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Livestock Management Within a Traditional Agrosilvopastoral System in Northern Minas Gerais, Brazil: A Model for Reconciling Livelihoods and Conservation at a Time of Environmental Change

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Abstract
We examine the ongoing transformation of the livestock raising component of a complex agrosilvopastoral management system associated with the Geraizeiro of northern Minas Gerais state, Brazil. Increasing droughts and regional climate change, associated with large-scale corporate enclosures of upland rangelands and conversion to eucalyptus plantations for industrial charcoal production have undermined *solta*, a customary form of extensive cattle raising and centerpiece of Geraizeiro lifeways. In response, farmers are adapting and transforming another, more intense form of livestock raising associated with managed agroforestry in lower-lying areas, *manga*. Using a social-ecological systems approach and drawing on extensive interviews and ecological inventories, we consider such changes within the overall integrity of the system, suggesting the need to reconsider the role of the Geraizeiros and their use of cattle and fire as a potentially useful tool in reconciling livelihoods and conservation, particularly amidst accelerating social and environmental change and the concomitant threats to the savanna biocultural biome.

Keywords Agroforestry · Cerrado uplands · Fire · Silvopastoral systems · Livestock raising · Social-ecological systems · Geraizeiro · Minas Gerais State · Northern Brazil

Introduction

Occupying 26 % of the earth's surface and using 33 % of the world's agricultural lands, commercial large-scale cattle ranching is the single most important direct and indirect global driver of deforestation, converting biodiverse managed landscapes into structurally and functionally degraded systems (McAlpine *et al.,* 2009) and contributing significantly to the production of greenhouse gases, with attendant negative impacts on climate, biodiversity, soils, watersheds, and local livelihoods (FAO, 2009; Müller-Hansen *et al.,* 2019).

In Brazil, the impact of such cattle ranching-driven deforestation is especially evident in the Cerrado biome (Alencar *et al.,* 2020). Covering close to a quarter of Brazil's land surface, the Cerrado is not just the richest savanna in the world with high levels of endemism; it also provides critical environmental services to the entire region, particularly as its watersheds feed into the major river basins and aquifers of Brazil (Ribeiro & Walter, 2008). Despite its strategic environmental importance, over the past 50 years, 45 % of the original vegetation in the Cerrado has been replaced with commercially sown pastures, soybean monocultures, and eucalyptus plantations (Alencar *et al.,* 2020) (Fig. 1), disrupting the hydrological cycle and intensifying the effects of regional and global climate change (Arantes *et al.,* 2016). The expansion of agribusiness has also aggravated existing social inequalities, displacing smallholders and increasing the unequal concentration of land and income (Sawyer, 2009).

Given the severe environmental and social consequences associated with large-scale commercial cattle ranching, it is

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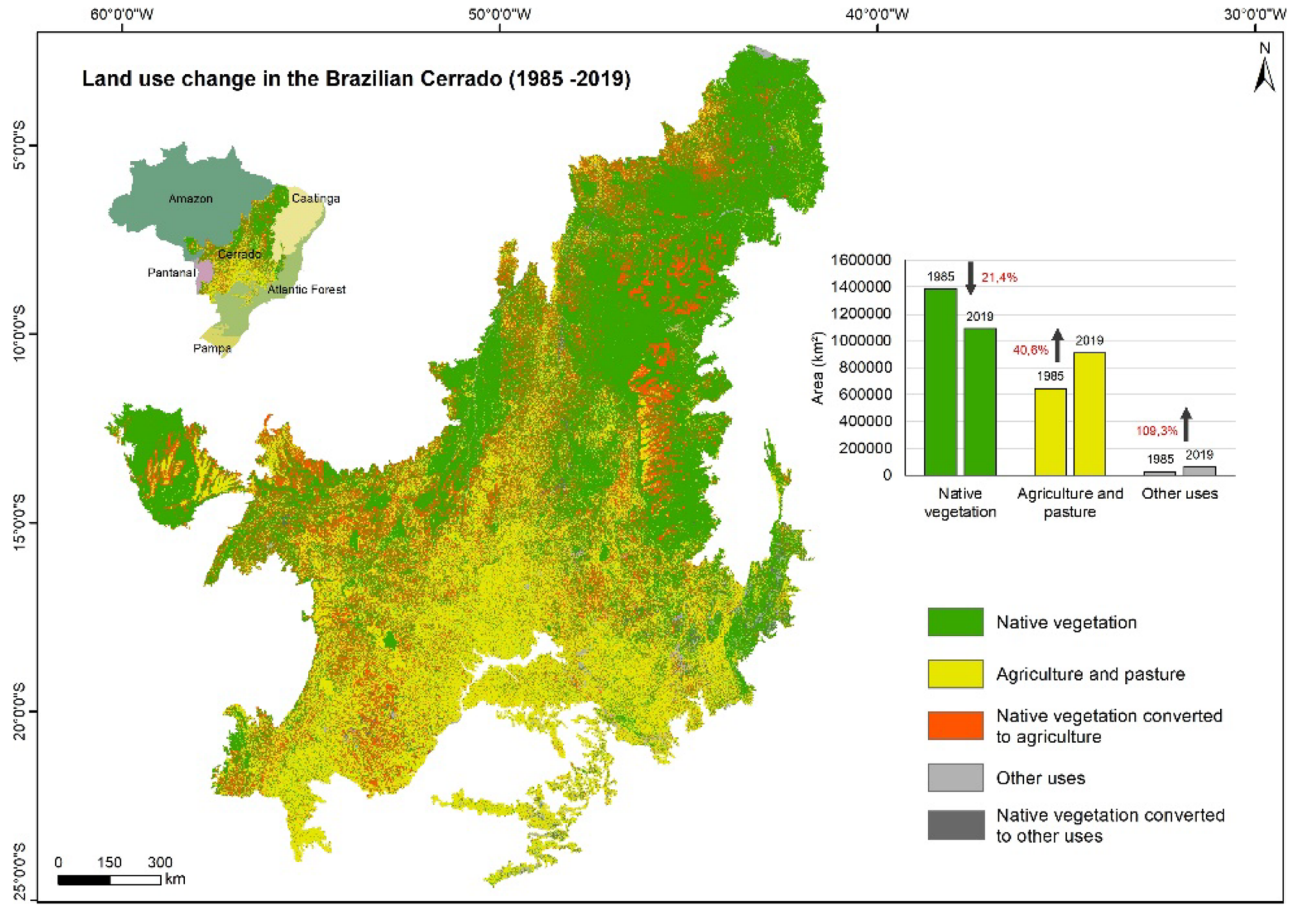

Fig. 1 Land use change in the Brazilian Cerrado from 1985 to 2019

understandable that cattle are widely stigmatized by environmental managers, with policies in place to discourage or even ban the raising of cattle in protected areas and legal reserves[1] (Spinola & Filho, 2019). The chief argument used by Brazilian environmental organizations is that raising cattle, with its concomitant reliance on the use of fire to manage pastures, is not compatible with conservation (Lúcio, 2013). This view prevails in Cerrado biome, despite evidence supporting the role of fire management in maintaining the savanna and preventing uncontrolled and destructive fires (Durigan & Ratter, 2016).

Here we report on a small-scale, local livestock management system that appears to maintain ecosystem structure, function, and resilience in ways that safeguard critical environment services and biodiversity while supporting local livelihoods. Our case study involves the *Geraizeiros*, traditional dwellers of the Cerrado in northern Minas Gerais state, who have historically raised cattle in the savanna uplands - *chapadas* - through a traditional form of extensive management, *solta*, itself part of a larger agrosilvopastoral system (Dayrell, 1998).

Widespread conversion of the uplands by agribusiness over the past 50 years has severely degraded the savanna biome and displaced scores of families, undermining the *solta* and, by extension, the rural communities and biocultural diversity supported by it (Nogueira, 2009). *Geraizeiros´* responses to these disruptions are diverse, complex, and ongoing.

We describe the ongoing transformation of livestock management practices and the agrosilvopastoral system in the Americana agroextractive settlement. Using a social-ecological resilience (SES) framework (Colding & Barthel, 2019), we reflect on the potential of this system for supporting local livelihoods and conservation, particularly in light of the environmental changes brought about by large-scale development, namely loss of biodiversity and increased frequency and intensity of droughts and fires, all of which are likely compounded by climate change. We end with a call for a need of a more supportive,

[1] The Brazilian Forestry Code requires the designation of 20% of rural land in the Cerrado to be preserved, with strict limitations imposed on use and management (Brazil, 2012).

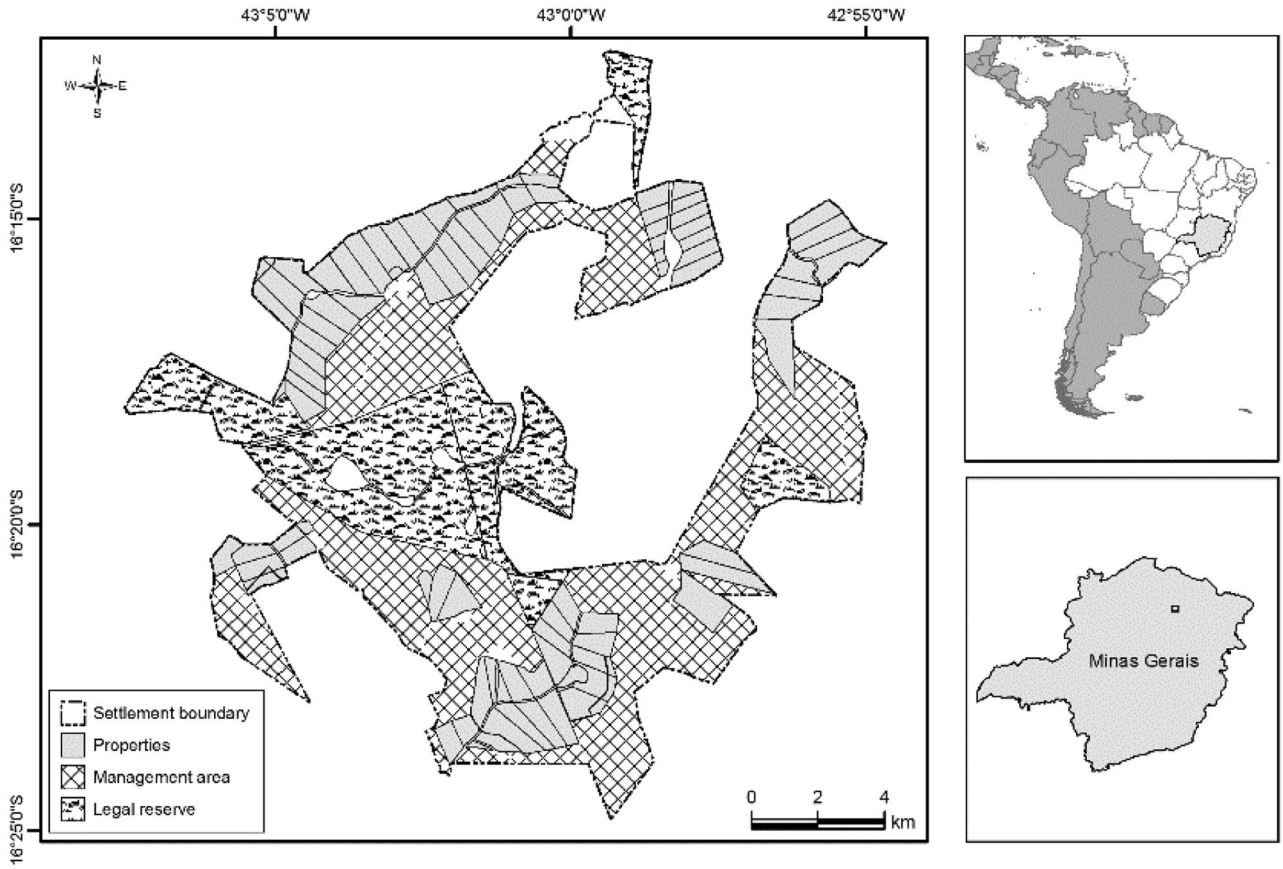

Fig. 2 Americana Agroextractive Settlement in Grão Mogol, northern Minas Gerais, southeastern Brazil

empirically grounded, and balanced policy response to such local agrosilvopastoral systems and in particular to their use of fire and cattle as tools to support resilient cultural landscapes.

Methods

Study Area: The Geraizeiros of Minas Gerais and the Americana Settlement

Geraizeiro is an ethnonym used by a large proportion of the rural population of the Cerrado in northern Minas Gerais, Brazil. Their ethnogenesis is linked to mixing between aboriginal societies, African slaves, and European colonists following the onset of extractive booms in the seventeenth century. After the collapse of gold mining in the eighteenth century, a rural peasantry with a distinct social and territorial identity consolidated around the savanna and extensive livestock raising (Nogueira, 2009).

In the 1970´s, Geraizeiro began to face a series of existential threats following extensive concessions of state-owned lands to companies who replaced the anthropogenic savanna with eucalyptus plantations for industrial charcoal production (Carrara, 2007). Converting half of the Cerrado vegetation in Minas Gerais, these corporate enclosures displaced large numbers of people, generating socioeconomic distress and conflict, ultimately catalyzing the formation of an identity and place-based social movement articulated around agroextractivism as a model for reconciling ecological sustainability with social inclusion and economic development (Dayrell, 1998).

It is in this context that the Americana Agroextractive Settlement was established in 2001, in Grão Mogol municipality, northern Minas Gerais, Brazil (16º22'S; 43º0'W) (Fig. 2), allowing families displaced from other parts of the region to settle in an area previously used for commercial charcoal production[2] (Carvalho, 2012). With a population of 256, the settlement includes 18,922 hectares, divided among a collective agroextractive management area (42%), a community-managed legal reserve (24%), and 76 family

[2] The *Assentamento Agroextrativista* is a modality of land reform specifically aimed at traditional communities whose livelihoods are centered on agrosilvopastoral and forest-based extractivism.

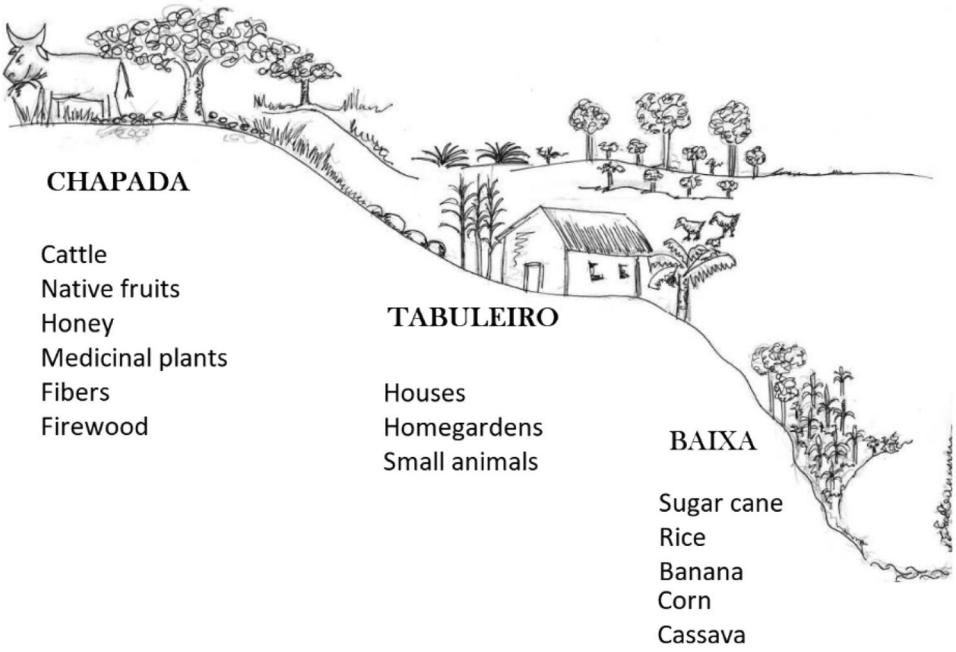

Fig. 3 *Geraizeiro* ecological and subsistence zones. (adapted from Nogueira, 2009)

properties (34 %) (Carvalho, 2012). The climate is markedly seasonal, with dry winters and rainy summers, annual rainfall of 750 mm, and average monthly temperatures between 18 and 30 °C (INMET, 2015). Local vegetation is Cerrado (*sensu stricto*), characterized by scattered trees and shrubs over an herbaceous layer (Ribeiro & Walter, 2008). Livelihoods are characteristically diverse, combining elements of subsistence and market economies through livestock raising, agriculture, and forest-based extractivism, complemented with occasional wage labor, as well as remittances and state pensions.

Geraizeiro subsistence is organized around a complex agrosilvopastoral system and associated patchwork of managed environments, encompassing three major ecological zones with attendant differences in slope, soil, vegetation, and management (Fig. 3). The upland chapadas (ca.850 mamsl),, are associated with an extensive form of cattle-raising, *solta*, and forest-based extractivism (Lima *et al.,* 2013). *Baixas* are low-lying areas where swidden fallow agroforestry is practiced, while the intermediate areas - *tabuleiros* - are used to build settlements, raise small animals and cultivate homegardens. More recently, as we describe below, tabuleiros have become sites for transformation and intensification of a customary livestock-management system, *manga*.

Cattle play a central role in the identity, social life, and subsistence of the Geraizeiro: they provide milk, meat, and manure, are used for traction and transport, serve as a source of capital during periods of crisis, and lie at the core of the diversified and fluid subsistence system that gives Geraizeiro society its resilience (Nogueira, 2009). Currently, farmers have 800 heads of cattle in their agrosilvopastoral system, including areas of *solta* and *manga*.

Data Collection

Field data were collected as part of several projects on the management, use, and conservation of plants in the Cerrado[3] and the study of Geraizeiro management practices (Lima *et al.,* 2012, 2013, 2017). An extended period of participant observation, involving multiple prolonged stays in the community, provided the context and backdrop for conducting a number of surveys and interviews focused on specific botanical and ethnographic aspects (Bernard, 2006; Martin, 1995)[4].

In order to understand the cattle-raising elements of the system, we applied a series of semi-structured and open-ended interviews (*sensu* Bernard, 2006) among 14 locally recognized expert informants. Interviews focused on a wide range of issues relating to livestock-raising practices and their underlying rationale, including breed selection, rotation between *solta* and *manga*, fire management,

[3] Manejo de Plantas do Cerrado: Subsídios técnicos para Políticas Públicas, Uso Sustentável e Conservação da Biodiversidade (Embrapa/TFCA/FUNBIO). Field data was collected by the main author as part of her doctoral fieldwork.

[4] Between 2012 and 2015 the main author and members of her team spent an average of ten days every two months in Americana, conducting fieldwork and participating in many aspects of daily life, including harvesting and processing native fruits and crops, and attending community meetings.

knowledge and use of native vegetation, forage and pastures, as well as socio-environmental trends and transformations. These were complemented with detailed phytosociological and ethnobotanical surveys in three different *mangas*, aimed at gaining a better understanding of management decisions and their impact on the native vegetation (Lima *et al.,* 2017).

Data Analysis

Details on the formal and statistical procedures employed to analyze botanical and ecological data are reviewed elsewhere (Lima *et al.,* 2017). For the analysis of the ethnographic data, we used standard qualitative methods (*sensu* Bernard, 2006) and drew on the existing, albeit limited, literature on the Americana settlement and the Geraizeiros.

Our analysis of the transformation of the agrosilvopastoral system and its role and potential for supporting livelihoods and critical ecosystem services amidst environmental and climate change draws on the social-ecological resilience framework. The social-ecological systems approach proposes that the tight coupling and interaction between social and biophysical processes requires a holistic, systems-based approach to their understanding (Colding & Barthel, 2019). Such an approach is especially relevant in anthropogenic landscapes, such as the Minas Gerais savanna, in which social and ecological formations have co-evolved and are mutually interdependent. Among the surprising properties of such complex adaptive systems are self-organization, emergence, resilience, and open-endedness (Preiser *et al.,* 2018). The concept of resilience speaks precisely to the ability of such systems to absorb shocks while retaining their core structural and functional coherence and identity (Folke, 2016). What is interesting, relevant, and useful about this heuristic for our case study is that this capacity to adapt dynamically to change draws on the ability of the actors - Geraizeiros in this case - to respond creatively, to innovate and, intentionally or not, to alter some features of the system at one level to preserve the system's integrity at a higher level.

The Geraizeiro Agrosilvopastoral Management System and Its Transformations

As noted above, the Geraizeiro agrosilvopastoral management system is organized around three major ecological zones: upland chapada, low-lying baixa, and intermediate tabuleiro (Fig. 3). Throughout this landscape, Geraizeiros manage and select plants in several ways, creating a complex mosaic of agroforestry systems and spaces that differ among households, zones, and over time (Lima et al., 2017).

We now describe how livestock are raised within this ecological continuum and, particularly, how two different cattle management systems, *solta* and *manga*, are changing in response to changing socio-environmental conditions and constraints.

The Cattle *Solta* System and Its Transformation

As a traditional form of extensive cattle farming and central element of Geraizeiro identity, the *solta* dates to the eighteenth century and is most commonly associated with the upland chapadas that are also used for harvesting a range of forest resources (Lima *et al.,* 2012). Access to these extensive commons became increasingly restricted after the 1970s, when industrial charcoal-producing companies began planting extensive areas with eucalyptus. At first, Geraizeiros attempted to graze their livestock among the eucalyptus saplings, but as these grew, animals began to die of thirst and pesticide poisoning.

Water shortages following declines in annual precipitation and more extreme and prolonged droughts became a growing challenge for Geraizeiros (Ganba *et al.,* 2016). Consequently, people started moving some of their animals to the lower-lying transitional tabuleiro, transforming and intensifying the pre-existing cattle management system associated with these areas, *manga*, a process described below.

Fire has traditionally played a key role in the *solta* system. Geraizeiros customarily burn the uplands before the rainy season, encouraging the growth of young palatable shoots and providing the cattle with minerals in the ash (Lúcio, 2013). The use of fire as a management tool has decreased in recent years, following stigmatization by state and non-state agents, particularly in protected areas. In the Americana settlement, for example, the use of fire is prohibited within the legal reserve portion of the community and discouraged by the institution that provides technical support to farmers. According to Geraizeiros, the decrease in the use of fire results in a greater accumulation of biomass and to more intense and destructive fires, an observation that is widely corroborated in Minas Gerais and in other areas of Brazilian savanna (Eloy *et al.,* 2018a; Schmidt *et al.,* 2018).

Despite these disruptions, and albeit reduced in size, chapadas persist to this day in Americana. *Solta* remains a common and valued practice, with cattle foraging on a range of plants of the Cerrado vegetation (Table 1) and Geraizeiros attempting to adapt to water shortages by locating their cattle near ponds and placing water troughs in strategic locations. The system is also changing; the traditional *curraleiro* cattle breed, for example, has been replaced by the faster-growing Indian *nelore* breed. Increasingly too, farmers rotate cattle between the *solta* and the more intensive, lower-lying *manga* system.

Table 1 Native foraging species used by cattle in Americana

Scientific name	Popular name	Consumed parts
Acosmium dasycarpum	Unha-danta	Leaves
Allagoptera campestris	Côco-de-espiga	Fruits and leaves
Attalea geraensis	Côco-catolé	Fruits, flowers and leaves
Brosimum gaudichaudii	Salva-vida	Leaves
Butia capitata	Coquinho-azedo	Flowers, fruits and leaves
Caryocar brasiliense	Pequi	Flowers on the ground
Guapira noxia	Pau-de-urubu	Leaves
Hancornia speciosa	Mangaba	Fruits
Handroanthus ochraceus	Ipê-marelo	Leaves and flowers
Hymenaea stigonocarpa	Jatobá	Fruits
Magonia pubescens	Tingui	Leaves
Passiflora cincinnata	Maracujá-nativo	Fruits, leaves
Pouteria torta	Fruta-de-leite	Fruits
Schefflera macrocarpa	Violeiro	Leaves
Swartzia sp.	Ingá-do-Cerrado	Leaves
Syagrus flexuosa	Côco-de-vassoura	Fruits and leaves
Tontelea micrantha	Rufão	Fruits

The *Manga* System: Cattle Raised in Silvopastoral Systems

Mangas, fenced enclosures in the intermediate-lying tabuleiro areas (Fig. 3), were traditionally used as holding spaces for animals that were sick or in need of attention. As upland grazing land and water became scarcer, farmers started relying more on *manga* to support their herds, with more farmers fencing more and larger enclosures, seeding them with new kinds of grasses, and developing a more intense, yet diverse, livestock-raising system that complements *solta*.

For an area to become managed as a *manga*, and to allow the seeded grass to grow (*Andropogon* sp., *Braquiaria* sp.), farmers first selectively clear some of the original woody vegetation, sparing or even promoting useful and valued species, ultimately creating an agroforestry system that includes an assortment of over 31 timber, fruit, fodder, and medicinal species (Tables 2 and 3). Our preliminary data (Table 3) suggest that these agroforestry plots retain a high proportion of the original species richness and diversity, even just two to three weeks after the initial thinning and seeding with introduced grasses (Lima *et al.,* 2017).

The expansion and intensification of *manga* within the tabuleiro and *Geraizeiro* livelihoods, evidenced in the increased numbers of livestock raised and investments of land, labor, and capital made by an increasing number of households, are best understood in the context of the broader socio-environmental changes unfolding in the area and their impact on different parts of the system, most importantly the *solta*.

Solta and *Manga* As an Integrated, Adaptative Management System

In response to the increased frequency and intensity of droughts, a growing number of *Geraizeiros* rotate livestock between *solta* and the *manga* according to a seasonal cycle. At the onset of the rainy season, in October, they release livestock into the chapada, where they remain until the beginning of the dry season, six to eight months later. As the availability of native forage decreases, they move the cattle to the lower seeded pastures of the manga, by which time the grass will have grown to about 60 cm in height. Once the grass is grazed to about 30 cm, livestock once again return to the chapada, allowing the manga grass to grow and re-seed, until it reaches a height of 60 cm again, when the cycle begins anew.

Throughout the entire cycle, cattle also rely on the leaves, fruits, and flowers of a whole range of Cerrado species (Table 1). The combination of herbaceous and woody species adds an element of nutritional diversity and thus resilience to the livestock's diet (Calle *et al.,* 2009). Leguminous trees, for instance, produce high-quality, digestible forage, critical during the dry season when other forage and grasses become unavailable (Dagang & Nair, 2003). Native fruit species (Table 2), managed in the *manga* agroforestry plots, also contribute to the resilience of the system, providing fodder to cattle and a source of income (Calle *et al.,* 2012, Lima *et al.,* 2017).

During the dry season, farmers also supplement the cattle´s diet with sugarcane from their agricultural plots in the baixa, though this practice is diminishing due to the growing water shortages. Some also provide livestock with an additional home-made supplement of urea, corn meal, and mineral salt, reportedly increasing their appetite, and allowing them feed on dried-out plant matter. How long the cattle remain in the *manga* depends on the size of the area, the quantity and quality of grass available, and the density of livestock, that is, on the specific constraints and affordances facing each farmer and site.

The ability of *Geraizeiros* to mediate between three tightly coupled social-ecological zones, each with their distinct and shifting affordances, generates multiple possibilities, yielding the diversity, adaptability - and hence resilience - that characterizes such complex systems (Folke, 2016). Seen from a systems perspective, the individual and collective

Table 2 Use category of plant species spared during *manga* management. (adapted from Lima *et al.,* 2017)

Scientific name	Popular name	Use category
Acosmium dasycarpum	Unha-danta	Medicinal, timber and fodder
Annona crassiflora	Panã/Araticum	Fruit tree
Aspidosperma macrocarpon	Chapéu-de-couro	Medicinal
Aspidosperma tomentosum	Pereiro-de-chapada	Timber
Astronium fraxinifolium	Gonçalo	Timber and medicinal
Bowdichia virgilioides	Sucupira-branca	Timber
Caryocar brasiliense	Pequi	Fruit tree
Dalbergia miscolobium	Cabiúna	Timber
Eriotheca gracilipes	Embiruçu-paulista	Timber
Eugenia dysenterica	Cagaita	Fruit tree
Guapira noxia	Pau-de-urubu	Timber and fodder
Handroanthus ochraceus	Ipê-amarelo	Timber and medicinal
Hymenaea stigonocarpa	Jatobá	Timber; medicinal and fruit tree
Hyptidendron sp1	Alecrim-de-tabuleiro	Timber
Lafoensia pacari	Pacari	Medicinal
Machaerium opacum	Jacarandá	Timber
Magonia pubescens	Tingui	Timber
Plathymenia reticulata	Vinhático	Timber
Plenckia populnea	Mangabeira-brava	Timber
Qualea grandiflora	Pau-terrão	Timber and medicinal
Qualea parviflora	Pau-terrinha	Timber
Roupala montana	Espinheira-santa	Medicinal
Schefflera macrocarpa	Violeiro	Fodder
Sclerolobium cf. *aureum*	Pau-fede	Timber and medicinal
Strychnos pseudoquina	Quina-de-papagaio	Medicinal
Stryphnodendron adstringens	Barbatimão	Medicinal
Tabebuia aurea	Caraíba	Timber
Terminalia argentea	Capitão	Timber and medicinal

ability of *Geraizeiros* to preserve the structural and functional integrity of the agrosilvopastoral system hinges on their ability to transform certain of its lower-level components, such as *manga*. The manga and tabuleiro's strategic location between the upland and lowlands and their proximity to settlements is itself a resource insofar as it allows farmers to manage nested and growing uncertainties and constraints.

The example of the transformation of *manga* thus not only reflects the adaptability of the agrosilvopastoral system and transformability of various elements within it, but also illustrates how resilience is related to people's ability to engage with the three interdependent ecological zones at multiple scales[5]. Such environmental and social heterogeneity and diversity are attributes of many resilient social-ecological systems (Leslie & McCabe, 2013), as indeed are the knowledge and creativity of the users. Understanding how the system operates and responds, its limits and its dispositions, is something *Geraizeiros* can do because of their long-standing and intimate relationship with cattle, landscape, and each other.

Table 3 Phytosociological parameters for trees with diameter at 30 cm from the ground level (DA30) ≥ 5 cm, surveyed before and after the implementation of a *manga.* (adapted from Lima *et al.,* 2017)

Parameter	Trees $DA_{30} \geq 5$ cm	
	Before	*After*
Number of individuals sampled	1,038	271
Richness	50	31
Botanical families	29	20
Density	692 ha^{-1}	181 ha^{-1}
Shannon-Wiener index	3.0	2.7
Equitability	0.76	0.78

[5] The concept of adaptability refers to people's ability to engender resilience through their actions, whereas transformability refers to their capacity to create a new system when the previous one becomes untenable (Folke, 2016).

Resilience and the *Geraizeiro* Agrosilvopastoral Management System: Re-assessing the Role of Cattle and Fire

Our short review illustrates how the practices of the Americana *Geraizeiro* form a complex, diverse, and fluid agrosilvopastoral management system that not only draws from and connects to knowledges, practices, and relations, but also extends across all domains of the biophysical environment: it constitutes, in effect, a social-ecological system (Westley *et al.,* 2002). We have also sought to show how farmers are adapting to change and external shocks by creatively transforming elements within the system, and how this ability itself hinges on a sophisticated understanding of their lived environment, of its transformability, and the importance of diversity and adaptability as ways to manage risk and uncertainty.

While a more comprehensive description of such a system and its environmental impacts and implications exceeds the scope of this paper, there are some of key aspects, issues, and challenges that we wish to highlight, particularly in relation to the two most controversial, interrelated, aspects of *Geraizeiro* management and relationship to the landscape: their customary reliance on cattle and, especially, fire.

In contrast with large-scale commercial ventures, the *Geraizeiro* do not rely on systematically eliminating or burning the forest cover, but rather on modifying it in ways that are attuned to the socioecological affordances of different biotopes, drawing on the use of fire in the chapada and on selective thinning and direct plant management in the tabuleiro. We briefly examine each of these, paying attention to the ecological and scale-dependent and complex role of disturbance as one contributing factor in generating ecological diversity and resilience (Bliege Bird, 2015; Ramos-Neto & Pivello, 2000).

The relationship between humans, fire, and the Cerrado rangelands is extremely old and likely precedes the Holocene (Cordeiro *et al.,* 2014; Pyne, 2019). This coevolution is evident insofar as much of the Cerrado vegetation is not only fire-resistant but also fire-dependent (Hoffmann & Moreira, 2002). Frequent fires reduce woody vegetation density and favor herbaceous and sub-shrub species, generating more open phytophysiognomies (Miranda *et al.,* 2002). On the other hand, systematic suppression of fire increases tree density and generates more closed phytophysiognomies (Hoffmann & Moreira, 2002), which may reduce herbaceous and sub-shrub diversity (Bond & Keeley, 2005) and increase biomass accumulation, a process that in turn is linked to 'hotter,' more destructive, fires (Ramos-Neto & Pivello, 2000).

There is evidence suggesting that savanna landscapes formed by a mosaic of unburned and burned patches at different intervals may help generate more diverse landscapes with higher species diversity (McGregor *et al.,* 2010; Ramos-Neto & Pivello, 2000). A critical distinction therefore is between the effects of smaller, more localized and carefully managed fires and those of much hotter, intense, large-scale fires resulting from, among other things, indiscriminate fire suppression policies (Durigan & Ratter, 2016).

The increasingly outdated views associated with indiscriminate fire suppression policies are giving way to a more nuanced understanding of the importance of fire as a tool for sound management, both within and outside protected areas, particularly in the savanna and rangelands of lowland South America (Pivello, 2011) and beyond (McGregor *et al.,* 2010). Associated with this is an increasing recognition of the value and sophistication of local fire management practices and knowledges and, in parallel, of the importance of fire in maintaining and supporting the biocultural diversity and socio-ecological resilience of savanna regions (Bilbao *et al.,* 2010; Eloy *et al.,* 2018a).

In those cases where fire suppression is the preferred management option, livestock can perform a function similar to fire, reducing biomass accumulation and the incidence of alien grasses (Bond & Keeley, 2005). There is some evidence to support that in combination, moderate grazing and fire use do not negatively affect plant richness or diversity in savanna areas and indeed may increase it (Savadogo *et al.,* 2007; Welch *et al.,* 2013). Combining low intensity fire in a mosaic of burned and unburned areas with moderate grazing and rotation of animals could allow sufficient recovery of the areas while maintaining the Cerrado biodiversity (Ramos-Neto & Pivello, 2000), supporting the notion that *solta* has an important place in the continued and effective management of uplands.

As the large herbivores and through their trampling, grazing and browsing actions cattle are themselves agents of disturbance, though, like other forms of disturbance, the effects are scale-dependent and in need of further investigation (Schieltz & Rubenstein, 2016). In this sense, farmers are keenly aware of the importance of limiting animal density and of rotation as ways to avoid soil compaction and overgrazing. *Geraizeiros* also assert that livestock favor seed dispersal and break seed dormancy of several species, an effect which may be linked to an observed correlation between grazing and a higher density of trees in some parts of the Cerrado (Lúcio, 2013).

While livestock production through the *manga* system is more intensive and entails selective thinning of the woody vegetation, the scale and extent of such disturbance contrast dramatically with the wholesale removal of forest cover associated with commercial cattle ranching. Its effect is not to create a simplified, pasture-dominated, landscape, but a distinct anthropogenic forest-savanna environment, one whose precise composition and species distribution reflects human needs, but whose overall structure and diversity - as

our data tentatively suggest - appears to retain the overall integrity and function of the system while supporting human needs and livelihoods. There is also a substantial amount of anecdotal and indirect evidence to suggest that the small-scale and uneven disturbance generated through thinning contributes to the creation of ecological heterogeneity and patchiness, which may itself serve important ecological functions, including maintaining diversity (Bliege Bird, 2015).

Conclusions

Through a brief description of the *Geraizeiro* agrosilvopastoral social-ecological system and through a particular focus on the raising of livestock and the use of fire, we have sought to make two general points. First, Geraizeiro use of cattle and fire is very different in form, function, and effects to those of large agribusiness. Not only are the low-level controlled burns associated with Geraizeiros management distinct from the indiscriminate and/or destructive burning associated with large-scale conversion of forests to pasture, but such local forms of fire management are potentially useful elements in the prevention of uncontrolled wildfires and in the effective management of savanna.

Second, and relating to the above, the resilience and viability of the *Geraizeiro* agrosilvopastoral system reflects and relies on its ability to change, adapt, and transform some of its components. The ecological diversity of the Cerrado environment, characterized by the chapada-tabuleiro-baixa triad, is critical in this regard, as is the fact that most families in Americana have access rights to all of these. Underpinning the entire system is the sophisticated knowledge and familiarity that people have with their lived environment, including their emotional attachment to the savanna and to the traditional practices that confirm their social identity.

The notion that such local agrosilvopastoral systems play an important role in supporting livelihood needs and conservation goals is supported by other case studies (Batista *et al.,* 2018; Carvalho, 2013; Eloy *et al.,* 2018b; Lúcio, 2013). The resilience framework, with its recognition of the role and importance of local social actors and institutions as agents of adaptive change and transformation, is a useful heuristic in light of the fact that regional and global capitalogenic climate and environmental change are introducing new kinds of risks and uncertainties (Folke, 2016). The unprecedented crisis signaled by novel fire and climate regimes highlights the need to encourage adaptive responses that promote socio-ecological resilience at multiple scales of governance (Gillson *et al.,* 2019; Ostrom & Janssen, 2004).

We hope these considerations will translate into more attention by researchers - and thus better understanding of the system and its potential - and to a greater degree sensibility and caution by environmental managers and policy makers, whose attitudes to *Geraizeiros*, cattle, and especially fire, are sometimes not attuned to these important differences. It would be doubly ironic, if not tragic, if *Geraizeiros* and other local resource managers were being sanctioned for the effects of cattle and fire that are not only of their own doing, but which are in fact the product of the very forces and interests that are threatening the *Geraizeiro's* own capacity to continue to sustain the anthropogenic landscape that is the Cerrado.

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Data Availability The datasets developed and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest The authors declare they have no conflict of interest.

Informed Consent Informed consent was obtained from members of Americana Settlement community.

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