

Impacts of the implementation of silvopastoral systems on biodiversity of native plants in a traditional community in the Brazilian Savanna

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Received: 10 February 2016 / Accepted: 24 June 2016 / Published online: 1 July 2016
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Abstract Large-scale commercial cattle ranching is the main driver of deforestation in the world, with several negative environmental and social impacts. To meet the growing demand for animal products, silvopastoral systems (SPS) can be an alternative as they have greater biodiversity and offer more environmental services than conventional cattle ranching systems. This paper aims to describe the implementation of SPS by traditional farmers in a rural settlement in southeastern Brazil, and the impacts on biodiversity of native plants. SPS were implemented by farmers in three selected areas that were cleared with a tractor. The impacts on the community and populations of native plants were estimated through vegetation sampling before and after the implementation of the SPS. Direct observations and semi-structured interviews were conducted to describe the implementation of the system and to understand the criteria employed to spare species, to manage native

plants and the advantages of these systems according to farmers' perceptions. Before the implementation, 1038 trees from 50 species and 29 botanical families were surveyed in the three areas. The tractor cleared on average 72 % of the trees, decreasing the number of trees ha^{-1} from 692 to 180 and reducing tree richness in 43 %. On average, 89 % of the removed trees had diameter ranging from 5 to 10 cm, indicating farmers' preference in sparing the thickest trees. Farmers also spare useful species that have socio-economic importance, such as timber, fruit trees, fodder and medicine. According to the farmers, the advantages of the SPS are the high concentration of useful species, the environmental services provided and the increase in livestock production. The system described has great potential to ensure food security, generating socio-economic benefits for farmers and contributing to biodiversity conservation.

Keywords Agroforestry system · Cattle · Livestock · Cerrado · Geraizeiros

Electronic supplementary material The online version of this article (doi:10.1007/s10457-016-9981-4) contains supplementary material, which is available to authorized users.

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Introduction

The increasing demand for animal products has driven agriculture expansion, especially in developing countries, increasing deforestation (Matson et al. 1997; McAlpine et al. 2009; Steinfeld et al. 2006) and converting native areas into simplified and

homogeneous systems with reduced ecological functions (Lamb et al. 2005; Vitousek et al. 1997). Commercial cattle ranching is the main driver of deforestation in the world, occupying 26 % of the earth's surface and using 33 % of the world's agricultural lands for fodder production (FAO 2009; McAlpine et al. 2009). The activity implies in several negative impacts on biodiversity and peoples livelihoods, leading to species extinction, soil erosion and compaction, water pollution, increased greenhouse gases emissions and displacement of rural populations (FAO 2009; Fearnside 2001; Sawyer 2009; Steinfeld et al. 2006; Steinfeld and Wassenaar 2007).

In Brazil, the rapid agricultural expansion caused impacts on all biomes, especially in the Amazon (Fearnside 1990, 2001; Walker et al. 2009) and *Cerrado*, the richest savanna in the world, covering 23 % of the Brazilian geographical extension (Aguir et al. 2004; Klink and Machado 2005; Ribeiro and Walter 2008). Over the past 40 years, half of the original vegetation of the *Cerrado* has been replaced, mainly with planted pastures and soybean monocultures (MMA, IBAMA 2011). Despite the negative impacts, there is no indication that this trend will decrease, considering the rising demand for animal products, which is already high in developed countries and increasing in developing ones (FAO 2009; McAlpine et al. 2009; Steinfeld et al. 2006). This scenario of rapid biodiversity loss and environmental services disruption calls for innovative and non-conventional land uses that take into account not only economic but also environmental and social aspects.

Silvopastoral systems (SPS) are an environmentally friendly alternative to conventional pastures as they combine in the same area livestock, fodder plants, trees, shrubs, grasses and palm trees (Murgueitio et al. 2011). These systems have greater biodiversity and offer more environmental services than conventional cattle ranching systems (Calle et al. 2009; Haile et al. 2010; Hermuche et al. 2013; McAdam et al. 2007). Besides that, SPS can be more productive (Calle et al. 2012; Dagang and Nair 2003), durable (Steinfeld et al. 2006) and resilient to climate changes (Calle et al. 2009; Murgueitio et al. 2011).

Plants in SPS offer a variety of direct benefits, such as fuelwood, medicine, edible fruits, seeds and flowers, which can be consumed or traded (Bellefontaine et al. 2002; Calle et al. 2012; Foresta et al. 2013). Beyond direct benefits, trees can also mediate

ecological processes, increasing soil moisture and fertility, contributing to reduce soil erosion and compaction and to increase carbon sequestration (Jose 2009; Jose and Bardhan 2012; Wedderburn and Carter 1999).

Despite these positive aspects, the impacts of the implementation of SPS on biodiversity have been poorly studied (McAdam et al. 2007; Mosquera-Losada et al. 2009). To contribute to fill this gap we used a combination of field inventories with ethnobotanical surveys to assess the impacts of the implementation of SPS on biodiversity of native plants within a traditional community in the Brazilian savanna. We addressed the following questions: (1) what are the effects of the implementation of the SPS on plant richness, diversity and abundance? (2) which species and plant sizes are spared during the implementation of the SPS? and (3) what are the advantages of this system compared to conventional cattle raising systems?

Materials and methods

Study area

The Americana Settlement is located in Grão Mogol municipality, northern Minas Gerais, southeastern Brazil (16°22'S; 43°0'W) (Fig. 1). The local vegetation is a transition between two ecosystems, known as *Cerrado* and *Caatinga*, with predominance of *Cerrado* formations (Dayrell 1998). The climate is Aw (Köppen classification), with dry winters and rainy summers (Peel et al. 2007), average annual rainfall of 800 mm and average monthly temperature between 18 and 30 °C (INMET 2015).

The Settlement comprises 76 households, mainly *Geraizeiros* (77 %)—a traditional population originated from a mixture of indigenous, white and black people, including European colonists and African slaves (Nogueira 2009). The Settlement has 18,922 hectares, divided into legal reserve (24 %), private properties (34 %) and a collective management area (42 %) (Carvalho 2012) (Fig. 1). The landscape is classified by local people according to slope, soil, vegetation, uses and management (Carvalho 2013; Dayrell 1998). The highest areas are rangelands used to raise cattle and harvest forest products. The intermediate areas are used to build houses, raise

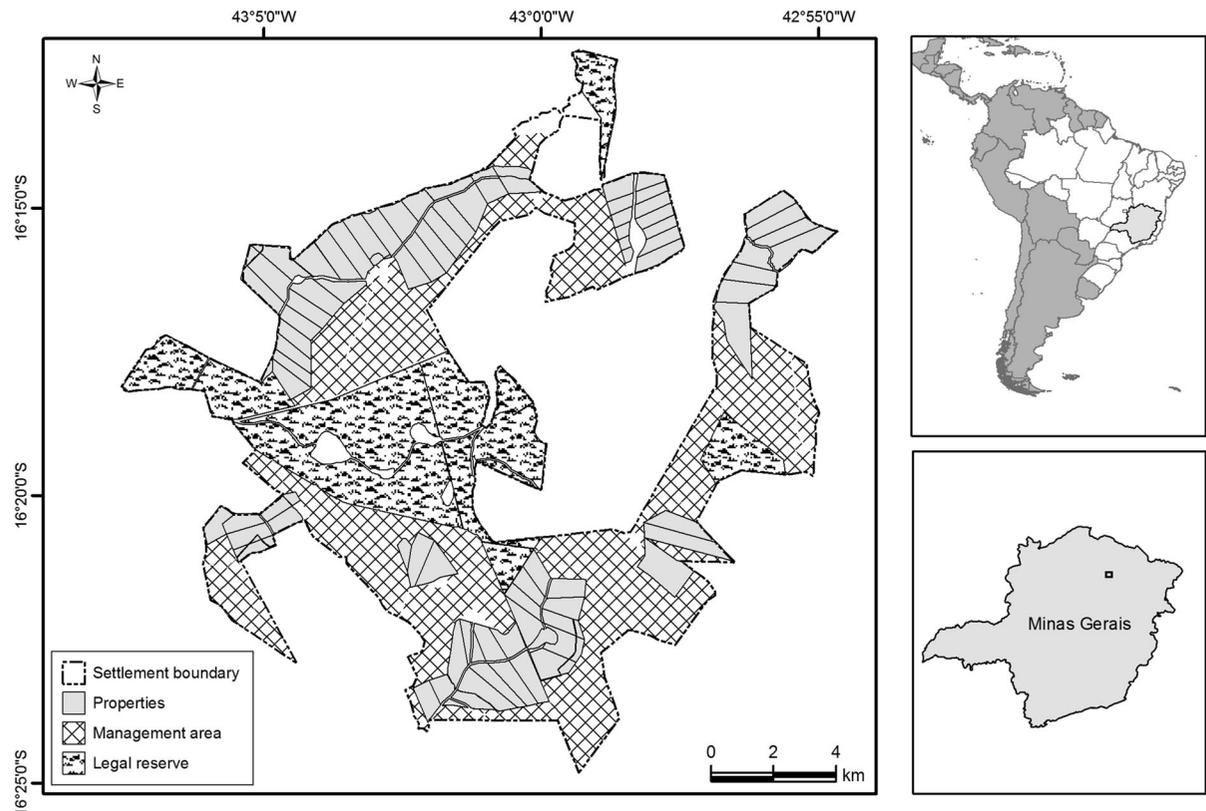


Fig. 1 Americana Settlement in Grão Mogol, northern Minas Gerais state, southeastern Brazil, indicating areas of collective management and legal protection

small animals and cultivate homegardens. The lowest areas are used for agriculture, usually in rotational and diversified systems, historically based on slash and burn (Dayrell 1998; Nogueira 2009).

Implementation of SPS and impacts on native plants biodiversity

SPS were implemented in three areas by *Geraizeiros* through a participatory methodology (Sithole et al. 2002). The areas (total size = 2.5 hectares) were cleared with a tractor which cut the herbaceous/shrub layer and thin trees. The thicker and desirable tree species were indicated by the farmer to be spared. After removal of the selected trees, the tractor was used to plow the soil and the African grass *Andropogon gayanus* Kunth was sown manually.

To estimate the impact of the SPS implementation on biodiversity of native plants, two phytosociological surveys were conducted in each of these three areas,

the first one before and the second one after the implementation of the SPS. All trees with diameter at 30 cm from the ground level ($DA_{30} \geq 5$ cm) were sampled in plots of 0.5 hectare each (total size = 1.5 ha). Sampled trees were identified and measured in DA_{30} and total height.

Outside the three SPS implemented, a third survey was conducted aiming to estimate the impacts of the tractor on herbs, shrubs and trees with $DA_{30} \leq 5$ cm. For this survey, 12 plots of 9 m² were allocated, six on plowed areas and six on adjacent non-plowed areas. All plants within these plots were identified and had diameter at soil level and total height measures recorded. Each individual was excavated around the stem to verify whether the plant was originated from seeds or sprouts.

The effects of the SPS implementation in the plant community in the three areas were analyzed in richness, density, basal area, Shannon diversity (H') and Pielou equitability (J') (Mueller-Dombois and

Ellenberg 1974), through the software Fitopac 2.1 (Shepherd 2010). The paired t-test was used to check for significant differences between these parameters within the first and the second surveys. To compare the distribution of diameter class of the tree community and the population structure of the tree species, before (first survey) and after (second survey) the implementation of the SPS, it was performed the Kolmogorov–Smirnov test, using the software R (R Core and Team 2015). For the third survey, the same phytosociological parameters were analysed and the t-test was used to check for significant differences between plowed and non-plowed areas. Botanical specimens of plants not identified in the field were collected and deposited in the Herbarium CEN—Embrapa Genetic Resources and Biotechnology, in Brasília-DF, for later identification consulting the literature and specialists.

Ethnobotanical surveys

A complete description of the implementation of the SPS was obtained through semi-structured interviews and direct observations in the three areas, during the implementation process (Bernard 2006). Ethnobotanical surveys were conducted in the field, after clearing the areas, to understand the criteria employed to spare species (Martin 1995).

To understand how *Geraizeiros* manage native plants, their perception of the ecological processes mediated by native plants and the advantages of SPS when compared with conventional cattle ranching systems, we conducted semi-structured interviews (Bernard 2006) with 14 peasants.

Results and discussion

Implementation of SPS—impacts on native plants biodiversity

The implementation of SPS requires clearing natural vegetation, which can be done manually or mechanically. The tractor has been widely used by farmers for making the process easier and faster. According to farmers, clearing the vegetation enables grass development and felling trees is not always necessary, but it is inevitable when using a tractor.

Before the implementation of the SPS, a total of 1038 trees from 50 species and 29 botanical families

were surveyed in the three areas. Mean tree density was 692 ha⁻¹ (388–1006) and mean species richness was 32.3 (25–39). The tractor felled on average 72 % (64.5–77) of the trees. Tree average density therefore decreased by 74 %, from 692 to 180.6 ha⁻¹ ($t = 3.3$, $df = 2$, $p = 0.07$) and average total basal area decreased by 47 %, from 2.8 m² ha⁻¹ (2.4–3.2) to 1.5 m² ha⁻¹ (1.2–1.8) ($t = 3.94$, $df = 2$, $p = 0.05$).

The SPS implementation caused a reduction in the tree Shannon diversity from 2.7 nats/ind (2.6–2.9) to 2.3 nats/ind (2.0–2.6) ($t = 5.1$, $df = 2$, $p = 0.03$) and a reduction of 43 % (38.5–48.0 %) in tree richness ($t = 15.4$, $df = 2$, $p < 0.01$) (Table 1). However, these reductions are possibly apparent, because most *Cerrado* species are resilient to disturbances, sprouting through mobilization of reserves stored in roots or stem (Bond and Midgley 2001; Dayamba et al. 2011; Miranda et al. 2002; Neke et al. 2006), as demonstrated in the third survey comparing plowed and non-plowed areas. Despite the significant reduction in plant density in the plowed areas ($t = 5.09$, $df = 8.40$, $p < 0.01$), plant richness ($t = 0.95$, $df = 8.44$, $p = 0.37$), Shannon diversity ($t = 0.63$, $df = 7.59$, $p = 0.55$) and equitability ($t = 1.90$, $df = 6.42$, $p = 0.10$) were not statistically different in plowed and non-plowed plots, indicating the great resprouting capacity of the species after mechanical clearing (Table 1).

On average, 89.2 % (88–94 %) of the removed trees had diameter (DA₃₀) ranging from 5 to 10 cm, indicating the preference of the peasants for removing the thinner trees and sparing the thickest ones. The distributions of diametric classes before and after removal of the trees are statistically different (Kolmogorov–Smirnov; $D_{area1} = 0.28$, $D_{area2} = 0.44$, $D_{area3} = 0.31$, $p < 0.01$), with more pronounced reduction in the smaller classes (Fig. 2). Diameter class distribution of 18.5 % of the species sampled were significantly modified after mechanical clearing ($D = 0.34$, $p < 0.01$) (Table 2). Additionally, 19 tree species sampled in the survey before mechanical clearing were not sampled after.

Besides prioritizing cutting down trees with smaller diameter, farmers purposefully spare specific species—generally trees providing timber, fruits, fodder and medicine. Among the 31 tree species spared in the three areas, 18 are used for timber (58 %), 13 are medicinal (41.9 %), four are fruit trees (12.9 %), three are fodder (9.6 %) and only three do not belong to any use category (Table 2; Fig. 3).

Table 1 Phytosociological parameters for trees with $DA_{30} \geq 5$ cm, surveyed before and after the implementation of SPS; and herbs, shrubs and trees with $DA_{30} \leq 5$ cm surveyed in plowed and non-plowed areas

Parameter	Trees $DA_{30} \geq 5$ cm		Herbs, shrubs and trees $DA_{30} \leq 5$ cm	
	Before	After	Non-plowed	Plowed
Number of individuals sampled	1,038	271	582	378
Richness	50	31	88	85
Botanical families	29	20	39	43
Density	692 ha ⁻¹	181 ha ⁻¹	5.4 m ⁻²	3.5 m ⁻²
Shannon-Wiener index	3.0	2.7	3.8	3.9
Equitability	0.76	0.78	0.9	0.9

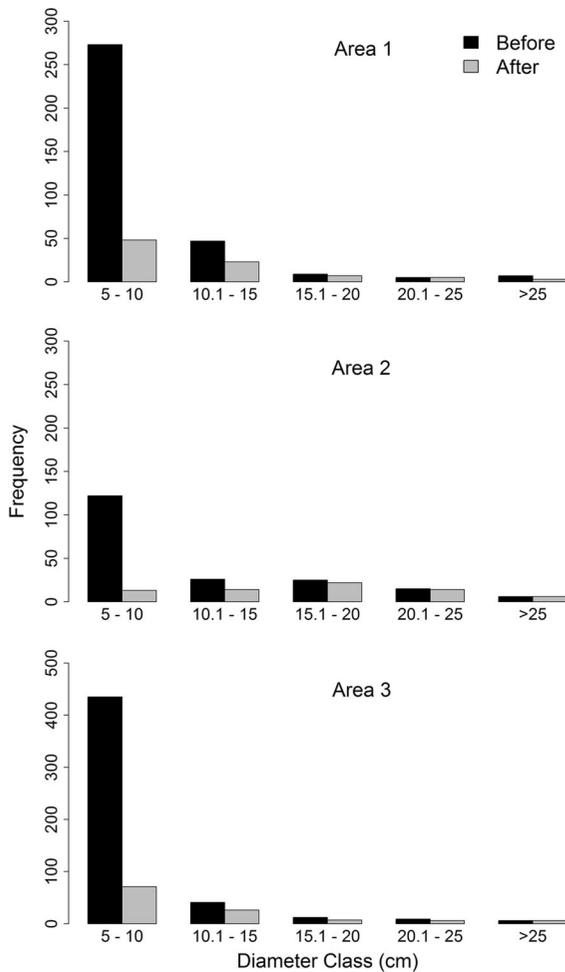


Fig. 2 Size class distributions of the tree community in three areas before and after clearing for the implementation of silvopastoral systems

Among the species with highest density before clearing the areas, the lowest clearing rates were for *Caryocar brasiliense*, with a mean spare rate of 71.2 % and *Bowdichia virgilioides*, with a mean spare rate of 55.6 % (Fig. 3; Table 2). Both species have high socio-economic importance for farmers. *C. brasiliense*, whose felling is illegal, produces the main forest product in the region—fruits widely used and sold in the regional market (Oliveira and Scariot 2010). *B. virgilioides* has high quality timber, used mainly for furniture making (Almeida et al. 1998).

To complete the SPS implementation, the grass is manually sown after the clearing, in the beginning of the rainy season. Generally, farmers plant only two grass species—*Andropogon gayanus* and *Brachiaria decumbens*—both of African origin. African grasses have higher productivity than the native ones due to high photosynthetic capacity, higher seed production and faster germination (Pivello et al. 1999). Furthermore, they tolerate fire and grazing (D’Antonio and Vitousek 1992). Between 3 and 6 months after germination, the grass reaches around 60 cm of height; when pastures are ready to receive livestock for grazing.

Management and advantages of SPS according to farmers’ perceptions

A remarkable feature of SPS implemented in the Americana Settlement is the high number of sprouts from different species. Of the 961 herbs, shrubs and trees with $DA_{30} \leq 5$ cm surveyed in plowed and non-plowed *Cerrado* plots, 93.6 and 85.7 % ($t = 1.15$,

Table 2 Plant uses of native tree species spared in SPS; density before and after clearing the areas and the results of the Kolmogorov–Smirnov test (D), indicating differences in the population structures before and after the implementation of the system

Species	Popular names	Use category	Density (ha ⁻¹) before	Density (ha ⁻¹) after	Density reduction (%)	D test
<i>Acosmium dasy carpum</i>	Unha-danta	Medicinal, timber and fodder	46.7	6.0	87.1	0.35; p = 0.27
<i>Annona crassiflora</i>	Panã/ Araticum	Fruit tree	5.3	4.0	25.0	–
<i>Aspidosperma macrocarpon</i>	Chapéu-de-couro	Medicinal	0.7	0.7	0	–
<i>Aspidosperma tomentosum</i>	Pereiro-de-chapada	Timber	11.3	4.0	64.7	0.37; p = 0.56
<i>Astronium fraxinifolium</i>	Gonçalo	Timber and medicinal	18.0	3.3	81.5	–
<i>B. virgilioides</i>	Sucupira-branca	Timber	72.0	40.0	44.4	0.18; p = 0.14
<i>C. brasiliense</i>	Pequi	Fruit tree	39.3	28.0	28.8	0.14; p = 0.68
<i>Dalbergia miscolobium</i>	Cabiúna	Timber	30.0	6.0	80.0	0.49; p = 0.05
<i>Eriotheca gracilipes</i>	Embirçu-paulista	Timber	89.3	15.3	82.8	0.41; p = 0.003*
<i>Erythroxylum</i> sp1	#	#	0.7	0.7	0	–
<i>Eugenia dysenterica</i>	Cagaita	Fruit tree	8.7	1.3	84.7	0.53; p = 0.69
<i>Guapira noxia</i>	Pau-de-urubu	Timber and fodder	23.3	2.7	88.6	0.77; p = 0.027*
<i>Handroanthus ochraceus</i>	Ipê-amarelo	Timber and medicinal	9.3	1.3	85.7	0.85; p = 0.15
<i>Hymenaea stigonocarpa</i>	Jatobá	Timber; medicinal and fruit tree	23.3	5.3	77.2	0.46; p = 0.12
<i>Hyptidendron</i> sp1	Alecrim-de-tabuleiro	Timber	10.0	1.3	86.7	0.36; p = 0.97
<i>Lafoensia pacari</i>	Pacari	Medicinal	14.7	3.3	77.3	0.28; p = 0.9
<i>Licania</i> sp1	#	#	0.7	0.7	0	–
<i>Machaerium opacum</i>	Jacarandá	Timber	57.3	7.3	87.2	0.42; p = 0.05*
<i>Magonia pubescens</i>	Tingui	Timber	10.7	1.3	87.5	–
<i>Plathymenia reticulata</i>	Vinhático	Timber	6.0	4.0	33.3	0.27; p = 0.94
<i>Plenckia populnea</i>	Mangabeira-brava	Timber	4.7	1.3	71.5	0.57; p = 0.69
<i>Qualea grandiflora</i>	Pau-terrão	Timber and medicinal	104.7	25.3	75.8	0.37; p < 0.001*
<i>Qualea parviflora</i>	Pau-terrinha	Timber	22.7	4.7	79.4	0.56; p = 0.05*
<i>Roupala montana</i>	Espinheira-santa	Medicinal	15.3	2.0	87.0	0.21; p = 0.99
<i>Schefflera macrocarpa</i>	Violeiro	Fodder	4.0	0.7	83.3	0.8; p = 0.66
<i>Sclerolobium</i> cf. <i>aureum</i>	Pau-fede	Timber and medicinal	2.0	1.3	33.5	0.66; p = 0.66
<i>Strychnos pseudoquina</i>	Quina-de-papagaio	Medicinal	5.3	2.0	62.5	0.62; p = 0.36
<i>Stryphnodendron adstringens</i>	Barbatimão	Medicinal	16.0	2.7	83.3	0.21; p = 0.99

Table 2 continued

Species	Popular names	Use category	Density (ha ⁻¹) before	Density (ha ⁻¹) after	Density reduction (%)	D test
<i>Stryphnodendron polyphyllum</i>	#	#	0.7	0.7	0	–
<i>Tabebuia aurea</i>	Caraíba	Timber	5.3	2.0	62.5	0.62; p = 0.36
<i>Terminalia argentea</i>	Capitão	Timber and medicinal	10.0	1.3	86.7	0.43; p = 0.89

* Indicates significant differences ($p < 0.05$); # indicates that the species has no known popular name or use; – indicates insufficient data for the Kolmogorov–Smirnov test

df = 9.9, $p = 0.27$), respectively, were originated from sprouts and not from seeds. According to farmers, sprouts have a key role in the system. Besides feeding livestock, especially in the dry season when grass availability is lower, sprouts help to improve the soil, retaining moisture and preventing compaction. Excess of sprouts, however, can be harmful because it prevents the development of recently sown grass. Thus, farmers remove the excess of sprouts through weeding, usually before the rainy season, after the dispersal of grass seeds and cattle grazing. During weeding, sprouts of species that have no direct benefit for farmers are removed and sprouts of useful species such as timber, fruit trees and medicinal plants are selected and spared.

According to the farmers, one of the advantages of the SPS is the high concentration of useful species which provide products such as fodder, timber, firewood, fruits and medicinal plants. These forest products play a fundamental role in complementing agricultural activities, contributing to improve livelihood and generate income (Arnold and Pérez 1998; Bharucha and Pretty 2010; Campbell and Luckert 2002; Gunatilake et al. 1993; Shackleton et al. 2011).

Other advantages are the environmental services these systems provide and the increase in livestock production. Trees in SPS help to prevent soil erosion and compaction and improve nutrient cycling. They also provide shade, which helps to retain soil moisture, maintaining grasses green for a long time. The cattle, besides diversifying their diet by feeding on branches, fruits, flowers and shoots of native species, also benefit from the shade of the trees, reducing stress and energy waste (Calle et al. 2009). In this sense, SPS can be more productive and profitable than conventional cattle ranching systems, showing a great potential to contribute to poverty reduction in rural areas (Calle

et al. 2012) and improve food security (Herrero et al. 2010).

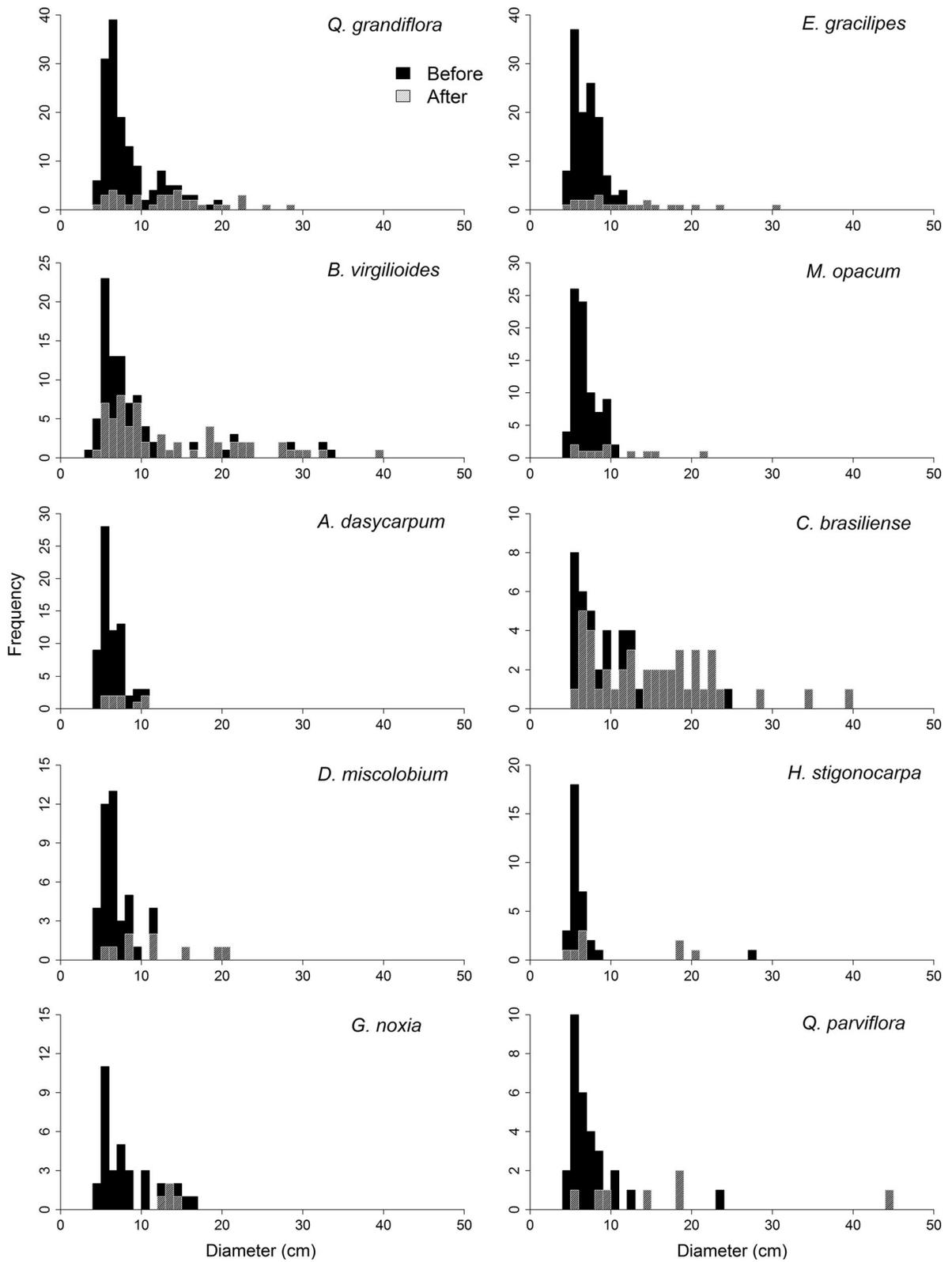
Conclusions and implications for conservation

Less intensive and small-scale production systems generally integrate agriculture and cattle raising with forest management, using resources efficiently, generating income to smallholder farmers, providing food for the poor and maintaining environmental services (Herrero et al. 2010; Perfecto and Vandermeer 2010). An example of this are the SPS of *Geraizeiros*, practiced in the Brazilian Savanna of northern Minas Gerais.

This system turns out to be a viable alternative to agricultural intensification as it is able to reconcile production with biodiversity conservation. Besides the reduction in native plants biodiversity, the system maintains high concentration of useful species, providing several environmental services and increasing livestock production.

Thicker and useful tree species such as those providing timber, fruits, fodder and medicine are generally spared from clearing and the products derived from them can be consumed or traded, generating socioeconomic benefits and contributing to local livelihoods (Bellefontaine et al. 2002; Calle et al. 2012; Foresta et al. 2013). Trees in SPS can also mediate ecological processes, increasing soil moisture and fertility, contributing to reduce soil erosion and compaction and to increase carbon sequestration (Jose 2009; Jose and Bardhan 2012; Wedderburn and Carter 1999).

For these reasons, the SPS studied can serve as templates to a more equitable and environmentally friendly cattle raising system, which is capable to



◀ **Fig. 3** Number of trees by diameter class of the 10 most abundant species, before and after clearing the areas for the implementation of silvopastoral systems

ensure food security, meet the growing demand for food and contribute to biodiversity conservation and poverty alleviation in rural areas in the tropics.

Acknowledgments This research was supported by Funbio/TFCA, CNPq and CAPES grants and fellowships. Embrapa (Cenargen) provided technical and logistic support. Juárez P. Amaral, José M. Mendonça, Nilton F. Barbosa, João Benedito Pereira, Pedro Vasconcelos and Elisa Pereira helped with fieldwork. We acknowledge all farmers of the Americana Settlement, especially Maria Elei N. Souza, Aparecido A. Souza, João Altino Neto and Cristovino F. Neto. We appreciate the valuable contributions by Miguel Alexiades and the revision by Bruno Ubiali.

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