UNIVERSIDADE FEDERAL DE MATO GROSSO DO SUL
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ECOLOGIA DE FORMAÇÕES MONODOMINANTES DE *BYRSONIMA CYDONIIFOLIA* A. JUSS. (MALPIGHIACEAE) SOB INFLUÊNCIA DA INUNDAÇÃO, FOGO E GADO BOVINO

Campo Grande-MS
FEVEREIRO – 2024

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SUMÁRIO

1. Resumo geral

Formações monodominantes são aquelas em que mais da metade dos indivíduos de determinado estrato é constituída por uma única espécie de planta e estão entre as principais características fitofisionômicas do Pantanal. Entre tais formações, podemos destacar os canjiqueirais, cuja principal espécie é *Byrsonima cydoniifolia* A. Juss. – Malpighiaceae, de hábito arbustivo a arborescente, cujo fruto é comestível, possuindo rico valor nutricional, e cuja presença é tida como indesejada por parte dos pecuaristas, sendo constante a remoção de tais plantas das áreas de pastagens. Nesse estudo, temos como objetivo verificar como varia a riqueza, densidade e area basal dos canjiqueirais em relação aos eventos de fogo e inundação e à presença de gado bovino. Também tivemos como objetivo compreender os conhecimentos de moradores locais acerca tais relações. Para tal, foram selecionados e delimitados, através do uso de imagens de satélite, fragmentos de vegetação com potencial para serem canjiqueirais nas regiões de Miranda e Abobral, Corumbá – MS. Em seguida, utilizando-se de imagens obtidas pelos satélites Landsat-5, Landsat-7, Landsat-8 e Resourcesat-1, foi feito um levantamento dos eventos de fogo que atingiram a região entre os anos de 2000 e 2021, obtendo-se áreas com histórico de 1 a 7 eventos de fogo no período. Foram então selecionadas 26 áreas para visitação e coletas de dados de vegetação tais como altura, comprimento na altura do peito de cada ramo, marcas de fogo e água de indivíduos de porte arbustivo e arbóreo, sendo para cada área realizada a coleta em quatro parcelas de 25x25m. Os conhecimentos locais foram averiguados a partir de entrevistas semiestruturadas feitas com moradores das comunidades locais de Passo do Lontra, Porto Esperança e de cinco fazendas da região, que responderam perguntas sobre como as canjiqueiras respondiam aos eventos de fogo e inundação e qual era sua relação com o manejo de gado. Suas respostas foram analisadas levando-se em consideração seu local de residência, sexo, idade, e tempo de moradia na região. Após análise dos dados de vegetação, constatou-se que a inundação é fator limitante para a presença de indivíduos adultos de *B. cydoniifolia* e o fogo, bem como a presença de gado, ainda que não interfiram na densidade populacional da planta, diminuem a área basal média dos seus ramos, bem como a quantidade de ramos mais espessos. Após análise de conhecimentos populares, por sua vez, constatamos que as canjiqueiras resistem às inundações e possuem alta capacidade de rebrota após incêndios, o que reforça os dados obtidos na análise de vegetação. Foi possível notar também que os conhecimentos acerca da ecologia da planta são partilhados de forma similar pela população local, sendo as únicas diferenças encontradas no que diz respeito aos conhecimentos acerca da resistência ao fogo e à inundação, os homens conhecem mais, e as diferentes visões sobre a relação entre o manejo de gado e as canjiqueiras, que tendem a ser positivas entre moradores das comunidades e negativas para os das fazendas.

Palavras-chave: nicho de persistência; áreas úmidas; etnobotânica

2. Abstract

Monodominant stands are vegetal formations in which over 50% of a vegetation stratum is composed of individuals from the same species and can be considered one of the most common landscapes in Brazilian Pantanal Wetlands. Among such formations, we can highlight canjiqueirais, monodominant stands of *Byrsonima cydoniifolia* A.Juss. – Malpighiaceae (canjiqueira tree), a species of shrub or tree, which bears an edible and highly nutritious drupe, and which is considered an undesirable plant by livestock farmers, who constantly remove such plants from their cattle pastures. This study aims to analyze how *B. cydoniifolia* density and basal area are affected by both abiotic (fire and flood events) and biotic (livestock raising) factors that occur in Pantanal wetlands. We also aimed to comprehend how local inhabitants understand those relationships. To do so, we selected and delimited fragments of vegetation which might be canjiqueirais stands in the Pantanal wetlands subregions of Miranda and Abobral, Corumbá, Mato Grosso do Sul, Brazil, through the usage of satellite imagery. After such selection, through the usage of satellite imagery obtained by Landsat-5, -7 and -8 and Resourcesat-1, we selected wildfires that occurred between the years 2000 and 2021, selecting areas with between 1 and 7 episodes of fire, 26 of them being visited to the collection of data such as tree height, diameter at breast height of each branch, fire and watermarks of trees and shrubs. For each area 4 plots, measuring 25x25 meters, were selected. Folk knowledge has been investigated through interviews conducted with inhabitants of Passo do Lontra and Porto Esperança communities and five local farms, who answered questions about how canjiqueiras reacted to fire and flood events and how cattle management dealt with this species, being their answers analyzed following four categories: place of residence, sex, age, and length of residence in the region. After the analysis of vegetation data, it has been stated that water is a limiting factor to the presence of adult individuals of *B. cydoniifolia* and fire events and cattle decreases the basal area of canjiqueira trees' branches, although neither of those factors had any influence over the other species that were found in canjiqueirais. Folk knowledge analysis stated that local inhabitants consider canjiqueira trees a species that can endure flood seasons and resprout after fire events, which is consistent with data found in vegetation analysis, and also common knowledge regarding the ecological characteristics of this plants are similarly shared among local inhabitants, being the only remarkable differences between men and women over the ecology of the plant, as women were less aware of canjiqueira's survival from fire and flood, and the view regarding the relationship between canjiqueira trees and cattle management, which is seen in a negative way by farmer inhabitants but positively by local communities reisdents.

Keywords: persistence niche; wetlands; ethnobotany

3. Introdução geral

Formações monodominantes são áreas em que mais de 50% da cobertura vegetal é formada por uma única espécie (CONNEL & LOWMAN, 1989). Tais formações são comuns savanas (STEVENS et al., 2013, BUENO et al., 2014, HOUDANON et al., 2019, DAMASCENO-JUNIOR et al., 2021a, DAMASCENO-JUNIOR et al., 2021b, KENFACK et al., 2021, MANRIQUE-PINEDA et al., 2021), sendo comumente encontradas na África e na região neotropical. Apesar de diversas hipóteses terem sido levantadas ao longo dos anos para explicar a existência de tais formações, dentre as quais podemos citar solos pobres em nutrientes (HART et al., 1989; KENFACK et al., 2013) ou com características fisioquímicas limitantes (DAMASCENO-JUNIOR et al., 2021a); efeitos alelopáticos (DAMASCENO-JUNIOR et al., 2021b); baixo alcance da dispersão de sementes (CONNEL & LOWMAN, 1989); inundação (LOPEZ & KURSAR, 1999; LOPEZ & KURSAR, 2007), não existe um único fator que leva uma espécie em uma determinada área a formar monodominância, o que torna tais tipos de vegetação fonte de diversos estudos.

O Pantanal se destaca pela presença de tais formações, havendo registro de pelo menos 27 espécies vegetais que formam áreas de monodominância (DAMASCENO-JUNIOR et al., 2021b), dentre as quais podemos destacar palmeiras (ex.: *Attalea phalerata*, *Copernicia alba*, *Mauritia flexuosa*) espécies de hábitos herbáceos (ex.: *Andropogon hypogynus*, *Cyperus giganteus*, *Typha dominguensis*) e espécies lenhosas (ex.: *Handroanthus heptaphyllus*, *Tabebuia aurea*, *Vochysia divergens*). A ocorrência de tais formações está associada a solos com características químicas peculiares e à frequência de eventos de inundação (DAMASCENO-JUNIOR et al., 2021a, DAMASCENO-JUNIOR et al., 2021b), que atuam como fatores determinantes de qual formação monodominante consegue se estabelecer em tal área. Os eventos de fogo sazonais também são considerados como uma das causas da monodominância à medida que tanto eliminam espécies que não possuem adaptações aos incêndios, como súber espesso, estruturas fotossintetizantes protegidas e capacidade de rebrota pós-queimada, quanto causam alterações imediatas na composição de nutrientes no solo e quantidade de biomassa e cobertura vegetal nele presente, favorecendo o estabelecimento e propagação de organismos adaptados a esse tipo de perturbação (MANRIQUE-PINEDA et al., 2021).

Dentre as espécies lenhosas que constituem formações monodominantes no Pantanal, podemos destacar *Byrsonima cydoniifolia* A.Juss. (Malpighiaceae), popularmente conhecida como "canjiqueira", espécie arbustiva com altura variando de 1 a 6 metros e copa arredondada, com folhas verde-acinzentadas (POTT & POTT, 1994, DAMASCENO-JUNIOR et al., 2021b). Suas formações monodominantes, conhecidas como "canjiqueirais", ocorrem em áreas de solos arenosos, pobres em

Ca e Mg (DAMASCENO-JUNIOR et al., 2021a) se expandem durante longos períodos de seca para as planícies mais suscetíveis a inundação (POTT & POTT, 1994, SCREMIN-DIAS et al., 2011), tendo sua ocorrência limitada por esse fator em anos de cheia. Os frutos da espécie, drupas amareladas cuja dispersão ocorre entre os meses de setembro e abril, são poucos consumidos pelos habitantes locais, sendo incentivado o consumo por projeto de extensão especialmente *in natura* ou como suco (DAMASCENO-JUNIOR et al., 2010). Possuem elevado valor nutracêutico, apresentando altos índices de ácidos graxos, reverastrol, flavonoides e derivados do ácido gálico, além de minerais como Cu, Fe, K, Mg e Mn, possuindo propriedades anti-inflamatórias e anti-hiperalgésicas (SANTOS et al., 2017, ARAKAKI et al., 2020), fazendo com que seja uma planta com alto potencial alimentício.

A casca é usada para o curtimento de couro e como tratamento antidiarreico e antifebril, e a madeira, como lenha para fogueiras ou fogões (POTT & POTT, 1994). Considerada invasora de pasto pelos moradores do Pantanal, é constante sua remoção para o aproveitamento de espaço para pasto (POTT & POTT, 1994; JUNK & CUNHA, 2012; BERSELI et al., 2019). Esta atividade está intrinsecamente relacionada à presença de gado bovino (*Bos taurus* Linnaeus, 1758), elemento importante no cenário socio-econômico – e, atualmente, ambiental – pantaneiro. Com a introdução do gado bovino na região ao final do século XVII (WILCOX, 1992), a pecuária se mostra como elemento importante para a constituição da paisagem pantaneira em função do desmatamento e substituição de pasto nativo por introduzido (SEIDL, SILVA & MORAES, 2001). Para as formações monodominantes, Damasceno-Junior et al. (2021b) registram diversas interações com o gado bovino, a exemplo do achatamento de murundus provocados por suas pisadas em paratudais (formações monodominantes de *Tabebuia aurea*), sombra para os animais em pimenteirais (formações monodominantes de *Leptobalanus parvifolius*) e forrageamento de folhas em lixeirais (formações monodominantes de *Curatella americana*). Para canjiqueirais, reportou-se que folhas mais jovens podem ser ingeridos pelo gado bovino (DAMASCENO-JUNIOR et al., 2021b). Contudo, não podemos excluir a possibilidade de o gado interagir de outras formas com as plantas, como se alimentando de frutos ou usando sua copa como abrigo do sol.

Além do gado, podemos citar o fogo como outro elemento de origem antrópica importante para a formação das paisagens do Pantanal. Ainda que haja incêndios naturais, a ação humana é responsável por até 95% dos eventos de fogo anualmente no Pantanal (MENEZES et al., 2022). É comum o uso do fogo como ferramenta de manejo de vegetação por comunidades tradicionais de todo o mundo (ANDERSON, 1996; BELEMIE & KEBEBEW, 2006, PIVELLO, 2011; PAUDEL et al., 2020), o qual está diretamente relacionado ao conhecimento de como este elemento afeta a fenologia e sobrevivência de plantas em diferentes estágios de desenvolvimento (ARMATAS et al.,

2016; PINTO et al., 2016, MCKEMEY et al., 2020) e na arquitetura das plantas (GINOCCHIO, HOLMGREN & MONTENEGRO, 1994; ARCHIBALD & BOND, 2003, DODONOV et al., 2011). Apesar de o fogo ser comum no Pantanal, sendo tema central de diversos estudos conduzidos na região, a maior parte de tais estudos está voltada para os impactos diretos e formas de prevenção de incêndios (MATAVELI et al., 2021; OLIVEIRA et al., 2021; MARTINS et al., 2022) ou para as diversas adaptações a esses eventos que os seres vivos do Pantanal desenvolveram como forma de garantir sua permanência no local (BUENO et al., 2014; OLIVEIRA et al., 2014; MANRIQUE-PINEDA et al., 2021; SILVA et al., 2021; ARRUDA et al., 2022; ARRUA et al., 2023). Estudos acerca dos conhecimentos tradicionais de populações locais acerca de como não só o fogo, como também outros elementos como as inundações e o manejo de gado afetam diretamente as comunidades vegetais que podem ser encontradas nos canjiqueirais ainda são escassos.

O estudo dos conhecimentos de comunidades tradicionais fornece informações tanto acerca de como aquelas comunidades atuam sobre o ambiente que ocupam como também permite entender a própria dinâmica interna de tais populações humanas. Estudos com diversas comunidades demonstraram que características como sexo, idade, atividade desempenhada e tempo de residência em um determinado local (CHEIKHYOUSSEF et al., 2011; GUIMBO, MULLER & LARWANOU, 2011; GANDOLFO & HANAZAKI, 2014; BORTOLOTTO et al., 2015; COSTA et al., 2017; KUNWAR et al., 2018; MIGUÉIS et al., 2019; OLIVEIRA et al., 2020; COSTA, GUIMARÃES & MESSIAS, 2021; LAUER-LEITE & NOVAIS, 2021; MECHAALA, BOUATROUS & ADOUANE, 2021; TEIXIDOUR-TONEU et al., 2021, TNG et al., 2021) determinam o nível de conhecimentos que os moradores detêm acerca das espécies de plantas da região onde vivem, sendo alguns grupos mais propensos a deterem conhecimentos que outros.

Além do conhecimento acerca do uso de plantas por membros de comunidades humanas, há também os conhecimentos acerca dos processos ecológicos a que tais espécies estão submetidas como parte da observação, convívio e forma de interagir com o ambiente. Ainda que estudos sobre os conhecimentos ecológicos populares sejam mais escassos do que aqueles sobre usos de plantas (NAAH & GUUROH, 2017), eles também se mostram como uma boa ferramenta para a compreensão do entendimento das próprias peculiaridades das comunidades e de como se dão os processos ecológicos. Assim, etnobotânica e ecologia podem ser consideradas aliadas e complementares, visto que a primeira, tal como a segunda, estuda relações entre seres vivos e como estas podem alterar ou ser influenciadas pelo ambiente ao seu redor (HURREL & ALBUQUERQUE, 2012).

Para a compreensão de como se dá a influência dos eventos de fogo e inundação e do gado sobre os canjiqueirais, bem como entender quais os conhecimentos locais acerca desses eventos,

formulamos as hipóteses de que: ainda que resistam à inundação, as canjiqueiras terão a sua densidade populacional afetada negativamente por ela, sendo os canjiqueirais com maiores níveis de inundação aqueles com menos indivíduos; que o fogo afetará positivamente a densidade populacional de canjiqueiras e negativamente as de outras espécies do estrato arbustivo/arbóreo presentes, sendo uma das causas da monodominância; que, em áreas com presença de gado, os indivíduos de *B. cydoniifolia* apresentarão menor população, terão menor porte e possuirão ramos menos espessos que naquelas áreas onde o gado está ausente; que os resultados encontrados para essas hipóteses serão condizentes àquelas informações indicadas pelos moradores locais e; que os moradores das comunidades tradicionais e das fazendas, ainda que possuam conhecimentos similares sobre as relações ecológicas das canjiqueiras, terão visões diferentes no que diz respeito à sua relação para com o manejo de gado.

4. Objetivos

Geral

Compreender como os eventos de fogo e inundação, além do manejo de gado bovino, alteram a riqueza e densidade nos estratos arbustivo e arbóreo das formações de canjiqueirais e como a arquitetura das canjiqueiras é influenciada por tais fatores, bem como analisar os conhecimentos das comunidades humanas locais sobre essa dinâmica.

Específicos

1) Verificar como os fatores abióticos (fogo e inundação) e bióticos (gado bovino) alteram a riqueza do estrato arbustivo/arbóreo dos canjiqueirais, além de influenciarem a densidade, área basal, altura e arquitetura tanto das canjiqueiras como das outras espécies que ocorrem em suas formações monodominantes;
2) Verificar se os moradores de comunidades e fazendas locais conhecem a relação das canjiqueiras com tais fatores abióticos e bióticos e, caso positivo, se há alguma distinção entre os conhecimentos desses moradores em razão de sua idade, sexo, local onde residem ou tempo que habitam a região.

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Ecology of *Byrsonima cydoniifolia* A.Juss. (Malpighiaceae) monodominant stands under the influence of flood, fire and cattle

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Abstract

Monodominant stands are vegetal formations in which over 50% of a vegetation stratum is composed of individuals from the same species and can be considered one of the most common landscapes in Brazilian Pantanal Wetlands. Among such formations, we can highlight canjiqueirais, monodominant stands of *Byrsonima cydoniifolia* A.Juss. – Malpighiaceae (canjiqueira tree), a species of shrub or tree, which bears an edible and highly nutritious drupe, and which is considered an undesirable plant by livestock farmers, who constantly remove such plants from their cattle pastures. This study aims to analyze how *B. cydoniifolia* density and basal area are affected by both abiotic (fire and flood events) and biotic (livestock raising) factors that occur in Pantanal wetlands. We also aimed to comprehend how local inhabitants understand those relationships. To do so, we selected and delimited fragments of vegetation which might be canjiqueirais stands in the Pantanal wetlands subregions of Miranda and Abobral, Corumbá, Mato Grosso do Sul, Brazil, through the usage of satellite imagery. After such selection, through the usage of satellite imagery obtained by Landsat-5, -7 and -8 and Resourcesat-1, we selected wildfires that occurred between the years 2000 and 2021, selecting areas with between 1 and 7 episodes of fire, 26 of them being visited to the collection of data such as tree height, diameter at breast height of each branch, fire and watermarks of trees and shrubs. For each area 4 plots, measuring 25x25 meters, were selected. Folk knowledge has been investigated through interviews conducted with inhabitants of Passo do Lontra and Porto Esperança communities and five local farms, who answered questions about how canjiqueiras reacted to fire and flood events and how cattle management dealt with this species, being their answers analyzed following four categories: place of residence, sex, age, and length of residence in the region. After the analysis of vegetation data, it has been stated that water is a limiting factor to the presence of adult individuals of *B. cydoniifolia* and fire events and cattle decreases the basal area of canjiqueira trees' branches, although neither of those factors had any influence over the other species that were found in canjiqueirais. Folk knowledge analysis stated that local inhabitants consider canjiqueira trees a species that can endure flood seasons and resprout after fire events, which is consistent with data found in vegetation analysis, and also common knowledge regarding the ecological characteristics of this plants are similarly shared among local inhabitants, being the only remarkable differences between men and women over the ecology of the plant, as women were less aware of canjiqueira's survival from fire and flood, and the view regarding the relationship between canjiqueira trees and cattle management, which is seen in a negative way by farmer inhabitants but positively by local communities reisdents.

Keywords: persistence niche; wetlands; etnobothany

1. Introduction

Monodominant stands are areas in which over 50% of canopy level trees consists of one single species (Connel and Lowman, 1989). Such formations occur in rainforests (Peh et al., 2011; Nascimento et al., 2013; Hall et al., 2019; Houdanon et al., 2019; Cardoso et al., 2020) and savannas (Stevens et al., 2013; Bueno et al., 2014; Houdanon et al., 2019; Damasceno-Junior et al., 2021a; Damasceno-Junior et al., 2021b; Kenfack et al., 2021; Manrique-Pineda et al., 2021), being most common in Africa and neotropics. Several hypotheses have been proposed to explain the existence of those formations, including soil lacking nutrients (Hart et al., 1989; Torti et al., 2001; Kenfack et al., 2013) or with limiting physiochemical traits (Damasceno-Junior et al., 2021a); mycorrhizal associations between monodominant species' individuals, enhancing nutrients absorption (Connel and Lowman, 1989; Houdanon et al., 2019); allelopathic effects (Damasceno-Junior et al., 2021b); poor seed dispersal range (Connel and Lowman, 1989) and flood (Lopez and Kursar, 1999; Lopez and Kursar, 2007) are some of the factors that lead to monodominance, which means that there is not one single cause that drives a species to become monodominant in some areas, making those kinds of vegetation source from several studies.

South American Pantanal wetlands hold a considerable number of monodominant stands, as at leas 27 plant species being capable of monodominance (Damasceno-Junior et al., 2021b), including palms (e.g.: *Attalea phalerata* Mart. ex Spreng., *Copernicia alba* Morong, *Mauritia flexuosa* L.f.), herbs (e.g.: *Andropogon hypogynus* Hack., *Cyperus giganteus* Vahl, *Typha domingensis* Pers.) and wood plants (e.g.: *Handroanthus heptaphyllus* (Vell.) Mattos, *Tabebuia aurea* (Silva Manso) Benth. & Hook.f. ex S.Moore, *Vochysia divergens* Pohl). The occurrence of monodominant stands is associated with soils bearing peculiar chemical characteristics and flood events frequence (Damasceno-Junior et al., 2021a; Damasceno-Junior et al., 2021b), that act as determining factors of which stand can be stablished at some specific area. Other determinant factor are seasonal fire events that eliminate species lacking fire-resistant traits such as thick bark, protected photosynthesizing structures and resprouting ability and cause immediate changes of nutrients, total biomass and vegetation coverage in and over the soil, favoring the establishment and propagation of organisms adapted to this kind of disturbance (Manrique-Pineda et al., 2021).

Amongst the wood species that form monodominant stands in Pantanal wetlands, we highlight *Byrsonima cydoniifolia* A. Juss. (Malpighiaceae). Popularly known as "canjiqueira", *B. cydoniifolia* is a shrub, 1-6 meters tall, with greyish-green leaves and roundish canopy (Pott and Pott, 1994; Damasceno-Junior et al., 2021b). Its monodominant stands, called "canjiqueirais" by local people, occur in sandy soils, with low levels of Ca and Mg (Damasceno-Junior 2021a) and are not much prone to resist flood for long periods, expanding their occurrence areas during long dry periods to

plains more susceptible to flooding (Pott and Pott, 1994; Scremin-Dias et al., 2011). As the plant possesses some traits of xerophytes, long termed exposition to flood causes the death of individuals, restricting its occurrences to areas less prone to inundation (Scremin-Dias et al., 2011). The fruits of canjiqueira are yellow drupes dispersed from September to April and, although edible, are poorly consumed by local human populations, being the consumption stimulated by extension projects and most common in the form of juices or *in natura* (Damasceno-Junior et al., 2010). Their nutraceutical value is high, with high levels of fat acids, resveratrol, flavonoids and gallic acid derivates, besides minerals such as Cu, Fe, K, Mg and Mn and possessing anti-inflammatory and anti-hyperalgesic properties (Santos et al., 2017; Arakaki et al., 2020). Therefore, canjiqueira fruits can be considered to have high food potential.

The bark is used to leather tanning and, in folk medicine, to extinguish diarrheic and fever, and the wood is used as fuel for fireplaces and ovens (Pott and Pott, 1994). It is considered a pasture invader species by local inhabitants, being constantly removed to assure more viable areas for grazing plants to livestock farming (Pott and Pott, 1994; Junk and Cunha, 2012; Berseli et al; 2019), which is the main economic activity that drifts socio-economic – and, currently, environmental – scenarios of Pantanal wetlands. Several interactions between livestock farming and monodominant stands in Pantanal wetlands (Damasceno-Junior et al., 2021b), for instance, cattle are known to flatten murundus (small earth elevations) in paratudais (monodominant stands of *Tabebuia aurea*), shelter under the canopy of pimenteirais (monodominant stands of *Leptobalanus parvifolius* (Huber) Sothers & Prance) and eat leaves of the main individuals of lixeirais (monodominant stands of *Curatella americana* L.). Canjiqueira tree leaves are also eaten by cattle, as their youngest leaves and buds are ingested by oxen (Damasceno-Junir et al., 2021b), but we can not exclude the possibility of other interactions between cattle and those plants, such as fruit feeding and sheltering under their canopy.

Not only cattle, but fire is also an important element related to human activity that plays an important role in Pantanal landscape. Even though there are some natural fires, human management is responsible for circa 95% of fire events that take place at Pantanal yearly (Menezes et al., 2022). Fire is commonly use as a vegetation management tool by traditional people worldwide (Anderson, 1996; Belemie and Kebebew, 2006; Pivello, 2011; Paudel et al., 2020), being directly related to how knowledge over such element affect phenology and survival of plants in different stages of development (Armatas et al., 2016; Pinto et al., 2016; McKemey et al., 2020) and concerning aspects such as germination (Pausas and Lamont, 2022), blooming (Lamont and Downes, 2011) and plant architecture (Ginocchio, Holmgren and Montenegro, 1994; Archibald and Bond, 2003; Dodonov et al., 2011). Despite fire events commonness in Pantanal wetlands, being the main object of many studies conducted in that biome, most of those studies concerns the direct impacts and mechanisms

of prevention of wildfires (Mataveli et al., 2021; Oliveira et al., 2021; Martins et al., 2022) or focus on the different adaptations that living beings – especially, animals and plants – developed in order to endure fire events and assure their survival and permanence at Pantanal (Bueno et al., 2014; Oliveira et al., 2014; Manrique-Pineda et al., 2021; Silva et al., 2021; Arruda et al., 2022; Arrua et al., 2023). Studies regarding traditional knowledge of local human populations about not only fire, but also flood and livestock farming affect local plant communities at Pantanal wetlands are scarce.

In fact, studies over knowledge of traditional human communities not only provides information about how such communities reshape the environment they live on but also allows the understanding of the internal dynamics of such communities. Studies conducted with several traditional communities have shown that characteristics such as gender, age, main economic activity and length of residence at the studied site (Cheikhyoussef et al., 2011; Guimbo, Muller and Larwanou, 2011; Gandolfo and Hanazaki, 2014; Bortolotto et al., 2015; Costa et al., 2017; Kunwar et al., 2018; Miguéis et al., 2019; Oliveira et al., 2020; Costa, Guimarães and Messias, 2021; Lauer-Leite and Novais, 2021; Mechaala, Bouatrous and Adouane, 2021; Teixidour-Toneu et al., 2021, Tng et al., 2021) determinates the amount of knowledge about local plants members of a community are prone to hold, being observed tendencies such as elders holding more knowledge over species than younger people and women having wider information about medicinal and food uses of plants whereas men know handicraft and construction uses.

Therefore, besides local knowledge over several uses of plants by human communities, we can also highlight those communities' knowledges regarding ecological processes by which said species are subjected as part of their observation, coexistence, and interactions with environment. Even though studies regarding folk ecological knowledge are uncommon when compared to studies over plant uses (Naah and Guroh, 2017), it is important to state that those studies are an important tool to the comprehension of communities' peculiarities and how local ecological processes occurs, as, mostly, a scientific research is short termed whereas local inhabitants can witness such processes over years or decades. Therefore, ethnobotany and ecology can be considered not only allied but also complementary sciences, since both of them aim to understand the relationship between living beings and how such relationships can modify or be influenced by the environment they take place (Hurrel and Albuquerque, 2012).

This study aims to understand how fire and flood events, besides livestock farming, alter the richness and density of trees and shrub in monodominant stands of *B. cydoniifolia* and how the architecture of those plants is influenced by such factors. Also, it aims to analyze local knowledge held by human communities that live in Pantanal wetlands over those dynamics. Our hypotheses are: even the canjiqueira trees resist flooding, their population density will be negatively affected by this factor, being the more floodable canjiqueirais the ones with less individuals; fire will affect positively

the population density of canjiqueiras and negatively the density of other tree and shrub species, being one of the causes of the monodominance; cattle presence will decrease the density of *B. cydoniifolia* and lead the species' individuals to be shorter and bear less thick branches than those canjiqueirais without livestock farming; results found by vegetation data collection and analysis will befit with information provided by local inhabitants and; that although inhabitants of traditional communities and farms share similar knowledge over canjiqueirais ecological relationships, their opinions regarding the relationship between canjiqueira trees and cattle management will be different.

2. Material and Methods

2.1 Study site

The study was conducted in areas located in livestock farms and traditional communities located nearby Estrada Parque Pantanal (MS-184) road and by the eastern side of Paraguay River in the municipality of Corumbá, state of Mato Grosso do Sul, Brazil (figure 1), being all locations part of Brazilian Pantanal wetlands.

Pantanal wetlands is world's largest floodplain, mostly located in Brazilian territories, in which such biome spreads across an area of approximately 140,000 square kilometers and is divided in 11 subregions (Silva and Abdon, 1994), having this study being conducted in Miranda, Abobral and Nabileque subregions. Vegetation in Pantanal is formed by capões (circular forest spots, usually located over elevations slightly above the surrounding ground level), cordilheiras (long and narrow forests, also located above surrounding ground level), riparian forests, grasslands and monodominant stands (Damasceno-Junior and Pott, 2021c). The climate in the region is *Aw* according to Köppen-Geiger classification (Alvares et al., 2014), having wet and hot summers and dry and cold winters, with a rainy season lasting from October to April (mostly intense between December and March) and the wet season lasting between May and September. Flood consists of a monomodal pulse, with its peak between April and August. Increasing water comes from both Miranda river and northernmost Pantanal springs that flow through Paraguay river (Hamilton, 1996).

Selected areas to the vegetation study are located in livestock farms in Miranda, Abobral and Nabileque subregions, being accessible through Estrada Parque Pantanal or side roads. To study the knowledge of local inhabitants the communities of Porto Esperança and Passo do Lontra, respectively located in Nabileque and Abobral subregions, have been visited along with some local farms. Porto Esperança community is located on eastern side of the Paraguay river (19º36'35,06" S

57º27’17,73” W) and, according to the president of local women association, is constituted by 46 families, most of which are permanently residing at the community, leading to low levels of population fluctuation throughout the year. The main economic activities of Porto Esperança inhabitants are fishing and tourism, although some inhabitants are employees at nearby livestock farms. Although the most common monodominant stands near this community are paratudais, canjiqueira tree stands can be found approximately two kilometers far.

Passo do Lontra community is located in the margins of Miranda river, adjacent to the community’s namesake bridge at Estrada Parque Pantanal (19º34’30,64” S 57º02’15,35” W). Differently from Porto Esperança, this community has no inhabitants official representation or local association and most of its residents is temporary, settling in the region during fishing season and returning to other municipalities, specially Miranda and Corumbá, during piracema season (October – March), which is a season that fishing activities are legally prohibited due to fishes reproduction. The number of resident families is about 50 during the fishing season, dropping to less than half during piracema season, and main economic activities developed by local inhabitants are fishing and tourism. The nearest canjiqueira tree stand in located approximately five hundred meters from the community.

Lastly, local livestock farms main activity, beside cattle farming itself, is tourism, which is reflected by its inhabitants, most of them ranchers, cowboys, tour guides and domestic or management employees. Five of those farms have been visited, three focused on livestock farming and two on tourism services, and both employees and farmers have been interviewed. As farm inhabitants houses are disperse, the distance between those houses and canjiqueira tree stands can vary between fifty meters and approximately one kilometer.

2.2 Vegetation data

2.2.1 Area selection

To select canjiqueira tree stands, we used the software Google Earth (Google, 2024) in order to identify such monodominant stands. In satellite images (LANDSAT) canjiqueira tree stands are characterized by high reflectance areas, suggesting the presence of sandy soils, covered by treelets or shrubs with a greyish-green round canopy. A total amount of 108 spots with those characteristics have been identified in the studied region, all of which prone to flood during inundation season of Miranda and Paraguai rivers.

After the selection, the number of fire events that happened between the years 2000 and 2021 in

selected spots have been counted. Fire scars have been demarcated through the analysis of satellite imagery obtained for path 226/row 73 of Landsat-5 (years 2003-2011), Landsat-7 (2000-2001) and Landsat-8 (2013-2021), which are disponible at United States Geological Survey website (USGS, 2022), and imagery for path 320/ row 91 of Resourcesat-1 (2012), disponible at Brazilian Instituto Nacional de Pesquisas Espaciais website (INPE, 2022). Fire scars analysis was realized through software Qgis 3.12 (Qgis Development Team, 2020) using false-color combination of RGB bands 654, 543 and 765 (Landsat-5, -7, -8) and 421 (Resourcesat-1), which allows the identification of fire events for approximately two weeks after burning (figure 2). After those analysis, 26 canjiqueira tree stands areas, which have been through 1 to 7 fire events between the years 2000 and 2021, were selected (figure 3).

2.2.2 Vegetation sampling

Data has been collected through plot methodology suggested by Damasceno-Junior and Pott (2011). For each of the selected areas, four plots, measuring 25x25 square meters and at least 25 meters apart from each other, have been established, functioning as sampling units of this study. In each plot, all *Byrsonima cydoniifolia* and other woody species' individuals have been counted, tagged and had their diameter at breast height (d.b.h., standardized as 130 cm above ground) for each branch, height, fire scar heigh, water mark since last flood height and total of thin (d.b.h. less than 35 cm) and thick (d.b.h. equal or superior than 35 cm) collected. Fire scars height were considered as an indication of fire intensity at visited plots, and water mark height can be used as a mean of determinate how much time a plot tends to be flooded, as higher marks indicate sites in which flood levels take more time to decrease. The limit between thin and thick branches has been determined during fieldwork due to branches with at least 35 cm d.b.h. were noticeably more robust, less flexible, and more unlikely to break when pushed or pulled. Treelets or shrubs with no branch with d.b.h. over 15 cm were considered regenerants, not being tagged or having their data collected, and only being counted if they were *B. cydoniifolia* individuals. For each plot, also, cattle presence or absence has been noted, being such presence determined by direct observation of not only animals themselves but also their footprints, manure or bones and, if any of these elements were not seem, by herbaceous strata height, being those areas with herbs and bushes over 30 cm tall considered non used as farming sites.

A total amount of 26 areas has been visited (figure 1), three of which have gone through a single fire event during the time length between the years 2000 and 2021, four areas for each of the amounts of 2, 3, 4 and 6 fire events, five areas that have gone through 5 fire events and two areas that have

gone through 7 fire events. Also, three other areas have been discharged due to not fitting the established criteria for the research.

2.2.3 Data analysis

In this study, environmental factors of the plots such as water mark and fire scars height, number of fire events and cattle presence or absence were considered as predictor variables, whereas species richness, adults individuals' density, tree and shrubs mean height and total and mean basal area (mean basal area defined as total basal area/number of branches) were considered as response variables. For canjiqueiras trees, along with aforementioned factors, the number of thin and thick branches has also been considered a response variable, not being analyzed to other species' individuals due to most of them being trees, branching far over 130 cm above ground.

Sampled data have been analyzed through R software (R Core Team, 2021) aiming to find relationships between predictor and response variables. In order to do so, we held three sets of analysis: the entire community (canjiqueira tree and other species), only canjiqueira trees and only other species, aiming to understand each group particularities. Canjiqueira trees' analysis was held with Generalized Linear Models (glm). Other species and community overall were analyzes through Generalized Linear Mixed Models Using Template Model Builder (glmmTMB) through "pscl" package (Jackman, 2020), a inflated zero model, which was necessary due to a considerable number of plots lacking non-canjiqueira tree individuals.

2.3 Ethnobotanic data

2.3.1 Local inhabitants' knowledge

Aiming to estimate local human populations knowledge regarding canjiqueira trees ecology, we held semistructured interviews with people from both sexes and aged over 21 years in local farms and traditional communities of Passo do Lontra and Porto Esperança. Interviews have been realized individually, at places chosen by the participants, and with a single person in each visited house in order to avoid biasing. Sampled people have been selected through snowball technique (Albuquerque et al., 2014).

The interview questions (attached) involved knowledge of local inhabitants over the ecological relationships with abiotic (fire and flood regimes) and biotic (cattle management) factors. Questions regarding socio-economical aspects and use of canjiqueira trees and frugivorous animals that feed

on their fruits will be included in further studies. Interviewed local inhabitants answered questions about their knowledge regarding following aspects of canjiqueira trees: if they are resistant to fire and flood events; if, after a fire event, new branched sprouted from aerial parts and/or roots of damaged canjiqueira trees; if recruitment of new individuals from seeds could be seen after fire events and/or flood season; if the species was undesired at farming areas used for cattle grazing. The sprouting of new branches after flood season was not put in question as those events are not considered to be destructive.

2.3.2 Ethical and legal aspects

As legally determined by Law 13.123/2015 (Brasil, 2015), attended communities were visited prior to the research aiming to explain the methodology and aspects of the research to local inhabitants. Prior consent terms have been signed to community representants after reunions with local inhabitants and representants of local farmers union.

As it is required in research involving human beings and accordingly to resolution 466/2021 (Brasil, 2012), this study has been summited to Ethical Aspects and Research Committee of Federal University of Mato Grosso do Sul, which approved its execution (feedback sheet number 6.093.848). Before being interviewed, each participant has listened to a reading of free and informed consent term, which was spontaneously signed by them. In case of illiterate participant, fingerprints have been collected instead of hand signature and a local inhabitant, not involved with the researchers, signed as testimony.

2.3.3 Data analysis

Previously cited data have been divided in classes accordingly to the inhabitants demographics. Analyzed classes were a) place of residence: traditional communities inhabitants (24) and farms inhabitants (12); b) sex: men (24) and women (12); age: adults (24) and elders (12) and; length of residence: natives (9), residing for less than 10 years (8), residing for 10 to 20 years (12) and residing for over 20 years (7). Inhabitants that have lived in the region since ages below 10 years old were considered natives along with those inhabitants that were born and never moved away from studied location.

Collected data have been analyzed through chi-square tests using R software (R Core Team, 2021) in order to verify if there were any differences regarding knowledge distribution among local populations.

3. Results

3.1 Vegetation study

A total of 1119 individuals were sampled, representing 13 trees and shrubs species, all but one of them native to the region (table 1). For each plot, the number of species found varied between 1 and 8, and the number of sampled individuals, between 2 and 28.

Water mark varied between 16 and 115 centimeters above the ground level, with an average height of 51.8 centimeters and being visible in 489 (43.7%) individuals. Fire marks varied between 16 and 2000 centimeters above the ground level (being the taller ones bared by *Tabebuia aurea* individuals), with an average height of 226.3 centimeters and were present on 516 (46.1%) individuals. *B. cydoniifolia* average heigh was 3.71 meters, being the shortest individual 1.2 meter and the tallest, 8 meters height.

Species richness and individuals' density showed no relationship with number of fire events nor fire intensity. However, flood intensity was inversely proportional to individuals' density ($z=-3.064$, $p=0.00218$. Table 2), whereas cattle presence was directly proportional to species richness ($z=2.09$, $p=0.0366$. Table 2), as plots where cattle grazed bared a maximum amount of 7 tree or shrub species and plots without cattle grazing presented a maximum amount of 4 species (figure 4). Fire intensity was directly proportional to both community's total basal area ($z=3.247$, $p=0.00117$. Table 2) and average height ($z=3.16$, $p=0.00158$. Table 2) and non-canjiqueira tree species total basal area ($z=2.697$, $p=0.00701$. Table 2), average basal area ($z=2.596$, $p=0.00938$. Table 2) and average height ($z=2.824$, $p=0.00475$. Table 2), as those values increased with the number of fire events per plot (figures 5a and 5b).

Regarding *B. cydoniifolia* population, 894 adult individuals have been sampled, 45 (5.03%) of which had their aerial parts dead due to previous fire events, having its bark and wood carbonized, and 10 of those individuals presented resprouts emerging from its underground part. Canjiqueira tree density has not been affected by neither fire events or intensity (table 2). Flood intensity, however, was inversely proportional to population density, which decreased as average water mark increases ($z=-3.533$, $p=0.000411$. Table 2). Even though most of the plots had average water mark of approximately 50 centimeters above ground level, there is a decrease in density at higher flood levels, specially at areas with an average water mark over 70 centimeters (figure 6)

The thickness of *B. cydoniifolia* branches was related to the number of fire events, as plots that were affected by more fire events presented a lower number of thick branches (d.b.h $\geq$ centimeters or basal area $\geq$ 97.5 centimeters) ($z=-2.343$, $p=0.0191$. Table 2), as plots that have been through 1

to 3 fire events had the highest number of thick branches and plots that have been through 4 to 7 fire events had a continuous decrease in this amount (figure 7). Cattle presence had a similar effect than fire, as plots where cattle grazed presented both a lower total ($z=-2.028$, $p=0.0426$. Table 2) and average ($z=-2.926$, $p=0.00344$. Table 2) basal area of branches (figure 8) and a lower number of thick branches ($z=-2.3$, $p=0.0214$. Table 2, figure 9).

3.2 Ethnobotanic study

Fire resistance has been cited by 15 (41.7%) participants. Of those, 10 (27.8%) said that the plant is able to resprout from its underground parts (roots), 2 (5.6%) said that resprouting could occur from both underground and aerial parts and 3 (8.3%) said that resprouting occurs from aerial parts only. Sixteen (44.5%) participants said that the plant is not fire resistant. It is important to highlight, though, that only 2 (5.6%) of those participants did not mention any form of resprouting after fire events, whereas 12 (33.3%) of them said that there is resprouting since underground systems, as roots are protected from flames by the soil, and a single participant (2.8%) said to not know any type of resprouting after fire. Five (13.8%) participants alleged not knowing any form of fire resistance or resprouting. Besides resprouting, seed recruitment after fire events has been mentioned by 3 (8.3%) participants.

Canjiqueira trees resistance to flooding was cited by 33 participants (91.7%) and mentioned as unknown by 3 (8.3%). Seventeen (47.2%) mentioned that the species can endure the average length of flood season (4 months), 8 (22.2%) participants mentioned resistance for about half a year of flooding, a single participant (2.8%) mentioned eight months of resistance and 3 (8.3%) participants mentioned resistance to even longer periods of flood, from one to four years; the remaining 7 (19.5%) participants were unaware of how long canjiqueira trees can resist flood. Also, 9 (25%) participants mentioned that adult individuals could even survive after being totally submerged during more intense floods, although only for a short, non-specified, length of time. Recruitment of seedlings right after flooding season was mentioned by 29 (80.6%) participants, whereas 4 (11.1%) participants claimed that there was no relationship between flood and recruitment, and 3 (8.3%) participants were unaware of such relationship.

The relationship between canjiqueira trees and cattle farming was considered to be negative by 13 (36.1%) participants, which claimed that the treelets and shrubs occupy areas that could be used for pasture and make it difficult to conduct livestock to grazing areas. Nineteen (52.8%) participants, on the other hand, claimed that canjiqueira tree stands are good places for cattle farming, as the shrubs canopy can be used as shelter during most sunny times and leaves are eaten by oxen in times when herbs and bushes are scarce. Four (11.1%) participants were unaware of such relationships.

The analysis of the answers regarding participants classes have demonstrated that local knowledge over canjiqueira trees ecology are, generally, shared by all inhabitants of studied region (table 3). There were differences in answers of farms and traditional communities' (TC) inhabitants regarding two aspects of canjiqueira trees ecology: firstly, sprouting from aerial parts after fire events (χ^2=6.3168, p=0.03748. Table 3), as TC inhabitants answered: no (50%), yes (25%) and unknown (25%) and farms' inhabitants answered: no (91.7%) and unknown (8.3%) (figure 10); secondly, the relationship of canjiqueira tree stands with cattle farming (χ^2=7.2843, p=0.008996. Table 3), viewed mostly positively by TC inhabitants (negative 20.83%, positive 79.17%) and mostly negatively by farms' inhabitants (negative 66.7%, positive 33.3%) (Table 3, figure 11). Also, there have been differences of knowledge of men and women regarding the resistance of canjiqueira trees to both fire (χ^2=6.1312, p=0.04198. Table 3) and flood (χ^2=6.5455, p=0.03148. Table 3) events, as women answered yes (25%), no (41.7%) and unknown (33.3%) for the resistance to fire and yes (75%) and unknown (25%) to resistance to flood and men answering yes (50%), no (45.83%) and unknown (4.17%) to resistance to fire and yes (100%) to resistance to flood (figure 12).

4. Discussion

Our initial hypothesis that *B. cydoniifolia* would react negatively to flooding has been confirmed by the decrease in individual density by plot as water mark levels, which are directly related to the length of the flooding season, increased (figure 6). However, it can be noted that flooding is a determinant factor to the occurrence of canjiqueira tree stands, as only 5.76% plots lacked visible water marks. This fact, however, is also not an indication that those areas are not floodable, as factors such as rapid floods, low water level and most noticeable fire marks on the bark of plants can prejudice the visualization or formation of water marks. Also, studied site is located adjacent to the basin of an alluvial sinuous river, at which the deposition of sandy soils at floodable areas is very common (Assine et al., 2015). As sandy soils are the most suitable substrate for the occurrence of canjiqueira trees (Damasceno-Junior et al., 2021a), flooding also contributes to canjiqueira tree stands occurrence and maintenance as this phenomenon deposits adequate soils for the species development.

Fire and cattle, on the other hand, are determinant factors to the architecture of *B. cydoniifolia* individuals, as obtained data demonstrates an inverse relationship between the number of fire events and basal area of branches, with a decrease in the number of branches with d.b.h. ≥ 35 centimeters (basal area ≥ 97.5 centimeters) as the number of fire events per plot increased; and the same effect being observed in plots with cattle presence when compared to those when there was no sign of cattle grazing. As *B. cydoniifolia* population is not affected by number of fire events or fire intensity, we

can conclude that this species is part of the persistence niche (Bond and Migley, 2001), which is occupied by plant species that prioritize resprouting instead of recruitment as a way of resistance to disturbance events take affects the environment they occupy. This strategy can be advantageous as other species that rely solely on seed recruitment are more susceptible to be killed during their juvenile stages. Based on vegetation data and reports from local inhabitants, we can affirm that *B. cydoniifolia* relies on the resprouting of buds from underground systems, which are mostly associated to the presence of xylopodia and take advantage of soils' low heat conductivity as a mechanism of defense from fire, surviving fires that kill aerial parts (Clarke et al., 2012). Furthermore, canjiqueira trees lack a thick bark, which is the most common form of fire defense of buds from aerial parts found in woody plants in savannas (Lawes et al., 2011a; Lawes et al., 2011b; Chiminazzo et al., 2021) and is not a tall plant compared to other Cerrado species that uses height as a strategy to keep buds and other parts away from flames during fire events that use to happen in this biome (Rodriguez-Cubillo, Pilon and Durigan, 2021). Resprouting from underground systems is reported from other species of *Byrsonima*, although resprouting from aerial parts is way more common for this genus (Medeiros and Miranda, 2008; Souchie et al., 2017), which led us to the conclusion that *B. cydoniifolia* strategy of relying on underground systems is a characteristic of this species.

Branches thickness is a noticeable result of the plant's adaptation to fire, as thicker branches (d.b.h. ≥ 35) are more common in plots with a lesser number of fire events. The lack of such kind of disturbance allows the branches to live for a longer period of time and increase its diameter. On the other hand, areas more constantly affected by fire will face a major destruction of aerial parts, resulting in a more constant resprout of branches, which will be, consequently, thinner. Also, interviewed local inhabitants answered that resprouting from the roots were a recurring event after fire, which can also be a folk knowledge evidence to the plants' strategy of concentrating resources in its undergrounding systems and, therefore, highlighting the species as part of persistence niche.

Cattle influences plant architecture as its presence is associated with the mechanical removal of trees and shrubs undesired at pasture areas. Some of the techniques employed by local farmers to remove those plants include chopping down aerial parts right before flood season, as it was mentioned by 8.3% of the interviewed people, and the technique known as "correntão" (Portuguese for "huge chain") (Pott and Pott, 1994; Berseli et al., 2019. Also mentioned by 5.5% of interviewed people), which consists in attaching a metal chain to two or more tractors or bulldozers and driving them into vegetation stands in order to tearing down trees and shrubs. Also grazing, cited in 36.1% interviews, is also one of the possible factors that influence branches diameter, as cattle grazing young leaves in seasons when lacks pasture may lead to destruction of buds and cracking of branches, therefore damaging plants' growth.

Sampled canjiqueira trees' height was not influenced by none of analyzed variables, which led

us to conclude that, even though it is not considered a tall species when compared to other woody plants that occur in the same areas such as *T. aurea* and *Vochysia divergens*, *B. cydoniifolia* prioritizes rapid growth, as individuals of different plots had the same size despite number of fire events and cattle presence or absence per plot. In other words, both plants that faced more and the ones that have been through less disturbance events tend to quickly grow to its maximum height, achieving the same height levels. This strategy of quick growth is adopted by several species that occur in areas prone to fire events (Archibald and Bond, 2003; Rodriguez-Cubillo, Pilon and Durigan, 2021) and can be also associated with the production of multiple branches when the plant is shorter, which also difficult the access of herbivore to leaves and buds (Archibald and Bond, 2003). Noticeably, as we could observe during our data sampling, canjiqueira trees also tend to sprout several branches, specially the shorter ones.

Fire intensity was a determinant factor to total basal area and average height of both the entire community and non-canjiqueira tree species, both of them increasing in plots with taller fire marks. This is related to the fact that plots with *T. aurea* individuals were the ones where taller fire marks have been spotted. Those trees average height is at least three times taller and have thicker stems than canjiqueira trees and are very resistant to fire events (Bueno et al., 2014; Manrique-Pineda et al., 2021). Also, *T. aurea* individuals are not only commonly found at canjiqueira tree stands but is also common for both species form monodominant stands close to each other (Damasceno-Junior et al., 2021b), as transition zones between both stands, where *B. cydoniifolia* and *T. aurea* density was the same, could been directly observed during our field trips. Average basal area was positively influenced by fire only for non-canjiqueira tree species, which can be explained by the fact that canjiqueira trees usually have more branches and the other species are single stemmed.

Cattle presence positively influences woody species richness at sampled plots. Although several studies conducted in other biomes indicate that cattle and other livestock presence is commonly associated with lower species richness at non-herbaceous strata (Tracy & Sanderson, 2000; Pykälä, 2004; Al-Rowaily et al., 2015; Schulz et al., 2019), our results can be linked to two factors. Firstly, herbs are shorter in areas grazed by cattle, which makes possible for seeds from trees and shrubs germinate and develop. As most pastures are composed of native species from the region, having little to no human interference rather than occasional removal of trees and shrubs, we can assume that the soil is plentiful of native woody plants, which germinate when light conditions after grazing are favorable. Secondly, the dispersion of propagules such as seeds or fruits through endozoochoric or epizoochoric vias by cattle is frequent in pasture areas. Choung et al. (2016) found 1342 seedlings belonging to 30 different plant species in cattle excrements and 4108 seed belonging to 19 species on cattle skin and fur during a study conducted in Californian pastures; Bartuszevige and Endress (2008), during a study of oxen and deer excrement conducted at pastures and forests in Oregon found

seeds belonging to 52 plant species and concluded that the ones found amongst oxen manure were more akin to germinate; Schaedler et al. (2021) suggested one-week quarantine after moving cattle from one pasture to other in order to avoid the establishment of seeds from potentially invasive species that could be present in cattle feces. Although studies regarding seeds dispersal by bovine cattle emphasizes herbs, we can not deny the possibility of tree and shrub species by those animals. Sampled plots contain species that bear berries and fleshy drupes such as not only *B. cydoniifolia* itself but also *Andira inermis*, *Couepia uiti*, *Eugenia florida* and *Psidium guineense*, which can be consumed deliberately or accidentally by cattle, besides some species with winged seeds such as *Handroanthus heptaphyllus*, *Tabebuia aurea* and *Vochysia divergens*, which may fall over animals skin or fur, or even at clothes worn by ranchers, and be carried away. It is important to highlight that, although canjiqueira tree stands might have a low richness at tree and shrub strata, as it has been demonstrated by this very study and, previously, by Damasceno-Junior et al. (2021b), there is no evidence that such low richness is related to cattle presence, as it has been demonstrated by other studies as a pattern at other vegetation areas.

In which concerns knowledge of local human populations about the relationship between canjiqueira trees and fire, flood and cattle, we came into uniformity regarding what people from traditional communities and farms know. Concerning the plant responses to fire events, the only noticeable difference was the mention of resprouting from aerial parts after fire events, which was mentioned only by 6 inhabitants of traditional communities (25%) and none of farms inhabitants. As the second group is the one that is more familiar with canjiqueira trees, the lack of such knowledge indicates that TC inhabitants are likely to have mentioned such type of resprouting based on observations of another plant species or during conversation with other people, which can lead to twisted conclusions. Also, TC inhabitants more commonly mentioned not knowing any kind of resprouting for canjiqueira trees (25%) than farms inhabitants (8,3%), which can be considered an evidence of the less frequent contact they have with those trees. It is noticeable, however, that the majority of TC inhabitants mentioned that the plant does not resprout from the aerial part, whereas 58.33% of them and 75% of farm inhabitants mentioned resprouting from underground systems, which lead us to conclude that, even resprouting from aerial parts may occur, it is a rarer phenomenon.

Farms and TC inhabitants also diverged on their opinions about the relationships between cattle management and canjiqueira trees, as 79.17% TC inhabitants said that the tree stands were positive to cattle farming but only 33.3% of farm inhabitants had the same opinion. As the majority of farms inhabitants works with cattle ranching and farming, it was expected that the predominant view over the species would be negative, as the plant is considered to be “pasture invader” due to its size, as the low-heighted canopy can difficult herbs growth bellow them and make it hard to ranchers to

conduct the cattle from one pasture to another, as it was both mentioned by participants and is registered in literature (Pott and Pott, 1994; Junk and Cunha, 2012; Berseli et al., 2019). On the other hand, people from both TC and farms that had a more positive view regarding the canjiqueira trees/cattle relationship mentioned that the plant leaves and sprouts are eaten by cattle during harsh times when there is lack of pasture and, mostly, the tree canopy provides shade to the animals during hotter time periods, specially at pasture areas where there are no taller trees such as cambarás (*V. divergens*) or piúvas (*H. impetiginosus*).

The only differences regarding men and women knowledge were related to canjiqueira trees resistance to fire and flood events. For both aspects, men knowledge has been more heterogeneous, demonstrating to be more aware of such relationships than women. On flood resistance, no participant, man or woman, mentioned that canjiqueira trees did not tolerate flooding events, and only 3 (25%) women mentioned to be unaware if the plants resisted or not those events, which can lead us to the conclusion that there are no divergences regarding this ecological aspect of the plant, only eventual lack of knowledge. On fire resistance, woman showed lack of knowledge and mentioned that it did occur or not in equal proportions, whereas only one man was unaware of this aspects and the others mentioned that it occurred or not also in equal proportions. Noticeably, it is important to highlight that the local inhabitants concept of "not resisting fire" is appliable only for the destruction of aerial parts, as only two of the participants that said canjiqueira trees did not resist fire mentioned no resprouting from underground systems and one was unaware of resprouting, whereas the others mentioned resprouting. Apart from fire and flood resistance, all other questions had not different answers from both men and women, which lead us to the conclusion that knowledge over ecological aspects of *B. cydoniifolia* are commonly shared disregarding a person's sex. Bortolotto et al. (2015) also found similar results in a research involving knowledge over edible plants within traditional communities by Paraguay river, as there has been not spotted any differences of men and women knowledge over those plants and their uses, which lead us to the conclusion that, at Pantanal communities, knowledge is not likely to be retained by a particular group. Other fact that also strengths this conclusion is that there has not been spotted any difference between adults and elder nor between the inhabitants despite their length of living at the region. This way, knowledge over canjiqueira trees ecology is constantly being transmitted between local inhabitants, which indicates people living at studied sites interact frequently with those plants, leading the knowledge of their aspects to be useful and observable during local daily life. The constant flow of people between different places of Pantanal, constantly mentioned by local inhabitants and caused by many factors (work on different farms, marrying a person from a different community, harsh environmental conditions, etc.), also facilitates the refreshment of such knowledge, as canjiqueira tree stands are distributed throughout all the subregions of Pantanal wetlands (Damasceno-Junior et al., 2021b). In

each case, even if factors as age and length of living use to positively influence popular knowledge (Costa et al., 2017; Miguéis et al., 2019; Mota, Lauer-Leite and Novais, 2021), some cases, such as observed here and Wayland and Walker (2014), demonstrate the variability of dynamics between human communities, not only internally but also regarding their relationships to the environment they occupy.

Results found during the ethnobotanical study were consistent with the ones we found at vegetation study as it was previously expected. Resprouting after fire events, mentioned by most of the local inhabitants, has also been indicated by the highest number of thin branches in plots that faced more fire events. Also, resistance to flood, which was nearly unanimous among participants, can be confirmed by the average water mark found in the majority of plots, which indicates that, even if canjiqueira trees tend to not occupy areas where flood is intense, they do survive normal length flood seasons and depends on flooding to form monodominant stands, although it was not possible to confirm for how long the plants can survive during unusually long flood periods, as no areas with those characteristics where found and the research length would not permit such observations. Other fact that was mentioned by local inhabitants and could not be measured or observed during our research period was the recruitment of seedlings after flood season. This can be explained by the fact that the studied sites had been through a long period of drought, during which canjiqueira trees did not blossom between the years 2019 and 2022 (as observed by both researchers and local inhabitants), flowering only during springtime of 2023, when the data collection was already being concluded. Consequently, the youngest individuals of *B. cydoniifolia* were the ones that germinated at least some years before our studies have started, which lead to no conclusion over these aspects of the specie's life cycle.

5. Conclusions

This study over vegetation aspects and knowledge of local human populations showed that canjiqueira tree stands are influenced not only by natural factors of Pantanal wetland, but also shaped by human activity at this region: even though flooding is no related to human presence at Pantanal, cattle farming and, in most cases, fire events are directly related to humans, and the three factors interfere with different aspects of canjiqueira trees and their monodominant stands phytosociology. Also, this assemblage of different elements having different influences over those stands can be added to the set of evidences of Pantanal landscapes being the result of a mosaic of factor, biotic and abiotic, anthropogenic and natural.

It is also important to point out that, even though it is not common, ecological and ethnobiological studies can be mutually contributive and reinforce each other, as local human

populations empirical knowledge of surrounding environments can be verified through analysis of sampled data and aid the comprehension of how a studied site's natural factors are related to each other. Also, empirical knowledge can be a strong allied to science not only as it provides hypothesis to be tested, but also ideas for future experiments and researches.

Finally, it is important to state that Pantanal wetlands are not a wild environment, which mankind must not interfere, but a combination of vegetation stands that, more or less evidently, are molded by a combination of both natural elements and knowledge, practices and management of human populations that have occupied the region for over decades or centuries and, therefore, it can not be studied without considering those human agents long-termed presence.

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7. Conflicts of interest

The authors declare they have no conflict of interests that could have influenced this research.

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9. Attachments

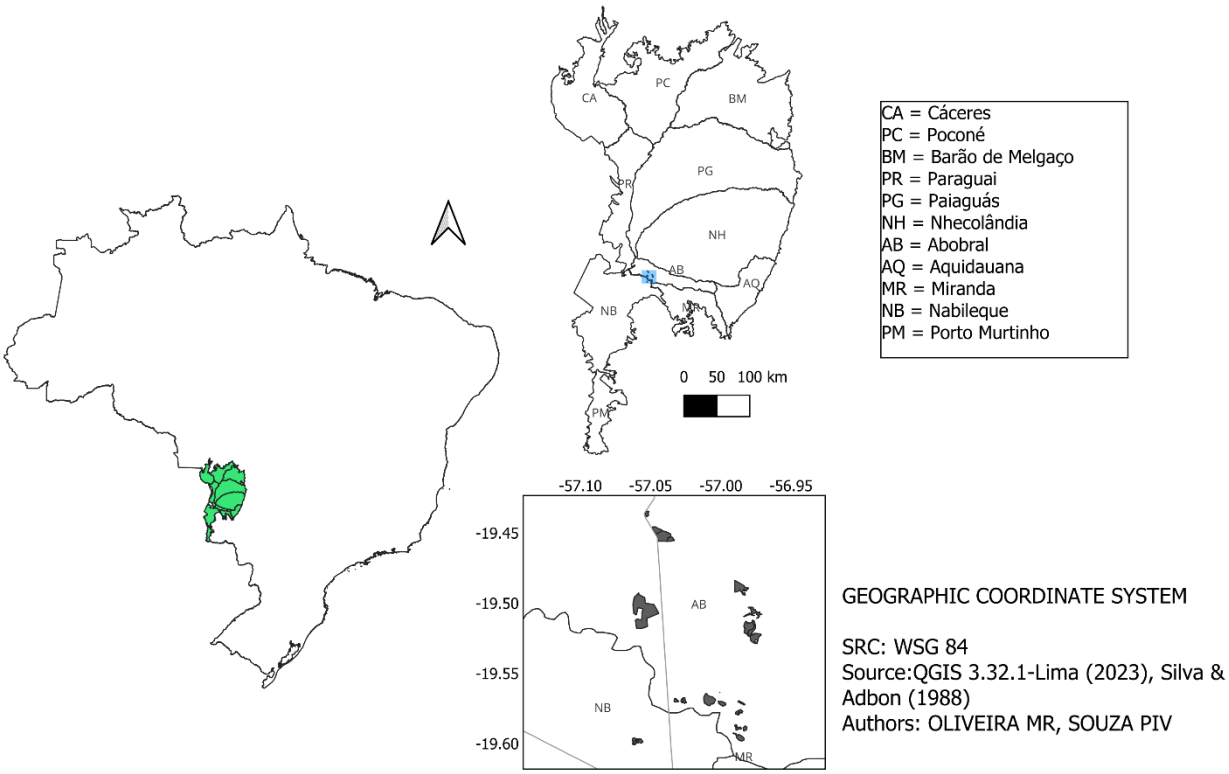


Figure 1. Brazilian map, with Pantanal and its subdivisions. Estrada Parque Pantanal is highlighted, and the canjiqueira tree stands are colored in dark grey.

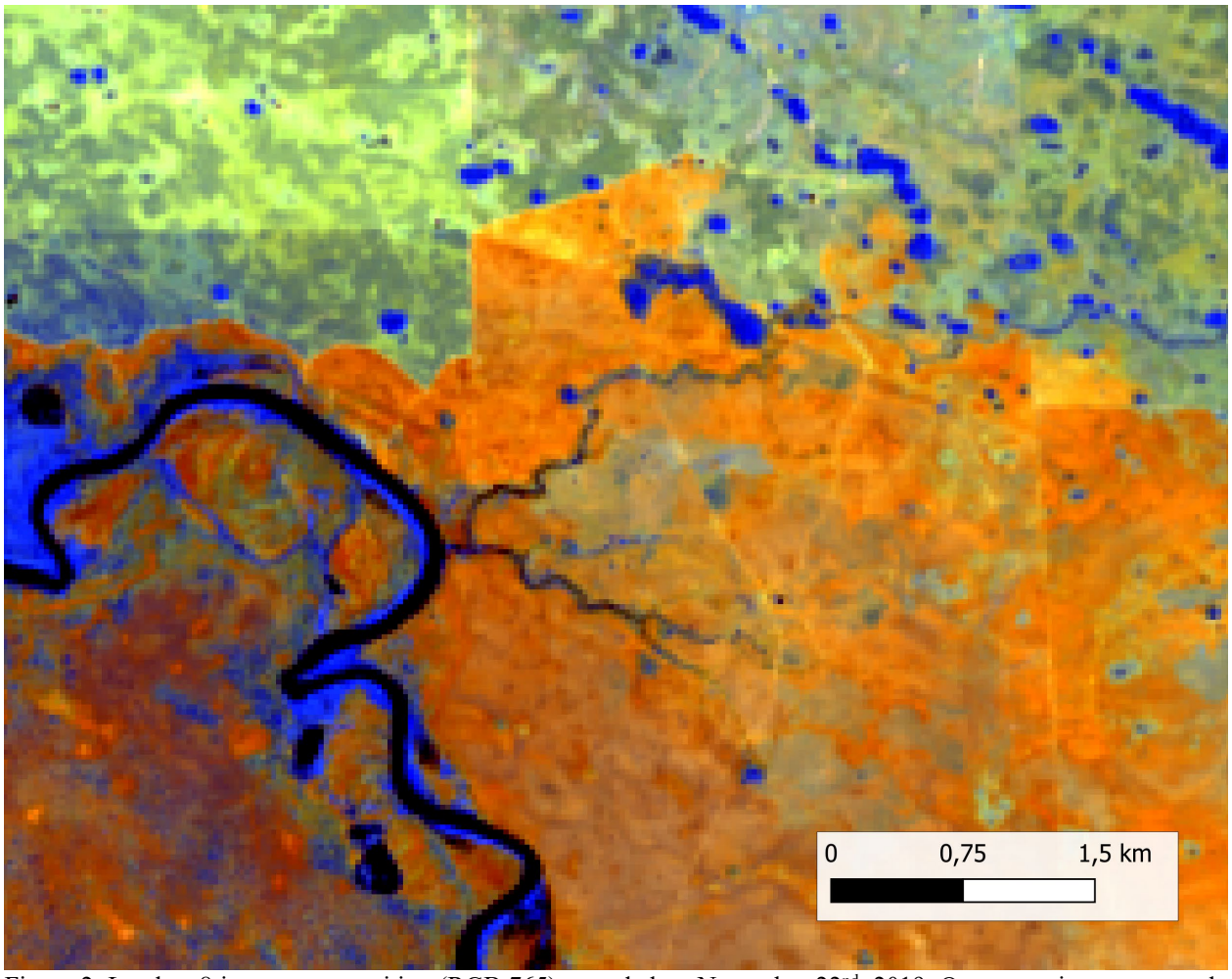


Figure 2. Landsat-8 images composition (RGB 765) recorded on November 22nd, 2019. Orange region corresponds to fire scars in a canjiqueira tree stand area on the shore of Miranda River (Corumbá – MS) (19.582493 S, 56.982942 W)

Figure 3. Canjiqueira tree stand at São Miguel Farm (19.600332 S, 57.061338 W)

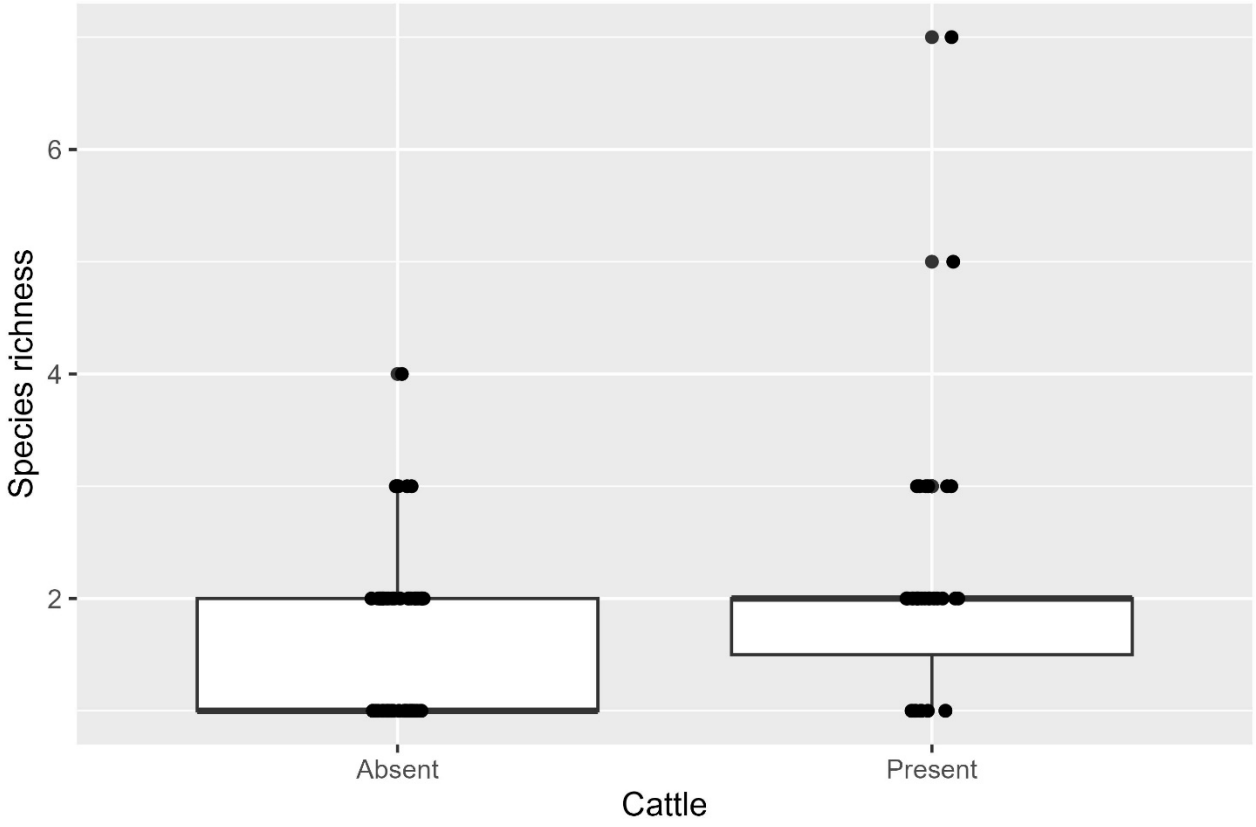


Figure 4. Relationship between cattle presence or absence and woody plant species richness found at studied plots.

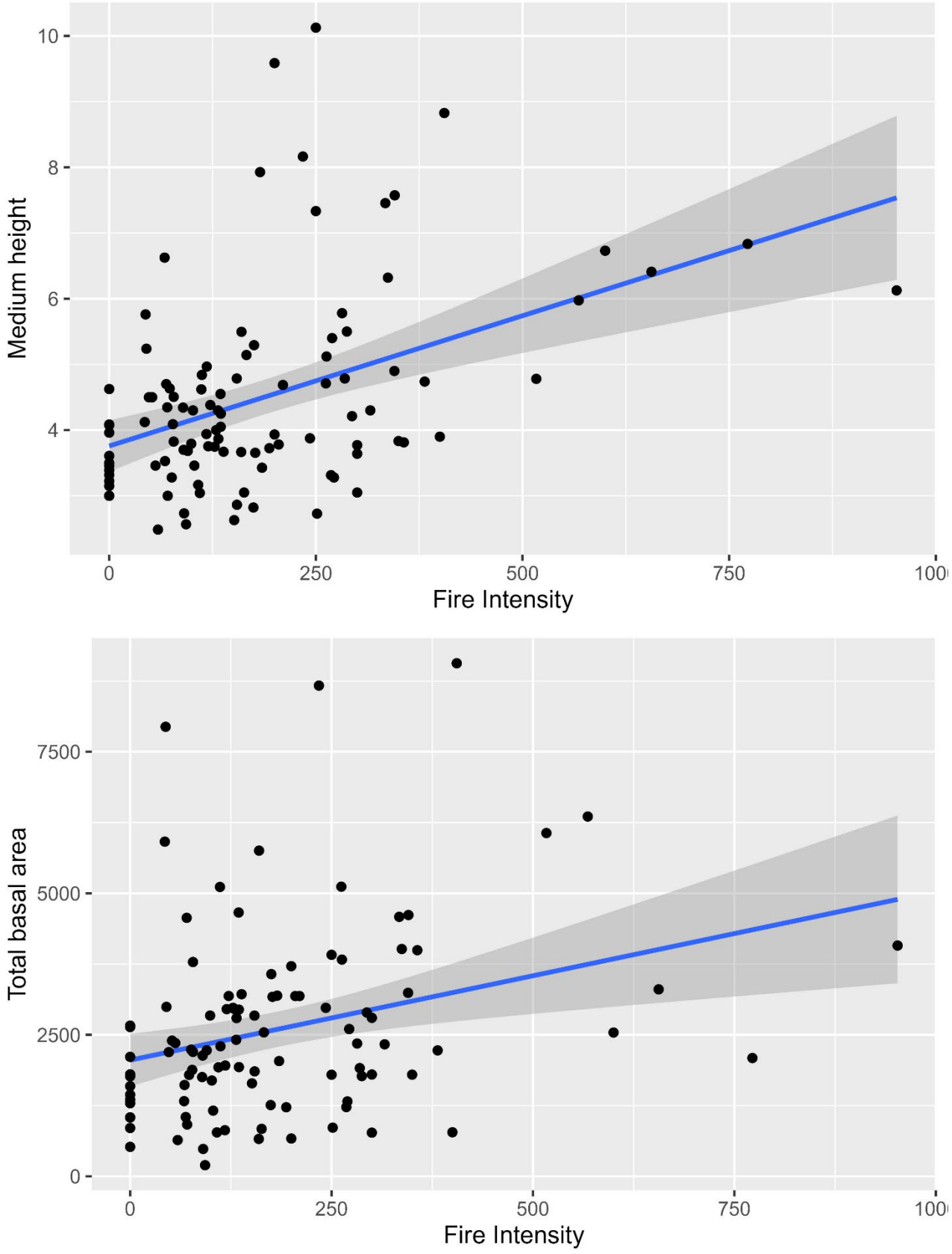
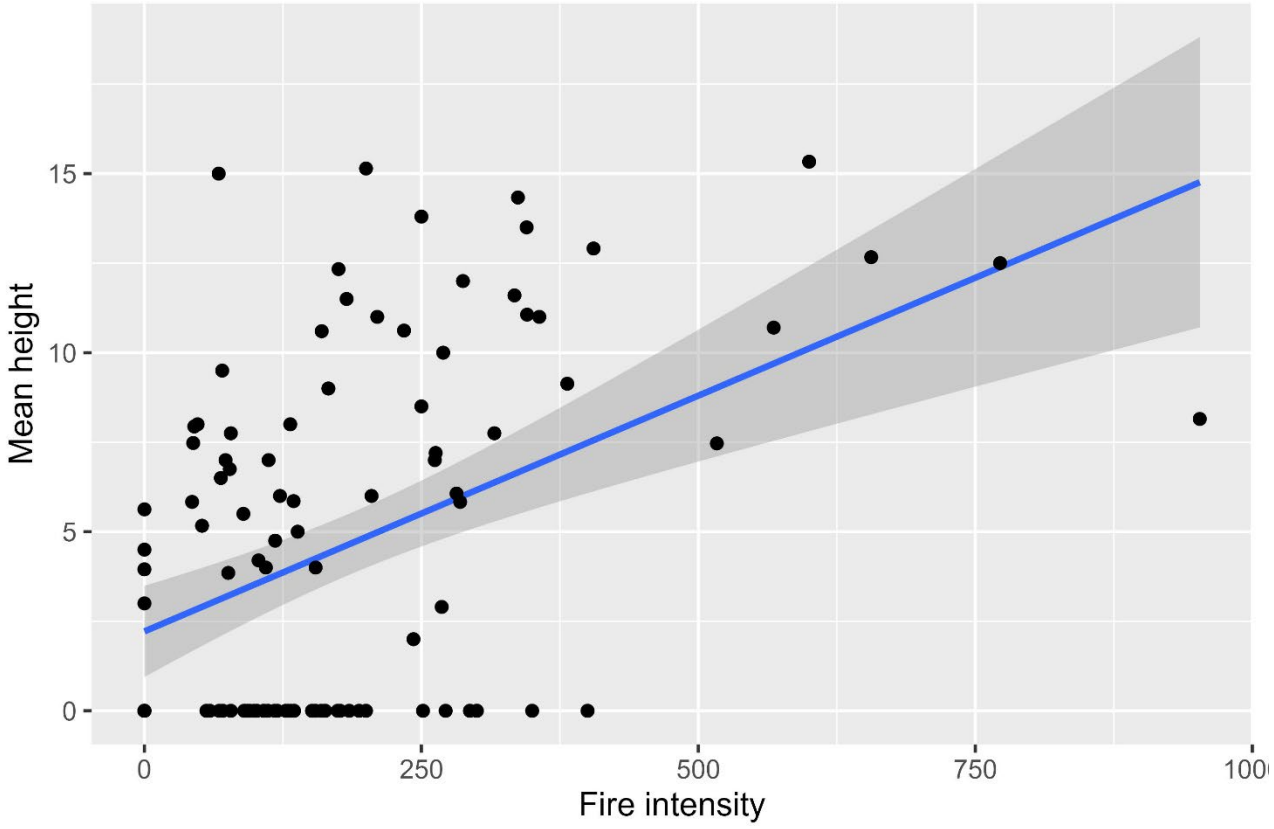
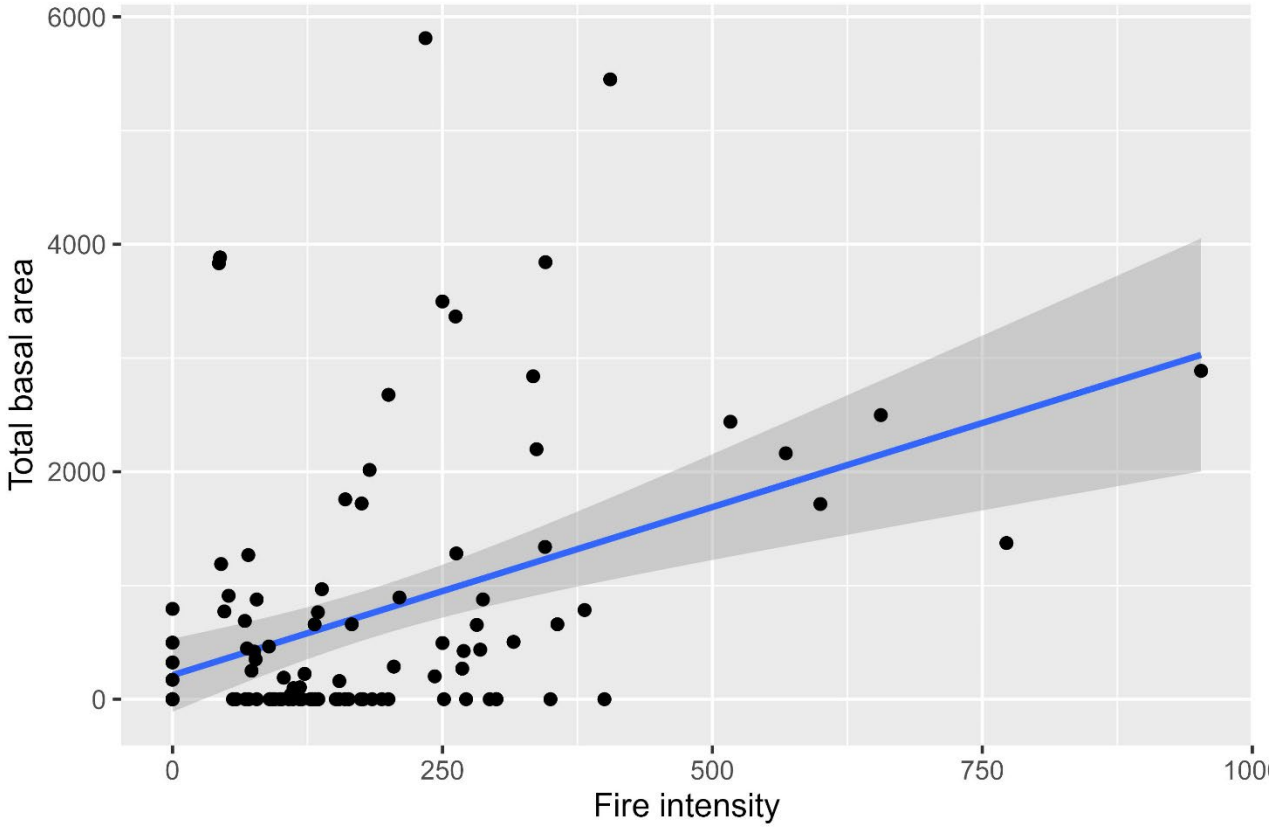


Figure 5a. Plant community average height and total basal area relative to fire intensity per plot


Mean height
15
10
5
0
0
250
500
750
100
Fire intensity


Total basal area
6000
4000
2000
0
0
250
500
750
100
Fire intensity

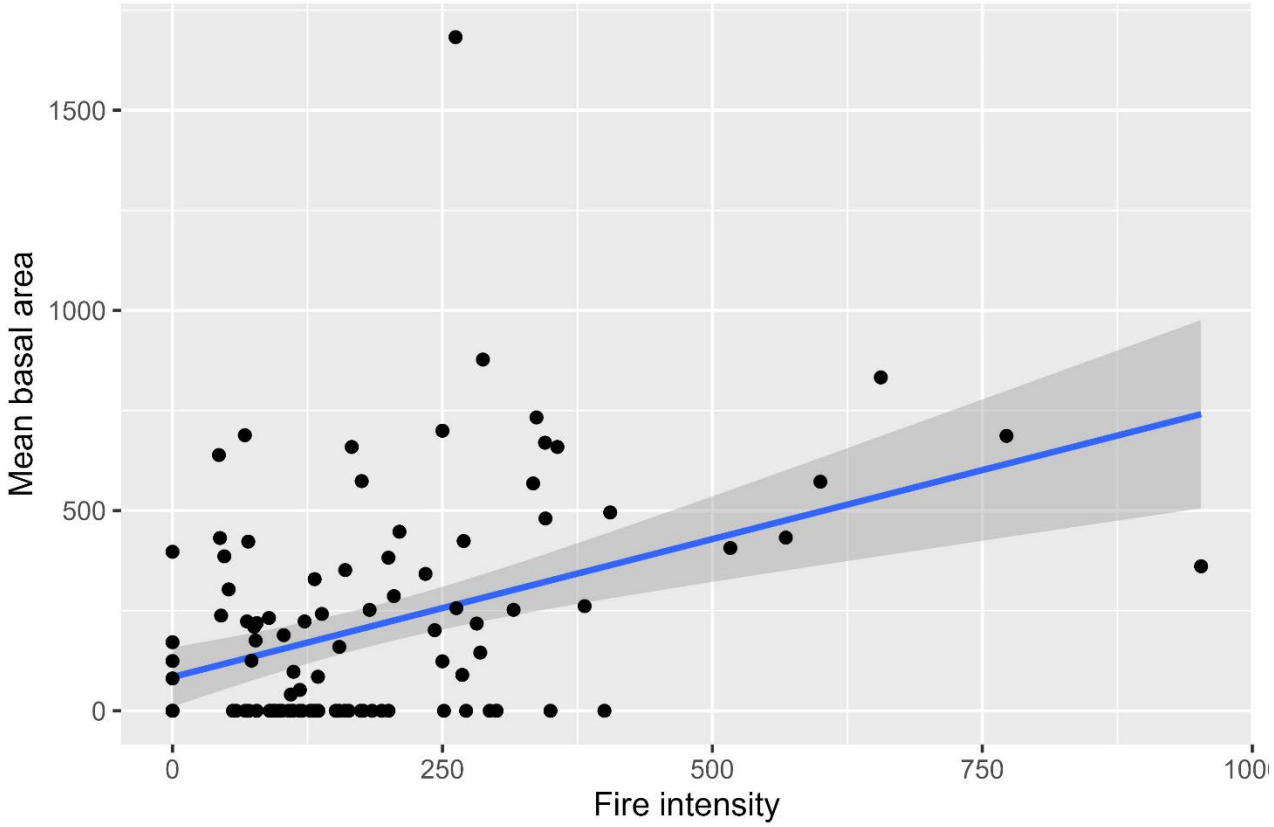


Figure 5b. Non-canjiqueira plants average height and total and average basal areas relative to fire intensity per plot.

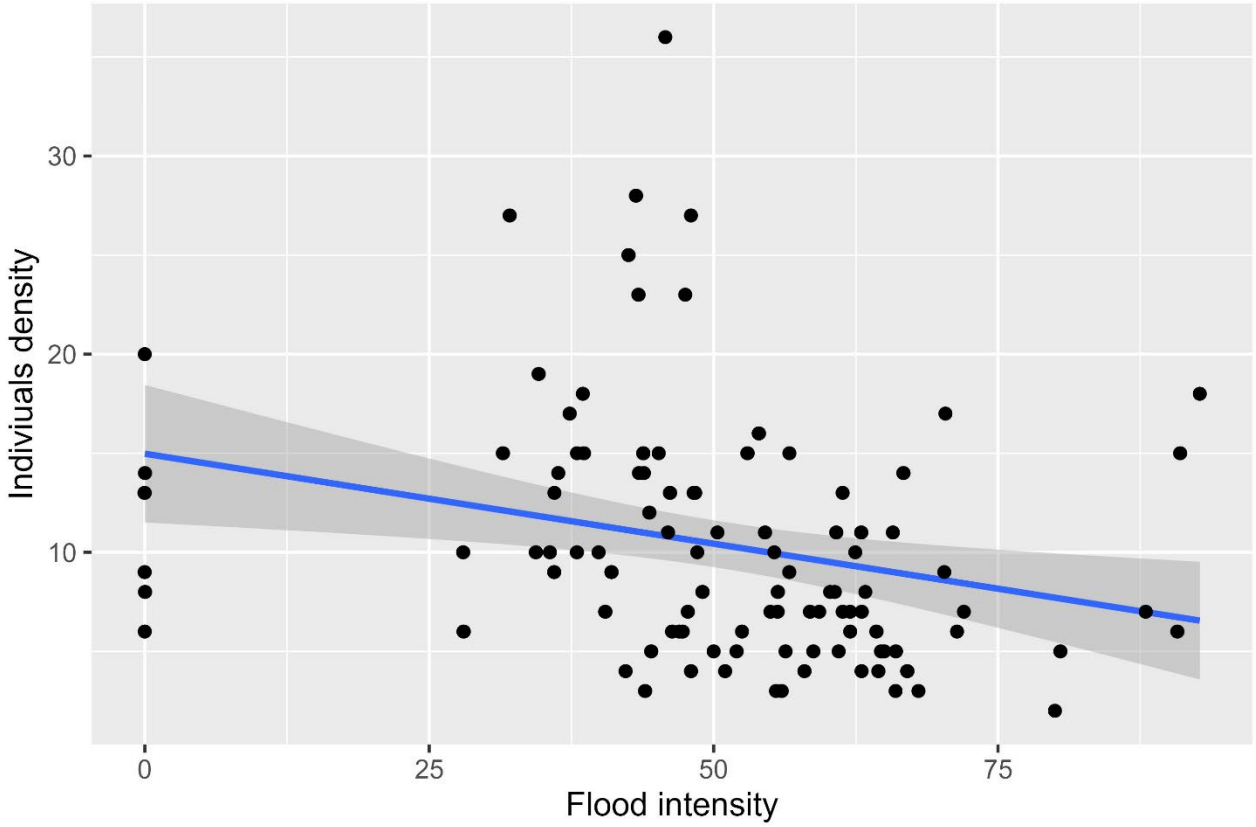


Figure 6. Relationship between *B. cydoniifolia* adult individuals density and average flood intensity by plot.

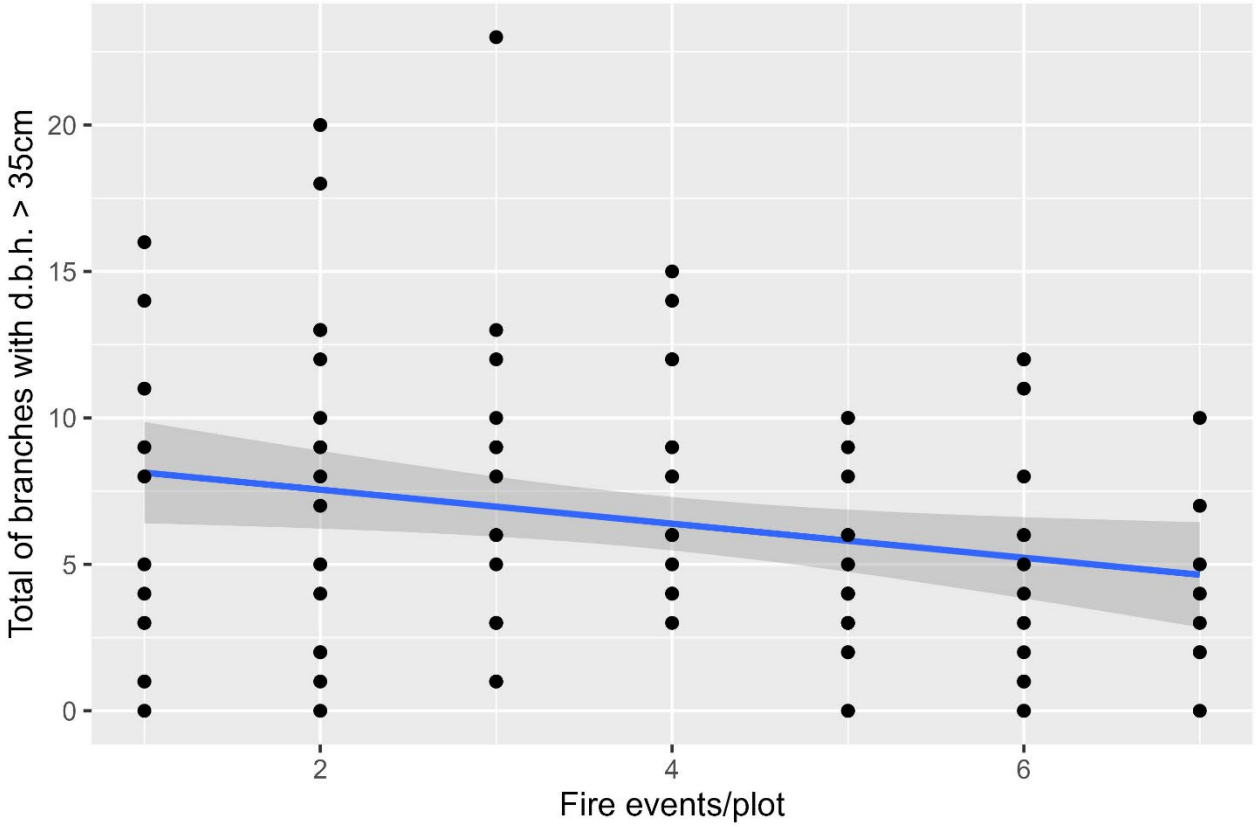


Figure 7. Relationship between the number of branches with d.b.h. > 35 centimeters and the number of fire events/year by plot.

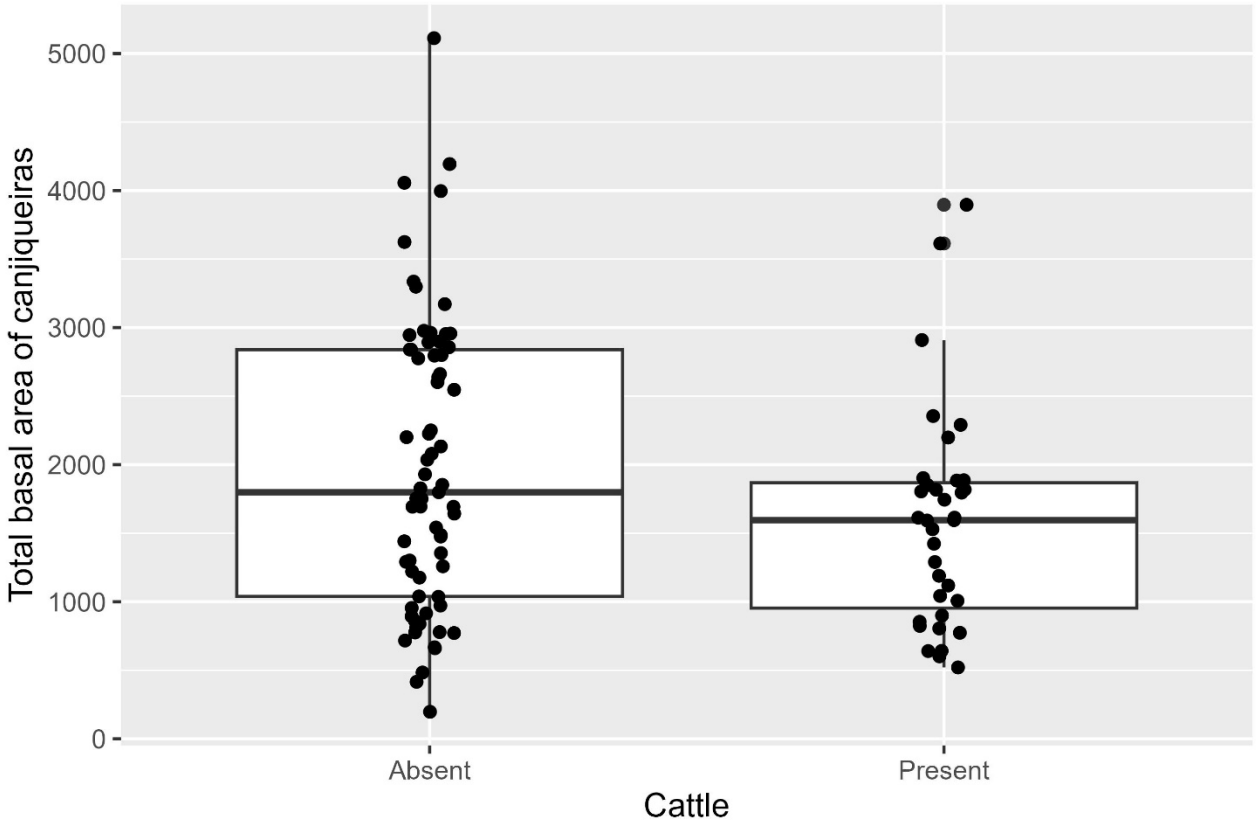


Figure 8. Relationship between cattle presence or absence and total basal area of branches per plot.

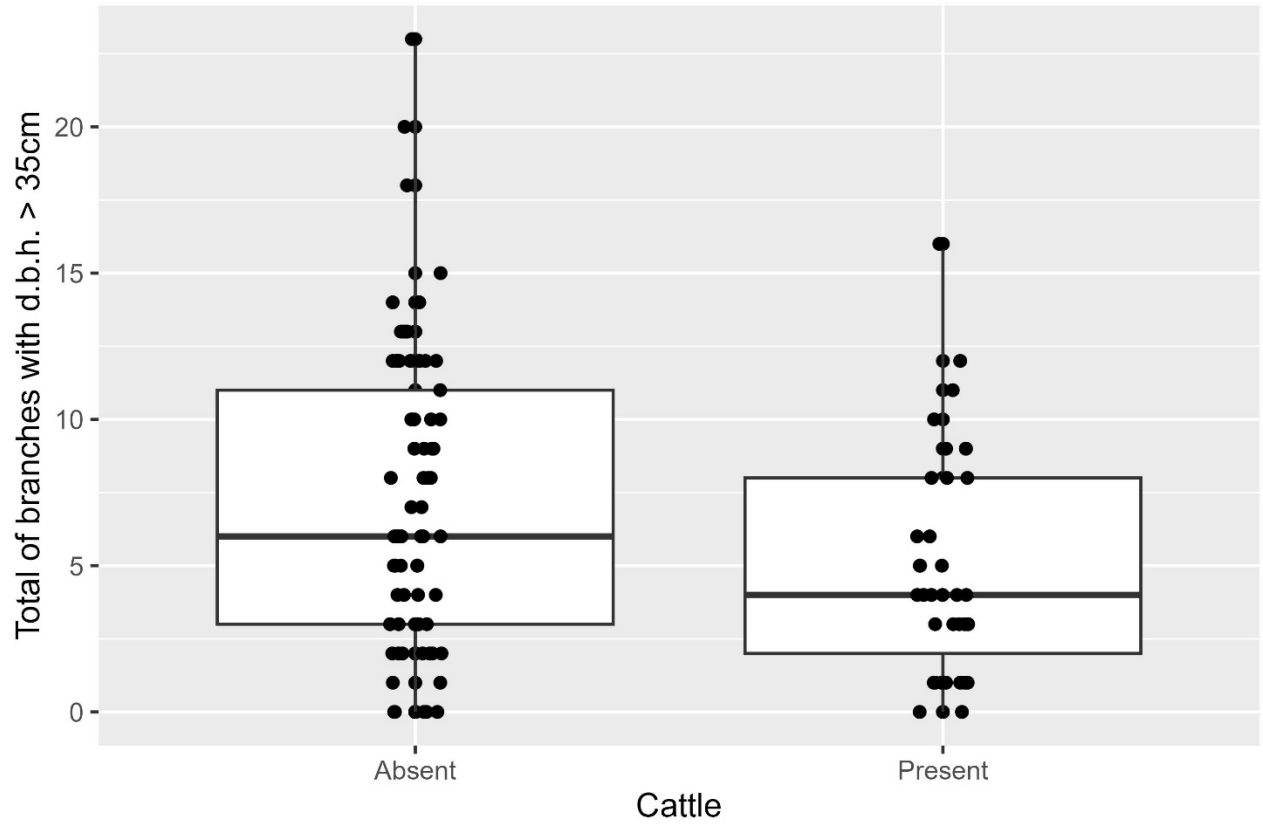


Figure 9. Relationship between cattle presence or absence and number of branches with a d.b.h. > 35 centimeters.

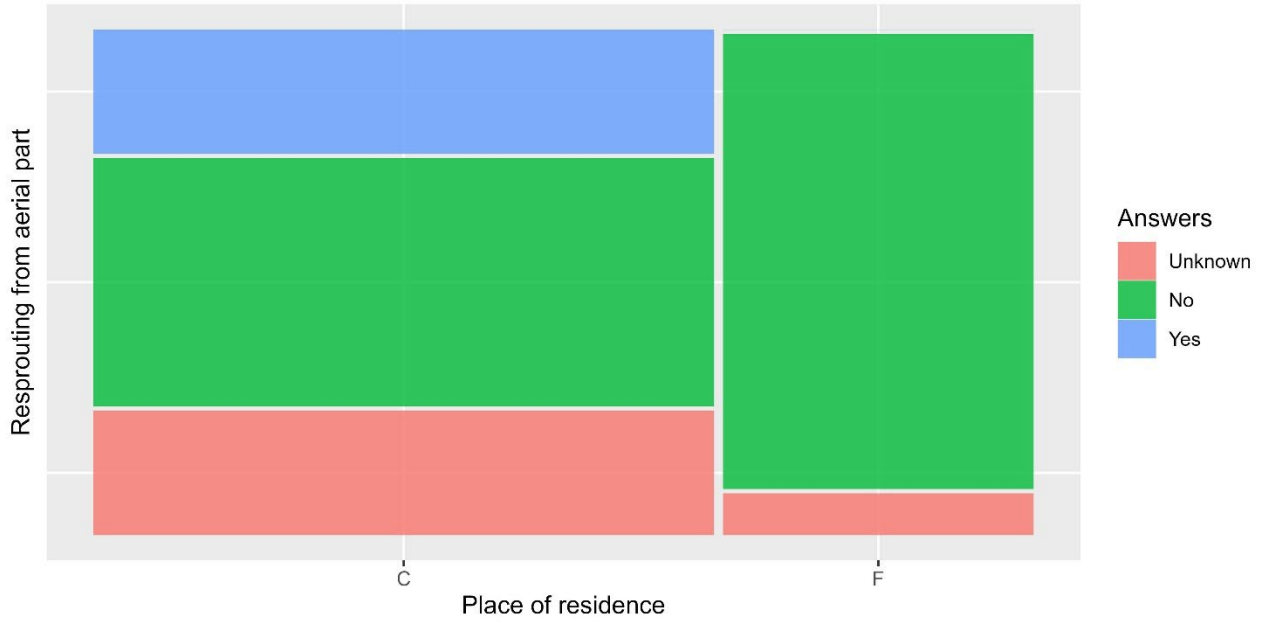


Figure 10. Answers of local communities (C) and farms (F) inhabitants when asked about the resprouting of new branches from aerial parts of canjiqueira trees after fire events.

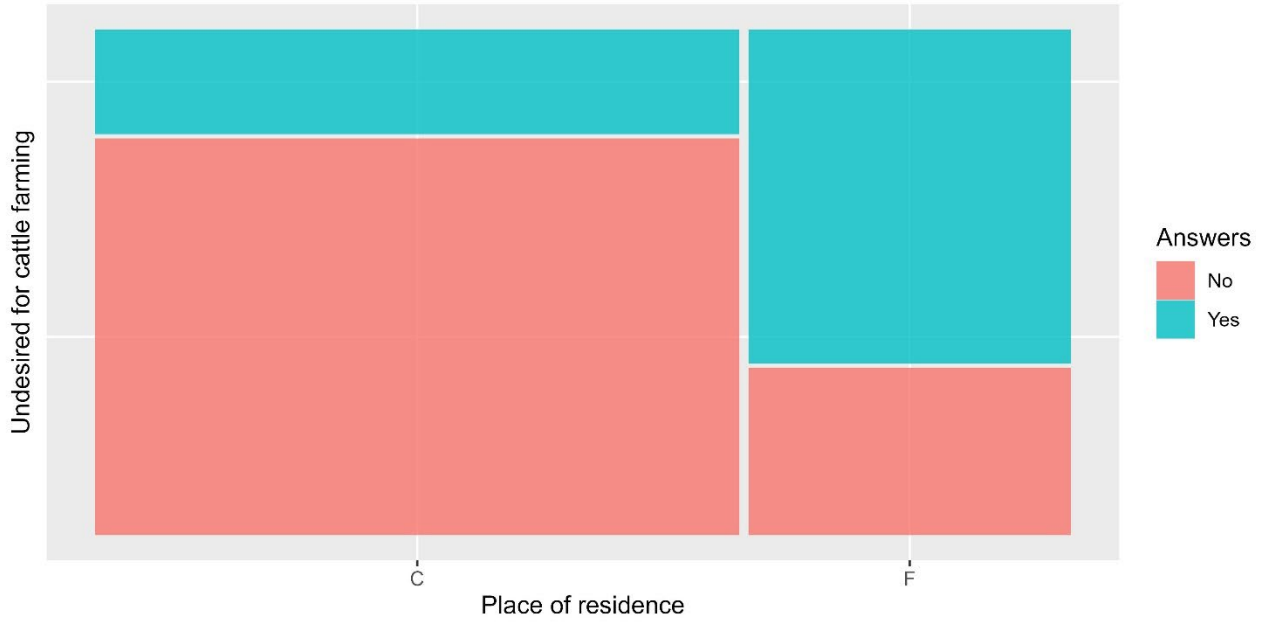


Figure 11. Opinion of local communities (C) and farms (F) inhabitants regarding the relationship between canjiqueira trees and livestock farming.

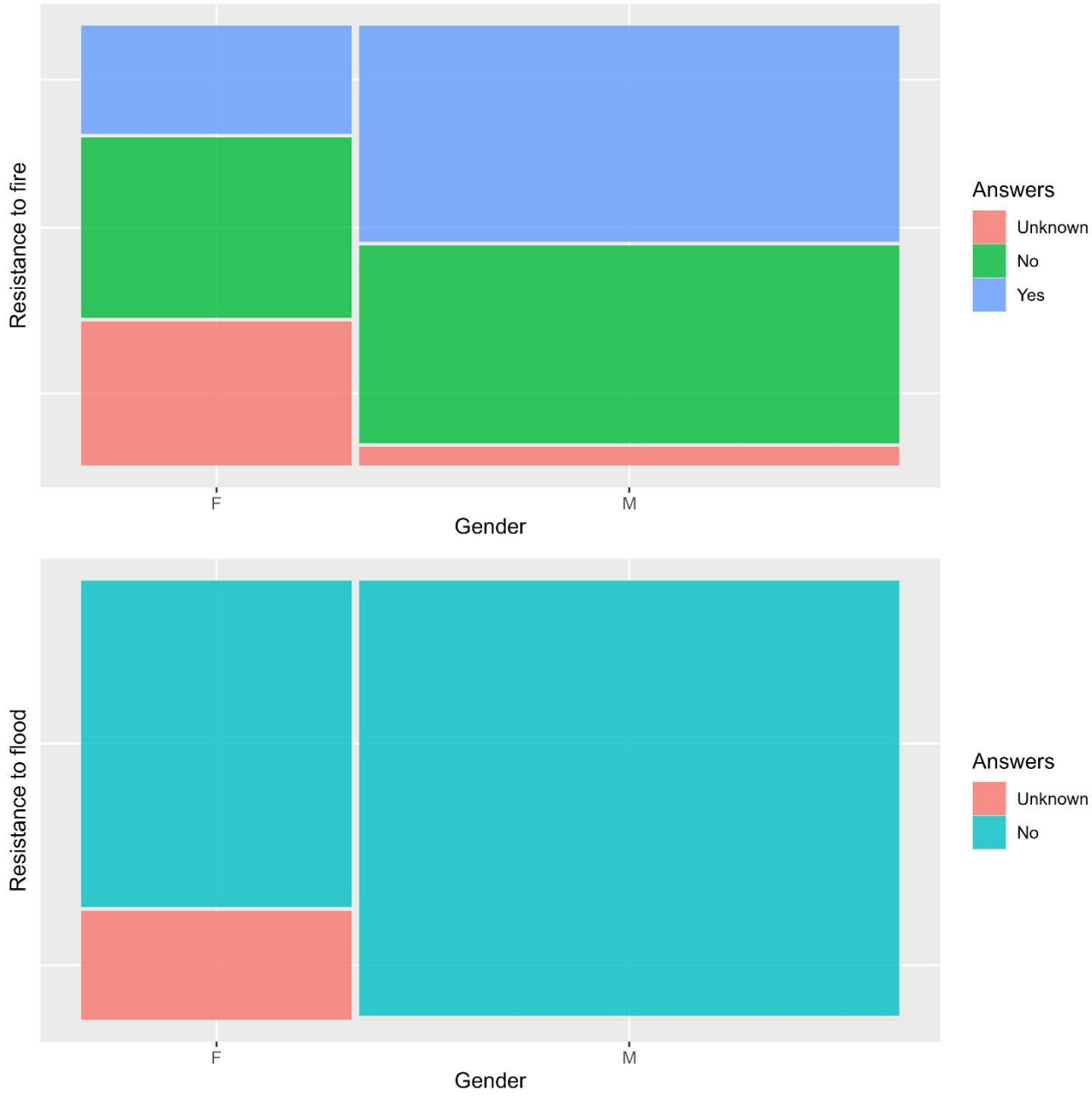


Figure 12. Answers of women (F) and man (M) regarding the resistance of canjiqueira trees to both fire and flood events.

Table 1. Woody species found and canjiqueira tree stands at the regions of Miranda, Abobral and Nabileque (Corumbá, MS), represented by family, species, total of individuals found (density) and number of fire events faced by the plots the species have been found in.

Family	Species	Density	Fire events/plot
Anacardiaceae	*Mangifera indica* L.*	1	2
Arecaceae	*Copernicia alba* Morong.	1	2
Bignoniaceae	*Handroanthus heptaphyllus* (Vell.) Mattos	2	2,4
	Tabebuia aurea (Silva Manso) Benth & Hook	149	All
Chrysobalanaceae	*Couepia uiti* (Mart. & Hook.) Benth & Hook f.	24	1,2,3,4,5
Erythroxylaceae	*Erythroxylum anguifugum* Mart.	21	1,2,4,5,6,7
Fabaceae	*Andira inermis* (W. Wright) DC.	4	4,5
Malpighiaceae	*Byrsonima cydoniifolia* A.Juss	894+612**	All
Moraceae	*Ficus pertusa* L.f.	1	4
Myrtaceae	*Eugenia florida* DC.	1	4
	Psidium guineense Sw.	3	4,7
Rutaceae	*Zanthoxylum rigidum* Humb. & Bonpl. ex Willd.	1	4
Vochysiaceae	*Vochysia divergens* Pohl.	17	1,2,3,4,5

*Non native species

**Both adults and regenerant individuals (d.b.h. < 15cm), respectively

Table 2. Statistical analysis of canjiqueira tree stands relationships to flood, number of fire events, fire intensity and cattle presence. The analysis consider the entire Community, Only canjiqueira trees and the other species data separately.

	Flood	Fire events	Fire intensity	Cattle presence
Community				
Total richness	z=-0.952	z=-0.648	z=0.74	**z=2.09**
	p=0.341245	p=0.517221	p=0.459	**p=0.0366**
Total density	**z=-3.064**	z=-0.708	z=1.915	z=0.16
	p=0.00218	p=0.479	p=0.554	p=0.872
Total basal area	z=-1.193	z=-1.706	**z=3.247**	z=-0.18
	p=0.0558	p=0.088	**p=0.00117**	p=0.857
Average basal area	z=0.919	z=-1.67	z=1.342	z=-0.58
	p=0.358	p=0.0949	p=0.18	p=0.562
Average height	z=-0.685	z=-0.106	**z=3.16**	z=0.733
	p=0.493	p=0.915	**p=0.00158**	p=0.44
Canjiqueira trees				
Density	**z=-3.533**	z=-0.265	z=0.503	z=-0.741
	p=0.000411	p=0.791	p=0.615	p=0.459
Total basal area	z=1.015	z=-1.972	z=0.048	**z=-2.028**
	p=0.31	p=0.054	p=0.962	**p=0.0426**
Average basal area	z=1.46	z=-0.44	z=0.203	**z=-2.926**
	p=0.144	p=0.66	p=0.839	**p=0.00344**
Number of branches d.b.h.<35cm	z=-1.173	z=0.003	z=-0.275	z=0.286
	p=0.241	p=0.998	p=0.783	p=0.775
Number of branches d.b.h.≥35cm	z=-0.744	**z=-2.343**	z=1.268	**z=-2.3**
	p=0.457	**p=0.0191**	p=0.205	**p=0.0214**
Height	z=0.392	z=0.746	z=0.589	z=-0.527
	p=0.742	p=0.458	p=0.556	p=0.589
Regenerants	z=1.274	z=0.941	z=0.435	z=0.856
	p=0.202777	p=0.347	p=0.664	p=0.392
Other species				
Density	z=-0.449	z=-1.171	z=1.615	z=0.285
	p=0.6178	p=0.2417	p=0.1062	p=0.07753
Total basal area	z=-1.158	z=-0.892	**z=2.697**	z=-0.194
	p=0.24693	p=0.37215	**p=0.00701**	p=0.84601
Average basal area	z=-1.806	z=-0.529	**z=2.598**	z=0.334
	p=0.07090	p=0.59671	**p=0.00938**	p=0.73866
Average heigh	z=-0.727	z=-1.095	**z=2.824**	z=1.607
	p=0.46722	p=0.27339	**p=0.00475**	p=0.10812

Table 3. Analysis of local populations knowledge regarding canjiqueira trees relationship with fire, flood and cattle based on residence place (communities or farms), age (adults or elders), gender (male or female) and lenght of residence (native, less than then years, between 10 and 20 years and over 20 years).

	Residence	Age	Gender	Length of residence
Fire resistence	χ^2=2.952 p=0.2634	χ^2=4.6312 p=0.1319	**χ^2=6.1312** **p=0.04198**	χ^2=8.0765 p=0.2569
Resprouting (root)	χ^2=1.4907 p=0.5322	χ^2=0.90839 p=0.7891	χ^2=5.9627 p=0.05547	χ^2=7.3142 p=0.3003
Resprouting (aerial part)	**χ^2=6.3168** **p=0.03748**	χ^2=3.6149 p=0.2319	χ^2=5.8649 p=0.07296	χ^2=9.705 p=0.1414
Post-fire recruitment	χ^2=6 p=0.07646	χ^2=1.6667 p=0.6042	χ^2=2.0417 p=0.6887	χ^2=3.8069 p=0.7741
Flood resistance	χ^2=1.6364 p=0.5117	χ^2=1.6364 p=0.5252	**χ^2=6.5455** **p=0.03148**	χ^2=4.3636 p=0.2829
Pos-flood recruitment	χ^2=2.2759 p=0.3518	χ^2=1.694 p=0.6543	χ^2=3.556 p=0.1659	χ^2=7.5948 p=0.2729
Undesired in livestock farming areas	**χ^2=7.2843** **p=0.008996**	χ^2=0.2408 p=0.7381	χ^2=2.9498 p=0.1249	χ^2=2.1156 p=0.5562

FORMULÁRIO 1. DADOS SOCIOECONÔMICOS

DADOS DA ENTREVISTA E DO PESQUISADOR

1. Nome do pesquisador:
2. Data da entrevista:
3. Local da entrevista (fazenda/comunidade):
4. Número da entrevista:

DADOS DO (A) ENTREVISTADO (A)

5. Data de nascimento:
6. Sexo:
7. Local de nascimento:
8. Estado civil:
9. Escolaridade:
10. Atividade principal (ocupação):
11. Nº de moradores da família (maiores/menores):
12. Nº de filhos:
13. Sabe ler e escrever? ( ) sim ( ) não
14. Tem acesso a internet? ( ) sim ( ) não Se sim, usa qual(is) rede social(is)?
15. Há quantos anos você mora aqui no local? |___|*anos* ***OU*** *desde que nasceu*|___| ***OU*** *estimativa* |___|*anos*
16. Já morou em outra ou em outras regiões do Pantanal antes de mudar para este local?

    (.) SIM. (.) NÃO

    A. Se sim, em qual ou quais outra (s) região (ões) do Pantanal você morou? _____

    B. Por quanto tempo você morou nessa (s) parte (s) do Pantanal? |___|*anos ou* |___| meses *(Se morou em mais de uma região, anotar os anos em cada região.*

FORMULÁRIO 4. Dados sobre o conhecimento, o uso e manejo da biodiversidade sujeita ao fogo e à inundação com ênfase às espécies **alimentícias e forrageiras** (para gado bovino e fauna silvestre).

Estudo da Canjiqueira - *Byrsonima cydoniifolia* A. Juss

1. Quais são os usos da canjiqueira? (alimento ou forrageiro)

2. Qual a parte utilizada para cada tipo de uso? (frutos, folhas, outra)

3. Quais as formas de uso na dieta humana? (farinhas, óleo, cozida, fermentada)?

4. Quais as formas de preparo para a dieta humana? (descrever o processo)

5. Alimento humano:
   5.1.Como é feita a colheita (meses do ano, horário do dia, lua)

   5.2.A colheita dos frutos é feita no chão ou diretamente da planta?

   5.3.Os frutos amadurecem fora do pé?

   5.4.As pessoas costumam consumir mais antes do que hoje em dia?

   5.5.A que se deve o aumento/diminuição do consumo?

6. Forrageira
   6.1. Quais animais usam a planta como alimento? (gado bovino, animais silvestres, outros);

   6.2.Qual a parte utilizada? (frutos, folhas, outra)

   6.3.Qual o efeito do forrageamento para a planta?

   6.4.Em que época do ano ocorre o forrageamento? (ano todo ou especificar – relacionar a época com períodos de fogo e inundação)

7. Quais os outros usos da planta? (Medicinal, construção, Tecnologias ou outros). Nesse caso, quis são as partes utilizadas e o modo de preparo?

8. As canjiqueiras são resistentes ao fogo? Depois de uma queimada, nascem novos ramos nas plantas antigas ou novas plantas do chão? Muito ou pouco?

9. As canjiqueiras são resistentes à cheia? Por quanto tempo? Depois que uma área inundada seca, nascem novas plantas do chão? Muitas ou poucas?

10. Ela é uma planta indesejada nas áreas de pastagem do gado bovino? Se sim, poderia explicar o motivo?

11. Você faz/já fez uso de qualque parte da canjiqueira (folha, tronco, frutos, raízes)? Se sim, há quanto tempo conhece a planta para esse fim?

12. Como aprendeu sobre o uso? Quem ensinou?

13. Ensina para alguém? Para quem?