

Resprouters quickly rebuild fuel in Cerrado grassland, even when it occurs as an enclave within the Caatinga

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Abstract

Purpose

Fire is a natural disturbance in fire-prone landscapes such as the Cerrado, a Brazilian savanna. However, disjunct Cerrado areas embedded within the Caatinga biome remain poorly understood. Here, we evaluated the influence of fire on vegetation recovery in a Cerrado grassland enclave (open savanna) within the Caatinga.

Methods

We sampled vegetation attributes in eight 20×20 m² plots two years after a wildfire. Four of these plots were then subjected to experimental burning and all eight plots were resampled one day, five months, and twelve months after fire. We calculated diversity metrics and assessed fire influence on vegetation using variance analyses and multivariate approaches.

Results

Fire caused rapid and substantial changes, consuming live and dead biomass, increasing ash deposition on the soil surface, and expanding bare-soil areas. Vegetation diversity changed only on the first day after burning, and a strong seedling pulse occurred five months after fire, preceding the consistent recovery of resprouting plants one year after burning. Fire strongly influenced the Cerrado grassland and homogenized the vegetation, although a woody Fabaceae species contributed to structural heterogeneity.

Conclusion

The high resilience and rapid fuel accumulation of Cerrado grasslands highlight the important ecological role of fire in this savanna system, even when occurring as an enclave within Caatinga. Our study advances fire-ecology knowledge in South American tropical grasslands and provides essential data on biomass and vegetation recovery dynamics, supporting the definition of suitable fire-return intervals for fuel-load management and for planning prescribed burns.

Introduction

Fire plays a central role in the Brazilian neotropical savanna (Cerrado) (Coutinho 1982, 1990; Ramos-Neto and Pivello 2000; Simon et al. 2009; Abreu et al. 2017), a highly diverse biome (Mittermeier et al. 2004) that covers roughly one-quarter of Brazil's territory and is essential for water supply in South America, particularly in the Paraguai, Parnaíba, São Francisco, and Tocantins–Araguaia river basins (Lima and Silva 2007). However, agricultural expansion and biological invasions have eliminated large areas of native vegetation, intensifying biodiversity loss and increasing pressure on land and water resources—processes that have worsened over the last decade and are now unsustainable (Ratter et al. 1997; Latrubesse et al. 2019; Rodrigues et al. 2022; Overbeck et al. 2022). Land conversion and vegetation fragmentation have resulted in the loss of key ecosystem services, and the current network of protected areas is insufficient to conserve the Cerrado's full pool of plant and animal species (Latrubesse et al. 2019). Compounding this issue, legislation fails to protect hydrologically critical areas (Durigan et al. 2022), and restoring degraded Cerrado grasslands remains challenging (Pilon et al. 2023), increasing the vulnerability of these ecosystems.

Biodiversity conservation and management in the Cerrado depend on fire (Simon et al. 2009; Freire-Jr et al. 2025), which drives numerous ecological processes (McLauchlan et al. 2020). Recurrent fires alter plant composition by increasing the diversity and dominance of grasses and species that resprout and flower efficiently after burning, promoting the expansion of open savanna vegetation (Coutinho 1990; Moreira 2000; Conceição 2021; Pilon et al. 2021). In contrast, fire suppression leads to forest encroachment and reduced plant diversity (Durigan and Ratter 2016; Abreu et al. 2017). In Cerrado grasslands, fire typically consumes nearly all aboveground biomass, whereas in denser physiognomies the woody component is more resistant (Kauffman et al. 1994; Castro and Kauffman 1988; Conceição and Pivello 2011). The open habitat and increased nutrient and light availability after fire stimulate flowering and fruiting (Carbone et al. 2025) and enhance seedling establishment, improving genetic variability (Fontenele and Miranda 2022). Given its ecological importance and management potential, fire is a valuable conservation tool. Prescribed burning can reduce the risk of large wildfires caused by fuel accumulation and help protect natural resources and nearby communities (Coutinho 1982, 1990; Ramos-Neto and Pivello 2000; Miranda et al. 2002; Pivello 2006; Cochrane and Bowman 2021).

Due to the high beta diversity of the Cerrado's herb–shrub layer (Amaral et al. 2017), open savanna enclaves within the Caatinga (Seasonally Dry Tropical Forest) represent important but understudied systems, as they lie outside the Cerrado core area and remain poorly known in terms of vegetation and post-fire regeneration (Nepomuceno et al. 2021; Overbeck et al. 2022). Among these enclaves, the disjunct savannas of the Chapada Diamantina province are among the most fire-affected areas in the Caatinga (Martins et al. 2024). For instance, the Chapada Diamantina National Park (CDNP) was the Brazilian national park most affected by wildfires between 2003 and 2006 (Mesquita et al. 2011), and between October 2008 and February 2009, wildfires burned approximately 41% of the park, threatening local communities and biodiversity and requiring substantial resources for fire combat (Mesquita et al. 2011). In 2015, a large wildfire burned about 16 ha of neotropical mountain grasslands (campos rupestres) in the southern CDNP (Santos et al. 2020, 2022). Although vegetation recovered within nine months, the authors emphasized the need for local-scale assessments of fire effects on plants.

Existing studies on plant responses to fire in the Chapada Diamantina have focused primarily on the fire-prone campo rupestre (Neves and Conceição 2010; Araújo and Conceição 2021; Conceição et al. 2024) and on the emblematic candombá (*Vellozia pyrantha*), a fire-dependent resprouter endemic to campo rupestre that flowers only after burning and provides fire-driven pulses of resources (Conceição and Orr 2012; Conceição et al. 2013; Conceição 2018; Souza et al. 2018). Despite being a disjunct Cerrado area included among the world's 34 biodiversity hotspots (Mittermeier et al. 2004) and experiencing recurrent fires (Mesquita et al. 2011), little is known about post-fire dynamics in its savanna vegetation, except for evidence of strong positive fire effects on flowering and fruiting in Cerrado grassland (Conceição 2021) and high consumption of fine fuels (e.g., Poaceae and Cyperaceae) by fire (Conceição and Pivello 2011). Surrounded by Caatinga, this enclave is relatively isolated from the Cerrado core, making it of particular interest for biodiversity conservation (Silveira et al. 2016; Colli Silva et al. 2019).

Lightning-caused fires are most frequent in elevated, open savannas (Ramos-Neto and Pivello 2000), facilitating the spread of wildfires from Cerrado grasslands to campos rupestres in the Chapada Diamantina (Neves and Conceição 2010; Conceição and Pivello 2011; Araújo and Conceição 2021). These fires burn mountaintop vegetation and affect many endemic and specialized species adapted to cycles of drought and fire (Conceição et al. 2016, 2024; Silveira et al. 2016; Souza et al. 2018). Thus, the high flammability and biodiversity of the Chapada Diamantina highlight the need to understand plant responses to fire and how fire influences fuel accumulation and plant diversity in open savannas, supporting adaptive fire management in South American neotropical grasslands.

Here, we aim to provide information on a neglected region of the Brazilian semiarid by examining the influence of fire on plant regeneration in a Cerrado grassland enclave within the Caatinga, contributing to fire management in tropical grasslands. Although the studied Cerrado grassland lies within the Caatinga—where therophytes (annual plants) dominate savanna enclaves (Nepomuceno et al. 2021; Gonçalves et al. 2024)—we expect a high dominance of resprouters during post-fire recovery, particularly flammable graminoids, since the area is prone to fire (Mesquita et al. 2011; Martins 2024). These species rapidly rebuild vegetation, reduce bare-soil exposure, and accumulate fuel within a short period, as observed in core Cerrado areas (Kauffman et al. 1994; Pilon et al. 2021). We hypothesize that: (1) fire induces profound changes in Cerrado grassland through ash accumulation and reductions in vegetation cover, plant height, and fuel; (2) the open spaces created by fire promote resprouting and germination; and (3) floristic composition, vegetation structure, functional groups, and plant diversity are affected by fire but recover rapidly after disturbance. Accordingly, we studied a Cerrado grassland (campo sujo) enclave in the Chapada Diamantina, where we conducted experimental burnings and evaluated bare-soil and ash percentages, vegetation cover and biomass, plant height, and fuel quantity. We then monitored plant regeneration and identified floristic, structural, and functional patterns driven by fire.

Materials and methods

Study area

We conducted the study in Cerrado areas of the Cercado Valley (Sítio Calumbi: 12°26' S, 41°27' W; 750 m a.s.l.), located within the Marimbus–Iraquara Environmental Protection Area, in the municipality of Palmeiras, Serra do Sincorá, Chapada Diamantina, Bahia, Brazil (Fig. 1).

The Chapada Diamantina is recognized as an ecoregion within the Brazilian semiarid Caatinga (Velloso et al. 2002) and as a phytogeographic province associated with high plant endemism in the northern Espinhaço Range in Bahia (Colli-Silva et al. 2019), surrounded by the Southern Depressão Sertaneja district of the Caatinga Dominion (Moro et al. 2024). The Chapada Diamantina consists of mountain ranges exceeding 1,000 m in elevation, with peak reaching 2,033 m. At the mountaintops, *campo rupestre* predominates—a highly diverse grassland–shrubland vegetation established on sandy sediments or directly on sandstone, surrounded by savanna, with evergreen forests occurring on some slopes and riverbanks (Harley 1995; Conceição and Pirani 2005; Juncá et al. 2005; Funch et al. 2009; Conceição et al. 2007, 2016, 2024; Grillo 2008; Couto et al. 2015; Neves et al. 2016).

The disjunct Cerrado of the Cercado Valley is highly relevant for conservation and restoration (Tourinho et al. 2023). Soils in this region are medium-sandy, acidic, nutrient-poor, and rich in aluminum. The vegetation displays the typical gradient of Cerrado physiognomies, ranging from *cerradão* (forest) to *cerrado sensu stricto* (savanna) and *campo* (grassland) (Grillo 2000, 2008). In lower and flatter areas between large hills, deeper soils support a mosaic of forest and savanna, with crooked woody plants bearing thick bark and coriaceous leaves, surrounded by an herbaceous layer dominated by Poaceae and Cyperaceae (Grillo 2000, 2008; Costa et al. 2009). At higher elevations, grassland formations predominate on sandy substrates with rocky outcrops on slopes, forming an ecotonal and highly flammable vegetation between Cerrado and *campo rupestre* (Conceição and Pivello 2011; Conceição 2021; Araújo and Conceição 2021).

In 2009, when we conducted experimental burning and field surveys, annual rainfall at the site was 1,211 mm and mean temperature was 21.8°C. Rainfall in the two months preceding the burn totaled 284 mm (254 mm in October and 30 mm in November). Mean relative humidity during the 30 days before the burn was 39% (minimum 22.4%), and mean air temperature was 22.1°C (maximum 32.8°C) (Conceição and Pivello 2011).

Study design and Cerrado grassland sampling

The Cercado Valley was selected because it is a savanna enclave within the Chapada Diamantina mountains in the semiarid region, where fire is a frequent disturbance connecting wildfires between Cerrado and the megadiverse *campo rupestre* at higher elevations. Additionally, the owner of Sítio Calumbi authorized the experimental burnings. The specific study site (Fig. 1) was chosen because it contains grassland vegetation at the mountain base, with relatively homogeneous areas and a known fire history over the 10 years preceding 2009 (wildfires in 2001 and 2007).

We established eight 20 × 20 m² plots randomly within the Cerrado grassland (*campo sujo*) vegetation. Four plots were randomly assigned to burning (B plots), and the remaining four served as controls (C plots). In each plot of 20 × 20 m², we randomly placed ten 1 × 1 m² subplots where we estimated the cover of all vascular plant species and measured maximum plant height (Fig. 1). We also estimated the cover of bare soil, ash, and dead phytomass (80

cover subplots). To evaluate post-fire regeneration (Pausas et al. 2017), species were classified as resprouters, non-resprouters (seeders and post-fire colonizers), or resprouter seedlings (when seedlings of resprouting species were observed). Seedlings were counted and categorized by height (<3 cm and 3–10 cm) in each subplot.

After the first sampling (24 months since the last fire), we burned the vegetation in the four B plots (B1, B2, B3, and B4) on 29 November 2009. The surface fire consumed herbaceous plants and reached shrubs and scattered trees. Fire spread rates ranged from 4.3 to 4.4 m min⁻¹, and wind speed ranged from 1.2 to 21.8 km h⁻¹ (means 4.5–4.9 km h⁻¹) (Conceição and Pivello 2011). The four unburned plots served as controls (C1, C2, C3, and C4). We resampled the Cerrado grassland in the same subplots one day after burning and again at five (April 2010) and 12 months (November 2010) after burning, totaling sampling periods at 1 day and 5, 12, 24, 29, and 36 months since fire (Fig. 1).

Additionally, at five (April 2010) and 12 months (November 2010) after burning, we collected the aboveground biomass of each vascular plant species in five randomly selected 1 × 1 m² subplots within each plot of 20 × 20 m². Thus, we quantified biomass in 40 burned subplots (5 and 12 months after burning) and 40 control subplots (29 and 36 months after wildfire). Dead phytomass was separated into charcoal, litter, and dead plants. Living and dead fine biomass were summed to estimate fuel (g m⁻²). Biomass was oven-dried at 60°C and weighed using an analytical balance (Brower et al. 1998). Voucher specimens were deposited in the Herbarium of the Universidade Estadual de Feira de Santana (HUEFS), and species were classified following APG IV (2016) and updated using SpeciesLink (CRIA 2024, <https://specieslink.net/>) and *Flora e Funga do Brasil* (2025, in preparation).

Data analysis

We analyzed changes in the Cerrado grassland using bare soil and ash cover, dead and living plant cover and biomass, maximum plant height, and fuel (fine dead and living biomass). We also included fuel data collected 24 months after wildfire and 1 day after burning from the same fire experiment (see Conceição and Pivello 2011). Vegetation structure was analyzed using species cover and biomass.

Species richness and the Shannon–Wiener index (natural logarithm) (Brower et al. 1998; McCune and Grace 2002) were calculated using the number of species or cover in the pool of ten 1 m² subplots per plot at each sampling time. We also analyzed species number per m² (subplot), a good proxy for diversity in Cerrado grasslands (Campos et al. 2025).

We used PAST 4.11 (Hammer et al. 2001) to compare parameters between treatments (burned vs. control) over time since the last fire. Data from the ten cover subplots or five biomass subplots were merged per 400 m² plot. ANOVA and post hoc tests were applied when assumptions of normality and homoscedasticity were met; otherwise, we used the nonparametric Kruskal–Wallis test (Sokal and Rohlf 1995). For cover data from repeated measurements in the same subplots, we used repeated-measures tests. We also performed regression analyses to examine the relationship between open soil area (bare soil + ash) and plant species cover.

Using PAST, we performed hierarchical cluster analyses to compare floristic composition and vegetation structure, applying UPGMA with Jaccard and Bray–Curtis similarities (McCune and Grace 2002), based on binary or biomass matrices for species in burned and control plots sampled at two time points after burning (April 2010 = 5 months after burning and 29 months since last wildfire; November 2010 = 12 months after burning and 36 months since last wildfire). We also performed NMDS (McCune and Grace 2002) based on biomass matrices of species or functional groups in subplots at contrasting times since the last fire (5, 12, 29, and 36 months).

Results

Influence of fire on the Cerrado grassland

Fire consumed most of the aboveground vegetation, and one day after burning, a large portion of the soil surface was covered by ash (Fig. 2a). Five months after the fire, extensive bare soil was still present, but it gradually decreased over time since the last fire (Fig. 2a). In contrast, plant height (Fig. 2b) and dead phytomass (Fig. 2c) increased as time progressed. Vegetation cover (Fig. 2a), living plant cover (Fig. 2c), living plant biomass (Fig. 2d), and fuel loads (Fig. 2f) all increased and remained high 24–36 months after fire. Bare soil cover decreased gradually after fire, while plant species cover increased following an exponential trend (Fig. 2e).

Post-fire regeneration strategies and seedlings

Approximately 99% of all living plant occurrences and covers were resprouting species, many of which were also observed as seedlings (59% of occurrences and 52% of cover). Non-resprouters (post-fire colonizers and seeders) were extremely rare, representing only 0.92% of occurrences (Fig. 3a) and 0.09% of total cover. Seedling abundance was higher in burned plots, especially for short seedlings (up to 3 cm tall) five months after burning (April 2010). Taller seedlings (3–10 cm) were few and were recorded only in the final sampling in November 2010 (Fig. 3b).

Floristic composition, abundances, plant diversity, and functional groups

A total of 70 vascular plant species from 24 families were recorded in 160 1 × 1 m² plots, where species cover and biomass were quantified (Table 1). Seven families accounted for 67% of all species: Poaceae (13 species), Fabaceae (10), Asteraceae (6), Euphorbiaceae (6), Rubiaceae (5), Cyperaceae (4), and Malvaceae (3). Eleven families were represented by a single species, and six families by two species.

Based on total biomass, Poaceae accounted for 76.9%, Fabaceae for 16.8%, and the remaining 20 families together for only 6.3%. The relative biomass of Poaceae decreased over time since the last fire, whereas Fabaceae tended to increase (Fig. 4a). Malpighiaceae and Euphorbiaceae increased in relative biomass up to one year after burning and then declined. Euphorbiaceae showed marked variation: 1.7% of biomass at five months, 3.8% at 12 months, 0.2%

at 29 months, and 0.3% at 36 months (Fig. 4a). The herb *Euphorbia potentilloides* dominated at five months, while the subshrub *Microstachys bidentata* dominated at 12 months (Fig. 4b).

The two species with the highest biomass were the tufted grass *Sporobolus cubensis* (Poaceae), representing 26.5% of total biomass, and the woody tree *Styphnodendron rotundifolium* (Fabaceae), representing 16.6%. The next six most abundant species were all Poaceae (*Andropogon*, *Axonopus*, *Echinolaena*, *Elionurus*, *Oncorachis*, and *Trachypogon*), together accounting for 47% of total biomass—three rhizomatous and three cespitose species.

Species richness (S) and the Shannon–Wiener index (H') were lower only one day after burning (Fig. 5a–b). Species richness per m² in control plots ranged from 8 to 21 (24–36 months since the last wildfire), whereas one day after burning it ranged from 1 to 7. Five and 12 months after burning, richness ranged from 9 to 19 species per m² (Fig. 5c–d). Among functional groups, only graminoids showed significant differences across sampling times, with biomass increasing up to 29 months and decreasing at 36 months (Fig. 5e).

Cluster analysis based on a binary matrix (Fig. 6a) showed high floristic similarity among all plots (65%), with burned and control plots intermixed. At 80% similarity, only one of the three groups consisted exclusively of burned or control plots. Only burned plots formed pairs of the same plot sampled at different times (B1 and B3 at 5 and 12 months). Cluster analysis based on biomass (Fig. 6b) grouped plots at 0.49 similarity. Time since fire strongly influenced the four groups at 0.6 similarity: a) seven of eight burned plots (5 and 12 months), b) burned plot B3T3 (12 months) grouped with 36-month control plots (similarity 0.69), c) three of four control plots at 29 months (similarity 0.72), and d) two control plots at 29 and 36 months. Only burned plots formed pairs of the same plot sampled at different times (B1, B2, B4). NMDS based on species biomass (Fig. 6c) separated all burned plots (5 and 12 months) along axis 1 (explaining 0.66% of variation), except B3T3, which grouped with control plots.

NMDS based on functional groups (Fig. 6d) separated trees from the herb–shrub layer along axis 1 (76% of variation). Most plots clustered in the graminoid–shrub–forb sector. The gradient between non-graminoid herbs (forbs and subshrubs) and graminoids was driven mainly by plots at 5 and 12 months after burning, reflecting the high relative biomass of two Euphorbiaceae species: *E. potentilloides* (dominant at 5 months) and *M. bidentata* (dominant at 12 months).

Discussion

Even though this Cerrado grassland is a disjunct enclave within the Caatinga, fire produced profound changes through ash accumulation and reductions in vegetation cover, plant height, and fuel loads. The open spaces created by fire favored plant resprouting and germination, and the floristic composition, vegetation structure, functional groups, and plant diversity were all affected but recovered rapidly after disturbance. Thus, our hypotheses were supported within Caatinga.

The abrupt changes observed in the Cerrado grassland of the Chapada Diamantina were driven by the high consumption of fine fuels, predominantly produced by graminoid species (see also Conceição and Pivello 2011). The large accumulation of ash and the low plant cover and phytomass one day after burning reflect the deep environmental and structural changes caused by fire, a recurrent pattern in fire-prone South American grasslands (Kauffman et al. 1994; Castro and Kauffman 1998; Ramsay and Oxley 1996; Safford 2001; Bilbao et al. 2009; Cianciaruso et al. 2010; Neves and Conceição 2010; Conceição et al. 2016, 2024; Figueira et al. 2016; Le Stradic et al. 2018, 2025; Pilon et al. 2021; Araújo and Conceição 2021; Baronio et al. 2024; Alves et al. 2025).

Vegetation increased rapidly as resprouters occupied the open spaces created by fire, following an exponential recovery pattern within 24 months (see Fig. 2e). This reflects a fast post-fire dynamic characteristic of fire-adapted systems. In the first months, resprouted non-graminoid herbs increased in relative importance because grasses had not yet reestablished their biomass. This pattern was first evident in the small herb *Euphorbia potentilloides*, followed by the taller subshrub *Microstachys bidentata*, which is less easily overtopped by graminoids. Two years after fire, resprouting Poaceae and Fabaceae dominated the community, while non-graminoid herbs, shrubs, and bare soil declined. The dominance of resprouters reflects the high resilience of this vegetation and the importance of below-ground organs (Pilon et al. 2021), whereas annual plants remained inconspicuous, as is typical of Cerrado core areas (Batalha and Martins 2002).

However, our results also show that seeds play an important role in maintaining resprouter populations. Non-dormant seeds produced after fire increase genetic variability (Fontenele and Miranda 2022), and five months after burning we recorded a high number of seedlings following a pulse of fire-stimulated flowering and fruiting two to three months after fire (see Conceição, 2021), when bare soil cover was high. The seven graminoids and three geophytic herbs classified as fire-stimulated flowering species are exclusive to fire-prone vegetation, including *E. potentilloides* and five dominant grasses (*Sporobolus*, *Andropogon*, *Axonopus*, *Elionurus*, *Oncorachis*), whereas the six fire-inhibited flowering species, including *M. bidentata*, are shrubs that also occur in non-fire-prone environments (Conceição 2021). Thus, fire opened space, plants resprouted and flowered, flammable graminoids typical of fire-prone vegetation produced seeds, and seedlings increased, while the environment and vegetation gradually recovered with time since fire.

Due to the dominance of graminoids in Cerrado grasslands, dead plant fuel is mostly fine, dry, and highly flammable (Kauffman et al. 1994; Castro and Kauffman 1998; Conceição and Pivello 2011; Simpson et al. 2016, 2022; Zanzarini et al. 2022). In our study, the consistent recovery of grass biomass and the accumulation of dead fuel allowed fire to spread again two years after the wildfire. One year after the experimental burning, total plant cover and biomass were still slightly lower than in control plots. However, in 2010—three years after the 2007 wildfire—we documented high fuel loads, much of it dead biomass, which increases flammability (Simpson et al. 2016; Zanzarini et al. 2022).

Based on our experiment, a fire interval of two to six years appears suitable for prescribed burning in the Cerrado grasslands of the Chapada Diamantina. Such an interval would reduce fuel loads and help prevent uncontrolled wildfires from spreading into forests and the megadiverse *campo rupestre*. This management practice would promote biomass control, nutrient cycling, transient habitat changes, flowering, fruiting, seedling establishment, and the

maintenance of savanna plant populations. Our recommendation considers the central role of fuel accumulation in fire-prone vegetation (Husari et al. 2006; Cochrane and Bowman 2021), the fire dependence of Cerrado grasslands (Abreu et al. 2017; Pilon et al. 2021), the rapid fuel regrowth observed within two years (2007–2009), and the substantial increase in dead fuel over three years (2007–2010).

Another factor supporting the use of prescribed fire in the Cerrado grasslands of the Chapada Diamantina is the rapid recovery of plant diversity, a pattern also observed in other tropical grasslands affected by fire in the region (Neves and Conceição 2010; Conceição et al. 2016; Araújo and Conceição 2021; Conceição et al. 2024) and in other South American savannas (Bilbao et al. 2009; Cianciaruso et al. 2010; Le Stradic et al. 2018, 2025; Pilon et al. 2021; Baronio et al. 2024). The predominance of resprouters promotes plant persistence, and species richness was reduced only briefly. Floristic composition remained largely similar. Except for the sampling one day after burning, species richness per 1 m² subplot ranged from 8 to 21 in both burned and control plots, matching the pattern of 9–22 species per m² in undisturbed Cerrado grasslands (Campos et al. 2025). This demonstrates that diversity was reestablished within five months and that Cerrado grasslands in the Chapada Diamantina follow the same pattern as core Cerrado areas, even after recent fire and within the Caatinga biome.

The mixing of burned and control plots in the floristic cluster analysis (Jaccard similarity) suggests little fire effect on species composition. However, the strong similarity between the same burned plots sampled at different times—contrasting with the lack of such pairs among control plots—indicates fire-driven floristic homogenization. The biomass-based cluster analysis reinforces this homogenization and highlights the strong effect of fire on vegetation structure: all plots five months after burning were separated from control plots, as were most plots 12 months after burning, except B3T3, which had high abundance of the woody Fabaceae *Stryphnodendron rotundifolium*.

In the NMDS of functional groups, plots positioned along the tree gradient were mostly controls, but also included B3T3, the only burned plot grouped with controls in both cluster and NMDS analyses. This underscores the importance of the woody component for structural heterogeneity in Cerrado grasslands. The broader tree gradient likely reflects high variability in tree biomass, which does not occur in graminoids, as grasses are continuously distributed in space, unlike isolated trees. This spatial heterogeneity also explains why the gradual increase in tree biomass over time since fire was not statistically significant.

Fabaceae was also one of the most species-rich families in previous studies in the Cerrado of the Cercado Valley (Grillo 2008; Costa et al. 2009). Together with Poaceae, Asteraceae, Euphorbiaceae, Rubiaceae, and Cyperaceae, the six main families in our study are also species-rich in other Cerrado areas of the Chapada Diamantina, representing 51% (109/213) (Harley et al. 2005) or 39% (35/90) (Costa et al. 2009) of recorded species. Graminoids are consistently the most representative group in seasonal Cerrado grasslands (Sarmiento 1984, 1992; Tannus and Assis 2004; Bilbao et al. 2009), mainly Poaceae, which is also abundant in wetlands along with Cyperaceae (Tannus and Assis 2004; Munhoz et al. 2008; Munhoz and Felfili 2008). Their abundance is explained by growth forms that produce dense tussocks or rhizomatous/stoloniferous individuals widely distributed across the vegetation (Munhoz et al. 2008).

Due to the predominance of herbaceous and shrubby species, we recorded only 12 tree species across the eight plots, five of which (*Annona coriacea*, *Kielmeyera coriacea*, *Hancornia speciosa*, *Plathymenia reticulata*, and *Hymenaea stigonocarpa*) are among the 40 most frequent trees in core Cerrado areas (Ratter et al. 2003). This reinforces the Cerrado floristic identity of this enclave in the semiarid Chapada Diamantina. Additionally, all 13 Poaceae species sampled were resprouters (Table 1), seven of which are fire-stimulated flowering species restricted to fire-prone grasslands (Conceição 2021). In contrast, other Cerrado enclaves in the Brazilian semiarid contain high numbers of annual species, including many annual Poaceae (Nepomuceno et al. 2021; Gonçalves et al. 2024).

Thus, the fire characteristics and plant responses observed in the Chapada Diamantina resemble those of core Cerrado areas but differ from patterns documented in other semiarid Cerrado enclaves. This contrast likely reflects differences in post-fire regeneration strategies, as vegetation recovery depends on species-specific post-fire traits (Pausas et al. 2017; Pilon et al. 2021). In the Chapada Diamantina, resprouting is the dominant strategy—consistent with patterns reported for fire-prone tropical grasslands (Tannus and Assis 2004; Munhoz and Felfili 2008; Neves and Conceição 2010; Conceição et al. 2016; Le Stradic et al. 2018, 2025; Souza et al. 2018; Conceição 2021; Araújo and Conceição 2021; Baronio et al. 2024).

Conclusions

We present the first detailed assessment of fire influence on a Cerrado grassland community (open savanna, or *campo sujo*) within the Caatinga biome (Seasonally Dry Tropical Forest) and the Chapada Diamantina province/ecoregion. Although this vegetation occurs as an enclave in the Brazilian semiarid, its post-fire regeneration was driven mainly by resprouting species—similar to other fire-prone South American grasslands—rather than by annual plants, as might be expected in other savanna enclaves of the Brazilian semiarid.

Our results confirm the importance of fire in Cerrado grassland dynamics, as it alters environmental conditions, promotes seedling establishment, and homogenizes species composition and vegetation structure, while plant biomass and cover recover rapidly. Because persistence and regrowth from fire-protected perennial organs predominate, plant diversity changed only briefly after fire, highlighting the high resilience of this system.

We also provide data on plant biomass and vegetation-recovery dynamics that can help define suitable fire intervals for fuel-load management and guide when prescribed fires should be applied to protect villages, houses, sensitive species, landscapes, and headwaters, while supporting decisions related to adaptive management.

Declarations

The authors have no financial or proprietary interests in any material discussed in this article.

Author Contribution

AAC conceived the idea, designed the experiment, and performed the field study and laboratorial activities. AAC and GAL analyzed the data. AAC wrote the first draft. AAC and GAL contributed to revisions.

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Data Availability

The data supporting this study are available from the corresponding author upon reasonable request.

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Table

Table 1. Seventy vascular plant species from 24 families sampled in 160 subplots (1 m × 1 m), with their respective functional groups (F. Group), post-fire regeneration strategies (PFRS), and voucher specimens (collector number). R: resprouter; RS: resprouter with seedlings; NR: non-resprouter. Cerrado grassland in the Cercado Valley, municipality of Palmeiras, Chapada Diamantina, Brazilian semiarid region.

APG IV Family	Vascular Plant Species	F. Group	PFRS	Voucher
Amaranthaceae	<i>Pfaffia jubata</i> Mart.	forb	RS	Conceição, A.A. 3272
Annonaceae	<i>Annona coriacea</i> Mart.	tree	R	Carvalho, P.D. 63
Apocynaceae	<i>Hancornia speciosa</i> Gomes	tree	RS	Castro, R.M. 946
Apocynaceae	<i>Himatanthus drasticus</i> (Mart.) Plumel	tree	RS	Conceição, A.A. 3260
Asteraceae	<i>Ayapana amygdalina</i> (Lam.) R.M.King & H.Rob.	shrub	RS	Conceição, A.A. 3238
Asteraceae	<i>Baccharis</i> cf. <i>brevifolia</i> DC.	shrub	R	Conceição, A.A. 3270
Asteraceae	<i>Calea harleyi</i> H.Rob.	shrub	RS	Conceição, A.A. 3243
Asteraceae	<i>Chromolaena horminoides</i> DC.	shrub	NR	Conceição, A.A. 3209
Asteraceae	<i>Chrysolaena simplex</i> (Less.) Dematt.	forb	R	Conceição, A.A. 3273
Asteraceae	<i>Eremanthus incanus</i> (Less.) Less.	tree	NR	Lima, GA 100
Bignoniaceae	<i>Anemopaegma glaucum</i> Mart. ex DC.	shrub	R	Conceição, A.A. 3254
Boraginaceae	<i>Euploca salicoides</i> (Cham.) J.I.M.Melo & Semir	forb	NR	Conceição, A.A. 3244
Clusiaceae	<i>Kielmeyera coriacea</i> Mart. & Zucc.	tree	R	Guedes, ML 5453
Convolvulaceae	<i>Evolvulus</i> cf. <i>linoides</i> Moric.	forb	R	Neves, S.P.S. 311
Convolvulaceae	<i>Ipomoea</i> cf. <i>bahiensis</i> Willd. ex Roem. & Schult.	forb	R	Conceição, A.A. 3305
Cyperaceae	<i>Bulbostylis capillaris</i> (L.) C.B.Clarke	graminoid	RS	Conceição, AA 560
Cyperaceae	<i>Bulbostylis junciformis</i> (Kunth) C.B.Clarke	graminoid	RS	Conceição, A.A. 3246
Cyperaceae	<i>Rhynchospora exaltata</i> Kunth	graminoid	R	Conceição, A.A. 3301
Cyperaceae	<i>Rhynchospora marisculus</i> Lindl. & Nees	graminoid	RS	Conceição, A.A. 3282
Erythroxylaceae	<i>Erythroxylum</i> cf. <i>polygonoides</i> Mart.	shrub	R	Conceição, A.A. 3253
Euphorbiaceae	<i>Croton velutinus</i> Baill.	shrub	R	Grillo, AA 170
Euphorbiaceae	<i>Euphorbia potentilloides</i> Boiss.	forb	RS	Conceição, A.A. 3249
Euphorbiaceae	<i>Maprounea guianensis</i> Aubl.	tree	RS	Neves, S.P.S. 235
Euphorbiaceae	<i>Microstachys bidentata</i> (Mart.) F.Dietr.	forb	RS	Conceição, A.A. 3255
Euphorbiaceae	<i>Microstachys daphnoides</i> (Mart.) F.Dietr.	forb	RS	Grillo, AA 188
Euphorbiaceae	<i>Sapium glandulosum</i> (L.) Morong	shrub	RS	Conceição, A.A. 3192

APG IV Family	Vascular Plant Species	F. Group	PFRS	Voucher
Fabaceae	<i>Ancistrotropis firmula</i> (Mart. ex Benth.) A. Delgado	liana	R	Conceição, A.A. 3210
Fabaceae	<i>Chamaecrista flexuosa</i> (L.) Greene	forb	RS	Neves, S.P.S. 248
Fabaceae	<i>Chamaecrista mucronata</i> (Spreng.) H.S.Irwin & Barneby	forb	RS	Conceição, A.A. 3206
Fabaceae	<i>Ctenodon paniculatus</i> (Willd. ex Vogel) D.B.O.S.Cardoso, P.L.R.Moraes & H.C.Lima	forb	R	Conceição, A.A. 3262
Fabaceae	<i>Plathymania reticulata</i> Benth.	tree	RS	Carvalho, PD 24
Fabaceae	<i>Senna macranthera</i> (DC. ex Collad.) H.S.Irwin & Barneby	shrub	RS	N. Roque 718
Fabaceae	<i>Stryphnodendron rotundifolium</i> Mart.	tree	R	Conceição, A.A. 3256
Fabaceae	<i>Stylosanthes debilis</i> M.B.Ferreira & Sousa Costa	forb	NR	Conceição, A.A. 3212
Fabaceae	<i>Stylosanthes gracilis</i> Kunth	forb	RS	Conceição, A.A. 3247
Fabaceae	<i>Tachigali vulgaris</i> L.G.Silva & H.C.Lima	tree	R	Conceição, A.A. 3242
Iridaceae	<i>Pseudotrimezia cathartica</i> (Klatt) Ravenna	forb	R	Conceição, A.A. 3271
Iridaceae	<i>Sisyrinchium vaginatum</i> Spreng.	graminoid	R	Conceição, A.A. 3283
Lamiaceae	<i>Aegiphila verticillata</i> Vell.	shrub	RS	Guedes 1428
Malpighiaceae	<i>Byrsonima crassifolia</i> (L.) Kunth	tree	RS	Grillo, A.A. 143

Malpighiaceae	<i>Stigmaphyllon paralias</i> A.Juss.	forb	RS	Castro, R.M. 953
Malvaceae	<i>Pavonia cancellata</i> (L.) Cav.	forb	NR	Conceição, A.A. 3207
Malvaceae	<i>Pavonia sidifolia</i> Kunth	forb	NR	Esteves, GL 2340
Malvaceae	<i>Sida linifolia</i> Cav.	forb	NR	Carvalho, P.D. 55
Melastomataceae	<i>Clidemia sericea</i> D.Don.	shrub	R	Carvalho, PD 18
Melastomataceae	<i>Miconia albicans</i> (Sw.) Steud.	shrub	RS	Guedes, ML et al. 3029
Myrsinaceae	<i>Myrsine guianensis</i> (Aubl.) Kuntze	tree	RS	Guedes, ML et al. 1037
Myrtaceae	<i>Eugenia punicifolia</i> (Kunth) DC.	shrub	R	Carvalho, P.D. 59
Passifloraceae	<i>Passiflora foetida</i> L.	forb	R	Hatschbach, G et al. 56
Passifloraceae	<i>Passiflora misera</i> Kunth	forb	R	Conceição, A.A. 1141
Poaceae	<i>Andropogon selloanus</i> (Hack.) Hack.	graminoid	RS	Conceição, A.A. 3277
Poaceae	<i>Andropogon virgatus</i> Desv.	graminoid	R	Melo, E. 5323
Poaceae	<i>Anthraenantia lanata</i> (Kunth) Benth.	graminoid	RS	Conceição, A.A. 3281
Poaceae	<i>Aristida torta</i> (Nees) Kunth	graminoid	R	Conceição, A.A. 3245
Poaceae	<i>Axonopus grandifolius</i> Renvoize	graminoid	R	Conceição, A.A. 3298
Poaceae	<i>Axonopus pellitus</i> (Nees ex Trin.) Hitchc. & Chase	graminoid	R	Conceição, A.A. 3300
Poaceae	<i>Echinolaena inflexa</i> (Poir.) Chase	graminoid	RS	Conceição, A.A. 3135
Poaceae	<i>Oncorachis ramosa</i> (Zuloaga & Soderstr.) Morrone & Zuloaga	graminoid	R	Conceição, A.A. 3257
APG IV Family	Vascular Plant Species	F. Group	PFRS	Voucher
Poaceae	<i>Panicum</i> sp.	graminoid	R	
Poaceae	<i>Paspalum carinatum</i> Humb. & Bonpl. ex Flügge	graminoid	R	Conceição, A.A. 3292
Poaceae	<i>Sporobolus cubensis</i> Hitchc.	graminoid	R	Conceição, A.A. 3276
Poaceae	<i>Trachypogon spicatus</i> (L.f.) Kuntze	graminoid	RS	Conceição, A.A. 3202
Polygalaceae	<i>Senega poaya</i> (Mart.) J.F.B.Pastore	forb	R	Conceição, A.A. 3062
Rubiaceae	<i>Declieuxia fruticosa</i> (Willd. ex Roem. & Schult.) Kuntze	forb	RS	Conceição, A.A. 3252
Rubiaceae	<i>Hexasepalum apiculatum</i> (Willd.) Delprete & J.H.Kirkbr.	forb	RS	Conceição, A.A. 3250
Rubiaceae	<i>Mitracarpus frigidus</i> (Willd. ex Roem. & Schult.) K.Schum.	forb	NR	Conceição, A.A. 1751
Rubiaceae	<i>Palicourea rigida</i> Kunth	shrub	R	Guedes, ML; et al. 5490
Rubiaceae	<i>Perama hirsuta</i> Aubl.	forb		Queiroz, LP 6333
Turneraceae	<i>Piriqueta duarteana</i> (Cambess.) Urb.	forb	RS	Conceição, A.A. 3307

Figures

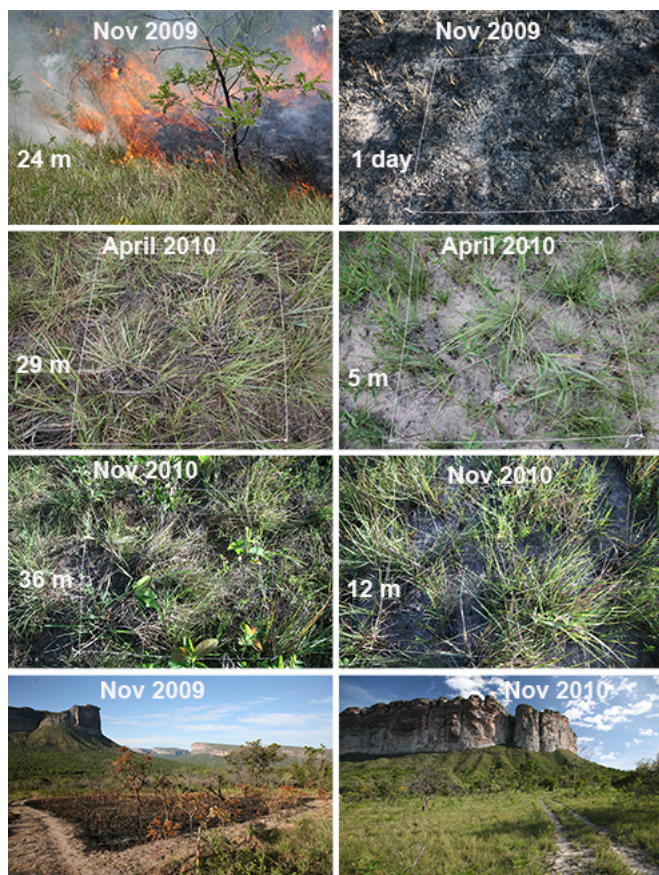


Figure 1

The study of Cerrado grassland in eight $20 \times 20 \text{ m}^2$ plots started 24 months after a wildfire in November 2007. In each plot, cover and biomass of vegetation were sampled in $1 \times 1 \text{ m}^2$ subplots. Four plots were then burned experimentally in November 2009, and all eight plots were resampled 1 day, 5 months (April 2010), and 12 months (November 2010) after fire. Overall, the time since the last fire evaluated was 1 day, and 5, 12, 24, 29, and 36 months (**m**). Cercado Valley, Palmeiras municipality, Chapada Diamantina, Brazilian semiarid region.

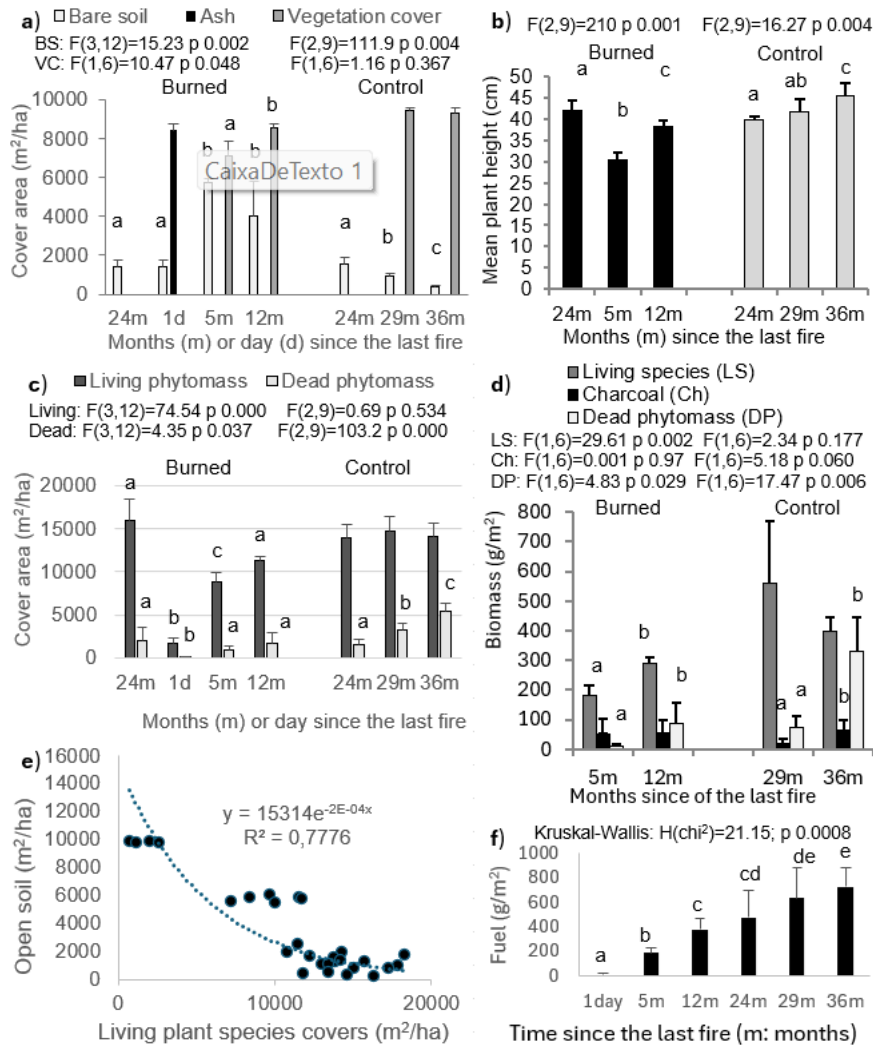


Figure 2

Attributes sampled in a Cerrado grassland area (burned and control) at different times since the last fire in the Cercado Valley, Palmeiras municipality, Chapada Diamantina, Brazilian semiarid region. Distinct letters on bars indicate significant differences among sampling times ($P < 0.05$). A: cover of bare soil (BS), ash, and vegetation (VC). B: mean maximum plant height. C: cover of living and dead phytomass. D: aboveground biomass of living species, charcoal, and dead phytomass. E: regression between open soil and living plant cover, showing the best-fit exponential trend. F: fuel (living and dead fine phytomass) accumulated over time since the last fire (data for 1 day and 24 months after fire from Conceição and Pivello 2011).

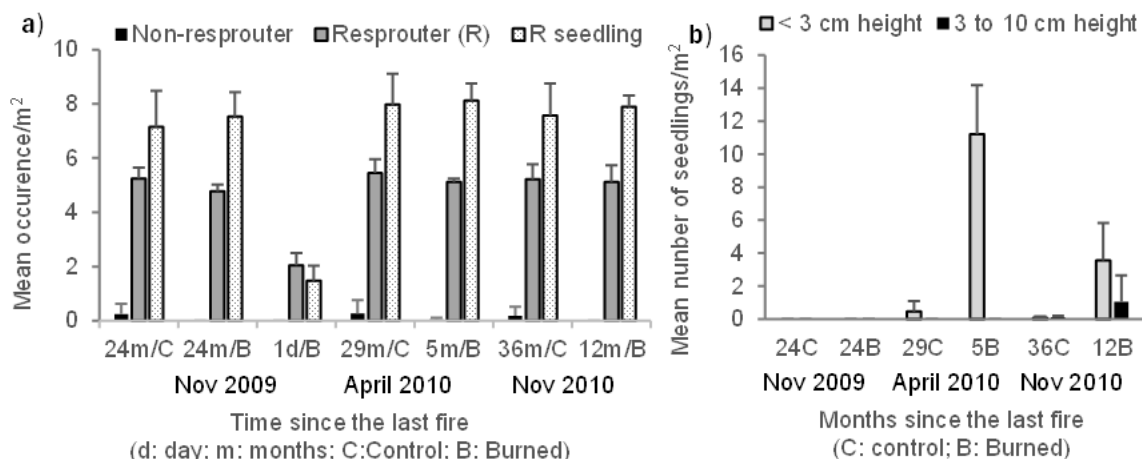


Figure 3

A: mean occurrence of vascular plant species classified as resprouters (R), non-resprouters (post-fire colonizers and seeders), and resprouters with seedlings in a Cerrado grassland. B: mean number of seedlings per m². Cercado Valley, Palmeiras municipality, Chapada Diamantina, Brazilian semi-arid region.

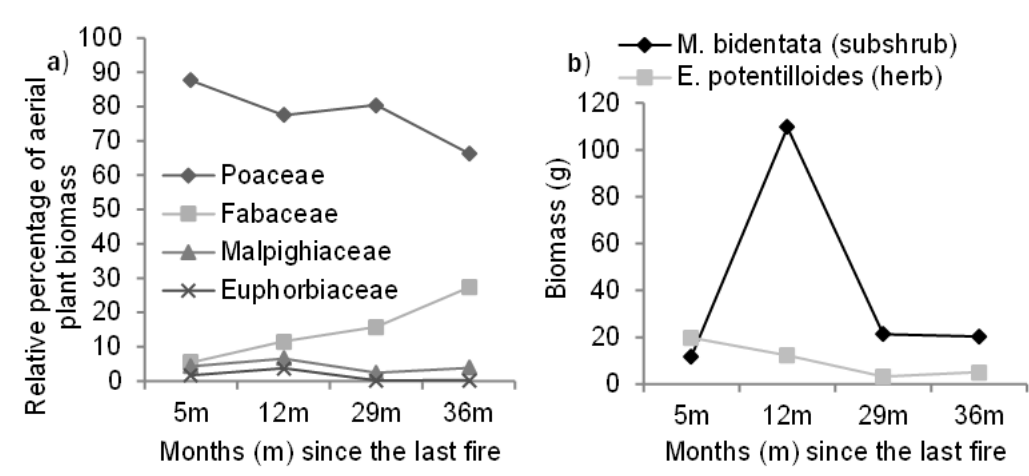
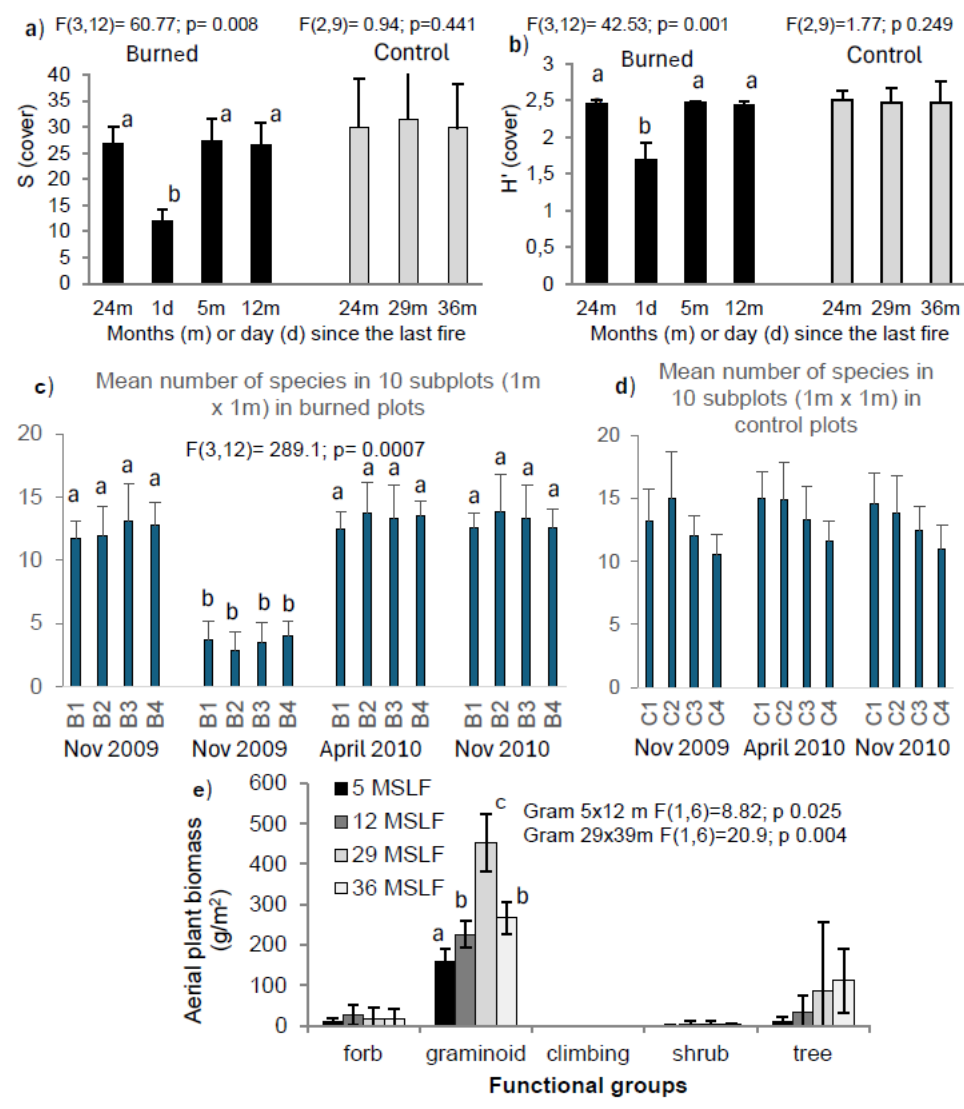


Figure 4

A: relative aboveground biomass of the most abundant plant families in a Cerrado grassland across times since the last fire (other families ranged from 0.5% to 2.1%). B: absolute aboveground biomass of the two most abundant Euphorbiaceae species: the herb *Euphorbia potentilloides* and the subshrub *Microstachys bidentata*. Cercado Valley, Palmeiras municipality, Chapada Diamantina, Brazilian semi-arid region.



Diversity attributes and functional groups in a Cerrado grassland community compared across different months since the last fire (MSLF) in burned and control plots, Cercado Valley, Palmeiras municipality, Chapada Diamantina, Brazilian semiarid region. A: species richness (S) in the pool of ten 1 m² subplots per 20 × 20 m² plot. B: Shannon–Wiener index (H'). C–D: mean number of species per m² (ten subplots) per plot. E: aboveground biomass of functional groups. Distinct letters on bars indicate significant differences among sampling times (P < 0.05).

