literature (Tahamtan et al. 2016). More prestigious scientific journals tend to be more rigorous in the article selection process, requiring innovative researches and greater methodological rigor (Aksnes 2003). Papers published in these journals, usually, may be perceived as having better quality. Besides that, publishing a research in a more respected journal gives it greater visibility and, consequently, increases its chances of being cited (Aksnes 2003).

In addition, our model shows that reviews papers receive more citation than original articles (in general, fieldwork studies). In the medical literature, meta-analysis usually are more cited than all the other kinds of researches (such as randomized trials, case studies, cohort studies, and nonsystematic reviews) (Patsopoulos et al. 2005). Moreover, systematic reviews are more cited than narrative reviews (Montori et al. 2004). It's likely that reviews studies are more cited because they are perceived as a useful starting point to understand a certain subject since they are excellent scientific knowledge transmission route by connecting all the recent findings about a subject (Ho et al. 2017). In the literature about CAD, most of the reviews do not talk about just CAD, instead of they are about disturbances in general. Therefore, they may be of broader interest than the original articles.

The hightest h-index between the authors of each paper also influenced the rate citation. Hurley et al. (2013) have found similar outcome for biomedical literature. Since the h-index is a measure based in the citations that an author receives and the number of papers that they have published, this is an evidence that the presence of an author highly cited in a paper authorship may increase the probability that this paper receive citations. According Garfield (1981), most of the highly cited sientists are man aged between 37 and 50 year, therefore, probabily senior researchers. Thus, it seems that the presence of a senior author may contribute to the study quality, and consequently to a study be cited in the future.

In our perspective, the fact that the human development index of the countries where the authors work had no effect in the rate citation model was surprising. There is a clear sovereignty of countries with high HDI regarding the number of papers published and the number of citation these papers receive (King 2004). Geographically highly cited environmental scientists are almost exclusively from North America and Western Europe (Parker et al. 2010). Since CAD is of greater concern in tropical regions (at least, in terrestrial environments), it is likely that few researchers from high HDI countries are interested in build a research line about this topic, and, consequently, even if they publish some paper about it, they do not receive the acknowledege through citations.

A related finding is that the papers whose authors who publish an intermediate number of papers about CAD are the most receive citations, while the authors who publish many papers about this matter not always receive many citations. A probable explanation for this phenomenon is that this recognition, indeed, takes time to materialize. But another explanation may be related to the nationality of the authors. There are a few European authors who publish about the effects of bottom trawling fishing on benthic invertebrates, they seems to be beginning to build a research line about this matter, and their paper usually receive many citations. While the most prolific authors of the CAD literature are from Brazil or Mexico and their papers not always receive many citations. Thus, it is possible that some kind of psychosocial bias regarding nationality influences the low recognition of these authors. This explanation is supported by the findings of Meneghini et al. (2008) who observed that even though Latin American researchers publish studies in high impact journals, they receive less citations than authors from the United States, Europe or Japan.

Self-citation behavior in the ecological literature about chronic anthropogenic disturbances

The most important drivers of self-citation rate in the CAD literature are the presence of authors with high h-index and the presence of authors who are building and structuring this subject area. These findings may be justified because self-citation is a widely common process in the scientific literature, and are a clear indicative that researchers are continuing a particular line of research or because they wish to reinforce their authority in a particular sub-area of study (Hyland 2003). Self-citation is an inevitable process for researchers who wants to expand or to improve previous studies (Gálvez 2017). Therefore, researchers do not cite themselves in an irrelevant way, they do it because they are building a theoretical corpus bases in their previous studies.

Concerning the effect of the highest h-index between the papers, we have already expected it, when we argued based in Mishra et al. (2018) that self-citations are the *hallmark* of highly productive authors (Mishra et al. 2018). Authors highly cited are expected to undertake high self-citation rates because they may be building their theoretical research lines. Thus, there should be a change in the way researchers perceive self-citation (usually seen in a negative perspective).

Finally, low HDI authors seems to undertake more self-citations. Ladle et al. (2012) found that economically emerging countries (including Brazil, India, Russia, China, and former Soviet Union members) have a higher proportion of self-citations, probably because they have scientific agendas that are less related to global scientific agendas (Ladle et al. 2012). In our case, it is possible that countries with high self-citation rates are dealing with ecological patterns that are more specific to certain ecological zones. For example, it is possible that the findings on the effects of chronic disturbances on plant communities of the Caatinga (a type of seasonal dry tropical forest located in northeastern Brazil) arouse greater interest of Brazilians.

Final considerations

Understand the bibliometric patterns in a research area is fundamental to identify gaps, and to indicate how this area may structure up in the future. Due the acknowledgement that low impact anthropogenic disturbance may affect the biodiversity, there is increasing interest in this research topic. We have demonstrated that there are some gaps in the content of the literature about chronic anthropogenic disturbances, and we have proposed some different directions that this research line may be expanded. In addition, we identified there are biases related to the ecological zones where the studies about chronic disturbances are undertake. This indicates that we still understand very little about how chronic disturbances can affect in distinct ways different ecological communities. These gaps, and the biases created by them, are likely to be overcome if researchers make efforts to replicate their studies in distinct biological ecosystems and communities and/or through collaborations with researchers from other institutions or who work with groups with distinct types of environments and communities.

Moreover, we have demonstrated that the most important way to researches about chronic disturbances get acknowledgement and visibility from other researchers may be to publish in high impact journals and widening the study scope by collaboration with senior researchers. Moreover, the authors who are building this research line undertake plenty self-citations, but this is a natural process in any topic of research.

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5. Wood collect for domestic use has low effects on plant community structure in a dry tropical forest

Artigo submetido ao periódico Forest Ecology and Management

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Abstract

Dry tropical forests are potentially threatened by climate change and by human action. Little is known about the effects of wood collection for domestic use on the structure of plant communities.

We assessed whether the species pool used for building fences is similar to the species composition in near forest areas, in Northeastern Brazil. We also tested the additive effects of rainfall and the wood collection (wood used for firewood and for f building fences) on the structure of the shrub-tree community. In addition, we tested whether there is a correlation between the density of the dominant species in the landscape and the effects of wood collection. In general, the species pool used for building fences in different from the forest community composition. People use a mix of common and rare species. Species diversity, especially the number of rare species, is positively associated with annual rainfall. The wood collection increases community evenness and seems to have a negative effect on species richness and on total density in communities. In general, there is no correlation between the density of the dominant species and the effects of wood collection. Our findings suggest that the domestic use of wood products may have low effects on diversity in dry forests. Moreover, the dominant species in the landscape may be reasonably tolerant of the effects of wood collection. Conservation and restoration strategies for landscapes affected by domestic wood collection could be guided by the recovery of affected populations, development of sustainable stoves and by stimulate the use of living fences.

Keywords: Ethnobotany, Eco-evolutionary dynamics, Caatinga.

Introduction

The collection of wood from forests is a fundamental activity for livelihood in many rural populations, mainly in developing countries. According to FAO (Food and Agriculture Organization of the United Nations), about 1/3 of the world population depends on the forest biomass (firewood or charcoal) for cooking (FAO, 2014). Because of this, approximately 50% of wood extracted from forests is used for this purpose (FAO, 2014). Besides that, about 1.3 billion people depend on forest products for house construction, mainly in countries in Asia, Oceania, and Africa (FAO, 2014).

In recent years, there seems to be an increase in the number of studies that try to understand how local populations choose plant species for fuelwood and construction. These studies show that people have preference criteria that guide their choices. For example, for firewood, people may prefer to use species with high calorific potential, with long-lasting flames and embers, and which are easily ignited (Ramos et al., 2008; Tabuti et al., 2003). Regarding the species used for construction, the durability and resistance to attack by termites and beetles are criteria that affect the choice of species (Dahdouh-Guebas et al., 2000; Gaugris and van Rooyen, 2009; Kakudidi, 2007). Moreover, a recent meta-analysis indicates that the species abundance influences the use of species for wood (Gonçalves et al., 2016a). Thus, the use of species for wood may be, at least in part, focused on the most abundant species in the landscape.

From an ethnobotanical perspective, there is evidence that the wood collection for domestic use has the potential to affect plant communities. Regarding the collection of wood for construction, people generally collect whole trunks from some trees in order to build fences or houses (de Medeiros et al., 2011; Nascimento et al., 2009). This collection behavior seems to affect the local vegetation, since Nascimento et al. (2009), for example, found that some of the species most used for building fences in areas surrounding a dry tropical forest are rare in local vegetation. The behavior of wood collection for firewood is different since people generally collect dry wood branches (Campbell et al., 1997; Luoga et al., 2002). Despite this, in many rural populations, there is a daily demand for firewood (Medeiros et al., 2011). Therefore, the collection of wood for firewood may pose a more significant threat to ecosystems than the collection of wood for construction.

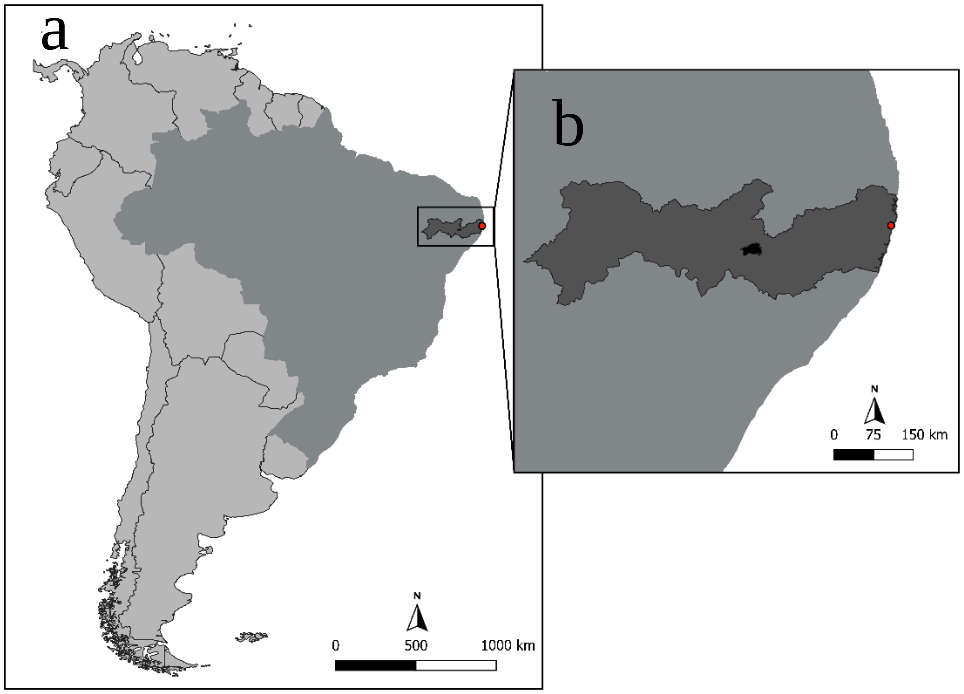
In dry tropical forests (the setting of this study), the effects of anthropogenic disturbances (including wood collection) there seems to be mediated by water availability (accessed through rainfall levels) (Rito et al., 2016; Sfair et al., 2018; Zorger et al., 2019). In these areas, the rainfall levels are a strong predictor of species composition (Rito et al. 2016). Also, in some areas with higher water availability, the increase in the degree of disturbances increases the diversity of plant species, whereas, in areas with less water availability, the increase in the degree of disturbances reduces diversity (Rito et al., 2016).

Overall, the ecological and ethnobotanical literatures provide some evidences that the wood collection for domestic use may affect plant community diversity, either by the use of some preferred species (reducing diversity) or by an indiscriminate use (affecting all the species or affecting the most abundant species). Therefore, we intend to answer the following questions: I. Do the species pool used for wood purpose is similar to the species composition in the forest fragments? II. Do the rainfall levels and the wood collection affect the structure of plant communities? III. Do the wood collection affect the density of the dominant species in the landscape?

Material and methods

Study area

We have carried out this in the region of the Catimbau National Park (8º24'00" and 8º36'35" S; 37º0'30" and 37º1'40" L), located in the state of Pernambuco, northeastern Brazil (**Figure 1**). The park has an area of approximately 60,000 hectares and has areas with different rainfall regime (from 480 to1100 mm per year) (Rito et al., 2016). Local ecosystems belong to the Caatinga domain, a seasonally dry tropical forest that exists only in Brazil. There is a high phanerogamic flora inside the park (more than 600 species); the families with the most substantial richness are Fabaceae (18% of species), Poaceae (8%), Euphorbiaceae (6.5%), Asteraceae (5.8 %) and Convolvulaceae (5.7%) (Athiê-Souza et al., 2018).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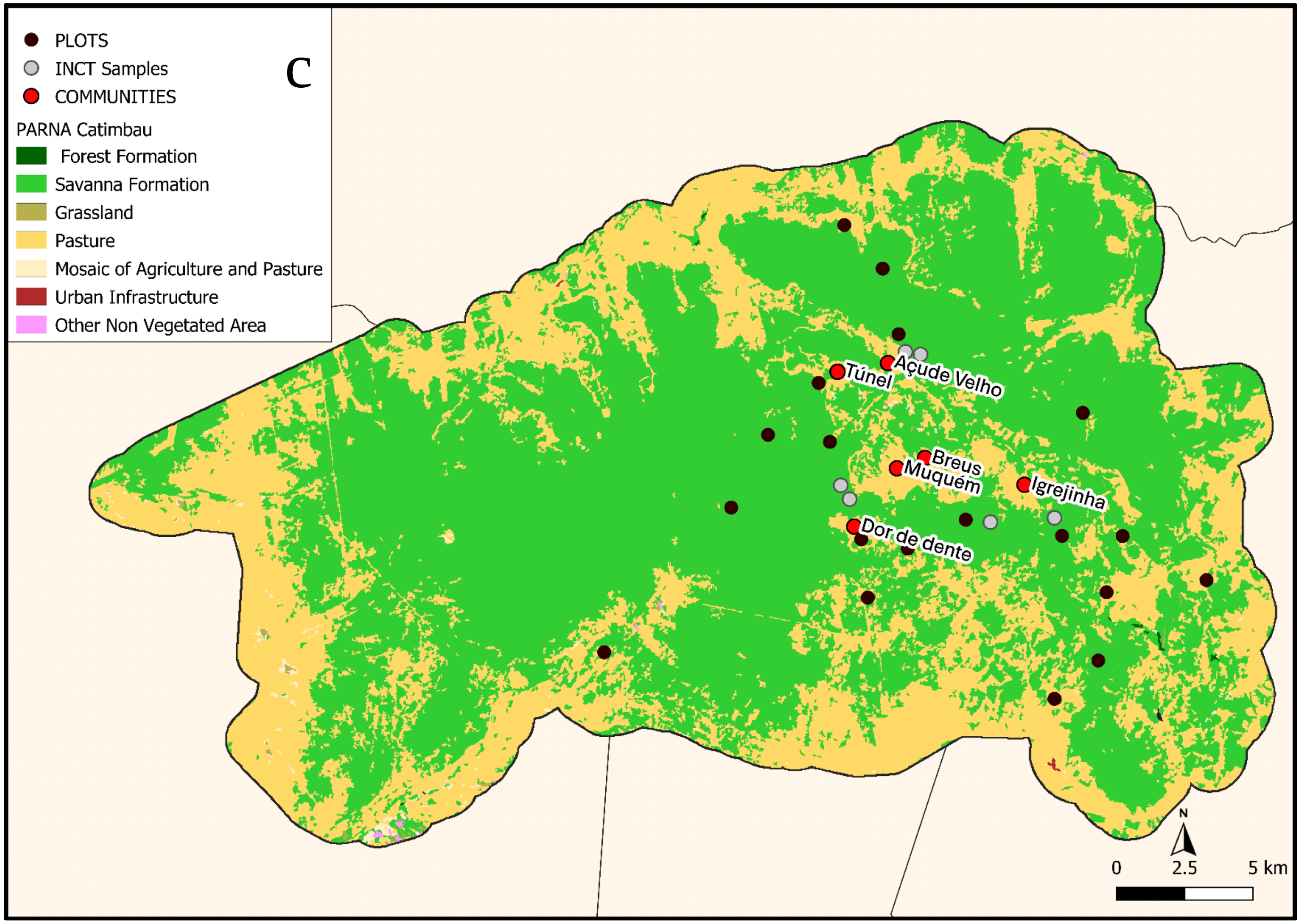

Figure 1. Location of the study area in Northeastern Brazil (a), and the study landscape (black inner area) in the Pernambuco state (b). The red point marks the capital of the Pernambuco state.. The Catimbau National Park, and the location of all the samples from Rito et al. (2016) (black dots), and the samplings from the INCT (grey dots), and the local communities studies are also indicated (c).

The human occupation of the region dates from about 7,000 years before present (BP) (MARTIN, 2005). The first inhabitants consisted of itinerant hunter-gatherers who consumed small mammals, reptiles, amphibians and bivalves, and fruits from palms such as *Syagrus coronata* (Mart.), and *Attalea speciosa* Mart. ex Spreng., and the fruits from *Spondias tuberosa* Arruda (Lima, 2009). From about 2,500 years BP, the region started to be occupied by sedentary groups, who are likely to have used the plant and animal resources in the area more intensively (Oliveira, 2006).

In the colonial period (centuries XVI and XVII), people belonging to the Prakió ethnic group (also called Paratió) inhabited the region, although more recently, part of the region's inhabitants identified themselves with the Kapinawá indigenous ethnic group (Andrade, 2014; Sampaio, 2011). In the late 1990s, FUNAI (the Brazilian Government's indigenous institution) ratified a territory of about 12,400 ha south of the park as the Kapinawá indigenous territory. However, part of the communities within the park recognized themselves as belonging to this ethnic group, and claim their permanence in the region, resulting in conflicts with IBAMA (Brazilian Institute of Environment and Renewable Natural Resources) (Andrade, 2014; Sampaio, 2011). Currently, in the interior of the park, there are about 300 families, distributed in 17 communities, which subsist, mainly, of extensive livestock, agriculture, and government welfare benefits. Many of these families extract different forest resources to use as firewood, building fences, medicine, and food (Specht et al. 2019).

Ethnobotanical data collection

Ethical and legal aspects

Before the surveys, we submitted the thesis project that resulted in this article to the Research Ethics Committee with human beings at the Federal University of Alagoas. The project was approved and was registered under the following number of Presentation Certificate for Ethical Appreciation (CAAE): 83182217.6.0000.5013. Before data collection, we have informed all the research participants about the objectives of the study and we asked them to sign an informed consent form, according to the recommendations of resolution 510 of the National Health Council (Brasil, 2016). However, most of the residents fear that the researches carried out by biologists in the region are related to the environmental inspection institutions and that we may contribute to the process of expropriating their land. Consequently, only 33% of the participants signed the free and informed consent term, while the rest of the individuals declared their consent only through oral expression, which is also acceptable according to article 5 of this same resolution.

Also, we have submitted this research to the Biodiversity Authorization and Information System (SISBIO) in order to obtain authorization to collect of botanical material in a conservation unit. The project has been approved under the registration number 69750-1.

Selection of the studied communities

For the collection of ethnobotanical data, we selected six communities located in different regions of the park (**Figure 1**, **Table 1**). This research focused just on non-indigenous communities Catimbau National Park, Northeast Brazil.

Table 1. Sampling aspects about the study of wood collection in the rural communities studied in the Catimbau National Park, Northeast Brazil.

Communities	**Total number of households**	**Firewood piles sampled**	**Households whose fences were sampled**	**Fences sampled**
Túnel	3	2	5[1]	8
Açude Velho	9	4	6	9
Muquém	16	16	21[1]	31
Dor de Dente	7	4	6	7
Igrejinha	51	27	35	39
Breus	8	4	5	5

1 – In the Túnel community, the number of families whose fences were sampled is higher than the number of families residing in this site because one of the families residing in the community of Açude Velho has a fence in the Túnel community. Besides that, we have sampled some abandoned fences.

Selection of a key informant

Before data collection, we selected a key informant, whose function was to identify the plants used for wood in each residence and to accompany the researchers during the data collection. In the region, be accompanied by a local informant increased local people trustfulness, since some inhabitants feared we had a relationship with the environmental inspection institutes.

Members of one of the communities studied indicated the selected key informant as being an individual with vast knowledge about plants used for wood in the region. During data collection, we found that, in most cases, the households corroborated the plants identification carried out by the key informant. However, on occasions when there was a disagreement, we followed the identification indicated by the head of the household.

Firewood use

To access the use of firewood, we used the weight assessment technique (Ramos et al., 2014). Each head of the family was asked to separate from his firewood pile the amount used in one day. At that time, if we realized that the pile of firewood present in residence has different species, we explained to the head of the residence that he could select firewood from different plants to represent his daily consumption. In cases where this stimulus proved to be ineffective, we asked the head of the household to pile up enough firewood for two days, to try to increase the richness of sampled plants.

Within the selected sub-sample, we have separated the woods by species and weighed each one using a HOUSETOOLS digital hand scale. We chose not to measure the biomass of the entire firewood stock in each residence because it was usually huge. Besides that, this procedure would take a long time and would result in greater discomfort on the part of the residents.

Wood use for building fences

To access the use of wood for building fences, we have undertaken an adaptation of the *in situ* inventory technique (Gaugris and van Rooyen, 2006) After conducting some pilot measures, we realized that there were different architectural fences types in the region, which differ in the types and number of fence posts per meter (see **Figure 2**). Therefore, we carried out an ethical classification (from the researchers' perspective) of the fences, regardless of the motivations that lead people to build fences with different architectures: I. Closed fences are those made of small diameter and quite juxtaposed stakes; II. Semi-open fences are those made of small diameter and loose juxtaposed stakes; III. Open fences are those made of stakes of intermediate diameter and spaced out; there are some large diameter stakes (called posts) used to secure the wires; IV. Very open fences are those made of piles of intermediate diameter, and arranged in a very spaced way; also, there are some large diameter stakes used to secure the wires, and V. The fences just with posts are made up only of posts quite spaced apart.

Therefore, we sampled the stakes present in different lengths in order to sample a similar number of stakes between the different fences types. For closed fences, we sampled two meters; for semi-open, four meters; for open fences, 50 meters; for very open ones, 70 meters, and the fences just with posts, 100 meters. If the same fence had sections of different structural constitutions, we carried out a sampling for each section. Concerning the sampling sufficiency, although it would be appropriate to increase our sampling effort according to the total fence perimeter, this procedure would be quite laborious and would require a long time to be accomplished in each residence, which could increase discomfort on the part of the residents.

The selection of the measured section was intentional. In general, we measured a section in front of the residence, so that the head of the residence could, if he (she) desired, observe or follow the research. For each stake in the measured section, the key informant identified the plant species. Then we measured its height and circumference. Subsequently, we covered the entire perimeter of the fence, using the odometer function of a GPSMap 60CSx, with an accuracy of 5 meters, to record its length. Also, a common situation in the studied region is that some residences share the same stretch of fence on its sides. In these cases, if both heads of household participated in te study, the shared perimeter was divided between the two. However, if only one participated, the shared section was considered to belong entirely to him (her).

Concerning the replacement of the stakes present in the fences, through informal interviews, we realized that such substitution is not uniform since the species differ in their durability. Therefore, at another time, we selected 11 people for structured interviews (de Albuquerque et al.,

2014) about the durability of the 15 species of the largest volume in the sampled sections of the fences. These 15 species together totalize 93.87% of the total wood volume used, except for the unidentified stakes. We chose not to ask people about the durability of all species because we considered that this would make the interview exhaustive, which could influence the respondents' responses. The criteria for selecting respondents were individuals that we identified as knowledgeable about the species used to build fences, and who were receptive for interviews.

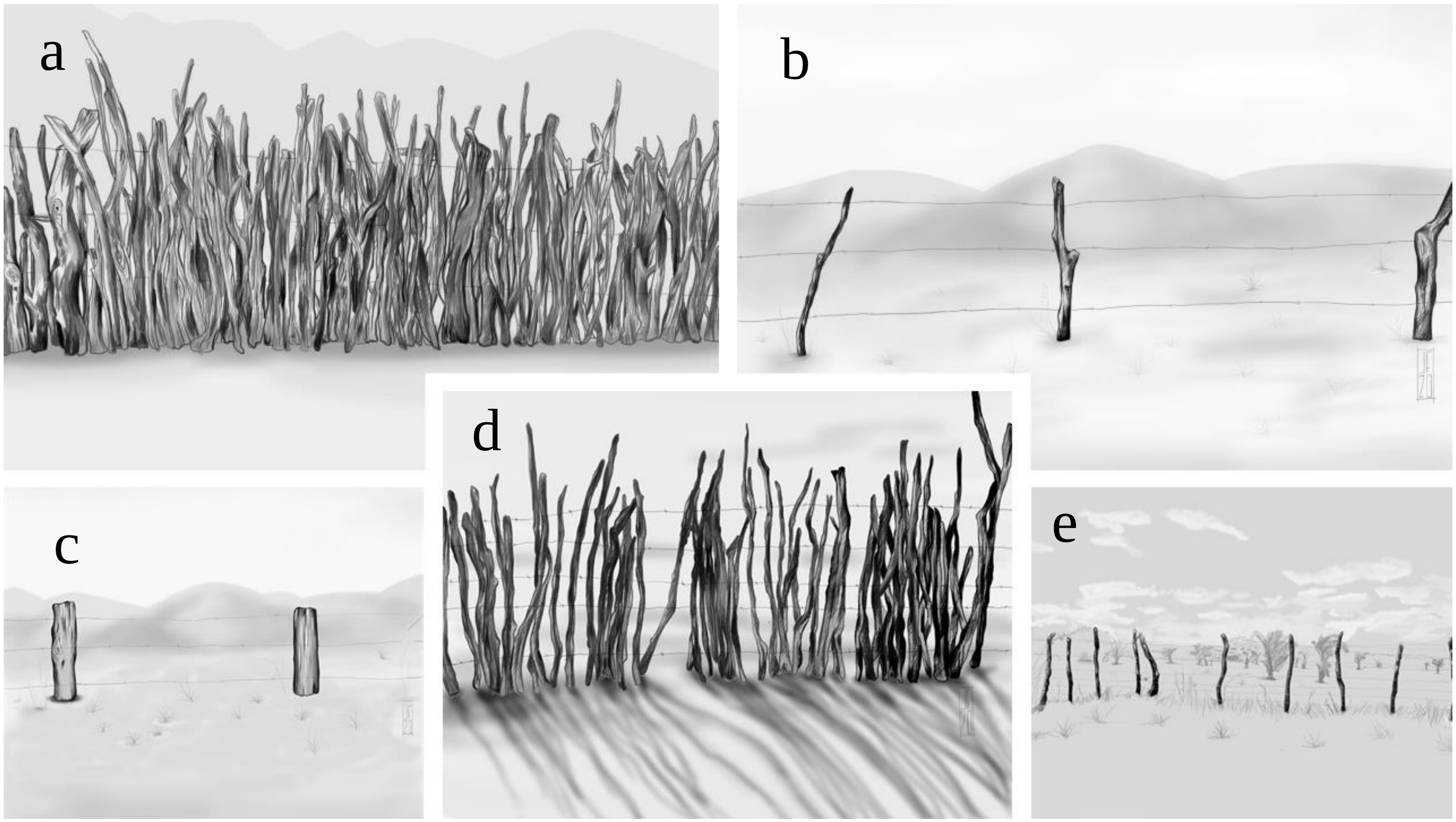

Figure 2. General architectural types of fences in the Catimbau National Park, Northeast Brazil: The closed fence (a), the wide-open fence (b), the fence just with posts (c), the semi-open fence (d), and the open fence (e).

Vegetation sampling and collection of botanical material

We have used two sets of data for plant communities. The first one is data from Rito et al. (2016) who sampled 19 areas, using the plot method, along with a gradient of anthropogenic disturbance and rainfall within the park. The second set of data refers to the sampling that carried out by the INCT researchers (National Institute of Science and Technology: Ethnobiology, Bioprospecting and Nature Conservation) in six areas indicated by key informants as being areas where local people collect forest products. The sampling method used was the point-centered quarter method. In each area, five lines of 100 meters in length, 20 meters apart, were established. In each row, we have established ten quadrants, and in each quadrant, we sampled the four closest individuals. All the individuals with a diameter at ground level ≥ 5cm were sampled, except Cactaceae species.

All the inventoried species were collected and sent for identification at the Agronomic Institute of Pernambuco (IPA). However, some of the plants recorded in the collection of ethnobotanical data were not found during the vegetation sampling. In order to collect samples of these species, we employed walking in the woods technique (Albuquerque et al., 2014) with the same key informant who participated in the collection of ethnobotanical data. This key informant did not know the identities of two species only and did not know where to locate them. In this case, other informants who declared to know the species were contacted for the guided tour, when they were collected. All botanical material collected were identified at the IPA.

Formulating a Wood Collection Index

Since the use of wood for firewood and building fences have different replacement rates, we transformed the data sampled into annual usage rates. Regarding the data on firewood use, for each community, we averaged the annual use of firewood (in kg) among the families we sampled and multiplied by the number of families using firewood in each community in order to take into account the use of resources by households that we have not sampled.

To estimate the annual use of wood for building fences, we focused only on the most used species, which were the ones for which we obtained information on the durability of their stakes. Initially, we calculated the volume of each of the stakes present in the sampled section, considering them as having an approximately cylindrical shape. Then, the volume data for each species in the sampled section were extrapolated, considering the entire perimeter of the fence. For example, in the case of closed type fences (in which we sample the stakes present within a 2-meter section), if the perimeter of the fence is 100 meters, we multiply the volume data obtained for each species by 50.

Subsequently, we excluded outliers in the data about perceived durability of the species. After this procedure, we calculated the average of the perceived durability of each of these species. Of the 11 species for which we found outliers in the values of perceived durability, ten were due to information obtained from the same informant. So, in general, only his response deviated from the others. Then, the extrapolated volume of each species was divided by the average of their respective perceived durability. A limitation of this approach is that we are assuming that local people would replace the stakes of one species by stakes of the same one. Just as we did for the use of firewood, we calculated the annual use of wood for building fences for each family. Then, we averaged usage among the families we sampled and multiplied by the number of families residing in each community.

After estimating the annual use of wood for firewood and for building fences, we formulated an index in order to predict the effects of wood collection in the vegetation plots. The Firewood Use

Index from a rural community x over a vegetation plot y is the ratio between the annual use of firewood in the community x and the square distance of that community to plot y. Then, the total Firewood Use Index affecting the plot y is the sum of these indexes for the six rural communities studied. We performed the same procedure to estimate the Fence Use Index. When we assume that the effects of wood collection over a plot is inversely proportional to the square of the distance from the communities, we are assuming that this effect declines exponentially with the distance. The distances between the studied communities and the plots were estimated using the *geodist* function of the *gmt* package (Magnusson, 2017), in the R environment.

Plant community descriptors

Since the sampling by Rito et al. (2016) was performed using 0.1 ha plots, we multiplied the species abundance data by 10 to obtain the respective densities per hectare. We estimated the species densities for the areas samples by the INCT using a script present in (Mitchell, 2010), in R environment.

To estimate the descriptors of the structure of plant communities, we estimated the alpha diversity indices, including Q^0 (species richness), Q^1 (the Shannon index exponential) and Q^2 (the inverse of the Simpson index), using the *entropart* package (Marcon and Herault 2015), in R environment. As Q^0 is the species richness, it attributes a disproportionate weight to rare species. The Q^1 index assigns proportional weight according to species densities, so it may mean the number of common or "typical" species in the community. The Q^2 index assigns higher weight to the most abundant species, so it may be interpreted as the number of very abundant or "dominant" species in the community. We also estimated the evenness factor, which consists of the ratio between Q^2/Q^0. The evenness factor represents the proportion of dominant species in the community. It varies between 1 (a community whose species have similar densities) and $1/Q^0$ (if the only one species dominates the community). Additionally, the total density of individuals was calculated from the sum of the densities of all species. Since we deal with two different data sets, we chose to use in our analysis only data from species that have been identified (except for the analysis referring to the total density variable).

For each sample of the plant community, we collect the average annual rainfall data from the WorldClim global climate data repository, with a resolution of 30-arc seconds or approximately 1 km of spatial resolution at the equator, using the *raster* (Hijman 2019) and *sp* packages (Pebesma et al. 2005; Roger et al. 2013), in R environment.

Data analysis

Initially, we found an outlier in the data of Firewood Use Index and tow outliers in the Fence Use Index. We removed one of the outliers that were common to both of these data. Subsequently, we found a strong correlation between these indexes (rs = 0.83, p = 2.06e-06), and between the Firewood Use Index and rainfall (rs = 0.51, p = 0.01). Consequently, we have chosen to join these indexes into a single measure (from now on called Wood Collection Index), using a principal component analysis (PCA). The first axis of this PCA explained 75.37% of the variation in the data, and we used it as the Wood Collection Index. This new index has no outliers and has no correlation with rainfall data (rs = 0.28, p = 0.17). Subsequently, we standardized the annual rainfall data, using the *scale* function in R environment, so that both predictor variables had the same numerical scales.

To assess whether the composition of species used to build fences is similar to the nearest plant communities, we converted both data (species used in the fences and plant communities data) into a Jaccard dissimilarity matrix. Then, in order to visualize this possible similarities among fences and plots, we performed a Non-Metric Multidimensional Scaling (NMDS). In order to exclude idiosyncrasies, we dropped species frequent in less than 5% of the fences or in less than three of the 25 forest plots. Also, we removed non identified species.

We have not tested the same for firewood use because we usually found few species in firewood piles. As it is a product of daily demand, people collect firewood frequently, thus we probably could not access the entire set of species that are used. Initially, we intended to repeat this sampling, but the local setting of socio-environmental conflicts did not allow us to go ahead.

In order to assess how the wood collection (based in the Wood Collection Index) and rainfall affect the structure of the plant community, we performed generalized linear models, with Gaussian distribution. Although two of our variables are count data (Q^0 and total density), both presented Gaussian distribution, which justified the choice of this distribution. We performed the model selection using the stepwise approach. In some situations, it was necessary to perform data transformation to fit the models better (see **Table 4**).

To test whether the increase in the Wood collection Index correlates with the densities of species widely distributed in the region (frequent in at least 50% of the sample units), we performed Spearman correlation tests. We chose this approach because the data did not fit to linear regression models.

Results

Wood products use in the Catimbau National Park

We identified 62 species used for wood purposes in the six rural communities studied. Of these species, 31 are used as firewood, and 59 are used to build fences (**Table 2**). The species most used for firewood are *Poincianella microphylla* (Mart. Ex G. Don) L.P. Queiroz, *Senegalia piauhiensis* (Benth.) Seigler & Ebinger and *Pityrocarpa moniliformis* (Benth.) Luckow & R.W.

Jobson. The species most used for fence construction are *S. piauhiensis*, *Senegalia bahiensis* (Benth.) Seigler & Ebinger, *Poeppigia procera* C. Presl and *Prosopis juliflora* (Sw.) DC.

Table 2. Static use (disregarding wood replacement) of wood as firewood and for building fences in six rural communities in the Catimbau National Park, Northeast Brazil.

Botanical family / Species	**Local names**	**Herbarium's register number**	**Daily use of firewood (kg)**	**Wood static volume used for building fences (m^3)**
Anacardiaceae				
Anacardium occidentale L.	Cajueiro	93683		0.19
Myracrodruon urundeuva Allemão	Aroeira		0.55	1.67
Schinopsis brasiliensis Engl.	Braúna/ Baraúna			10.64
Spondias tuberosa Arruda	Umbuzeiro			0.21
Annonacae				
Annona leptopetala (R.E.Fr.) H.Rainer	Pinha branca/ Umbigo de bezerro	93471		0.01
Asteraceae				
Moquiniastrum oligocephalum (Gardern) G. Sancho	Candeeiro branco	93423	28.27	7.94
Apocynaceae				

Aspidosperma pyrifolium Mart. & Zucc.	Pereiro	93686		18.77
Bignoniaceae				
Cuspidaria argentea (Wawra) Sandwith	Cipó de rego/ Mela-cu-de-cancão	93454		0.60
Handroanthus sp.	Pau d'arco		10.11	14.47
Boraginaceae				
Cordia trichotoma (Vell.) Arráb. ex Steud.	Frei Jorge	93684		0.05
Varronia curassavica Jacq.	Moleque duro	93444		0.07
Burseracea				
Commiphora leptophloeos (Mart.) J.B.Gillett	Umburana de cambão	93685	2.6	25.03
Cactaceae				
Pilosocereus pachycladus F.Ritter	Facheiro		4.61	0.51
Capparaceae				
Cynophalla flexuosa (L.) J.Presl	Feijão brabo	93438		0.22
Neocalyptrocalyx longifolium (Mart.) Cornejo & Iltis	Incó	93468		0.18
Euphorbiaceae				
Cnidoscolus pubescens Pohl	Favela/ urtiga	93460		2.23

Croton argyrophyllus Kunth	Marmeleiro branco	93463	3.44	5.54
Croton blanchetianus Baill.	Marmeleiro preto/ Marmeleiro do sertão	93426		0.43
Cf. *Croton cordiifolius* Baill.	Quebra-faca-do-sertão			6.10
Euphorbia tirucalli L.	Avelós			0.26
Jatropha mutabilis (Pohl.) Baill.	Pinhão	93472		0.26
Sapium argutum (Müll.Arg.) Huber	Pau de leite	93499		0.19
Erythroxylaceae				
Cf. *Erythroxylum revolutum* Mart.	Joãopirribão/ Rompe-gibão			6.39
Fabaceae				
Bauhinia acuruana Moric.	Mororó	93434		0.64
Dioclea grandiflora Mart. ex Benth.	Mucunã	93476		0.001
Chloroleucon dumosum (Benth.) G.P.Lewis	Jurema branca		0.89	0.60
Dalbergia cearensis Ducke	Violeta/ Violeiro/ Amora/ Namora	93689	1.75	1.5
Erythrina velutina Willd.	Mulungu			0.41
Hymenaea courbaril L.	Jatobá	93442		0.025

Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz	Pau ferro/ Jucá	93448		0.01
Lonchocarpus araripensis Benth.	Rabo de cavalo/ Sucupira/ Sucupira branca	93690	4.99	0.78
Mimosa tenuiflora (Willd.) Poir.	Jurema preta			4.96
Cf. *Myroxylon peruiferum* L.f.	Báximo/ Bálsamo			0.18
Parapiptadenia zehntneri (Harms) M.P.Lima & H.C.Lima	Angico branco/ Angico majola	93441		33.67
Peltogyne pauciflora Benth.	Coração de negro/ Miolo preto	93435	7.51	0.71
Piptadenia stipulacea (Benth.) Ducke	Espinheiro branco/ Jiquiri/ Rasga-beiço	93688	33.85	1.17
Piptadenia viridiflora (Kunth) Benth.	Espinheiro preto	93486	7.5	
Pityrocarpa moniliformis (Benth.) Luckow & R.W.Jobson	Canzenzo/ Folha miúda	93459	51.02	28.68
Poeppigia procera C. Presl	Chumbinho/ Madeira branca/ Pau branco	93432	14.37	40.53

Poincianella microphylla (Mart. ex G.Don) L.P.Queiroz	Catingueira	93473	79.45	35.78
Prosopis juliflora (Sw.) DC.	Algaroba	93440	11.67	40.73
Senegalia bahiensis (Benth.) Seigler & Ebinger	Carcará	93428	29.61	62.59
Senegalia piauhiensis (Benth.) Seigler & Ebinger	Piançaba/ Quebra-faca	93425	63.80	103.49
Senna acuruensis (Benth.) H.S.Irwin & Barneby	Madeira de besouro/ Lenha de besouro/ Fígado de galinha	93439	4.49	0.03
Senna cana (Nees & Mart.) H.S.Irwin & Barneby	Candeeiro preto	93424	0.41	8.22
Malpighiaceae				
Barnebya harleyi W.R.Anderson & B.Gates	Pau de serrote		0.44	
Byrsonima gardneriana A.Juss.	Murici	93437	2.88	0.02
Myrtaceae				
Algrizea minor Sobral et al.	Araçá	93451	1.78	0.21
Eugenia duarteana Cambess	Maçã do mato	93497	0.64	0.58
Eugenia stictopetala Mart. ex DC.	Fruta de cutia	93443		0.03
Nyctaginaceae				

Guapira cf. *laxa* (Netto) Furlan	Piranha		2.07	1.97
Ochnnaceae				
Ouratea blanchetiana (Planch.) Engl.	Bom nome			0.25
Olacaceae				
Ximenia americana L.	Ameixa		0.4	0.27
Polygonaceae				
Cf. *Ruprechtia laxiflora* Meisn	Caixão		0.92	0.007
Rutaceae				
Balfourodendron molle (Miq.) Pirani	Cocão	93687		1.11
Sapindaceae				
Talisia esculenta (Cambess.) Radlk.	Pitomba	93431		0.09
Sapotaceae				
Manilkara sp.	Maçaranduba			0.03
Solanaceae				
Solanum stipulaceum Willd. ex Roem. & Schult.	Sacatinga	93429	0.585	
Verbenaceae				
Lippia origanoides Kunth	Alecrim	93457	10.75	18.52
Unidentified species				

	Batinga		15.69	0.27
	Quiri		5.60	1.35
	Chorão			0.22

There seems to be no clear differences in species composition used to build fences among the communities studied (**Figure 3**). Nevertheless, it is likely the local people are very specialist in the use of species for building fences, since many species present in the forest plots are not used (**Figure 4**). The differences among fences and forest plot seems to emerge from the high frequency of some hardwood tree species in the fences such as *Schinopsis brasiliensis* Engl., *Parapiptadenia zehntneri* (Harms) M.P.Lima & H.C.Lima and *P. procera* (**Figure 4**).

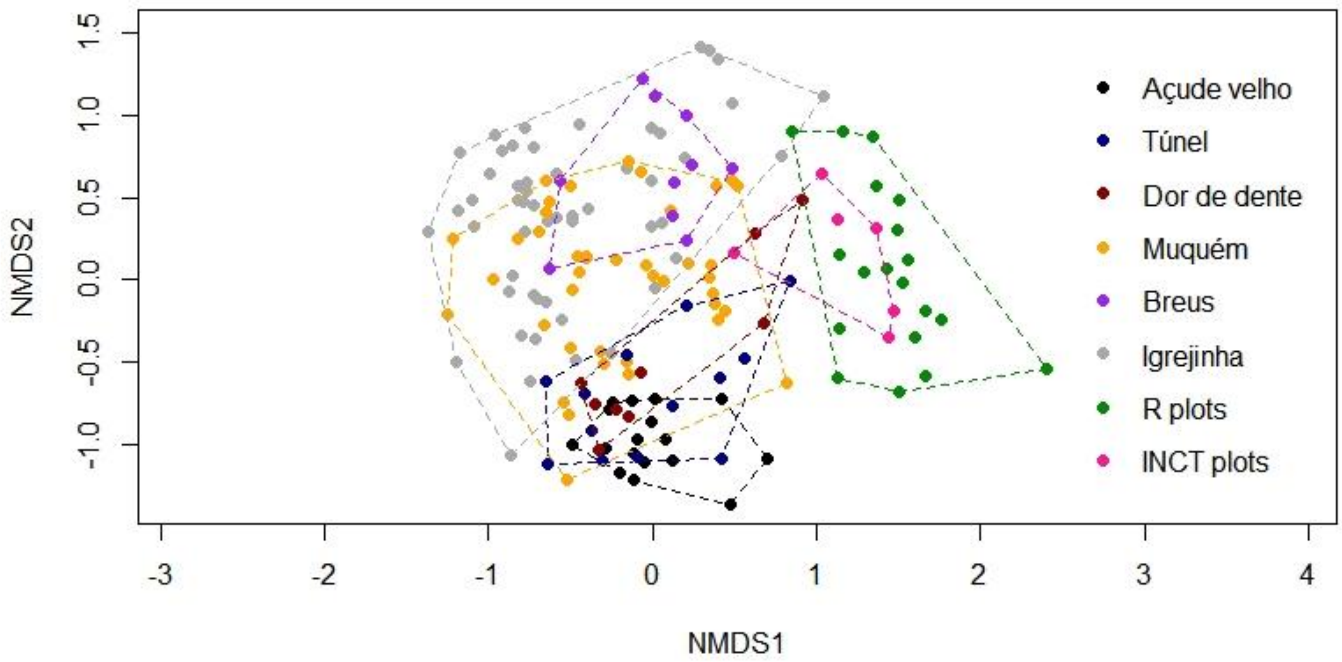

Figure 3. Non-metric multidimensional scaling of species dissimilarities used to build fences in six rural communities in the Catimbau National Park and in forest areas. Each point shows a site. The INCT plots were located in areas where local people collect forest products. The R plots are plots from Rito et al. (2016) which are located in areas of different levels of rainfall and anthropogenic disturbance.

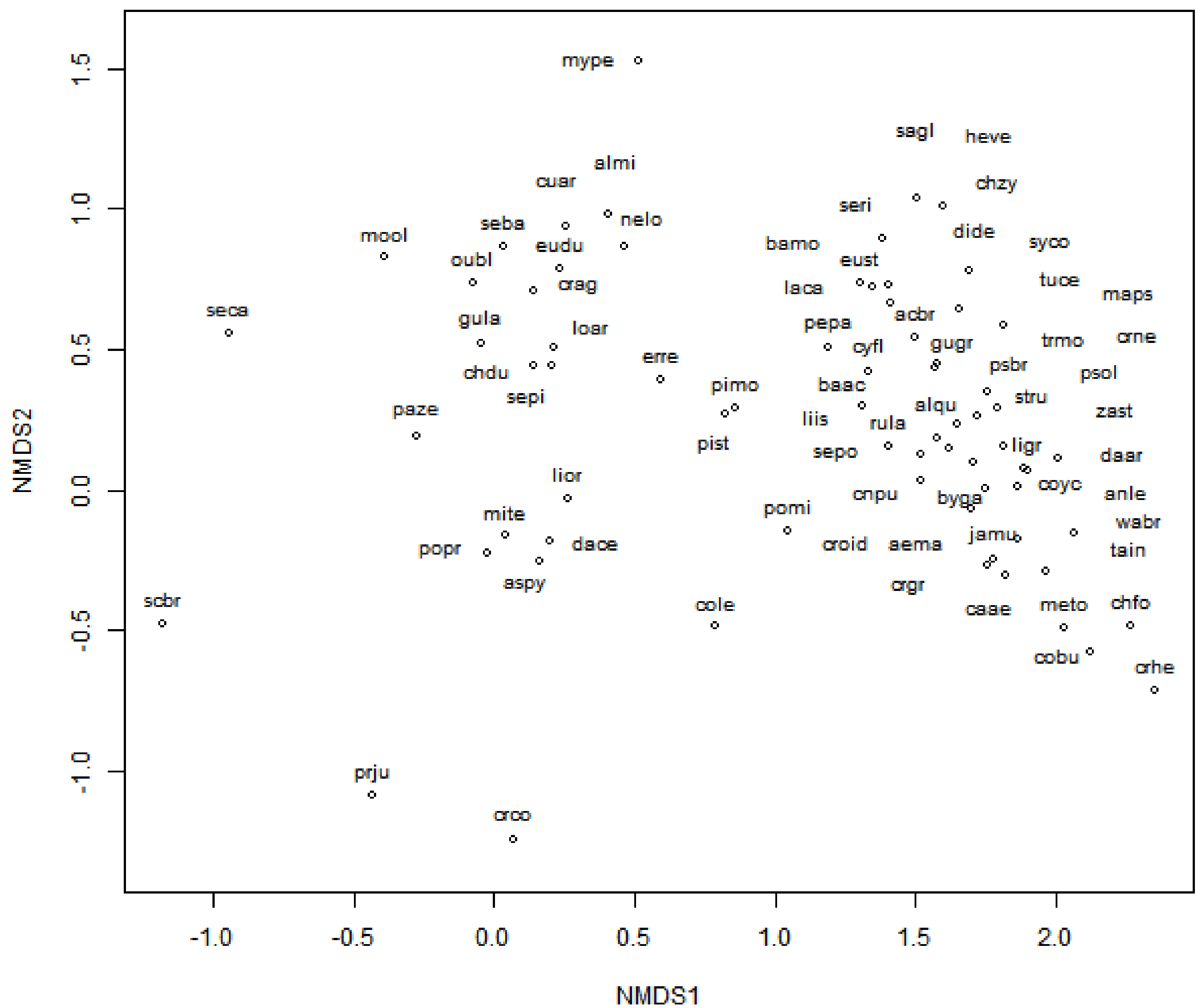

Figure 4. Non-metric multidimensional scaling of species dissimilarities used to build fences in six rural communities in the Catimbau National Park and in forest areas. The points indicate the species which drive dissimilarities among the sites. Plant species: acbr = Acalypha brasiliensis, aema = Aeschynomene marginata, almi = Algrizea minor, alqu = Allophylus quercifolius, anle = Annona leptopetala, aspy = Aspidosperma pyrifolium, baac = Bauhinia acuruana, bamo = Baulfourodendron

molle, byga = Byrsonima gardneriana, caae = Calliandra aeschynomenoides, chzy = Chamaecrista zygophylloides, chdu = Chloroleucon dumosum, chfu = Chloroleucon foliosum, cnpu = Cnidoscolus pubescens, coyc = Colicodendron yco, cole = Commiphora leptophloeos, cobu = Cordia bullata var. globosa, croid = Croton argyrophylloides, crag = Croton argyrophyllus, crco – Croton blanchetianus, crgr = Croton grewioides, crhe = Croton heliotropiifolius, crne = Croton nepetifolius, cuar = Cuspidaria argentea, cyfl = Cynophalla flexuosa, daar = Dahlstedia araripensis, dace = Dalbergia cearensis, dide = Ditaxis desertorum, erre = Erythroxylum revolutum, eudu = Eugenia duarteana, eust = Eugenia stictopetala, gugr = Guapira graciliflora, gula = Guapira laxa, heve = Helicteres brevispira, jamu = Jatropha mutabilis, laca = Lantana camara, liis = Lippia gracilis, ligr = Lippia grata, lior = Lippia origanoides, Loar = Lonchocarpus araripensis, maps = Manihot pseudoglaziovii, meto = Melochia tomentosa, mite = Mimosa tenuiflora, mool = Moquiniastrum oligocephalum, mype = Myroxylon peruiferun, nelo = Neocalyptrocalyx longifolium, oubl = Ouratea blanchetiana, paze = Parapiptadenia zehntneri, pepa = Peltogyne pauciflora, pist = Piptadenia stipulacea, pimo = Pityrocarpa moniliformis, popr = Poeppigia procera, pomi = Poincianella microphylla, psbr = Psidium browniano, psol = Psidium oligospermum, prju = Prosopis juliflora, rula, Ruprechitia laxiflora, sagl = Sapium glandulosum, scbr = Schinopsis brasiliensis, seba = Senegalia bahiensis, sepi = Senegalia piauhiensis, sepo = Senegalia polyphylla, seca = Senna canna, seri = Senna rizzinii, stru = Stillingia trapezoidea, syco = Syagrus coronata, tain = Tamarindus indica, trmo = Trischidium molle, tuce = Turnera cearensis, wabr = Waltheria brachypetala, zast = Zanthoxylum stelligerum.

Effects of rainfall and wood collection on plant community in a dry tropical forest

Considering the models with the best explanatory power, we found that species richness (Q^0) is positively and strongly affected by annual rainfall, and seems to be negatively affected (albeit in a weak way) by the wood collection (based in a Wood Collection Index) (Multiple R^2 = 0.46; p = 0.002; df = 21; AIC = 153.06; **Figure 5**). The number of common species (Q^1) was positively influenced by annual rainfall (Multiple R^2 = 0.17; p = 0.04; df = 22; AIC = -6.16). The number dominant species was not associated with any of the variables (Multiple R^2 = 0.09; p = 0.16; df = 22; AIC = -2.11). The evenness factor (Q^2/Q^0) is positively affected by the wood collection and appears to be negatively affected by rainfall (Multiple R^2 = 0.24; p = 0.06; df = 22; AIC = -21.14; **Figure 6**). The total density seems to be negatively influenced by the wood collection (Multiple R^2 = 0.15; p = 0.06; df = 22; AIC = -12.79).

Table 3. Summary of the final linear models to explain the effects of the annual rainfall and the wood collection (based in a Wood Collection Index) over vegetation community parameters.

	Estimate	**Std. error**	**t-value**	**P-value**
Q^0				
Intercept	20.37	1.08	18.79	1.3e-14
Rainfall	**4.82**	**1.15**	**4.17**	**0.0004**
Wood Collection Index	-3.72	2.13	-1.75	0.09
Log 10 (Q^1)				
Intercept	0.91	0.04	22.76	<2e-16
Rainfall	**0.09**	**0.04**	**2.16**	**0.04**
Log 10 (Q^2)				
Intercept	0.72	0.04	16.55	6.64e-14
Rainfall	0.06	0.04	1.44	0.16

Log 10 (Evenness Factor)				
Intercept	-0.56	0.03	-19.57	5.77e-17
Rainfall	-0.05	0.03	-1.58	0.13
Wood Collection Index	**0.13**	**0.06**	**2.37**	**0.03**
Log 10 (Total density)				
Intercept	3.35	0.03	96.20	<2e-16
Wood Collection Index	-0.13	0.06	-1.94	0.06

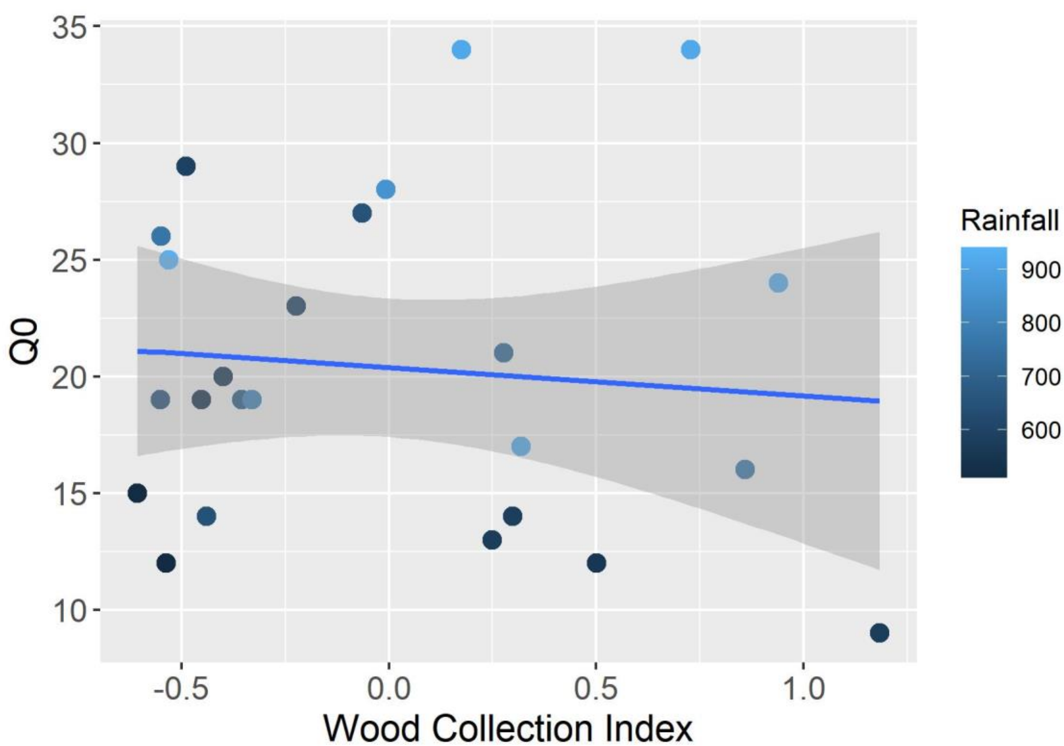

Figure 5. Effects of wood collection (based in a Wood Collection Index) and annual rainfall on species richness (Q^0).

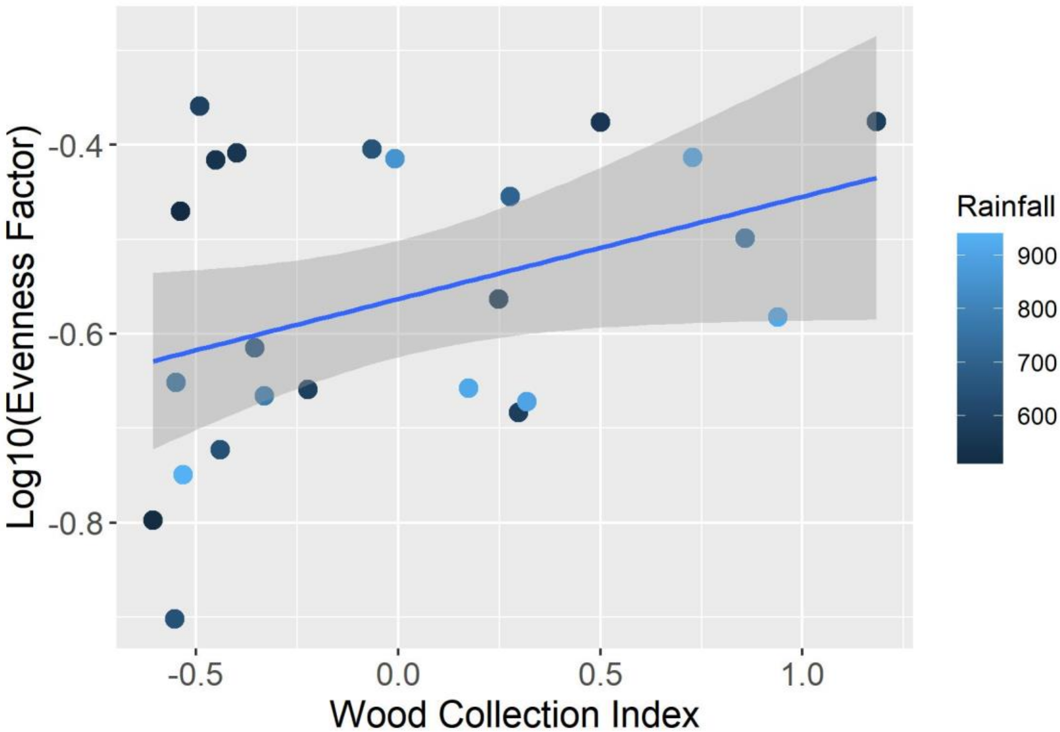

Figure 6. Effects of wood collection (based in a Wood Collection Index) and the annual rainfall on the evenness factor (EF).

The densities of the most frequent species are not associated to the wood collection

In general, the species frequent in the landscape did not have their densities associated with the wood collection (**Table 4**). The only exception is *S. piauhiensis*, whose density was weakly and positively associated to the Wood Collection Index.

Table 4. Correlations between the wood collection (based in a Wood Collection Index) and the densities of dominant species in the landscape of a dry tropical forest, in the Catimbau National Park, Northeast Brazil.

Species	**Wood Collection Index**	
	rs	**P-value**
Annona leptopetala	0.32	0.13
Cnidoscolus pubens	0.03	0.90
Commiphora leptophloeos	-0.28	0.18
Jatropha mutabilis	0.12	0.59
Peltogyne pauciflora	-0.13	0.54
Piptadenia stipulacea	-0.06	0.79
Pityrocarpa moniliformis	0.24	0.26
Poincianella microphylla	-0.25	0.23
Senegalia piauhiensis	**0.55**	**0.005**
Trischidium molle	0.10	0.65

Discussion

Rural fences as a relic of the past environment

We have found that local people have a somewhat specialist collection pattern of wood for build fences. They use a mixed of species which are common and rare in the environment. Then, from an ethnobiological perspective it is likely the local people choose to use hardwood species as way to maximize the benefits of resources use (Albuquerque et al., 2019). These hardwood species may be preferred because of their durability in the fences, as demonstrated by high mean perceived durability of some species.

From an ecological-evolutionary perspective, the wood collection for build fences may be considered a niche construction of the type inceptive disturbance because the people may initiate a change in their selective environment by physically modify their surroundings (Odling-Smee et al.

2003). In the long term, there may be the reduction in the abundance of large trees (be extensively collected) (Pereira et al., 2001; Specht et al., 2015). Furthermore, the reduction in total abundance in areas of high collect intensity may result in environmental changes, such as the increase in weathering due to the occurrence of more exposed soils (Silva et al., 2019). Consequently, there may be a proliferation of early successional shrub species (mainly some Euphorbiaceae species) (Rito et al., 2017), which have morphological traits that enable them to colonize and proliferate in degraded areas (Zorger et al., 2019).

From a conservationist perspective, the local extinctions of large species most used for wood purposes is detrimental not just to local people who depends on these trees. The decrease in the abundance of these species also may affect all the ecological interactions which these species take part. For example, in Caatinga region, some stingless bees nest in pre-existing cavities in living trees or trunks, mainly in trunks of *Commiphora leptophloeos* (Mart.) J.B.Gillett and *Poincianella pyramidalis* (Tul.) L.P. Queiroz (Fernandes et al., 2017; Martins et al., 2004). Furthermore, some species most used for wood in the region produce extrafloral nectar, a carbohydrate-rich food product that attracts ants, which, in turn, help to protect plants from herbivores (Silva et al., 2019). Therefore, the local extinctions of these trees may affect all of these ecosystem services.

Water availability acts as an environmental filter in dry tropical forests

Our findings corroborate the drought tolerance hypothesis proposed by Esquivel-Muelbert et al. (2017), according to which the species tolerance degrees to water scarcity determine the species distribution along rainfall gradients. According to this hypothesis, drought-tolerant species are widespread along rainfall gradients, whereas broad set of species is restricted to the most humid areas (Esquivel-Muelbert et al., 2017). Consequently, areas of higher rainfall levels have higher species diversity, especially in terms of species richness. Experimental and biogeographical findings demonstrate that drought tolerance affects the occurrence of adult individuals, more importantly than seedlings (Engelbrecht et al., 2007). In our case, the increase in rainfall levels affects mainly the occurrence of rare species, which indicates that despite the increased water availability in some areas, seasonal droughts seem to affect the survival of juvenile and adult individuals.

Low scale wood collection may increase the evenness of plant communities

Our finding of the effects of the wood collection indicates that the areas subject to greater wood collection intensity have higher evenness. A review study on the relationship between disturbance and diversity indexes shows that, in general, there is no relationship between the degree of disturbance and evenness, or that such relationship is negative (Mackey and Currie, 2001). This commonly observed negative association may be a consequence of the proliferation of early successional disturbance-tolerant species, and the decline of mature forest disturbance-sensitive species (Tabarelli et al., 2012).

We believe that the wood collection can drive an increase in evenness through two different processes. First, in some locations, the wood collection may be guided by local preferences (Ramos et al., 2015, 2008), then local people may overexploit some species. Consequently, this behavior can lead to a decrease in species richness (Q^0), as we have observed (see **Figure 3**). Another possibility is that very abundant species are the most used for wood purposes (Gonçalves et al., 2016). Once we find that the use of wood decreases the total density in the communities (**Table 3**), a high collection pressure on some very abundant species may lead may drive a moderate decrease in their densities, leading to the increased abundance of other species, which increase the Q^2 in the community. Finally, in some situations, in the same location, some families may behave indiscriminately (collecting the most abundant species), while others collect preferred species regardless of their abundance (Medeiros et al., 2011; Top et al., 2004), which would cause both of the described processes to occur. Therefore, forests moderately affected by the wood collection may have high species evenness.

Dominant species in Caatinga may be little affected by wood collection

The dominant species in the community are only slightly affected by the wood collection. An experimental study on the effects of different types of wood collection (ground level cutting, two meters high cuts, and removal of 20 to 30% of the branches from the crown) on populations of different species common in areas of Caatinga found that the collection of only a few branches (which may be the type of collection used for firewood) resulted in low mortality rates, especially among individuals of *P. pyramidalis* and *Croton sonderianus* Müll. Arg. (Milliken et al., 2018). However, since in the real scenarios, the frequency of collection is higher than in a controlled experiment, populations may face higher mortality rates in the long term.

The process of ground-level cutting of vegetation in the Caatinga (if not followed by anthropogenic fires) may induce a cyclical phenomenon in the populations of some species, such as *C. sonderianus*, *Mimosa* spp. and *P. pyramidalis* (Sampaio et al., 1998). Although early successional species are established soon after cutting, in the medium term, these species above mentioned tend to recover their densities (Sampaio et al., 1998). Therefore, the collection of wood may act as a selective pressure that favors regrowth or the rapid growth of these populations.

A study carried out in the same area we have studied shows that the increasing of wood collection is associated with a reduction in the abundance of species such as *P. moniliformis*, *Peltogyne pauciflora* Benth and *C. leptophloeos*. The other frequent species do not show a decrease in abundance (Sfair et al., 2018). However, the increasing in wood collection implied changes in the functional traits of some species, including the lower density of wood in *P. microphylla*, increase in the maximum height of individuals of *Piptadenia stipulacea* (Benth.) Ducke, and decrease in dry matter content in *P. stipulacea* and *Jatropha mutabilis* (Pohl) Baill. (Sfair et al., 2018). Thus, individuals of these species invest more in vegetative growth than in nutrients storage or supporting tissues. Therefore, this findings reinforce our proposal that the wood collection may drive eco-evolutionary dynamics in Caatinga.

Conclusions

To the best of our knowledge, this is one of the first studies that sought to access the effects of wood collections for subsistence purposes on a landscape scale and in a dry tropical forest. We found evidence that the wood collection increases species evenness and decreases density in plant communities, although it appears to have little effect on the abundance of the most common species.

From a theoretical perspective, there are likely physiological processes that cause some common species to continue to dominate communities even under the high intensity of wood collection. Probably, the wood collection may drive as a selection pressure that increase the frequency of traits related to regrowth and rapid growth. Finally, from a conservationist perspective, the wood collection may bebe associated with a decrease in the occurrence of some species. Also, the areas of higher collection intensity may have less availability of timber resources (due to their lower total density). Therefore, it is necessary to devise strategies that reduce the effects of wood collection, such as the development and distribution of sustainable wood stoves (with greater energy efficiency), the encouragement of the use of hedges, and the development of a management system that proposes alternating collection areas for wood products.

Study limitations

This study has some limitations, which puts our findings in perspective:

1. We only sampled wood use in six of the 17 communities in the Catimbau National Park. Two of the communities that we have not studied use wood products significantly (anecdotal observations). However, residents of these communities did not accept to participate in this study.
2. The number of individuals interviewed regarding the durability of species in the fences was low. These interviews were conducted at the end of the study. Then, the residents were feeling uncomfortable because they have been interviewed other times to other researches. The sampling of firewood stocks did not allow us to make conclusions regarding the composition of species used. For future studies, we suggest that in addition to weighing the biomass of firewood, the researchers make interviews about the species used.

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6. Livelihood strategies and use of forest products in a protected area in the Brazilian semiarid

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Abstract

The planning of conservation strategies in semiarid regions is challenging, since in general, local populations present marked social vulnerability, and are highly dependent on natural resources. Consequently, accessing the factors that determine knowledge and the use of forest products can be useful for planning conservation actions or for rethinking the strategies that have been used. We use the scenario of an environmental protected area in the Brazilian semiarid to describe the livelihood strategies adopted by the local people and to assess how socioeconomic variables affect the dependence on forest resources. Also, we tested whether areas that are better conserved (with greater vegetation cover) concentrate a greater number of useful species for local populations compared to the more impacted areas. Our findings demonstrate that the families with retired individual and individuals with non-farming occupations are that whose incomes are higher. We have found that men and older people are those who have more knowledge about native medicinal plants, while people with lower household income have more knowledge of native edible plants. Income and the number of residents in households do not explain the demand for wood forest products. Finally, the conservation levels of forest areas did not affect the number of useful species in the landscape. Apparently, the local populations have a low socioeconomic dynamism, being highly dependent on natural resources, regardless of local variations in socioeconomic profiles. It is likely the vegetation cover does not affect the distribution of useful species because this variable does not affect species composition, being just a proxy of total tree density. Finally, we recommend that the creation of fully protected areas in semiarid regions, a region with a history of human habitation, should be remodeled, prioritizing conservation units that allow reconciling the use of forest products and biodiversity conservation.

Keywords: Ethnobotany; Conservation conflicts; Protected areas.

Introduction

In tropical regions, 820 million people live nearby forests or savanna areas, of which about 640 million are below the poverty line (Food and Agriculture Organization of the United Nation, 2018). Consequently, these populations are highly dependent on forest products for their livelihood. About 20% of the income generated by these populations comes from the extraction of natural products, such as food products, fuelwood, and forage

(Vedeld et al. 2007). These poverty conditions and dependence on natural resources are exacerbated in arid and semi-arid regions, where water scarcity hinders agricultural practice, usually affecting food security (Bird and Shepherd, 2003; Naschold, 2012; Wossen et al. 2014).

Ethnobiological literature has demonstrated that socioeconomic differences among households affect their dependence on forest products. Usually, lower-income families and whose members have lower education levels are more dependent on natural resources, including medicinal and food plants and plants whose wood are used for fuelwood and for building houses and fences (Hedge and Enters, 2000; Medeiros et al. 2012; Ramos et al. 2015; Arruda et al. 2019). Furthermore, individual differences, such as age and gender, affect people traditional knowledge (Soldati et al. 2015; Torres-Avilez et al. 2016), which may determine that some individuals are more dependent on natural products. It is likely the effects of socioeconomic predictors over people dependence on forest products be exacerbated in semiarid regions because of the more hardship conditions.

This high dependence on the forest may affect the strategies that the local people performs to collect resources. In tropical humid forest, usually local people prefer to use plant species from secondary forests nearby their settlements (Chazdon and Coe, 1999; Aguilar and Condit, 2001). The species from anthropogenic habitats are more familiar and may contains greater diversity of pharmacologically active compounds than species found in old-growth forests (Voeks, 1996). In dry tropical forests, there is no unequivocal evidence about the preference of using species in anthropogenic areas, since conserved and degraded areas commonly have similar number of useful species (Lucena et al. 2012; Soares et al. 2013). However, we hypothesize that in areas of dry forests which people are highly dependent on natural resources, nearby forest areas may have a lower number of useful species because of the overexploitation.

In the last years, the concern with the conservation of ecosystems located in semi-arid regions has increased (Dryflor et al. 2016), resulting in the creation of conservation units (see for example, Bernard and Melo, 2019). However, in some situation, the creation of conservation areas can affect the livelihoods of local populations, who have to find new ways of survival (Cavalcanti et al. 2015). In addition, the ban on the use of natural resources can increase the socioeconomic vulnerability of some rural populations that depend on these resources, resulting in socio-environmental conflicts with environmental institutions (Baynham-Herd et al. 2018).

Then, we carried out a case study, aiming to describe the livelihood strategies adopted by rural populations inserted in the Brazilian semiarid, in a region in which a protected area has been created in a top down approach. Also, we assessed how socioeconomic factors affect knowledge about medicinal and food plants, and whether household income and the number of residents in each household influence the demand for wood products from the forest. Regarding the distribution of useful species, we tested whether the conservation degree of different forest areas (estimated by the vegetation cover) affects the occurrence these species.

Material and methods

Socio-environmental vulnerability in the Brazilian semiarid

The geographical area of the Brazilian semi-arid region stretches over 1,262 municipalities in eight states in the Northeast (Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte and Sergipe) plus the northern state of Minas Gerais (located in the southeastern region of Brazil), totaling an area of approximately 982.563 km^2 (Ministério da Integração Nacional, 2017). This region was delimited based on aridity indicators, such as annual rainfall lower or equal to 800 mm, Thornthwaite aridity index equal to or lower than 0.50, and a daily percentage of water deficit equal to or greater than 60%, considering every day of the year. According to the most recent demographic census (carried out in 2010), this region is inhabited by 22 598 318 people (Instituto Nacional do Semiárido, 2012).

The Brazilian semiarid region is characterized by a high variation in both the intra and inter annual rainfall levels, with most of the annual rainfall concentrated between the months of February and May (Toni and Holanda Jr, 2008). The projections for the climate of this region until the end of the 21st century, considering the climate changes resulting from global warming, range from an optimistic perspective of an increase in rainfall of up to 20% to more negative perspectives of a reduction of about 50% in rainfall (Krol and Bronstert, 2007; Marengo et al. 2009). Based on these negative scenarios, the decrease in rainfall may result in water supply crises. The rationale for this is that there would be a decrease in water storage capacity by the reservoirs, as well as an increased water demand for industrial activities and irrigated agriculture (Krol and Bronstert, 2007).

Historically, the region has been marked by major drought events, which boosted migratory flows. Initially, this happened within the northeast region, and later, towards the north and southeast regions of the country. In the 1910s and 1930s, for example, large migratory flows towards the capital of the state of Ceará led the local government to take the drastic attitude of creating concentration camps to provide “shelter” to the *retirantes* (as used to be called those who migrated from the Brazilian semiarid) (Neves, 1995). These concentration camps, which in total came to “house” more than 100,000 people, had the political-hygienist purpose of preventing the *retirantes* from reaching the capital of the city, where the local elite did not welcome the arrival of this miserable population. (Neves, 1995).

At the end of the 19th century, this intraregional migratory movement was greatly reduced, when new regions began to act as an attraction factor for immigrants. The beginning of the rubber cycle (material produced from the latex of the *Hevea brasiliensis* tree (Willd. Ex A.Juss.) Müll.Arg.) in northern Brazil, mainly in the state of Amazonas, attracted approximately 250,000 Northeasterners, who acted as cheap labor in the region (Ferrari, 2005). From the 1920s onwards, migration flows towards the southeast region intensified, mainly towards the state of São Paulo. Initially, immigrants sought employment in coffee farming, replacing the workforce of foreign immigrants (Ferrari, 2005). From the 1950s, with the intensification of the industrialization process in São Paulo, this continues to be the focus of northeastern migration, due to the job offer in the urban area of the state (Ferrari, 2005). In total, it is estimated that approximately 3.6 million Northeasterners migrated to São Paulo (Melo and Fusco, 2019).

People who chose not to emigrate usually had to work in exploratory conditions for large landowners in the region, since subsistence agriculture was not sufficient to ensure the livelihood of their families (Neves, 1995). In the years of great droughts, part of the local population used to be assisted by religious entities, or by the Productive Work Fronts (*Frentes Produtivas de Trabalho*, in Portuguese), which consisted of the employment of the local population as cheap labor in public works, such as construction of highways, dams or centers for the livestock rearing (Kenny, 2002). The region's politicians use to assist local people in exchange for votes for future elections, in a political practice called clientelism (Nelson and Finan, 2009).

In the late 1970s, the first political instrument of social protection that reached the Brazilian semiarid region was the rural retirement, a mechanism that allows small farmers to retire, even if they have not contributed to social security (Bursztyn and Chacon, 2011). However, it was from the 2000s that the poorest households began to be included in social protection systems. In the early 2000s, the President Fernando Henrique Cardoso extended an income transfer program to the poorest households throughout the country, which had the attendance to school by children as a counterpart, in order to reducing the intergenerational transmission of poverty (Bursztyn and Chacon, 2011). In 2003, President Luís Inácio Lula da Silva unified several federal assistance programs under the Programa

Fome Zero, which soon became the Bolsa Família Program. These welfare initiatives have had positive effects in reducing poverty and extreme poverty in Brazil (Campoli et al. 2019).

However, some researchers argue that this social protection system can function as a new form of clientelism (Bursztyn and Chacon, 2011; Hevia, 2011; Bendram-Martins and Lemos, 2017). Although the objective of this system is to try to transform the social reality of households, it may actually strengthen the position of the poorest as subordinates and incapable of achieving full citizenship. Consequently, out of gratitude to the politicians who provide these benefits or for fear of losing them, beneficiaries can become loyal to these politicians through voting (Licio et at. 2009; Bursztyn and Chacon, 2011).

However, this position is not undisputed among researchers. Other social researchers argue that the current welfare in Brazil can stimulate the exercise of citizenship through its counterparts, including the attendance to school by children (which helps prevent child labor), and frequencies to medical appointments (Pires and Garden, 2014). For many assisted households, this was the first experience of income receiving, and consequently, entering the consumer market, which can be an important step towards the exercise of citizenship (Rego, 2008). Also, a qualitative study showed that since the advent of the Bolsa Família Program, women in rural regions feel more respected within their households because they are less dependent on their partners, and contribute to household expenses (Suarez and Libardoni, 2008).

Study area

The Catimbau National Park is located in the state of Pernambuco, northeastern Brazil (8º23′17″ and 8º36′35″S; 37º11″00″–37º33″32″W) (Fundação Joaquim Nabuco, 2015) (**Fig. 1**). This park is located in a region of warm semiarid climate (BSh according to the Köppen classification) (Alvares et al. 2013). There is a variation rainfall within the park (from 480 to 1100 mm), which affect the structure of plant communities (Rito et al 2016).

Fig.1. Location of the study area, the Catimbau National Park, in the State of Pernambuco, Northeastern Brazil. The red point indicates the capital of the State of Pernambuco (Recife).

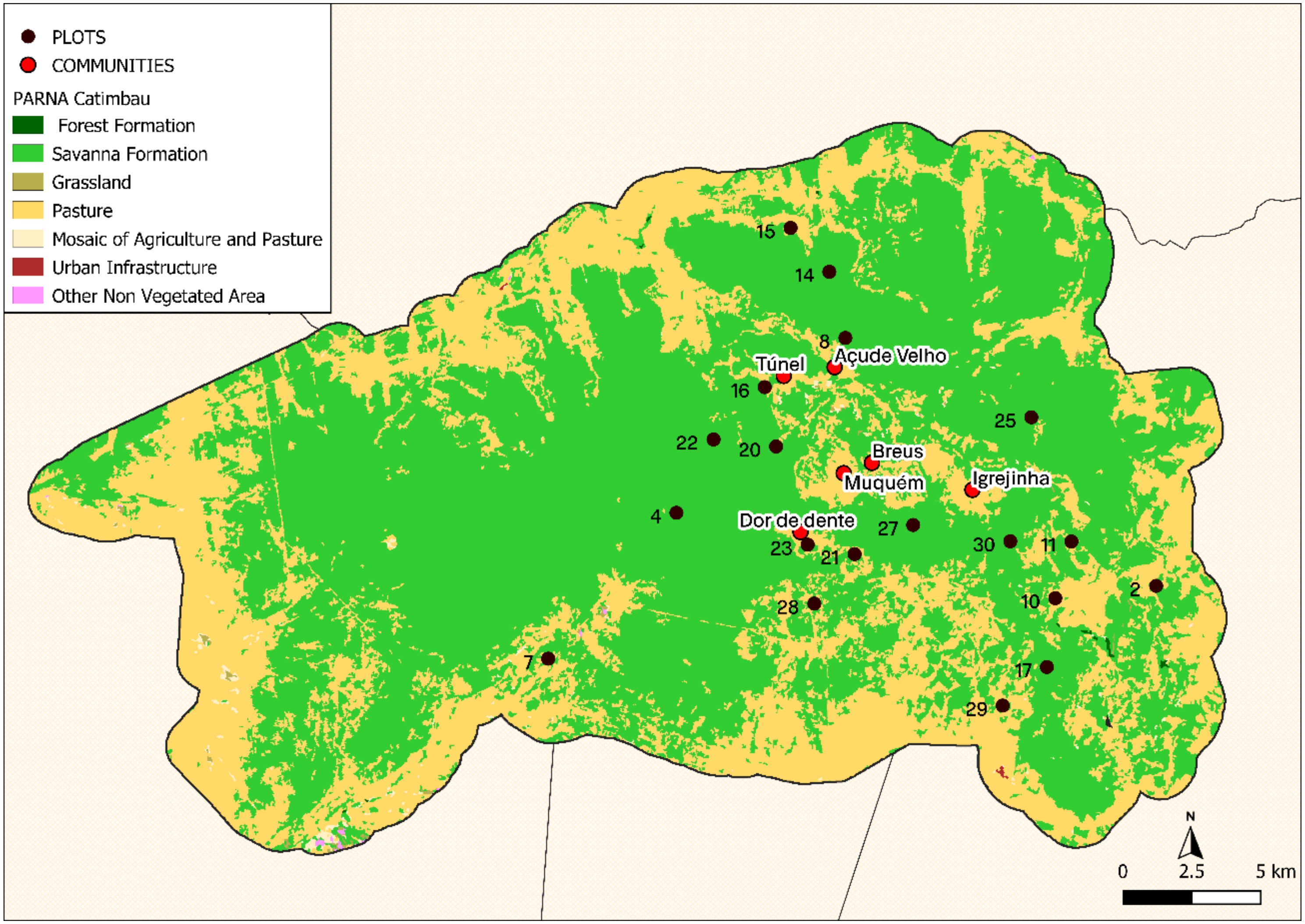

Fig.2. Map of vegetation cover in the Catimbau National Park region, Northeastern Brazil. Black points represent the location of the plots where the vegetation was sampled, and red points show the location of the six rural communities studied.

The region's ecosystems belong to the Caatinga’s domain, a seasonally dry tropical forest characterized by dense, thorny, and shrubby tree vegetation that grows in deep sandy soils (Fundação Joaquim Nabuco, 2015). The phanerogamic flora recorded in the park is composed of approximately 600 species, of which the families Fabaceae, Poaceae, Euphorbiaceae, Asteraceae, Convolvulaceae and Malvaceae are the ones that present the greatest species richness (Athiê-Souza et al. 2019).

Socio-environmental scenario of the Catimbau National Park region

During the Portuguese conquest of the inland area of the state of Pernambuco (17th century), the region of the Catimbau National Park was inhabited by people belonging to the Prakió ethnic group (also called Paratió) (Sampaio, 2011). Currently, part of the region's inhabitants identifies themselves with the Kapinawá indigenous ethnic group (Sampaio, 2011; Andrade, 2014). In the late 1990s, FUNAI (the official Brazilian State's indigenous institution) ratified a territory of about 12,400 ha south of the park as the Kapinawá indigenous territory. However, part of the communities within the park are recognized as belonging to this ethnic group. They claim their permanence in the region, which has resulted in conflicts with environmental enforcement institutions (Sampaio, 2011; Andrade, 2014).

The decree that instituted the Catimbau National Park does not allow the presence of human settlements within the park and, consequently, does not consent the direct use of natural resources (Brasil, 2000). The only officially permitted use of the landscape is ecotourism, an activity that is still underdeveloped locally. Despite having been instituted about two decades ago, the park does not yet have a management plan, and legal institutions are still starting to regularize land ownership. Thus, many residents were not compensated or did not have a judicial agreement aimed at expropriating the land.

We identified 10 communities within the park, three indigenous communities and seven non-indigenous communities. In total 750 individuals reside in these communities, 480 adults and 208 children. For this study, we sampled six of these communities, including the non-indigenous communities: Igrejinha, Breus, Muquém, Dor de Dente, Túnel and Açude Velho (**Fig. 2**). These six communities totalize 325 inhabitants, about 200 adults and 125 children from 109 households. In total, we obtained complete socioeconomic data from 81 people (40.50% of the total sampled) from 68 households (62.38% of the total sampled).

Data collection

Ethical and legal aspects

Prior to the beginning of data collection, we have obtained research approval by the Research Ethics Committee with human beings at the Federal University of Alagoas (CAAE: 83182217.6.0000.5013). We have informed all the research participants about the objectives of the study and we asked them to sign a free and informed consent form, following the recommendations of resolution number 510 of the National Health Council (Brazil, 2016).

Collection of socioeconomic data

From January 2017 to August 2018, researchers from the National Institute of Science and Technology: Ethnobiology, Bioprospecting and Nature Conservation (INCT) carried out intensive data collection campaigns in the six communities mentioned above. Using structured interviews (Albuquerque et al. 2014), they collected the following information: sex, age, occupation, education level, monthly household income, number of residents in the residence, and number of goats (for households that practice extensive livestock). Schooling data was categorized into three levels: illiterate (individuals who did not have access to formal education), elementary school (those who did not start high school), and high school (those who have completed or initiated a high school degree). Occupation data were categorized into farming activities (farmers and ranchers), domestic activities (housewives and retirees) and liberal professionals (individuals who had a non-farming occupation). Although the artisans make their work from native trees, we chose to categorize them as liberal professionals because their income is based on the trade of these products. So, it could be an alternative to farming.

Collection of data on knowledge of medicinal and edible plants

Alongside with the collection of socioeconomic data, the INCT researchers used the free listing technique (Albuquerque et al. 2014) to access people's knowledge about plants that are useful for medicinal and edible purposes. To non-wood forest products, we chose to use the knowledge as a proxy for dependence on these resources. For the purposes of this work, we focus only on native species, most of we have been collected and identified. We performed the the collection of botanical material using the walking in the woods technique (Albuquerque et al. 2014). All collected material was identified by taxonomists from the Agronomic Institute of Pernambuco (IPA).

Collection of data on households demand for wood forest products

In this research phase, we accessed the use of wood forest products from 78 households from these six communities. However, only 33% of the heads of household signed the free and informed consent term, while the rest of the individuals declared their consent verbally, which is also acceptable according to article 5 of resolution number 510 of the National Health Council (Brazil, 2016).

We used two proxies to evaluate the demand for wood by households in the region: the firewood use and the wood use for building fences. To estimate the firewood use, we used the weight assessment technique (Ramos et al. 2014), in which the head of each household was asked to demonstrate, from his firewood pile, the amount of wood which he (she) usually use in one day. With the help of a key informant (appointed as an expert on plants used as wood), we separated and weighted the wood selected by the household head.

To assess the wood use for building fences, we performed an adaptation of the *in situ* inventory technique (Gaugris and Van Rooyen, 2009). We have identified different architectural fences in the region. Then, we adopted different sampling procedures to each one. We have categorized local fences as follows: (1) Closed fences - those constituted by of small diameter and quite juxtaposed stakes; (2) Semi-open fences - those made up of small diameter and loosely juxtaposed stakes; (3) Open fences - those made of intermediate diameter stakes, and spaced out; there are some large diameter stakes (called posts) used to secure the wires; (4) Very open fences - those made of intermediate diameter and arranged in a spaced way stakes, with some posts to secure the wires; and V. Fences made up entirely by posts , which are widely space

To estimate the wood volume used in the construction of the fences, in each fence we measured the height and diameter of each stake. For each of the four types of fences described above, we sampled the stakes present in a different length in order to sample of a similar number of stakes between the different types of fences. For closed fences, we sampled 2 meters; for semi-open ones, 4 meters; for open ones, 50 meters; for the very open fences, 70 meters, and for the fences made up only of large diameter posts, 100 meters. If the same fence had sections of different structural components, a sampling was carried out for each section. Subsequently, to extrapolate the volume of wood sampled to the entire perimeter of the fence, we covered each of the fences using the odometer function of a GPSMap 60CSx, with an accuracy of 5 meters. Afterwards, we have collected and identified all the plant species used for wood, according to the methods described to the medicinal and edible plants.

Distribution of useful plants in the landscape

To access the distribution of useful flora in the landscape, initially, we compiled all useful species collected by INCT from different researches carried out in the six communities studied. Regarding the ecological data, we used the data from Rito et al. (2016). These authors set 19 plots of 20 x 50 m along gradients of rainfall and anthropogenic disturbances. We excluded from the data, taxa that were not identified to the species level.

In order to quantify vegetation cover in the areas of the 19 plots, we used the forest cover map of the Catimbau National Park from 2017, generated from images available on the collaborative platform of the Annual Mapping Project for Land Use and Cover in Brazil (MapBiomas Project, 2020). These maps are produced from the classification of the reflectance bands, spectral, temporal and texture indices by the Landsat satellites (with 30 meters of spatial resolution). Subsequently, we calculated the total forest cover in a 1 km buffer from the center of the plots, using the QGIS 3.6.0 program (QGIS Development Team, 2020).

Data analysis

To meet our first objective of assessing variation between socioeconomic factors in the region, we tested whether there are differences in the proportion of men and women between the three classes of schooling, using a chi-square test. To test whether there are differences in the age range between people with different levels of education, we applied the Kruskal-Wallis test. Both analyzes were performed with a sample of 81 people. To test the additive effect of certain characteristics related to the households' profile (presence of retired individuals, presence of individuals with a non-farming occupation, number of residents and size of the goat herd) on the variation of households income, we used a generalized linear model (GLM), with Gaussian error distribution. In order to better adjust the model, we transformed the household income data into a logarithmic scale. The sample size for this analysis was 68 households.

To test whether socioeconomic variables can explain the variation in knowledge on medicinal plants native to the region, we performed a GLM with Gaussian error distribution. To have a better adjustment of the model, we transformed the data of the number of native medicinal plants known) into square root + 1. The predictor variables were sex, education level, age, household income, number of residents and occupation. The sample size for this analysis was 77 respondents.

In order to test whether socioeconomic variables can explain the variation in knowledge about native edible plants, we performed a GLM with Poisson error distribution. We used the same predictive variables as the model for medicinal plants. To test over-dispersion in the model, we applied the *dispersiontest* function of the *AER* package (Kleiber and Zeileis, 2008). The sample size for this analysis was 46 interviewees. This smaller sample size occurred because less people cited edible than medicinal plants.

To test whether household income and the number of residents in each household influence household demand for wood forest products (firewood and wood for building fences) we used GLM with Gaussian error distribution. In order to obtain a better fit of the models, we transformed the firewood usage data into square root + 1 (due to the occurrence of some 0 values), and the wood usage data for building fences into log + 1. The sample size was of 42 families for the model for firewood use, and 43 families for the model wood used for building of fences. This smaller sample, if compared to the analyzes referring to the determinants of household income, occurred because many of the interviewed household heads did not want to participate in the research phase relative to the use of wood products.

To test whether the vegetation cover affects the richness of useful species in the landscape, we performed mixed regressions using the *lme* function of the *nlme* package (Pinheiro et al. 2020), since this analysis allows defining variables with random and fixed effects within a model. In our study, we considered the species richness in the plots as a random variable. We carried out this analysis considering four different response variables: the total number of useful species, and the number of species useful for firewood, building fences and for medicinal purposes. We transformed the data on species richness used as firewood and for building fences into on a logarithmic scale in order to meet the assumption of normality of the model residues. Since few edible species were mentioned, we chose not to carry out analysis for this use.

For analyzes regarding knowledge about medicinal and food plants, we excluded data from species cited by less than three people, in order to exclude idiosyncratic information. In all analyzes of generalized linear models, we performed the selection of the best model using the *MuMIn* package (Barton, 2019). Also, we access collinearity between the predictive variables of the models by the values of the variance inflation factor (VIF). In all models, the VIF values were < 5, indicating that there is no collinearity between the variables studied. We performed all analyzes in the R environment (R Core Team, 2020).

Results

Socioeconomic profile and livelihood strategies of the communities studied

Of the 81 people from whom we collected socioeconomic data, encompassing the six communities studied, 50.61% were women and 49.38% were men. The average age is 44.15 years (SD ± 16.95), and the average number of residents is 4.41 (SD ± 2.55). Regarding schooling, 48.15% had no access to formal education, 41.97% studied until to the elementary school, and 9.87% studied at least until the beginning of high school. There are no differences in the level of education in relation to sex ($\chi = 4.62$; $p = 0.09$; df = 2). However, there are differences in the age range among people with different education levels (Kruskal-Wallis chi-squared = 33.56; p = 5.14e-08; df = 2), since older people did not have access to formal education, although this scenario has changed in recent decades, with men and women having greater access to formal education.

Regarding occupation, 71.60% of respondents work in farming activities, 17.28% are engaged in domestic activities, and 11.11% work in non-farming activities. However, there are limitations in this categorization, since the limits of these categories are not clear. For example, some women in the are engaged in both domestic activities and agriculture, and people who have non-farming activities may have small goats herds (personal observations).

Some of the individuals from one of the communities studied (Igrejinha) have handcrafting as their main occupation, producing works of art from the trunks of the tree *Commiphora leptophloeos* (Mart.) J.B.Gillett. The income obtained through trade in these works is irregular, but some of these artisans have gained notoriety nationwide, having their pieces exhibited at craft fairs, museums and even in Brazilian soap operas. These artisans work in consortium with individuals who collect wood from *C. leptophloeos*, and report using only dead wood. However, this species has low densities in the local landscape (always less than 100 ind/ha).

The average household income is R$ 676.57 (US$ 206.27, in 2017 values), with a standard deviation of R$ 530.54 (US$ 161.75). The average per capita income is R$ 246.58 (US$ 75.18), with a standard deviation of R$ 305.63 (US$ 93.18). Therefore, 67.65% of local families live below the poverty line (with less than US$ 1.9 per person per day). In addition, based on the value of the basic food basket in the municipality of Recife (capital of Pernambuco), in December 2017 (R$ 332.15 or US$ 101.26), 29.41% of families are unable to buy one basic food basket. Our final model regarding the characteristics of families that influence household income shows that most of the variation in household income is due to the presence of retired individuals, and the presence of individuals with non-farming occupations (AIC = 91.15; adjusted R^2 = 0.64; df = 65; p = 1.83e-15) (see **Table 1**). The number of residents and the size of goat herds do not influence household income. Despite that, farming practices can be important for food security. Some ranchers reported that they commercialize their herds in times of financial difficulties, using them as an emergency resource.

Table 1. Final model results to test the effects of household characteristics on the variation in household income.

Independent variables	**Estimate**	**Std. Error**	**t value**	**P-value**
Intercept	5.83	0.07	87.03	<2e-16
Families with a member in	0.46	0.18	2.52	0.01*

non-farming occupations				
Families with retired individuals	1.33	0.12	10.60	8.27e-16*

Effects of socioeconomic factors on knowledge and use of forest products

The repertoire of native medicinal plants known to people in the communities studied is composed of 44 species. The most cited species are *Ximenia americana* L. (57.14% of respondents), *Sideroxylon obtusifolium* (Roem. & Schult.) T.D.Penn. (45.45%), *Pombalia arenaria* (Ule) Paula-Souza (36.36%), *Hymenaea courbaril* L. (36.36%), *Dysphania ambrosioides* (L.) Mosyakin & Clemants (35.06%) and *Myracrodruon urundeuva* Allemão (35.06%) (see **Supplementary material**). These species (with the exception of *D. ambrosioides*, which is grown in gardens and backyards, and *P. arenaria*, which is herbaceous) appear to be rare in the studied landscape as they were not found in samplings from the shrub-tree community. Our final model on the effects of socioeconomic variables on the knowledge of native medicinal plants demonstrated that age and sex explain approximately 1/3 of the variation in knowledge (AIC = 175.47; R^2 = 0.30; p = 2.18e-06) (**Table 2**).

Regarding the native edible plants, the repertoire known to people in the region consists of 12 species, of which the most cited are *Spondias tuberosa* Arruda (58.69% of respondents who cited food plants), camboim (unidentified, 54.35%) and *Syagrus coronata* (Mart.) Bec (34.78%). The final model on the effect of socioeconomic variables on the knowledge of food plants indicates that people from families with lower income are those who have the most knowledge (AIC = 205.93; **Table 2**). Moreover, it is likely that individuals from smaller families and men have greater knowledge about edible plants, although these findings were above the significance threshold.

Table 2. Result of the final models referring to the effect of socioeconomic variables on the knowledge of native medicinal and edible plants, and on household demand for wood products, in six rural communities in the National Park of Catimbau, Northeast Brazil.

	Estimate	**Std. Error**	**t value**	**P-value**
Number of medicinal plants known				
Intercept	2.18	0.26	8.33	3.09e-12
Age	0.02	0.005	3.93	0.0002*
Sex-women	-0.55	0.17	-3.23	0.002*
Number of edible plants known				
Intercept	2.16	0.18	12.04	<2e-16
Household income	-0.0004	0.0001	-2.72	0.006*

Number of residentes	-0.05	0.02	-1.90	0.06
Sex-women	-0.24	0.13	-1.82	0.07
Firewood use				
Intercept	2.95	0.25	11.89	1.05e-14
Household income	-0.00022	0.00024	-0.93	0.36
Wood use for building fences				
Intercept	1.54	0.31	4.89	1.59e-05
Number of residents	0.035	0.06	0.56	0.58

Concerning the use of wood forest products, we identified 62 used species in the six communities studied; 31 species used for firewood and 59 species used for building fences. The species most used for firewood are *Poincianella microphylla* (Mart. Ex G. Don) L.P. Queiroz, *Senegalia piauhiensis* (Benth.) Seigler & Ebinger and *Pityrocarpa moniliformis* (Benth.) Luckow & R.W. Jobson. The species most used for fences construction are *S. piauhiensis*, *Senegalia bahiensis* (Benth.) Seigler & Ebinger, *Poeppigia procera* C. Presl and *Prosopis juliflora* (Sw.) DC. In addition, we have found some of the important medicinal species in the survey for wood, such as *X. americana*, *M. urundeuva* and *C. leptophloeos*, which may raise concerns for their populations.

We observed that the household income and the number of residents in each household did not influence the demand for firewood (AIC = 113.44; adjusted R^2 = -0.003; p = 0.36; df = 40;) nor for wood used forfence construction (AIC = 124.70; adjusted R^2 = -0.01; p = 0.58; df = 41) (see **Table 2** for a description of the final models). After these findings, we wondered whether the *per capita* income would be the reason for the demand for these resources. Likewise, we found no effect of the *per capita* income on the demand for firewood (adjusted R^2 = -0.01; t = -0.76; p = 0.45) andfor fence construction (adjusted R^2 = -0.02; t = -0.16; p = 0.87). Considering only households that use firewood, the average biomass used per day is 7.94 kg (SD ± 5.06). And considering only households with fences, the average volume of wood used is 8.31 m^3 (SD ± 10.17).

Effect of the vegetation cover on the richness of useful species in the landscape

We found no effect of the vegetation cover (our proxy for conservation level) on the richness of useful species in general (AIC = 98.03; t = 0.47; p = 0.65;), neither in the other uses, such as firewood (AIC = 28.21; t = 1.80; p = 0.12;), building fences (AIC = 19.68; t = 0.79; p = 0.45;), and medicinal (AIC = 78.15; t = 0.55; p = 0.60;). Therefore, our findings indicate that there are a similar number of useful species in areas that present different conservation levels.

Discussion

A region of low socioeconomic dynamism and high dependence on welfare

Our findings demonstrate that the farming activities performed by the majority of the people in the communities surveyed seem to have a minor contribution to the income generation of households, since the families with the highest income are those who have retired individuals or individual with a non-farming occupation. Due to these low incomes, most of these families are assisted by federal welfare programs, such as the Bolsa Família Program, and are supported by non-governmental organizations. As we have already explained, some researchers see these assistance programs as a new form of clientelism (Bursztyn and Chacon, 2011; Bendran-Martins and Lemos, 2017). In our understanding, these forms of assistance are important because they contribute to the food security of families in the region.

These governmental cash transfer programs have been shown to be effective in reducing poverty and extreme poverty in Brazil (Campoli et al., 2019). Studies carried out in the Brazilian semi-arid region show that these programs may have contributed to an improvement in material aspects of quality of life (income, education level and access to health services), although they are not enough to reduce the socioeconomic vulnerability of small farmers (Bedran-Martins et al. 2018; Bedran-Martins and Lemos, 2017). During drought events, small farmers in semi-arid regions lose their production and need to spend more on food and water, which may force them into debt (Bedran-Martins et al. 2018). This can push them back to the condition of extreme poverty, resulting in a phenomenon named poverty trap (Maru et al. 2012).

According to poverty trap models, there are socioeconomic thresholds that need to be crossed in order for families to overcome poverty (Naschold, 2012). In the long run, some of the factors that contribute to overcoming these thresholds are the right to land tenure (which is usually a prerequisite for granting bank credits or access to crop insurance), the increase in the education level , the formation of cooperatives and the diversification of activities that generate income (Naschold, 2012). Therefore, although assistance programs are important, it is essential to fight not only the symptoms of socioeconomic vulnerabilities, but also their structural causes (Nelson and Finan, 2009). It is necessary that the old (and still current) ways of making policies be replaced by participatory management, investments in infrastructure and investment in human capital, generating diversification of economic activities (Nelson and Finan, 2009).

We propose that the local handicrafts produced from the timber of *C. leptophloeos* may be an unsustainable activity from an economic perspective, because this activity focuses on the use of a single species that has low density in the region (see Rito et al. 2016). Therefore, we strongly recommend recovery (or increase) strategies to be implemented to increase the abundance of this species. Probably a more efficient alternative would be planting with using techniques that guarantee faster growth, such as layering or grafting.

In our understanding, the designation of an environmental protected area in a region with this socioeconomic profile may have two kinds of consequences, depending on the direction of the management that is applied in the area. In a first scenario, people can be compensated and evicted from their properties, and forced to abandon the landscape with which they have emotional and historical ties. They would have to attempt to live on a new way of subsistence with which they are not used. In this scenario, the flora and the fauna could recovery without direct human interference.

In a second scenario, the park could be recategorized for a type of designation that allows the maintenance of families and the sustainable use of natural resources. In this case, the management plan for the conservation area needs to be prepared not only from an environmental perspective, but also from a political and social perspective. It is necessary that political managers, together with the local populations, think about alternatives for income generation and means of subsistence that are compatible with the conservation of local biodiversity. For example, the study area has great potential for socio-environmental tourism, which is under-explored, due to the lack of infrastructure and social organization.

Men as the greatest holders of knowledge about native medicinal plants

Most of the socioeconomic variables that we assessed did not affect knowledge about native medicinal plants, with the exception of sex and age. Most of the ethnobotanical literature shows that variables such as income (Almeida et al. 2010; Karunamoorthi and Tsehaye, 2012), occupation (Silva et al. 2011; Pérez-Nicolás et al. 2017) and education (Quinlan and Quinlan, 2007; Srithi et al. 2009) affect the number of plants known for medicinal use.

In general, these factors imply some abandonment degree or a decrease in traditional knowledge, since people with higher education level, non-farming occupations, or higher income would have less dependence on natural resources (Hegde and Enters, 2000; Lacuna-Richman, 2002). However, in the studied scenario, although there are differences in people's socioeconomic profiles, these differences probably do not imply lower dependence on natural resources. For example, although there are many retired individuals in our sample, these people may have higher health care expenses (Rowland and Lyons, 1996), and may be more frequent targets of financial scams and abuse (Tueth, 2000), a situation that we have seen in some families (personal observation).

The effect of gender on knowledge about medicinal plants is a subject that has been studied for a long time in the ethnobiological literature, and a recent study indicates that its effect varies at different scales (Torres-Avilez et al. 2016). These authors demonstrated that, globally, there is no difference in knowledge about medicinal plants between men and women. However, on a continental and national scale, the differences become clear. In Brazil, for example, there is evidence that women have more knowledge about medicinal plants than men (Torres-Avilez et al. 2016). These differences in regional scales are probably associated with differences in social roles and division of tasks between genders (Torres-Avilez et al. 2016), since in rural communities in northeastern Brazil women are normally responsible for primary family health care (Voeks, 2007; Vidal, 2013).

However, our findings showed that men have more knowledge than women. It is possible that this finding is associated with our scope since we focus only on native species. It is possible that men are more knowledgeable about native medicinal plants because they usually access forest areas more than women (Caniago et al. 1998). Another explanation refers to the difficulty in collecting some plants, since several of the important medicinal species appear to be locally rare. Thus, although women play the role of family health care, men seem to be responsible for collecting these resources.

Finally, greater knowledge about medicinal plants among older individuals is common in the ethnobotanical literature (Doyle et al. 2017; Silva et al. 2019). This is related to the process of cultural transmission of knowledge. Usually, people learn about medicinal plants from their parents or other older individuals in general, such as in-laws or grandparents (Soldati et al. 2015). In any case, these differences in knowledge related to gender or age may have little implications in terms of local dependence on natural resources. Therefore, families in the studied region seem to be equally dependent on medicinal plants for health care.

Household members with lower income have more knowledge about native edible plants

In the Brazilian semiarid region, the consumption of some native edible plants has historically been associated with times of great drought. In these situations, part of the local population resorted to these foods to supply their nutritional needs (Nascimento et al. 2012; Nascimento et al. 2013). Some of these plants, in particular legumes, need to undergo laborious processes to eliminate toxic compounds, so that they can be eaten (Nascimento et al. 2012). Thus, by referring to these times of great poverty, in some locates, there is currently a social stigma regarding the consumption of native edible plants , which has led to a decline in consumption (Cruz et al. 2014).

Moreover, since the introduction of the Bolsa Família Program the eating habits of families in the Brazilian semiarid region have changed. An increase in the consumption of ultra-processed foods (canned goods, sausage, instant noodles), and foods rich in refined carbohydrates (sweets, bread, cake, pasta, chocolate, yogurt) have been observed, resulting in a new problem in the region, childhood obesity (Saldiva et al. 2010; Pires and Jardim, 2014). Probably, our findings may be explained by the possibility that only very low-income people still have some degree of dependence on native edible plants, and therefore have more knowledge about these resources.

Household income and size do not affect demand for wood forest products

In contrast to the literature on the use of wood forest products for subsistence purposes (Marufu et al. 1997; Brouwer and falcão, 2004; Arabatzis and Malesios, 2011; Ramos et al. 2015; Moeen et al. 2016; Hernández-Garduño et al. 2017; Kim et al. 2017; Arruda et al. 2019; Jin et al. 2019), we found no effect of income and household size on the use of these resources. Probably, these findings can also be explained by the proposition that the variation found locally in socioeconomic factors is not sufficient to result in less dependence on natural resources.

It is possible that the households of the communities studied are devising different strategies to ensure their subsistence. For example, some of the households with incomes starting at R$ 500.00 have abandoned or reduced the firewood use, while others make greater use. Thus, our findings seem to corroborate the hypothesis of Medeiros et al. (2012) that the relationship between socioeconomic factors and the demand for wood is affected by the different choices that households make to save money. Some low-income households may decrease the firewood use but increase the wood use for construction, for example (Medeiros et al. 2012). Also, we emphasize that, in recent years, the price of cooking gas has increased considerably in Brazil, so that there is an increase in the percentage of households that use firewood throughout the country (IBGE- Brazilian Institute of Geography and Statistics, 2018). Furthermore, since the communities studied are far from an urban center, the use of cooking gas is even less accessible because it requires paying for transportation to the community.

The most conserved areas have no greater richness of useful species

With respect to our proxy for the conservation level in the forest areas (the vegetation cover), this had no effect on the richness of useful species in the landscape. Thus, our findings demonstrate that if we consider areas with similar species richness, the variation in vegetation cover does not affect the number of useful species. In the study area, vegetation cover is weakly associated with the total density of trees, but it has no effect on the total biomass of the vegetation or on the species composition (Rito et al. 2016). Thus, it is likely that what remains under the label of vegetation cover may be a variation in the total density of a vegetation dominated by few species.

There are some evidences that the collection of wood resources (one of the most detrimental extractivism practice) has a low effect on of the abundance of dominant species in the Caatinga, which have regrowth mechanisms that enable their populations to recover (Sampaio et al. 1998; Miliken et al. 2018). Thus, it is possible that the areas with the highest vegetation cover are dominated by the same species, but with greater absolute densities, as found in our study area (Rito et al. 2016).

Final considerations

Our findings show that socioeconomic factors have little impact on knowledge and demand for forest products in a protected area in the Brazilian semiarid region. In particular, increasing income does not reduce people's dependence on natural resources. So, it is important to reconsider strategies for designating protected areas in semiarid regions with a history of human occupation. The historical low socioeconomic dynamism of families living in these regions can result in socio-environmental conflicts, as people need to use resources, and may feel uncomfortable in an illegal situation. In addition, the ban on the use of resources and subsistence practices (agriculture and livestock) may further accentuate the socio-economic vulnerability of people, who often may not be able to get jobs in urban areas. Therefore, we suggest that planning conservation strategies in semiarid regions should be done with three axes in mind: strategies which allow people deal with the droughts, conserving biodiversity and generating income for local populations.

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7. CONCLUSÕES

Distúrbios antropogênicos crônicos são um desafio para a conservação da biodiversidade, especialmente em regiões semiáridas. Nessas regiões, o baixo dinamismo socioeconômico, agravado pelas secas frequentes e pela baixa vontade política em implementar estratégias de convivência com a seca e com os ecossistemas naturais, resulta em forte dependência dos recursos florestais. É preciso que sejam pensadas e implementadas estratégias duradouras de convivência com a seca e com a Caatinga que possam conciliar o uso de recursos naturais, a geração de renda e a conservação da biodiversidade. As experiências mais recentes nesse sentido, mostram que são fundamentais mudanças nas atividades de pecuária na região, a diversificação de estratégias de geração de renda, e o acesso a serviços básicos de saúde, educação e acesso à água potável.