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Chapter 3.3.

NEW FRONTIERS

3.3. ECOLOGICAL MANAGEMENT OF DEGRADED FOREST FRAGMENTS

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Introduction

Deforestation is one of the main causes of forest ecosystems degradation for affording a better access of the remnant habitats to activities such as hunting, and wood and non-wood forest product exploitation (Cullen Jr. et al., 2001; Gerwing 2002; Tabarelli et al., 2004). Correspondingly, disturbed forests become more susceptible to recurrent fires (Cochrane et al., 2002). On the other hand, independently of the direct anthropic action, the fragmentation – the break-up of the spatial continuity of forest areas – hinders gene flow between species and harms habitat quality, in consequence of the edge effect (Bierregarrd et al., 2001; Laurance et al., 2002).

As a result of the edge effect and the reproductive isolation, changes occur in the composition and structure of the community, with a decrease in the typical forest-interior species (shade tolerants) as well as animal dispersed species, and the increase in the ratio of typical vegetation of clearings and the invasion of exotic and competitor species, like lianas, bamboos and grasses (Rankin-de Mérona and Hutchings 2001; Benitez-Malvido and Martinez-Ramos 2003; Tabarelli et al., 1999).

Most studies on tropical forest fragmentation were carried out in regions where deforestation is relatively recent and the matrix is still predominantly forest, the Amazon for instance (Metzger, 1999; Bierregaard et al., 2001). Little is known about the dynamics of the older fragments inserted in landscapes where the matrix is not predominantly forest, and the results point to divergent tendencies, indicating the influence of factors as perturbation history. Small fragments (< 10ha), for example, may show communities where species at the initial stages of regeneration predominate, besides hyper-abundance of lianas and bamboos (Tabarelli and Mantovani, 1999; Tabarelli et al., 1999; Tabanez and Viana, 2000) or may be characterized by the presence of areas in successional evolution, with decrease in pioneers species and increase in late species (Oliveira Filho et al., 1997).

In Brazil, the Seasonal Semideciduous Forest (IBGE 1992) is a particular formation of the Atlantic Forest (Morellato and Haddad, 2000) that once covered 1,36 million Km^2, about 15% of the Brazilian territory. In the last 250 years, the Seasonal Semideciduous Forest has undergone a drastic area reduction, remaining today about 7.3% of its original cover (IBAMA, 2005) which is pulverized in small fragments (< 100ha) (Atlântica and Espaciais, 1993).

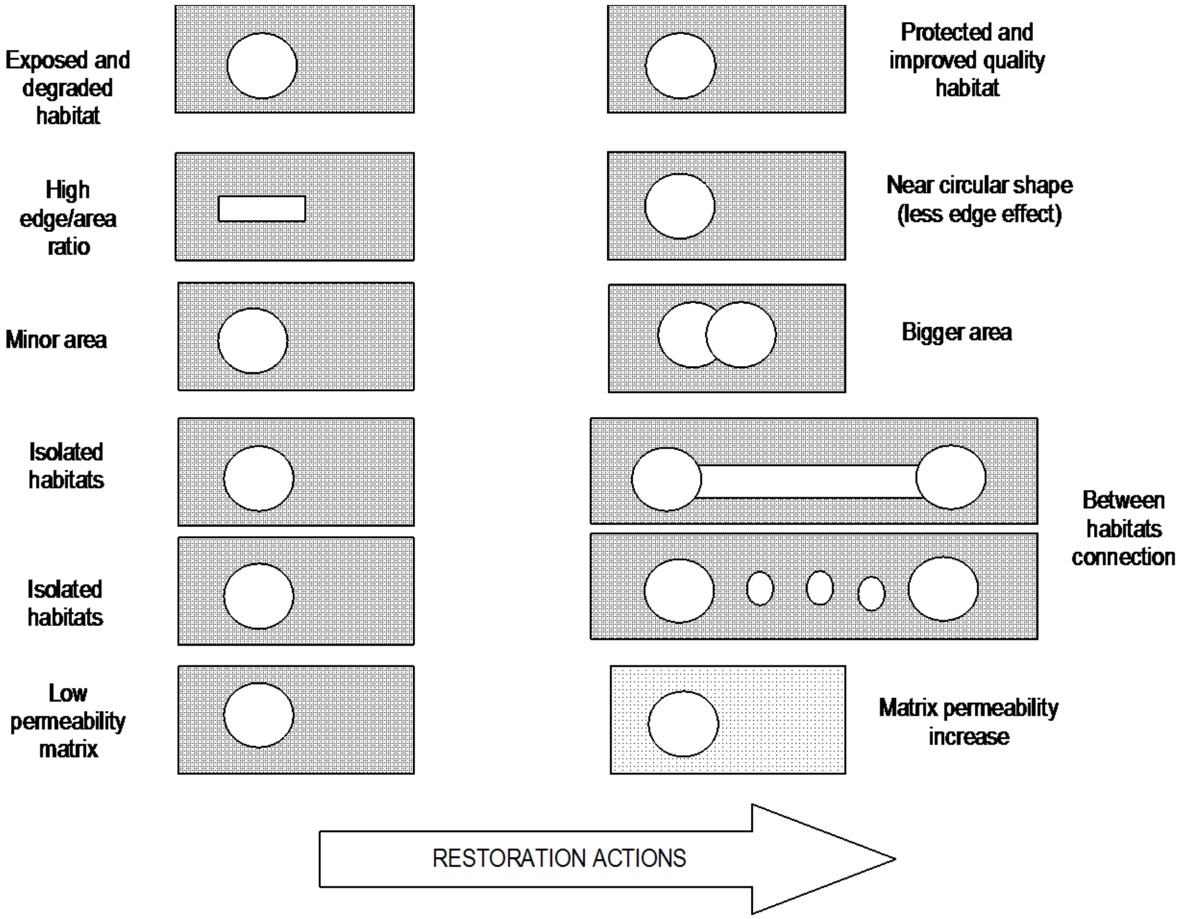


Figure 1. Main strategies for forest ecosystems restoration. The habitat is represented in white and the matrix in gray tones. The whiter tone indicates a more permeable matrix. Adapted from Metzger (2003) and Primack & Rodrigues (2001).

Numerous studies indicate that the Seasonal Semideciduous Forest spots still retain high diversity. They also emphasize the fact that the occurrence of disturbances (cattle grazing and treading, fire, trash, wood harvest, atmospheric pollution, etc.), small areas and high degree of isolation represent threats to the long term maintenance of the remnant biodiversity (Santin 1999; Lacerda et al., 1999, Tabarelli et al., 1999; Metzger, 2000; Tabanez and Viana, 2000;

Tabarelli and Mantovani 2000; Valladares-Pádua et al., 2002). These warnings agree with Turner and Corlett‘s (1996) affirmation that although the maintenance of large habitat areas are indispensable to guarantee the integral biota conservation, in several regions of the globe the small fragments constitute the only refuge for numerous species, as a gene bank available for initiatives of ecosystem restoration.

The protection and ecological management of degraded forest fragments are therefore indispensable and prioritary practices of forest restoration that together with revegetation actions and land use planning in deforested areas (matrix) can cause a decrease in the extinction risk for providing: (a) increase in the quantity and quality of the habitat areas; and (b) greater gene flow permeability between these areas (Figure 1).

The literature on restoration is poor of experimental data about degraded forest management, and it is concentrated in monitoring secondary succession, as well as reforestation experiments, in which one evaluates different species combinations, planting arrangements and spacings, fertilization, competitive species control techniques, etc. (Ashton et al., 2001; Honnay et al., 2002; Chazdon, 2003; Meli, 2003; Kammesheidt et al., 2002; Florentine and Westbrooke, 2004).

Still some generalizations are possible, and one can affirm that the challenges of managing degraded forests are alike to those found in the revegetation of deforested areas, and as continuously pointed in this book, they are related to the species dispersion and recruitment capacity, as a function of the landscape connectivity and the biological and physical conditions of the site under restoration (competition, herbivory, luminosity, temperature, humidity, density and soil fertility, etc.) respectively.

Materials and Methods

Study Area

The Santa Genebra Forest Reserve (SGFR) covers approximately 257 ha and it is the larger Seasonal Semideciduous Forest remnant in the municipality of Campinas (~ 1.000.000 inhabitants), Southeastern Brazil (Figure 2). It is an urban forest, with large part of its area undisturbed, in late secondary stage and predominance of big clearings (Nave 1999; Martins and Rodrigues, 2002, 2005; Martins et al., 2004). It became a reserve in 1983, and since than it has been used for research and educational activities (Morellato and Leitão Filho, 1995).

Some sites of the reserve are degraded, specifically some areas of forest edge and one called “burned area”, which was reached by a high destruction power fire in 1981. In these places the forest gave place to communities dominated by lianas.

Grasses, lianas and bamboos are recognized as competitive species, being able to compete vigorously with shrubs and trees and hinder the community successional advance in areas where they occur in high abundance, for example, abandoned pastures, forest edges and degraded forests (Tabarelli and Mantovani, 1999; Tabanez and Viana, 2000; Gerwing, 2002, Florentine and Westbrooke, 2004; Rodrigues and Gandolfi, 2004).

In the case of the burned SGFR area, the site remains as a degraded forest dominated by a dense mass of lianas, for at least 10 years (Nave, 1999; Rozza, 2003).

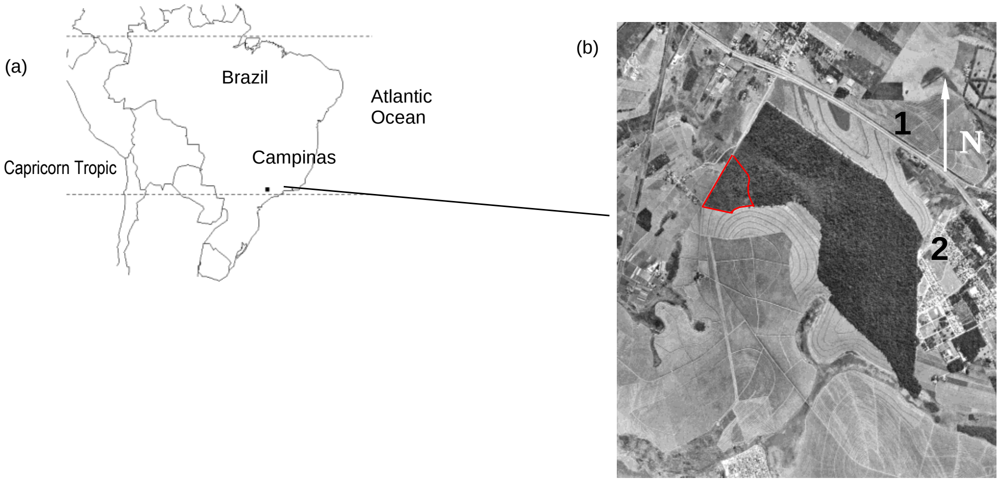


Figure 2. (a) Geographic localization of Campinas township, southeast Brazil. (b) Aerial photography of SGFR (june/1994), highlighting its around, occupied by cultivation (1) and urban nucleus (2). The red line indicates the burned area approximated limits, where the management experiment has been achieved (Rozza 2003).

Plant Guilds in Secondary Succession

A forest cycle can be arbitrarily divided in different phases or stages dominated by determined group of species to facilitate the understanding of its dynamics and to attain practical demands (Whitmore, 1989). Although there is an ecological amplitude for each species, their insertion in ecological groups takes into consideration their most common characteristics and performances (Swaine et al., 1987). The ecological groups are mainly separated by the species shade tolerance.

Pioneer Species

They are the species denominated by Budowski (1965) and Swaine and Whitmore (1988) as *pioneers*, by Denslow (1980) as big clearing specialists, or by Hubell et al. (1999) as high clearing dependent pioneers. Lieberman and Lieberman (1987) have referred to them as shade intolerant plants.

These plants grow very fastly in full sunlight (Coombe, 1960). Swaine and Whitmore (1988) have defined pioneer species as those that require full sunlight for germination and establishment, being these processes inhibited by canopy filtered light. Many studies indicate that even though germination may occur, the pioneer seedlings do not develop well in very small clearings (Alvarez-Buylla and Martinez-Ramos, 1992; Whitmore, 1996; Souza and Válio, 2001). These plants maintain substantial seed stocks in the soil, with long and latent viability, which have been germinating when taken from soils originated from the interior of mature forests (Guevara and Gómez-Pompa, 1972).

Early Secondary Species

This denomination was given by Budowski (1965). They correspond to some of those plants denominated by Denslow (1980) as small clearings specialists, or to a sub-set of those defined by Hubell et al. (1999) as intermediates. It is also inserted in this category some of the plants described by Swaine and Whitmore (1988) as pioneers, or still, some of the shade tolerants according to Lieberman and Lieberman (1987).

According to Gandolfi (2000), in comparison with the other ecological groups, these plants show an intermediate light dependence in processes such as germination, growth, development and survival. The required luminosity to support their vital processes is found in the interior of clearings, in their edges or even in the sub-canopy. Similar to pioneers, they show relatively fast growth speed (Budowski, 1965). According to Finegan (1996), the behavior of pioneer and early secondary categories differ more clearly in the secondary succession, with a frequent number of seedlings of the second (more longeve) passing to a new phase of succession below the canopy formed by short life pioneers. Many of these species may show high longevity, composing the canopy in sites of old clearings (Gandolfi, 2000).

Late Secondary Species

This group of plants is reported by Budowski (1965) as late secondary, as small clearings specialists by Denslow (1980), and as intermediates by Hubell et al. (1999). They correspond at the same time, to part of those denominated by Swaine and Whitmore (1988) as climax, or to a sub-set of plants defined by Lieberman and Lieberman (1987) as shade tolerants. These species have dormant or slow growing seedlings, which may persist in the sub-canopy for many years, growing under moderate shade (Liew and Wong, 1973 *apud* Denslow, 1980), or in other cases they do not persist in that condition for long time. In a clearing of adequate size, seedlings of this group are capable of fast growth. These species has the ability to germinate under closed canopy, although some opening is necessary to grow into the reproductive size. Species of this group may grow and become part of the forest canopy or the emergent condition (Gandolfi, 2000).

Understory Specialists

The remaining plants reported by Denslow (1980) as understory specialists, or part of those denominated by Budowski (1965) and Swaine and Whitmore (1988) as climax. Lieberman and Lieberman (1987) and Hubell et al. (1999) referred to them as shade tolerants. In this extreme, there are highly persistent species to deep shade, which emerge even without light increases as it happens in very small clearings (Whitmore, 1989). This group includes understory small trees that grow slowly and set few fruits (Frankie et al., 1974).

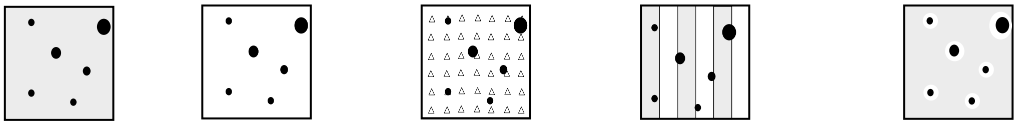
Conversely, Souza and Válio (2001), working with 15 tree species of a Seasonal Semideciduous Forest, reported that ranking species by a shade tolerance index do not fit into the dichotomy shade tolerant or intolerant, but they present a continuous graduation of degrees of shade tolerance. Besides, the authors observed that none of the species had survival rate higher in the shade than in the forest edge. This suggests that all species, even the most tolerant, require an open canopy to successfully establish. Tolerant species are capable of supporting deep shade and waiting for a canopy opening, nevertheless they may suffer high mortality during the waiting period (Nicola and Pickett, 1983).

Experiment 1 - Management of Competitive Species

Based on the premise that the hyper-abundance of competitive species is the consequence and not the cause of forest degradation, an experiment to verify the effect of hyper-abundant lianas management on forest regeneration was carried out in the burned SGFR area (Rozza, 2003; Farah, 2003).

A randomized block design, with 5 treatments and 4 repetitions comprising different liana management intensities, was used in the experiment:

Treatment C	liana cutting in the total area (100% of the plot area);
Treatment Cp	liana cutting in the total area and planting of fast growing pioneer species;
Treatment S	liana cutting in stripes (removing of liana cover in 50% of the plot area).
Treatment P	punctual liana cutting (removing mass of lianas over the trees and shrubs, cutting a 40-cm radius circle around the trunk base).
Treatment T	control without liana management (Figure 3).



Control without liana management (T)

Liana cutting in the total area (C)

Liana cutting in the total area and planting (C_p)

Liana cutting in stripes (S)

Punctual liana cutting (P)

Figure 3. Schematic presentation of competitor species management treatments in a Seasonal Semideciduous Forest area (Experiment 1). The squares represent the experimental plots (15 x 15 m, 4 blocs each one, random design), the black circles represent arboreal individuals present at the plots and the triangles are seedlings of fast growing native species (C*roton floribundus, Trema micrantha, Bauhinia forficata* and *Luehea divaricata*, 2 x 2.5 m spacing, 11 seedlings/species/plot). Shaded areas indicate lianas cover and white color are the locals where the management has been achieved, through drastic liana cuts (elimination of aerial parts). SGFR, Campinas/SP/Brazil.

The experiment lasted for 24 months, and following the initial cutting during the rainy season (summer - 1998), the liana resprouting was controlled by 4 maintenance cuttings in the subsequent rainy seasons (spring and summer - 1999 and 2000), as it is the favorable period for plant growth in regions of seasonal climate. The wood material from liana cutting was removed from the experimental plots and stacked outside them in order to reduce eventual impacts to shrub and tree regeneration (considering that the wood material from liana cuttings could impair seedling emergence).

Monitoring of forest regeneration was carried out using inventories of shrub and tree individuals, immediately after the experiment installation (time zero), and in the next 12 and 24 months. These inventories considered all the shrub and tree individuals with the height of the first trunk bifurcation at or above 1.30 m.

Experiment 2 - Management of a Young Forest with Low Floristic Diversity

Once it was identified the need to seek alternatives to assure the forest cover maintenance in the managed areas, which is necessary to avoid the regrowth of heliophyte competitive species and to guarantee the conditions to successional advance, the Experiment 2 was configured.

The Experiment 2 was performed within the areas of Treatment C (experiment 1 - managed areas for liana control), where there was a formation of a pioneer species grove starting from the initial management. The objective of this new experiment was to test soil revolving as a management strategy for the restoration of a young forest community.

It was started out since the hypothesis:

- Soil revolving could initiate new cycles of pioneers, which would occupy randomly formed clearings in the canopy, avoiding the sudden collapse of the young vegetation and the re-occupation by hyper-abundant lianas.
- The successional vegetation advance depends on the growth of pre-existent non-pioneer species (before liana control), as well as on the entrance of new species due to seed rain. The seed rain is considered an important source of non-pioneer species, as they do not form a permanent soil seed bank (Garwood, 1989; Daws et al., 2002; Fenner and Thompson, 2005).

Experimental Design

A randomized block design was used (Gomes and Garcia, 2002), with 4 repetitions (distributed in 4 blocks), totalizing 225 m^2 per treatment. In february/2001, the few liana individuals found bellow the young forest canopy were cut (at soil height), and scraps were removed from the plots. Subsequently, the following management practices were applied:

Non-revolved treatment - NR - the soil surface was not revolved;

Summer revolving treatment - SR - in february/2001 the whole plot had its superficial soil revolved (5 cm depth) with a hoe, and the existing litter partially incorporated to the soil, this operation was repeated in January/2002; *Winter revolving treatment* - WR - soil revolving was carried out in August/2001, and again in october/2001.

Each treatment was associated with a periodic liana resprout control in the plots, every 2 months.

Data Collection

Tree/shrub Flora of Height: ≥ 1m

Two surveys were carried out in each treatment, considering all the tree/shrub individuals of total height ≥ 1m found in the plots. The first, conducted in february/2001, characterized the initial condition in the experimental plots before beginning the treatments, and the final in september/2002. This inclusion criterion allowed the obtaining of data from the individuals considered properly established in the plots.

Seed Rain

From march/2001 to august/2002, samplings of seed rain were performed monthly. The seeds were captured by two 0.5 x 0.5 m collectors randomly installed, by raffling the position within the site, per each group of 3 neighboring plots (summer revolving, winter revolving and no revolving), with one collector at every 84.4 m^2.

Results and Discussion

Competitive Species Management

The first experiment showed that the best results were obtained in the treatments liana cutting in the total area, followed or not by pioneer-tree planting (Figure 4). The great difference in the density of individuals between the treatments with and without planting, 24 months after the experiment installation (with 5911 $ind.ha^{-1}$ exceeding treatment Cp), was not only due to the growth of the planted young trees (2000 $ind.ha^{-1}$), but mainly to natural regeneration (3911 $ind.ha^{-1}$).

However, the planting might have indirectly contributed to a higher regeneration in treatment Cp, by promoting soil movement during furrow opening. Liana cover removal followed by non-deliberate soil movement exposed the soil to light, allowing dormancy breakage and colonization by pioneer heliophyte species (Garwood, 1989; Fenner and Thompson, 2005). An experiment was carried out to test the hypothesis that the soil revolving contributed to stimulate the seed bank germination. At the same time, it was tested the effect of keeping the scrap wood from the liana cutting over the soil.

In the managed areas, the effect of removing the hyper-abundant liana masses can be compared to the action of severe disturbs, originating “new areas” or “open spaces” to the forest colonization, where the species stored in the seed bank, already present, have a competitive advantage and may establish rapidly in the site (Thompson, 2000; Pakeman and Small, 2005). It is important to emphasize that forest regeneration after disturbance strongly depends on the site characteristics, i.e., it can be immediate if there are stored seeds in the bank, and if abiotic conditions are favorable (for example, rainy season = moisture for germination), or may take decades, in the case of seed missing (bank and seed rain) and degraded soil (Guariguata and Ostertag, 2001; Florentine and Westbrooke, 2004).

In the burned SGFR area, there was a fast occupation of the space created by the liana management (from the first month after the experiment installation it was possible to observe the presence of a seedling cover above the soil surface), which occurred mainly by the emergence of few pioneer species: *Trema micrantha* Blume, *Ricinus communis* L., *Solanum erianthum* D.Don, *Vernonia polyanthes* Less).

Trema micrantha Blume was characterized as a dominant species, with most new individuals found within the managed areas 2 years after experiment installation. Besides being vigorous, the germination of this species occurred in a well-distributed pattern in the whole study area (see Annex 1).

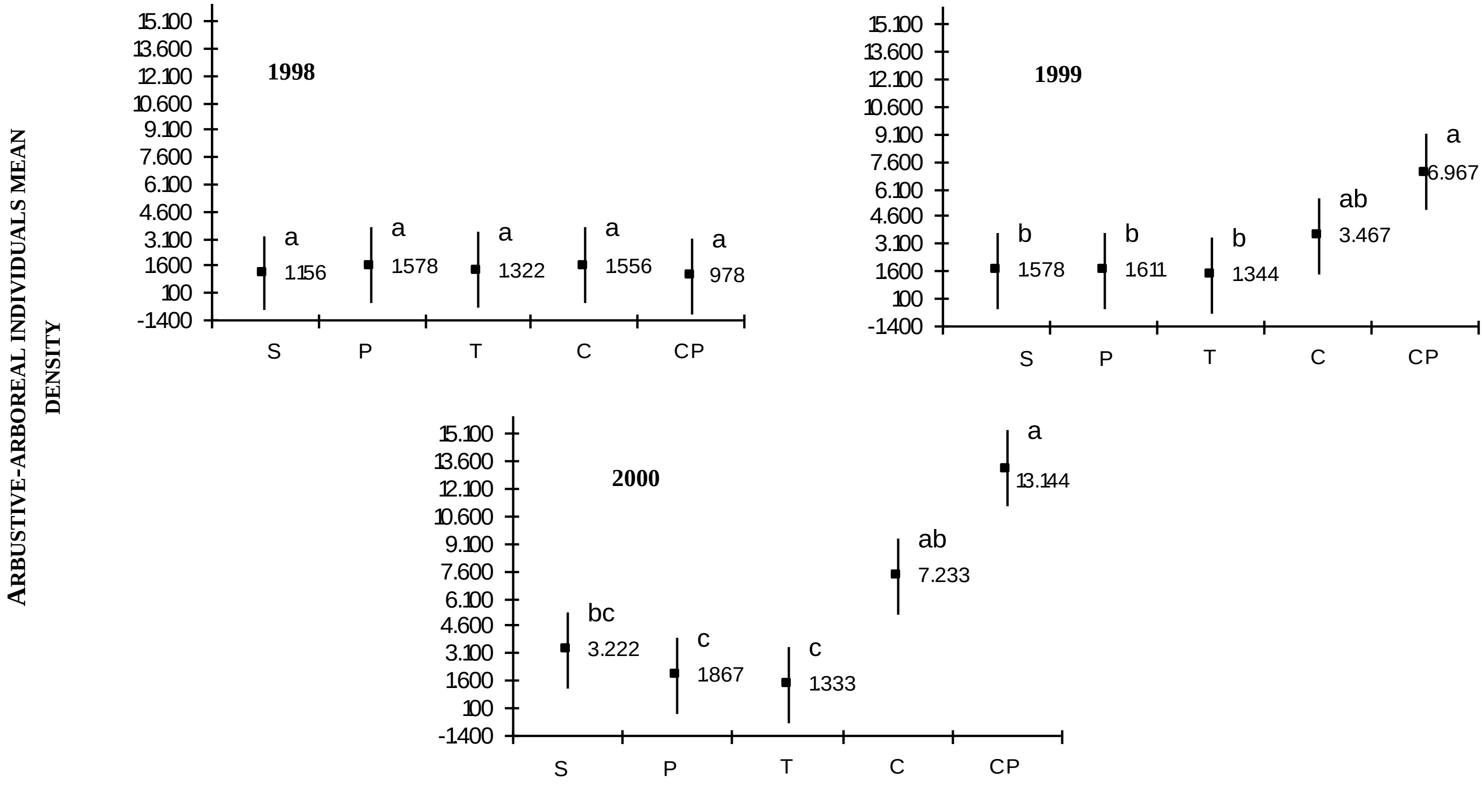


Figure 4. Arbustive-arboreal individuals density (height ≥ 1.3 m), after competitor species management (Experiment 1). Treatments: C = liana cutting in the total area; S = liana cutting in stripes; Cp = liana cutting in the total area and planting of pioneer trees; P = punctual liana cutting. T = control without liana management. Vertical lines represent the 95% confidence limit. Means followed by the same letter do not differ according to Tukey's test, ∝ = 0.05. SGFR, Campinas/SP/Brazil.

This species has documented capacity of colonizing new areas due to the combination of characteristics such as fast growth, efficient dispersion mechanism by birds and high longevity of the seeds (up to 9 years), forming a permanently seed bank (Vázquez-Yanes 1998; Kwit et al., 2000; Silvera et al., 2003).

In practice, in all areas where the mechanical impediment by the dense liana masses was removed, with the consequent soil exposition to direct light, the regeneration density was significant, with no need for planting (see Fig. 4: C and Cp). Where soil revolving followed liana management, pioneer tree regeneration was even greater.

The speed of canopy closure may be considered a key factor to the restoration process of degraded forests, because it acts in the regulation of the liana density and other light demanding competitive species, such as grasses and bamboos (Tabarelli et al., 1999; Parrotta and Knowles 2001; Souza and Batista, 2004; Yoshida et al., 2005). The pioneer forest cover plays the role of a *physical ecosystem engineer*[1], allowing future vegetation re-structuring through the reception of late species seeds or planting.

In addition to the regeneration of pioneer species, the liana management also made it possible the regeneration of new individuals of non-pioneer species in the shrub strata of managed areas (see Annex 1).

The non-pioneer species showed a less expressive density of new individuals entering the tree/shrub strata mainly by resprout and growth. That is, the non-pioneer species were already in the plot at the moment of the experiment installation, under the dense mass of lianas. With the liana cutting, these individuals were free to grow and were sampled in the tree strata only in the first or second year after the experiment installation.

The treatment P, punctual liana cutting, represents the situation of plots managed only to conduct pre-existent trees and shrubs, i.e., with the least entrance of new individuals due to an almost absent regeneration of pioneer species.

On the other hand, even without an expressive entrance of new individuals, the treatment P showed a significant increment in basal area in the first 24 months of the experiment, indicating that the management has stimulated the growth of trees and shrubs that were released from the mass of lianas (Figure 5).

The increase in the growth rate of trees and shrubs in the managed areas was expected as a result of removing the competition from lianas, which fight over resources (water, light, space, nutrients) with their host and may impair their rates of growth, reproduction and survival, with intensity varying as a function of the mass of lianas (Putz, 1980; Pérez-Salicrup and Barker, 2000; Pérez-Salicrup et al., 2001; Schnitzer and Bongers, 2002).

Its is possible to assume that in sites less degraded than the burned area of SGFR, as forest patches in the initial process of liana invasion, but with higher tree density (i.e., physiognomy still predominantly forest), the punctual management may be more efficient in providing the desirable understorey shade. In such conditions, perhaps only the freeing of the existent trees leads to canopy reestablishment through the growth of the individuals already present in the area.

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[1] Jones et al. (1997) developed the concept of *physical ecosystem engineers* - organisms controlling the availability of biotic and abiotic resources to other organisms, causing physical changes, maintenance or creation of habitats.

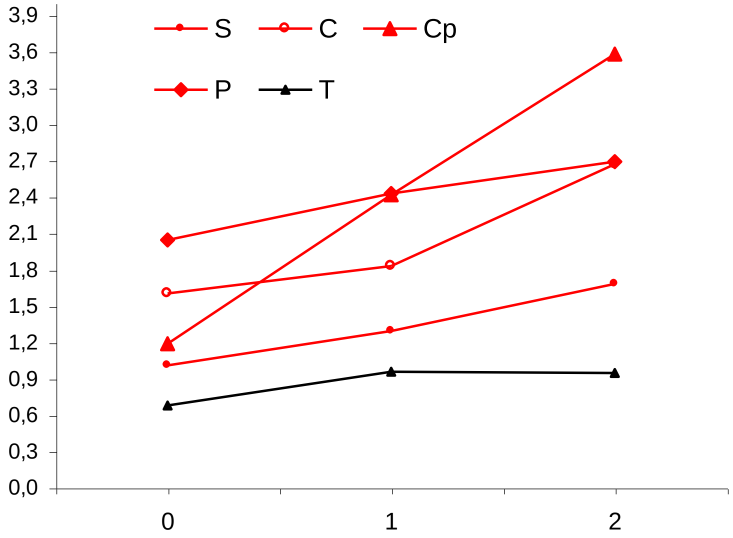


Figure 5. Mean basal area ($m^2.ha^{-1}$) of trees in the experiment of competitor species cutting, at the moment of installation (Year 0), and after 1 and 2 years (Experiment 1). Treatments: C = liana cutting in the total area; S = liana cutting in stripes; Cp = liana cutting in the total area and planting of pioneer trees; P = punctual liana cutting; T = control without liana management. Red lines indicate treatments that had significant basal area increase (Tukey's test, ∝ = 0.05). SGFR, Campinas/ SP/Brasil.

The results therefore indicate that the presence of the dense liana entanglements do not harm the regenerative capacity of degraded forests in short and medium terms, for the reason that after approximately 10 years in a non-forest condition, in areas covered by dense mass of lianas, the management allowed the rapid colonization of the study area by tree and shrub species (Figure 6).

The colonization was proportional to the 'space' created by the management, i.e., there was almost no seedling emergence in non-managed plots (control), as well as in the punctual managed plots (treatment P), however there was significant regeneration in treatments with liana cutting in stripes (S) total area (C) and total area with planting (Cp), where after two years, the number of tree and shrub individuals increased threefold, fivefold and thirteenfold, respectively.

It is worth emphasizing that the variance between means was high, in a way that the treatments could show large differences in the number of regenerating individuals, although these differences did not imply statistical significance (for example, treatments 24 months after the liana cutting in total area with and without planting, with 7,233 and 13,144 $ind.ha^{-1}$ respectively), nevertheless, they definitely imply ecological significance, as for example, in relation to the level of understorey shade.

The re-occupation of the managed areas was accomplished by a large number of individuals of few species, with short life cycle, that germinated at the same time. Due to the contemporaneity of these plants, it is reasonable to expect massive mortality events, as it was already registered for populations of colonizer or pioneer species of degraded forests

a) T = Control without liana management. In this degraded area of SGFR, lianas are the dominant form of life, covering the soil and major part of the existing arbustive-arboreal individuals.

(b) S = liana cutting in stripes. Stripe submitted to liana cutting (1) intercalated with non-cutting stripe (2). Note the residual wood material volume above the soil, originated from liana cutting.

(c) S treatment, after removal of the wood material originated from the liana cutting. Observe the low density of arbustive-arboreal individuals.

(d) C = liana cutting in the total area, after removal of the liana wood material. Observe the low density of arbustive-arboreal individuals.

(e) P = punctual liana cutting. The arrows indicate the arbustive-arboreal individuals present in the plot, which were liberated from the lianas bulk.

Figure 6. Forest restoration treatments in an area dominated by competitor species (Experiment 1). SGFR, Campinas/SP/Brazil.

(Nascimento et al., 1999). In an extreme situation, it is possible to predict a simultaneous mortality of more than 70% of the canopy individuals (corresponding to the *Trema micrantha* population), in nearly 10 years (Vazquez-Yanes, 1998). This scenario complies with the approach used in this book and emphasized by a number of authors (Wunderle Jr., 1997; Souza and Batista, 2003; Parrota and Knowles, 2003), in which the floristic diversity is a pre-requisite for the establishment of ecological processes guaranteeing long-term sustainability in tropical forests.

Summing up, the management of hyper-abundant liana populations in the SGFR burned area, with or without scrap removal, followed by soil revolving, made it possible the competitive exclusion in the managed areas for tree and shrub occupation. Occupation occurred through the establishment of dense populations of a small number of new pioneer species, particularly *Trema micrantha,* and growth (resprouting) of remnant non-pioneer species in the area.

Clues to the initial restoration of a degraded forest

- At seasonal climate regions, actions for regeneration stimulus, like liana cutting, must be achieved in the beginning of stable rainy periods, because even short periods of hydric deficit may lead to harm in seedling survival.
- With simple procedures it can be ascertained if the soil seed bank is present at the degraded forest. It is sufficient to delimitate small plots (2 x 2 m, p.e.), over the interest area, to the surface exposition (removal of liana, exotic herbs, or other hyper-abundant species) and soil revolving. If there is seed bank and favorable conditions (rainy period), the germination will occur in a few weeks.
- In degraded fragments, at anthropic landscapes, it is expected colonization to occur from succession along pioneer communities (herbs / liana ⇒ shrubs / trees), including exotic species. It is recommended to accompany the seed bank germination for at least three months.
- The soil revolving can promote the effective exposition of the superficial soil layer (5-10 cm of depth) and it can be achieved with hoe, opening small burrows, at regular intervals, or over total surface.
- The management costs concentrate at the initial cut, when there is a big volume of wood material to be removed; the maintenance cuts are easier, because they are applied on young, non-lignified vegetable structures. The first maintenance cut, achieved after the beginning of the arbustive-arboreal regeneration, requires much attention to avoid damages to the young established seedlings.

Management of a Young Forest with Low Floristic Diversity

Tree and Shrub Species

The management used in the plots with a pre-existent tree/shrub canopy caused a large variation in the number of individuals of pioneer species between the years 2001 and 2002, according to the treatment.

There was germination and increase in pioneers (27.5% of the individuals) in the plots revolved in the summer (warm and rainy season), whereas in the other treatments there was mortality, variations caused mainly by the decrease in the *Trema micrantha* population.

The mortality found at this stage of the forest (3 years old) may be attributed to the natural process of competitive thinning of the pioneer vegetation, and not to the end of the canopy pioneers' life cycle. Competitive thinning takes place when the increase in competition (for space and resources) between young growing trees leads to the decrease in density and increase in basal area, through the growth of remnant individuals (Vandermeer, 1994; Brown and Lugo, 1990). There were no significant gains for the early and late secondary trees, and in the first case, there was a rise in the number of trees in the winter (dry season) due to the growth of pre-existing individuals.

Considering the results of the three treatments together, the majority of the late secondary species were sampled in low density - only one individual (14.8 ind.ha^{-1}). *Aspidosperma polyneuron* Muell.Arg., with 4 individuals, showed expressive density of 59.3 ind.ha^{-1}, and *Metrodorea stipularis* Mart., with 6 individuals, 88.93 ind.ha^{-1}.

On the other hand, there were gains of individuals in all treatments (in average 40.58%), as a result of the *Hybanthus atropurpureus* Taub. emergence, with 67 individuals and high density (992.6 ind.ha^{-1}), indicating that this species was favored below the pioneer canopy.

In general, the soil revolving operation was not shown significantly helpful for obtaining regeneration from any ecological group, as the responses among the treatment replications were highly heterogeneous (Table 1).

Table 1. Probability values resulting from the tests for detection of differences between treatments according to gains in number of arbustive-arboreal individuals of height ≥ 1m in each ecological group, between the initial (February/2001) and final sampling (September/2002), in the experiment of competitor species control followed by different soil revolving treatments (Experiment 2). SGFR, Campinas/SP/Brazil

Comparisons	P	IS	LS	Sc
NR x R	t 0.9419	t 0.3455	t 0.8105	t 0.7896
NR x SR x WR	A 0.7616	A 0.0848	K 0.9932	A 0.5136

Obs.: NR x R.: comparison between the non-revolved and revolved treatments; NR x SR x WR.: comparison between the non-revolved, summer revolving and winter revolving treatments; P: pioneers; SI: initial secondaries; ST: late secondaries; Sc: sub-canopy specialists; t: t test; A: ANOVA with F test; K: Kruskal-Wallis test.

The increase in the number of pioneer individuals in the summer was due to the increased rainwater availability and high temperatures, stimulating germination. The increase in the densities of late secondary and subcanopy specialists resulted from the resprout of the existing individuals in the plots. Thus, the soil revolving is not recommended for vegetation with pioneer cover previously established, causing soil shading.

Seed Rain

During the sampling period, 5600 seeds of tree and shrub species and 130 seeds of lianas and herbaceous species were collected. Among all collectors, *Solanum erianthum* was the species with the largest number of sampled seeds (2372), followed by *Piper amalago* (1722) and *Trema micrantha* (860) (Table 2).

Table 2. Shrub and tree strata characteristics * (height ≥ 1.0 m) and those of the seed rain at the initial stages of secondary succession in a degraded forest area submitted to management (Experiment 2). SGFR, Campinas/SP/Brazil

Parameter	Arbustive-arboreal strata		Seed rain
	Young forest with approximately 3 years (February/2001)	Young forest with approximately 4 years (September/2002)	Main deposited seed species (and quantities)
Nº of individuals	560	593	
Nº of species	49	56	
Absolute density (ind.ha^{-1})	8296	8784	
Basal area (m^2)	2.574	3.283	
% Pioneers - P	78.4	74.9	
% Initial secondaries - IS	5.2	5.2	
% Late secondaries - LS	4.3	3.9	
% Sub-canopy specialists - Sc	10.7	14.5	
% Non-classified	1.4	1.5	
Main species** / ecologic group/ nº of individuals ** At the shrub and tree strata = species with the largest cover index value. At the seed rain = species with the largest number of deposited seeds.	*Trema micrantha* / P/ 270 *Abutilon peltatum* / P / 56 *Hybanthus atropurpureus* / Sc / 44 *Croton floribundus* / P / 31 *Solanum erianthum* / P / 25 *Piper amalago* / P / 23 *Vernonia polyanthes* / P/ 13 *Maytenus aquifolium* / Sc / 7 *Lonchocarpus muehlbergianus* / IS / 6	*Trema micrantha* / P / 191 *Piper amalago* / P / 26 *Abutilon peltatum* / P / 73 *Hybanthus atropurpureus* / Sc / 67 *Croton floribundus* / P /39 *Solanum erianthum* / P / 39 *Vernonia polyanthes* / P / 31 *Aloisia virgata* / P / 22 *Lonchocarpus muehlbergianus* / IS / 7 *Jacaratia spinosa* / P / 4	*Solanum erianthum* / P / 2372 *Piper amalago* / P / 1722 *Trema micrantha* / P / 860 *Vernonia polyanthes* / P / 414 *Urera baccifera* / P / 113 *Hybanthus atropurpureus* / Sc / 86 *Abutilon peltatum* / P / 27 *Aegiphila sellowiana* / P / 3 *Colubrina glandulosa* / IS / 3

* Considering in conjunction non-revolved, summer revolving and winter revolving treatments, which do not showed significant different regeneration.

These data indicate that the seed rain consisted basically of tree, shrub and liana seeds present in the managed areas (Table 2, Annex 1). Among the tree and shrub species, the pioneers appeared with the largest number of seeds, whose density of individuals and phenological characteristics led to abundant fruit set in the studied period.

Hence, the seed rain did not show the arrival of new species that could contribute to the enrichment and successional advance of the young forest. These results were considered surprising for the fact that the study area is an integrant part of a relatively large area of forest fragment (SGFR), which is protected, with high floristic diversity, and at least until a few years ago, it was considered little disturbed (Santos et al., 1996; Gandolfi 2000).

The main factor influencing the arrival (quantitative and qualitatively) of outer seeds to the regeneration areas are: (a) the degree of isolation between the donor communities and the receptor areas of seeds, which is defined by the distance and existing habitat types between these areas (Aide, 2000; Laurance, 2001; Lamb et al., 2005); (b) the presence of zoochory vectors (Stiles, 2000); (c) the degree of ‘attraction’ exerted by the area receptor of seeds on these vectors (Wunderle Jr., 1997), and (d) the characteristics of the communities serving as seed sources (the remnant forest) (Laurance et al., 2002; Kozlowski, 2002; Benitez-Malvido and Martinez-Ramos, 2003).

In this way, the distance (more than 100 m) between the plots and the areas of mature forests in the reserve, whose space was dominated by lianas, represented systems of floristic and structural complexity less attractive to the disperser fauna (Wunderle Jr., 1997), probably making seed arrival difficult.

It is note worthing that the individuals of non-pioneer species present in the study area were young - larger DBHs between 7-13 cm (diameter at breast height) - indicating that it will take them years to attain reproductive age and contribute to seed rain. On the other hand, the mature forest areas of SGFR, which would represent a seed source to the degraded areas – such as the one managed - are not performing this role well.

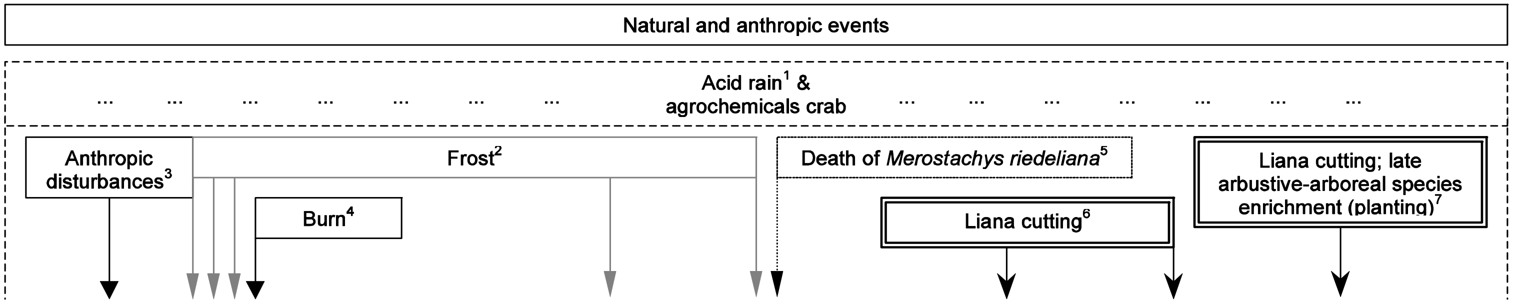
Clues to a pioneer forest management

- Achieve periodic control of competitor species – exotic or native hyper-abundant plants – to maintain the pioneer forest structure for a sufficient period, propitious to the arrival of seeds and to the establishment of individuals of non-pioneer species.
- If there is non-pioneer regeneration, but represented by insufficient number of individuals to in a near future, substitute the pioneer canopy, achieve densing planting with initial secondaries and late secondaries / climax species.
- The non-pioneer species addition may also be effectuated by direct seed planting, transplanting of litter, or by rescue of seedlings that germinate in high density at outer areas – surrounding forests.
- It is necessary to monitor the natural regeneration performance (density, height), the forest diversity and successional advance, implementing new actions until the vegetation have established the functioning of its ecological processes.

Successional Trajectory and Forecasts for the Studied Community

The successional trajectory of the managed plots can be understood by monitoring the dynamics of this forest patch from 1972, when the vegetation was in an initial secondary stage, to 2002, totaling 30 years (Figure 7). Each interval of this entire period was characterized by the dominium of one or more guilds of plants.

After the highly destructive fire in 1981, the regeneration of the burned area occurred by resprout (persistent species after fire) and mainly by the germination of pioneer trees and lianas (Castellani and Stubblebine, 1993; Matthes 1992). Subsequently, there was a decrease in pioneer trees with the persistence of some early secondary, late secondary and subcanopy species during 10 years in a vegetation dominated by hyper-abundant lianas. The liana management (Experiment 1) stimulated the growth and resprout of these non-pioneers and the regeneration of new pioneer individuals, which was monitored - by the management - for a total period of 4 years (plots used in Experiments 1 and 2). Following the managements, in september/2002, the final density of tree and shrub plants with height ≥ 1 m (considering the ecological groups together) was 8,784.5 ind.ha^{-1}, (grouping the soil revolving and non-revolving treatments, since they did not have significantly different performances).



Epoch	*?*	*...1972-1981*	*1981-1983*	*1984-1987*	*1988-1994*	*1994-1998*	*1998-2000*	*2001-2002*	*?*
Vegetal community observed situation	Mature forest	Secondary vegetation	Occupation by pioneer arbustive-arboreal, lianas and herbaceous species	Pioneer arbustive-arboreal populations decline and secondary populations expansion	Pioneer cycle ending; lianas populations expansion	Hyper-abundant populations dominium; arbustive-arboreal cover decline	Pioneer arbustive-arboreal regeneration	Sub-canopy regeneration	Mature forest, composing shaded sub-canopy
Involved ecological models	***Various***	***?***	***Facilitation[8]***	***Species substitution[9]***	***Species substitution***	***Inhibition[8]; Competitive exclusion[10]***	***Facilitation; Competitive liberation[11]***	***Facilitation***	***Inhibition***
Model explanation	—	—	Heliophyte species were capable of establish in the open area, under high luminosity.	Shade intolerant species, short cycle species gave place to more tolerant and higher longevity species.	The initial colonizers had their life cycles concluded and in conjunction with shade tolerant, lianas of various cycles and strategies, including the vegetative growing, gradually substituted them.	Since the occurrence of external and internal stress events (*Merostachys* death), there were lianas populations spreading (competitive species); those excluded the recruitment and inhibited the regeneration of shade tolerant arbustive-arboreal species.	Despite of arbustive-arboreal and liana pioneer species be capable to establish at the open area, the first ones achieved to do it when the last were controlled.	The environmental modification by pioneers allowed the recruitment of later species, present at the sub-canopy.	The sequence continues until the resident species no more facilitate the invasion and growing of hyper-abundant populations.

[1] Acid rain chemical elements brought by the wind, originated from highways, surrounding agricultural activities, highlighting the Paulínia Refinery (França *et al.* 2002); [2] Frost: the more recent occurred in 1975, 1979, 1981, 1988 and 1994 (Pinto *et al.* 1999); [3] Unknown anthropic disturbances: according to observations of aerial images by Nave (1999); [4] Burn: occurred in September/1981 (Castellani & Stubblebine 1993); [5] *M. riedeliana* Rupr. ex Dùll. had numerous bushes at the area, exerting allelopathy; in 1994 (frost year), the bushes died off concomitantly, leaving a big volume of rests, that prevented the arbustive-arboreal regeneration (Gandolfi 2000); [6] Lianas control: achieved by Rozza (2003) and Farah (2003); [7] Refers to future possible managements; [8] Connel & Slatyer (1977); [9] Horn (1975); [10] Gause (1934); [11] Diamond (1975).

Figure 7. Relationships between the vegetation dynamics before and after management and some ecological models. SGFR, Campinas/SP/Brazil.

If the management is finished, at the end of the experiments there are 799,6 ind.ha^{-1}, with height ≥ 1 m, considering only early and late secondary species. If we consider only the individuals with PBH (perimeter at breast height) ≥ 15 cm, the study areas showed, 48 months after management initiation (Experiment 1), density and diversity of non-pioneer species similar to those found in well preserved SGFR patches (Table 3).

Table 3. Comparison of final results obtained after the degraded forest management (Experiments 1 and 2) and those obtained at a mature vegetation area of SGFR, Campinas/SP/Brazil

	Experiments 1 and 2 – Young forest		**Gandolfi (2000) – Mature forest**
Sampling criteria	height ≥ 1 m	PBH ≥ 15 cm	PBH ≥ 15 cm
Sampled area (m^2)	675	675	3500
N° of species	56	39	37-90
Initial and late secondary plants (ind.ha^{-1})	799.6	518.3	663-760

PBH: perimeter at breast height.

One can assume that, once the maintenance of the pioneer forest canopy is guaranteed, providing inhibitory growing conditions to the light demanding competitive species, however beneficial to non-pioneer trees, there will be a favorable scenario for the gradual recovering of the vegetation and continuous increment of quality (i.e., attractiveness) of the managed areas for the dispersing fauna. In a long term, the non-pioneer species regeneration must be monitored, as well as whether the replacing of the canopy by these regenerants is occurring. Failing in the continuity of succession must be reported at once in order to take reparative actions, such as planting of non-pioneer species, before the pioneer canopy reaches senescence.

In the case of managed plots, with the gradual end of pioneers' life cycle, which is evinced by the death of many *Trema micrantha* individuals, the senescent structure will undergo a decline in few years. For SGFR, where the plots are within vegetation dominated by lianas, the density of non-pioneer species obtained until the end of the experiment seems to be insufficient (if compared to data reported by Gandolfi, 2000) for the formation of a future forest structure that will hinder the recurrent sprouting of a hyper-abundant liana population. Most probably, there will be ground spaces where the fast resprout of lianas and climbing shrubs will lead the community to a new stage under the dominium of these plants. In this case, it is recommended to begin the periodic management in the adjacent vegetation dominated by lianas, and at the same time, to carry out planting in all areas (previously managed plots and vegetation dominated by lianas) with tree and shrub early secondary and late secondary species to increase the density of plants from these groups, choosing the species from the reserve's flora, which was sampled in previous works. Together with the suitable management of hyper-abundant lianas, the expected result is the beginning of a regeneration cycle of pioneers in the new managed areas, which will nurse the height growth of the young late secondary species. Planting will guarantee the establishment of a forest structure more rapidly and safely than by the natural arrival of seeds. Thus, the possibility of new non-forest cycles, which would be characterized by the death of pioneers and dominium by lianas, will be reduced. In the short term, the Competitive Exclusion Model of tree and shrub regeneration will be established (Diamond, 1975); in the medium term, the Facilitation Model of secondary regeneration, and in the long term, the Inhibition Model (Connel and Slatyer, 1977) of liana growth (Fig. 7).

To summarize, we propose the control of competitive species and the monitoring of regeneration to provide conditions for the growth of the existent non-pioneer tree species or for those that will be establishing in the area through seed rain.

Final Considerations

The experimental work showed that a forest degraded by a number of causes, represented by vegetation dominated by lianas, could undergo an initial restructuring process stimulated by management actions.

The control of hyper-abundant liana populations and the removal of the scrap material outside the plots or above the soil, followed by soil revolving, allowed the competitive exclusion of regeneration. The emergence occurred as vigorous germination (pioneers) or resprouting (subcanopy specialists). The obtained regeneration, from autochthonous seed bank and seed rain, developed in an initially dense forest cover, consisted of fast growing pioneer species (early pioneers), which are efficient colonizers of non-forest habitats (Denslow, 1980).

This pioneer forest was established without the need of planting and created favorable conditions for the restructuring of forest vegetation. Nevertheless, the maintenance and sustainability of the system depend on the arrival, establishment and perpetuation of non-pioneer species in the site in a relatively short period of time (corresponding to the life cycle of the major canopy pioneers), which may represent a serious challenge, considering that is a community established in a degraded patch of an isolated fragment, where the conditions are favorable for the resprouting of lianas (remnant under the pioneer canopy and abundant in the surrounding non-managed sites).

Soil revolving was not shown efficient to stimulate significant regeneration of tree and shrub species under the pioneer canopy, indicating that the practice is more indicated for open areas, with more light, which, in association with the removal of competitive species (lianas, herbs, bamboos), may favor the germination of seeds stored in the soil.

We suggest that young tree communities, established from autochthonous resources of degraded forest patches, as in the present case, should be monitored to follow non-pioneer species regeneration and whether there is replacement of tree species in the canopy. Failing in the continuity of the successional process should be rapidly reported in order to take reparative action, such as the control of heliophyte competitors and the enrichment with species capable of replacing the canopy pioneers and of attracting fauna.

On the other hand, independently of monitoring, it is expected that new interventions in the site, focused on enrichment[12], may contribute to the reestablishment of the diversity needed for forest sustainability more rapidly and more safely than those expected by the spontaneous arrival of seeds. Thereby, the possibility of new non-forest cycles originated by

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[1] Through the direct seed planting, seedling rescue, outer litter transference, seedling planting, use of disperser-fauna attractive species, artificial perche installing, etc., as described in the chapters 3.2. and 6 of this book

the death of tree pioneers and dominium by non-tree heliophyte competitors would be reduced.

ANNEX 1

Species with the largest basal area at the arbustive-arboreal strata (trunk height > 1.30 m), at the moment of experiment installation (Year 0), and after 1 and 2 years

		Year 0		**Year 1**		**Year 2**	
		Species	**B.A.**	**Species**	**B.A.**	**Species**	**B.A.**
CP	1a	*Nectandra megapotamica* (2) -	0.09	*Ricinus communis* (264)	0.24	*R. communis* (199) - P	0.31
	2a	*Vernonia polyanthes* (13) - P	0.03	*N. megapotamica* (2) -	0.09	*T. micrantha* (567) - P	0.22
	3a	*Urera baccifera* (5) - P	0.02	*Trema micrantha* (175)	0.06	*N. megapotamica* (2) - IS	0.11
	4a	*Pisonia ambigua* (2) - Sb	0.02	*U. baccifera* (5) - P	0.05	*V. polyanthes* (87) - P	0.08
	5a	*Croton floribundus* (4) - P	0.02	*V. polyanthes* (21) - P	0.03	*S. erianthum* (99) - P	0.07
	6a	*Cariniana estrellensis* (3) - LS	0.02	*P. ambigua* (2) - Sb	0.03	*Croton floribundus*- P	0.05
	7a	*Colubrina glandulosa* (1) - IS	0.01	*Solanum erianthum* (81)	0.03	*U. baccifera* (6) - P	0.04
	8a	*Piptadenia gonoacantha* (3) - P	0.01	*C. floribundus* (5) - P	0.02	*A. virgata* (14) - P	0.03
	9a	*Aloysia virgata* (2) - P	0.01	*Cordia magnoliifolia*	0.02	*Cordia magnoliifolia* - IS	0.03
	10	*Cordia magnoliifolia* (1) - IS	0.01	*P. gonoacantha* (3) - P	0.02	*Bauhinia forficata* - P	0.03
	Total	***Species***	*32*	***Species***	*38*	***Species***	*46*
		Individuals	*85*	***Individuals***	*625*	***Individuals***	*116*
		Basal area	*0.38*	***Basal area***	*0.83*	***Basal area***	*1.24*
C	1a	*Lonchocarpus muehlbergianus*	0.09	*Trema micrantha* (124)	0.03	*Trema micrantha* (379) -	0.18
	2a	*Maclura tinctoria* (2) - IS	0.05	*L. muehlbergianus* (9) -	0.10	*L. muehlbergianus* (9) -	0.11
	3a	*Urera baccifera* (5) - P	0.05	*Maclura tinctoria* (2) -	0.05	*C. floribundus* (27) - P	0.07
	4a	*Croton floribundus* (11) - P	0.04	*Urera baccifera* (7) - P	0.05	*Urera baccifera* (8) - P	0.06
	5a	*Aloysia virgata* (1) - P	0.02	Croton floribundus (10)	0.05	*Maclura tinctoria* (2) -	0.06
	6a	*Aegiphila sellowiana* (2) - P	0.01	*Abutilon fluviatile* (45) -	0.04	*Abutilon fluviatile* (50) -	0.04
	7a	*Aspidosperma polyneuron* (5) -	0.01	*Aloysia virgata* (1) - P	0.03	*S. erianthum* (34) - P	0.03
	8a	*Jaracatia spinosa* (2) - P	0.01	*Piper aduncum* (5) - P	0.02	*A.polyneuron* (6) - LS	0.03
	9a	*Abutilon fluviatile* (43) - P	0.01	*Aegiphila sellowiana*	0.02	*Aloysia virgata* (4) - P	0.03
	10	*Astronium graveolens* (4) - IS	0.01	*A. polyneuron* (5) - LS	0.01	*Piper amalago* (24) - P	0.02
	Total	***Species***	*35*	***Species***	*38*	***Species***	*46*
		Individuals	*134*	***Individuals***	*307*	***Individuals***	*644*
		Basal area	*0.46*	*Basal area*	*0.60*	*Basal area*	*0.90*
S	1a	*Acacia polyphylla* (1) - IS	0.00	*Acacia polyphylla* (1) -	0.00	*Acacia polyphylla* (1) -	0.01
	2a	*Croton salutaris* (3) - P	0.05	*H. ovata* (12) - P	0.07	*T. micrantha* (143) - P	0.09
	3a	*Helicteres ovata* (1) - P	0.05	*C. salutaris* (3) - P	0.07	*H. ovata* (12) - P	0.09
	4a	*Croton floribundus* (6) - P	0.02	*C. floribundus* (6) - P	0.04	*C. salutaris* (3) - P	0.07
	5a	*Centrolobium tomentosum* (2) -	0.02	*T. micrantha* (33) - P	0.03	*C. floribundus* (10) - P	0.05
	6a	*Cordia magnoliifolia* (3) - IS	0.02	*C. magnoliifolia* (3) - IS	0.03	*C. magnoliifolia* (3) - IS	0.04
	7a	*Inga vera* (4) - Si	0.02	*C.tomentosum* (2) - IS	0.02	*C.tomentosum* (2) - IS	0.03
	8a	*Alchornea glandulosa* (1) - P	0.01	*Inga vera* (4) - IS	0.02	*Inga vera* (4) - IS	0.02
	9a	*Metrodorea stipularis* (8) - Sb	0.01	*P. amalago* (22) - P	0.01	*P. amalago* (22) - P	0.02
	10	*Trema micrantha* (9) - P	0.00	*Alchornea glandulosa*	0.01	*P. gonoacantha* (8) - P	0.01
	Total	Species	33	Species	37	Species	45
		Individuals	98	Individuals	138	Individuals	289
		Basal area	0.3	Basal area	0.41	Basal area	0.57

Species with the largest basal area at the arbustive-arboreal strata (trunk height > 1.30 m), at the moment of experiment installation (Year 0), and after 1 and 2 years (Continued)

P	1a	*C. glandulosa* (12) - IS	0.13	*C. glandulosa* (12) - IS	0.15	*C. glandulosa* (12) - IS	0.16
	2a	*Cordia ecalyculata* (2) - IS	0.05	*A. virgata* (6) - P	0.08	*A. virgata* (7) - P	0.08
	3a	*Aloysia virgata* (8) - P	0.05	*C. ecalyculata* (2) - IS	0.06	*C. ecalyculata* (2) - IS	0.08
	4a	*Piper amalago* (16) - P	0.02	*P. amalago* (15) - P	0.03	*P. amalago* (15) - P	0.04
	5a	*Aegiphila sellowiana* (4) - P	0.02	*Croton salutaris* (2) - P	0.02	*Croton salutaris* (2) - P	0.03
	6a	*Cedrela fissilis* (1) - LS	0.01	*Aegiphila sellowiana*	0.02	*T. micrantha* (19) - P	0.03
	7a	*Aspidosperma polyneuron* (6) -	0.01	*Cedrela fissilis* (1) - LS	0.02	*A. sellowiana* (4) - P	0.02
	8a	*Croton salutaris* (2) - P	0.01	*T. micrantha* (5) - P	0.02	*Cedrela fissilis* (1) - LS	0.02
	9a	*Centrolobium tomentosum (7)* -	0.01	*A. polyneuron (6)* - LS	0.01	*Croton floribundus* (3) -	0.02
	10	*Croton floribundus* (2) - P	0.01	*Croton floribundus* (3) -	0.01	*A. polyneuron* (6) - LS	0.01
	Total	Species	44	Species	45	Species	47
		Individuals	136	Individuals	140	Individuals	162
		Basal area	0.48	Basal area	0.63	Basal area	0.72
T	1a	*Trema micrantha* (9) - P	0.02	*Trema micrantha* (8) - P	0.03	*C. floribundus* (6) - P	0.03
	2a	*Croton floribundus* (7) - P	0.02	*C. floribundus* (7) - P	0.02	*T. micrantha* (8) - P	0.03
	3a	*Cordia magnoliifolia* (1) - IS	0.02	*C. magnoliifolia* (1) - IS	0.02	*C. magnoliifolia* (1) - IS	0.02
	4a	*Indeterminada* 1 (1)	0.01	*Indeterminada* 1 (1)	0.01	*Aloysia virgata* (1) - P	0.01
	5a	*Jaracatia spinosa* (1) - P	0.01	*Aloysia virgata* (1) - P	0.01	*Jaracatia spinosa* () - P	0.01
	6a	*L. muehlbergianus* (7) - IS	0.01	*Jaracatia spinosa* () - P	0.01	*P. amalago* (17) - P	0.01
	7a	*Aloysia virgata* (1) - P	0.00	*Piper amalago* (14) - P	0.01	*P. gonoacantha* (3) - P	0.01
	8a	*Cariniana estrellensis* (2) - LS	0.00	*L. muehlbergianus* (7) -	0.01	*L. muehlbergianus* (8) -	0.01
	9a	*Acacia polyphylla* (2) - IS	0.00	*Piptadenia gonoacantha*	0.01	*Astronium graveolens* (3)	0.00
	10	*Astronium graveolens* (3) - IS	0.00	*Acacia polyphylla* (2) -	0.01	*Cariniana estrellensis*	0.00
	Total	Species	41	Species	41	Species	40
		Individuals	115	Individuals	117	Individuals	117
		Basal area	0.23	Basal area	0.28	Basal area	0.28

Treatments: C = liana cutting in the total area; S = liana cutting in stripes; Cp= liana cutting in the total area and planting of fast growing pioneer species; P = punctual liana cutting; T = control without liana management. Values in brackets = number of individuals. P = pioneer, IS = initial secondary, LS = late secondary, Sc = sub-canopy specialist. B.A. = Basal area (m^2). SGFR, Campinas/SP/Brazil.

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