Journal of Tropical Ecology (2006) **22**:353–357. Copyright © 2006 Cambridge University Press
doi:10.1017/S0266467405003135 Printed in the United Kingdom

SHORT COMMUNICATION

Tropical dry-forest regeneration from root suckers in Central Brazil

Daniel L. M. Vieira*,†,[1], Aldicir Scariot*,‡, Alexandre B. Sampaio*,† and Karen D. Holl§

* Embrapa Recursos Genéticos e Biotecnologia, Laboratório de Ecologia e Conservação. Parque Estação Biológica, Av. W5 Norte/Final, Caixa Postal 02372, 70770-900 Brasília, DF, Brazil

† Pós-Graduação em Ecologia, Universidade de Brasília, Caixa Postal 04457, 70919-970, Brasília, DF, Brazil

‡ United Nations Development Programme, SCN quadra 2, bloco A, Ed. Corporate Financial Center, 7° andar, CEP 70712-901 Brasília, DF, Brazil

§ Department of Environmental Studies, University of California, Santa Cruz, CA 95064, USA

(*Accepted 6 October 2005*)

Key Words: abandoned pastures, coppice, deciduous forest, regeneration, resprout, savanna

Seed dispersal, predation, desiccation and seedling survival are strong bottlenecks that impede tropical forest recovery on abandoned agricultural lands (reviewed in Holl 2002). The ability to resprout after disturbances overcomes these barriers, as those individuals bypass the seed stage and have more vigorous shoots than seedlings (Bond & Midgley 2001, Kammesheidt 1999, Kennard *et al.* 2002). Resprouting is a particularly important recovery mechanism in tropical dry forests (reviewed in Vieira & Scariot 2006). There are a number of reasons why resprouting may be more important in dry forests than in rain forests, including slower decay rates of trunk bases (Ewel 1980), or adaptation of plants to drought (Bond & Midgley 2001, Sampaio *et al.* 1993).

Although resprouting is an important regeneration mechanism in tropical forests, many species lose resprouting ability after sequential cutting, fire and tillage (de Rouw 1993, Sampaio *et al.* 1993, Uhl *et al.* 1988). The ability of different species to resprout after repeated disturbances is not well known, particularly on sites that have been disturbed for a long period of time. If tropical tree species are able to resprout after decades of disturbance, this has important implications for tropical forest recovery and restoration, particularly since most woody tropical forest plants have seeds that do not form a long-lived seed bank (Vázquez-Yanes & Orozco-Segovia 1993).

We studied regeneration from root sprouts in three areas once covered by tropical dry forest, including a 10-y-old pasture, a 25-y-old pasture and an early successional forest, in order to determine whether species composition of resprouts changes with increasing disturbance intensity and time, relative to a mature forest. We also evaluated whether the number of species and individuals in the 25-y-old pasture decreased with distance from the mature forest; we hypothesized that there would be no significant correlation between tree species and density with forest distance, which would provide some evidence that tree seedlings were establishing from 25-y-old roots rather than from seeds that dispersed into and germinated in the pasture sometime after pasture establishment, and resprouted after the last ploughing.

Tropical dry forests in Central Brazil occur on rich soils, which results in intense deforestation for cattle pasture purposes (IBGE 1995). In the Paranã River basin, states of Goiás and Tocantins, there are many dry-forest remnants, however it is estimated that only 5% of the original forest remains (A. B. Sampaio, A. Scariot, unpubl. data). The study was carried out in north-eastern Goiás, in the municipalities of São Domingos and Guarani. The annual rainfall is 1236 ± 255 mm (SD, data from 1969–1994) with 89% of the precipitation falling during the wet season from October to March (www.hidroweb.ana.gov.br). The mean annual temperature is 23 °C and remains constant through the year. The landscape is flat and the geology is dominated by limestone. The dominant soil is a nitosol with a clayey texture (IBGE 1995). Seasonally deciduous forests have a canopy height between 17 and 23 m and a basal area of 23–28 m^2 ha^{-1} (dbh > 5 cm; Scariot & Sevilha 2000).

Generally, cattle farmers in the state of Goiás restore pastures every 7 y, ploughing the soil in the middle of the dry season and seeding grass at the beginning of the rainy season. This is a useful opportunity to survey resprouting species and not those establishing from seeds, as ploughing eliminates plant cover completely, allowing plants to begin resprouting after a few days. To be sure that sampled individuals all originated from root suckers we conducted the sampling in the same dry season as

[1]Corresponding author. Email: dvieira@cenargen.embrapa.br

the ploughing (i.e. no rain events at least 3 mo before ploughing and between ploughing and survey), before any germination.

We studied one early successional area and two pastures subjected to ploughing. Rosana (13°38′S, 46°43′W) is a 55.2-ha (800 × 690 m) early successional site, bordered by pastures on two sides and successional forests on the other two. The original forest was clear cut 8 y before the study for pasture establishment, but it was abandoned immediately. The site then developed into an early successional forest and was clear cut again and ploughed 1 mo after being clear cut and 5 mo before we surveyed it in October 2003. Vegetation cover was 35%, mostly tree root suckers (15–130 cm in height). The site had *c.* 15 remnant adult trees per ha (all *Cavanillesia arborea* K. Schum.).

Fazendinha (10-y-old pasture) (13°57′S, 46°38′W) is a 22-ha (1110 × 200 m) pasture, bordered by other pastures. The original forest was clear cut 10 y prior to the study for pasture establishment. For some time, it was not ploughed or cut, allowing some tree regeneration. One y before sampling the pasture was slashed and burned and *Zea mays* L. was planted in the rainy season. Finally, the pasture was ploughed 20 d before we surveyed it in October 2003. Vegetation cover was 5%, mostly tree root suckers (15–80 cm in height), although there were also liana and herb root suckers. The pasture had *c.* two remnant adult trees per ha.

Flor Ermo (25-y-old pasture) (13°39′S, 46°45′W) is a 43.4-ha (700 × 620 m) pasture, bordered by other pastures and by an intact forest fragment (270 ha), separated by a dirt road (30 m width). The original forest was clear cut for pasture planting 25 y before the study. It was ploughed twice, first 25 y before the survey and again 2 mo before our survey in August of 2002. In this pasture, vegetation is cut annually at 20 cm above the soil before the first rains, to stimulate grass sprouting. At the time of the survey, vegetation cover was 20%, mostly tree root suckers (15–110 cm in height), although there were some liana and herb root suckers. The pasture had *c.* four remnant adult trees per ha.

In the 25-y-old pasture, we established five parallel transects separated by 100 m, perpendicular to the forest fragment edge. Plots (10 × 10 m) were established on transects at 30, 80, 130, 180, 380, 430, 480, 530 and 580 m from the edge of the forest fragment. The pasture had a patch of shallow soil on a lateritic layer, resulting in a typical cerrado (savanna) vegetation, which prevented sampling at distances of 230, 280 and 330, and at other distances on certain transects. Therefore each distance from the forest fragment edge had 2–5 plots (total = 30 plots). In the 10-y-old pasture and the early successional site we established five parallel transects separated by 100 m, and randomly distributed six plots per transect. All individuals were identified. We determined an individual as one or more stems constituting one clump (group of closely aggregated stems), which originated from one root.

Species composition (presence/absence) in the three areas was compared to the intact forest fragment (250 ha) bordering the 25-y-old pasture with the Sørensen similarity index (Kent & Coke 1994). In the intact forest fragment, individuals > 5 cm (dbh) were sampled in 60 plots of 20 × 20 m. For the 25-y-old pasture, we determined the relationship between species richness and density with distance from the edge of the forest fragment using Pearson correlation (Zar 1999). We do not propose to compare the three ploughed areas, because the intrinsic characteristics of each area and the different histories of use do not permit generalizations about age or pasture management. Another factor that could affect the results is that time between ploughing and sampling was very short for the 10-y-old pasture; therefore, more individuals could have resprouted if we had sampled later.

At the early successional site we observed 182 ± 41 individuals per 100 m^2 of 40 species total (17.6 ± 2.3 species per 100 m^2, mean ± SD). At the 10-y-old pasture we observed 14 ± 6 individuals per 100 m^2 of 30 species total (6.5 ± 2.2 species per 100 m^2). At the 25-y-old pasture we recorded 42 ± 15 individuals per 100 m^2 of 39 species (11.8 ± 2.5 species per 100 m^2) (Table 1). Species richness found in the ploughed areas was slightly lower than in the intact forest, where 51 tree species were observed (6.0 individuals per 100 m^2, total 1444 individuals).

Species richness in the ploughed sites is much higher than those recorded in literature for disturbed tropical sites with comparable histories of land use. In Costa Rica, pastures abandoned for up to 8 y had *c.* 17% of tree species richness of a reference secondary forest (25–40 y old) (Zahawi & Augspurger 1999). In the eastern Amazon, 7-y-old pastures that had burned 1–2 times and were cut 4–6 times, had 1–5 tree species per 100 m^2 (10% of reference forest) and 0–6 individuals per 100 m^2, after being abandoned for 2.5–8 y. These were mostly composed of pioneer species regenerated from seeds (Uhl *et al.* 1988). In tropical dry forests, however, some studies show a higher frequency of resprouting after disturbance (Kennard *et al.* 2002, McLaren & McDonald 2003). McLaren & McDonald (2003) cut all stems (≥2 cm dbh) at 50 cm in height, and 14 mo later they verified coppice shoots in 48 of the 51 sampled species (81% of stems on average).

Species richness ($r = 0.05$, $n = 30$, $P = 0.79$) and abundance ($r = 0.22$, $n = 30$, $P = 0.25$) in the 25-y-old pasture did not decrease with distance from the edge of the forest fragment. Furthermore, in some plots located at

Table 1. Species resprouting after ploughing in an early successional site, a 10-y-old pasture, and a 25-y-old pasture, in a dry-forest region of central Brazil. Individuals were surveyed in 30 plots of 10 × 10 m (3000 m^2) in each area. Trees (> 5 cm dbh, 2.4 ha sampled) observed in an intact forest fragment adjacent to the 25-y-old pasture are shown. Values indicate relative abundance (%).

Family	Species	Forest fragment	Successional site	10-y-old pasture	25-y-old pasture
Anacardiaceae	*Astronium fraxinifolium* Schott	1.1	< 0.1	2.6	2.2
	Myracrodruon urundeuva Allem.	6.2	0.8	6.4	8.4
	Schinopsis brasiliensis Engl.	–	< 0.1	0.2	2.5
	Spondias mombin L.	1.5	4.2	–	–
Apocynaceae	*Aspidosperma pyrifolium* Mart.	3.1	1.3	0.5	1.5
	Aspidosperma subincanum Mart.	3.0	12.2	15.6	13.0
	Aspidosperma sp.	0.8	–	–	–
Bignoniaceae	*Jacaranda brasiliana* Pers.	–	< 0.1	–	–
	Tabebuia impetiginosa (Mart.) Standl.	7.9	7.1	4.7	1.3
	Tabebuia roseo-alba (Ridl.) Sandwith	1.1	1.2	0.9	–
Bombacaceae	*Cavanillesia arborea* K. Schum.	1.1	–	–	–
	Chorisia pubiflora (St. Hil.) Dawson	0.5	–	–	–
	Pseudobombax tomentosum (Mart. & Zucc.) A. Robyns	1.5	< 0.1	–	–
Boraginaceae	*Cordia glabrata* A.DC.	–	< 0.1	0.5	1.7
	Cordia trichotoma (Vell.) Arrab. ex I. M. Johnst.	–	2.4	–	–
Caesalpiniaceae	*Bauhinia* cf. *acuruana* Moric.	3.6	3.2	–	–
	Bauhinia brevipes Vog.	21.6	14.4	6.4	1.8
	Copaifera langsdorffii Desf.	0.2	–	–	0.1
	Hymenaea courbaril L. var. *stilbocarpa* (Hayne) Y. T. Lee & Langenh.	0.2	–	–	1.9
	Senna spectabilis (DC.) Irwin & Barneby var. *excelsa* (Schrad.) Irwin & Barneby	0.7	1.4	0.2	–
	Senna splendida (Vogel) H. S. Irwin & Barneby	–	0.1	–	–
	Swartzia multijuga Vogel	0.5	0.3	–	0.4
	Sweetia cf. *fruticosa* Spreng.	0.7	< 0.1	–	0.1
Celastraceae	*Maytenus floribunda* Reiss.	–	< 0.1	0.7	–
Chrysobalanaceae	*Licania* sp.	0.7	–	–	0.1
Combretaceae	*Combretum duarteanum* Cambess.	3.8	0.3	1.7	0.6
	Combretum sp.	6.1	–	–	0.2
	Terminalia sp.	0.2	–	–	–
Erythroxylaceae	*Erythroxylum* cf. *amplifolium* Baill.	–	< 0.1	–	–
Fabaceae	*Amburana cearensis* (Allemao) A. C. Sm.	0.2	–	–	–
	Dipteryx alata Vogel	–	–	–	0.6
	Lonchocarpus muehlbergianus Hassl.	4.1	0.9	8.0	5.2
	Machaerium brasiliense Vogel	3.4	1.9	13.5	1.8
	Machaerium scleroxylon Tul.	1.1	1.8	9.0	12.0
	Machaerium cf. *stipitatum* Vogel	7.0	28.5	1.7	7.9
	Machaerium villosum Vogel	0.8	1.6	4.7	0.1
	Platypodium elegans Vogel	0.5	0.1	2.1	–
Flacourtiaceae	*Casearia rupestris* Eichler	1.6	–	0.2	–
Meliaceae	*Cedrela fissilis* Vell.	0.8	–	–	–
Mimosaceae	*Acacia glomerosa* Benth.	0.2	0.4	0.2	2.9
	Acacia spp.[1]	1.0	8.0	1.4	0.2
	Albizia niopoides (Spruce ex Benth.) Burkart	0.2	–	–	–
	Anadenanthera peregrina (L.) Speg.	0.8	3.8	5.2	0.6
	Enterolobium contortisiliquum Morong	0.2	0.1	0.2	0.8
Moraceae	*Maclura tinctoria* (L.) D. Don ex Steud.	0.2	–	–	–
Myrtaceae	*Eugenia bimarginata* O. Berg	–	0.1	–	–
	Eugenia dysenterica DC.	1.0	< 0.1	6.9	5.4
	Eugenia sp.	3.6	–	–	10.9
	Myrtaceae sp. 1	–	0.2	0.2	–
	Myrtaceae sp. 2	0.2	–	–	–
	Myrtaceae sp. 3	0.2	–	–	–
Olacaceae	*Ximenia americana* L.	–	–	–	0.1
Rhamnaceae	*Rhamnidium elaeocarpum* Reiss.	0.2	–	–	0.2
Rubiaceae	cf. *Amaioua* sp.	0.5	–	–	–
	Coutarea sp.	0.2	–	–	–
	Randia armata DC.	0.8	0.3	0.9	1.0
	Simira sampaioana (Standl.) Steyerm.	–	< 0.1	–	–

https://doi.org/10.1017/S0266467405003135 Published online by Cambridge University Press

Table 1. Continued.

Family	Species	Forest fragment	Successional site	10-y-old pasture	25-y-old pasture
Sapindaceae	*Dilodendron bipinnatum* Radlk.	0.8	2.8	3.5	5.2
	Magonia pubescens A. St. Hil.	–	–	–	4.2
	Talisia esculenta Radlk.	2.8	–	–	0.6
Sapotaceae	*Pouteria gardneri* (Mart. & Miq.) Baehni	0.3	–	–	–
Simaroubaceae	*Simarouba versicolor* A. St. Hil.	–	–	0.9	0.2
Sterculiaceae	*Guazuma ulmifolia* Lam.	0.8	0.3	0.5	2.2
	Sterculia striata A. St. Hil. & Naud.	0.3	0.1	0.2	–
Tiliaceae	*Luehea divaricata* Mart.	–	–	–	1.0
Ulmaceae	*Celtis iguanaea* (Jacq.) Sarg.	0.2	< 0.1	–	0.8
Vochysiaceae	*Callisthene fasciculata* Mart.	0.2	–	–	0.2
	Qualea grandiflora Mart.	–	–	–	0.3

[1] It was not possible to assign species into *Acacia paniculata* Willd., *A. polyphylla* DC. or *A. farnesiana* (L.)Willd.

500 m from the forest edge, more than 20 individuals of the same species occurred occasionally, including *Aspidosperma subincanum*, *Machaerium scleroxylon* and *Eugenia* sp., which do not form seed banks (A. Salomão, pers. comm.) and are unlikely to disperse 500 m from the forest at high densities. These results suggest that at least some species resprout for 25 y in pasture conditions.

The Sørensen similarity index was relatively high between the forest fragment and the ploughed sites (early successional site: 0.67, 25-y-old pasture: 0.64, 10-y-old pasture; 0.67). Most species found only in the forest fragment or only in ploughed areas had low densities. These species are rare, such as *Amburana cearensis* and *Albizia* cf. *niopoides*, so the results may be the result of insufficient sampling. Other species found in high density in the fragment, but not found in the ploughed sites are species with low-density wood, such as *Cavanillesia arborea* and *Chorisia pubiflora*. *Spondias mombin* and *Pseudobombax tomentosum* have soft wood and were found only in the forest fragment and in the early successional site. Species with low-density wood could lose resprouting ability faster and sometimes do not resprout at all because of decay. Recognizing good resprouting species is important, as they can have higher potential for forest restoration from stakes (Itoh *et al*. 2002).

In the 25-y-old pasture that was grazed, mowed and ploughed, 39 tree species were found resprouting from roots. This result demonstrates that resprouting ability, even after long periods of disturbance, is a conspicuous functional trait of tropical dry forest tree species and should be better evaluated to inform restoration methods.

ACKNOWLEDGEMENTS

We thank Tião and Edson for the important contribution in the field work. A. Melo, E. Guarino and A. Sevilha gave insights to the study. The study was supported by FNMA, CNPq and Conservation International.

LITERATURE CITED

BOND, W. J. & MIDGLEY, J. J. 2001. Ecology of sprouting in woody plants: the persistence niche. *Trends in Ecology and Evolution* 16:45–51.

DE ROUW, A. 1993. Regeneration by sprouting in slash and burn rice cultivation, Taï Rain Forest, Côte d'Ivoire. *Journal of Tropical Ecology* 9:387–408.

EWEL, J. 1980. Tropical succession – manifold routes to maturity. *Biotropica* 12:2–7.

HOLL, K. D. 2002. Tropical moist forest. Pp. 539–558 in Perrow M. & Davy A. J. (eds). *Handbook of ecological restoration, vol. II.* Cambridge University Press, Cambridge.

IBGE. 1995. *Zoneamento geoambiental e agroecológico do estado de Goiás: região nordeste.* IBGE/Divisão de Geociências do Centro-Oeste, Rio de Janeiro. 178 pp.

ITOH, A., YAMAKURA, T., KANZAKI, M., OHKUBO, T., PALMIOTTO, P. A., LAFRANKIE, J. V., KENDAWANG, J. J. & LEE, H. S. 2002. Rooting ability of cuttings relates to phylogeny, habitat preference and growth characteristics of tropical rainforest trees. *Forest Ecology and Management* 168:275–287.

KAMMESHEIDT, L. 1999. Forest recovery by root suckers and above-ground sprouts after slash-and-burn agriculture, fire and logging in Paraguay and Venezuela. *Journal of Tropical Ecology* 15:143–157.

KENNARD, D. K., GOULD, K., PUTZ, F. E., FREDERICKSEN, T. S. & MORALES, F. 2002. Effect of disturbance intensity on regeneration mechanisms in a tropical dry forest. *Forest Ecology and Management* 162:197–208.

KENT, M. & COKE, P. 1994. *Vegetation description and analysis.* John Wiley & Sons Ltd., Chichester. 363 pp.

MCLAREN, K. P. & MCDONALD, M. A. 2003. Coppice regrowth in a disturbed tropical dry limestone forest in Jamaica. *Forest Ecology and Management* 180:99–111.

SAMPAIO, E., SALCEDO, I. H. & KAUFFMAN, J. B. 1993. Effect of different fire severities on coppicing of caatinga vegetation in Serra Talhada, Pe, Brazil. *Biotropica* 25:452–460.

SCARIOT, A. & SEVILHA, A. C. 2000. Diversidade, estrutura e manejo de florestas deciduais e as estratégias para a conservação. Pp. 183–188 in Cavalcanti, T. B. & Walter, B. M. T. (eds.). *Tópicos atuais em botânica.* Embrapa Recursos Genéticos e Biotecnologia, Brasília.

UHL, C., BUSCHBACHER, R. & SERRAO, E. A. S. 1988. Abandoned pastures in eastern Amazonia.1. Patterns of plant succession. *Journal of Ecology* 76:663–681.

VÁZQUEZ-YANES, C. & OROZCO-SEGOVIA, A. 1993. Patterns of seeds longevity and germination in the tropical rainforest. *Annual Review of Ecology and Systematics* 24:69–87.

VIEIRA, D. L. M. & SCARIOT, A. 2006. Principles of natural regeneration of tropical dry forests for restoration. *Restoration Ecology* 14:11–20.

ZAHAWI, R. A. & AUGSPURGER, C. K. 1999. Early plant succession in abandoned pastures in Ecuador. *Biotropica* 31:540–552.

ZAR, J. H. 1999. *Biostatistical analysis.* Prentice Hall, New Jersey. 663 pp.