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Chapter 2.3.

RESTORATION METHODOLOGIES

2.3. COMBINATION OF SPECIES INTO FILLING AND DIVERSITY GROUPS AS FOREST RESTORATION METHODOLOGY

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Introduction

The recovery of degraded ecosystems is an ancient activity, and examples of its existence in the history of several populations at different ages and regions can be found (Rodrigues and Gandolfi, 2004). Initially, recovery activities were used as planting practice of seedlings with specific objectives such as erosion control, conservation of headwaters, landscapes, stabilization of slopes, among others.

Only in the decade of 1980 with the development of the restoration ecology as science (Engel and Parrota, 2003), the recovery of degraded areas has been methodologically applied and defined as an activity linked to theoretical conceptions (Rodrigues and Gandolfi, 2004).

In this context, in the last decades, this science has searched to improve the forest restoration methodology through the development of technologies to produce seedlings and seeds, to plant, to combine successional groups in the field and other methodologies to reintroduce propagules, always with the objective of restoring ecological processes and reestablishing the functioning of the forest dynamics.

In the decades of 1960 and 1970, important works conducted by Budowski (1965) and Whitmore (1976) based on the dynamics of forests, introduced the successional question of the native species that led to great methodological changes in the forest restoration activities (Crestana et al., 1993; Kageyama, 2001; Kageyama and Gandara, 2004; Rodrigues and Gandolfi, 2004; Barbosa, 2004). For this reason, since the end of the decade of 1980 until current days, several combination models of species from different successional groups have been tested in the restoration of degraded areas (Durigan and Nogueira, 1990; Rodrigues et al., 1992; Macedo et al., 1993; Crestana et al., 1993; Rodrigues and Gandolfi, 2004; Barbosa, 2004, among others).

Since models were initially based on the concepts of the Ecology Classical Paradigm, the density of individuals from each species and their spatial distribution were defined based on the phytosociological parameters of the preserved forests of the region to be restored in the attempt of rebuilding a forest climax considered as single (Pickett et al., 1992; Kageyama and Viana, 1989; Kageyama et al., 1990; Kageyama, 2003).

In the classic ecology concepts in force back in that time, one believed that the natural systems were considered as closed and self-adjustable (Pickett et al., 1992; Pickett and Ostfeld, 1994) and succession was a deterministic process that occurred through the convergence of phases in order to reach a single climax (Clements, 1916, 1928; Odum, 1969). In this ecosystem, the support capacity of a population would be fixed and constant.

In all these models using successional groups, the initial succession species had the fast shading of the area to be restored as main objective (Rodrigues et al., 1987; 1992; Kageyama et al., 1990; 1994; Kageyama and Gandara; 2004) by creating a suitable environment for the development of the final succession species.

The successful introduction of the successional concept that allowed the implantation of the short-term forest semblance due to the use of pioneer species in addition to the difficulties found in the attainment of seeds of several final succession species for large-scale use, the diversity of species and forms of life matter has been left behind (Souza and Batista, 2004).

For this reason, in the decade of 1990, part of the restoration projects adopted the planting of a large proportion of individuals from few pioneer species (Barbosa, 2002) without concerning about the short life cycle of these species, about the number of species in each of the ecological groups and about the total diversity of species in the planted areas. This resulted in the senescence of the several individuals from the few initial succession species concentrated in the first post-planting decades, creating no adequate conditions for individuals from the other low density and diversity ecological groups to occupy the openings left by the death of the pioneer species, thus favoring the re-colonization of the restored area by invading exotic grassy species and hence the grass competition (Barbosa, 2002).

In the last decades, the methodological changes in the restoration ecological area has been based on the Contemporary Paradigm, also known as shifting paradigm (Pickett et al., 1992) – Flowing Nature. This paradigm accepts the theory that successional changes of vegetation may occur according to multiple trajectories (Pickett et al., 1992), with no convergence in the changes of the system in order to reach a "single climax point". The incorporation of these concepts into ecological restoration works is providing important methodological alterations.

According to the Contemporary Paradigm, three basic conditions are required for the succession processes in the area to be restored to occur: a) Availability of adequate site; b) Availability of different species; c) Availability of different performances among species (Pickett et al., 1987; Barbosa, 2004).

Thus, it was necessary to elaborate a methodology based on the concepts of the new Paradigm that includes the effective short-term initial recovering of the area to be restored and the creation of environmental conditions for the development of the high diversity final succession species, main characteristic of the riparian forest and basic requirement for the restoration of the ecological processes (Barbosa, 2004; Rodrigues and Gandolfi, 2004, Rodrigues et al., 2004b). The creation of these favorable environments aims at the reduction of the implantation costs and at increasing the implanted forest perpetuation chances (Rodrigues and Gandolfi, 2004). In this context, researches including the canopy form, light requirements, dynamics of the implanted forests and the genetics of populations may result in adequate conditions for groups of species to develop (Barbosa, 2004) and to create new restoration models (Kageyama and Gandara, 2004).

In this context, the objective of this work is to test a methodological model developed by the Forest Restoration Ecology Laboratory - LERF - ESALQ/USP (Rodrigues et al., 2001; Rodrigues et al., 2003a, 2003b, 2003c; Lopes et al., 2004; Fundação Florestal, 2004; Rodrigues et al., 2004b) of fast recovering of the area with high diversity. The method uses “Filling” lines with fast growing and good covering species and “Diversity” lines with a large number of species from the several ecological groups without fast growing or good covering characteristics. This model uses the maximum diversity in each line and the adaptation of these species to the local climatic and edaphic conditions.

Material and Methods

In this work, two group of species used in a forest restoration methodological model used by the LERF since 2001 in the Intermontes Farm, county of Ribeirão Grande, state of São Paulo, Brazil were tested for the covering efficiency of canopies. This methodology was based on a concept that presents fast recovery of the area and the use of high diversity as premise.

Within this concept, the LERF created two groups called as “functional groups” or “planting groups” namely “*Feeling group”* and “*Diversity group*” (Rodrigues et al., 2001; Lopes et al., 2004; Rodrigues et al., 2004b; Nave, 2005).

The *Filling group* is aimed at the fast recovering and shading of the area with diversity, providing canopy heterogeneity and at shading, use of resources, etc, creating an environment favorable for the development of individuals from the Diversity group and unfavorable for the colonization of the area by competing herbs such as grassy species, aggressive lianas, etc. Approximately 20 species are generally used in this Filling group that must present fast growing and good covering or soil recovering features. Although the Filling group presents a limited number of species, the maximum diversity as possible should be used in order to increase the complexity of the restored environment.

The *Diversity group* includes all other species to be planted unlike species from the Filling group, always presenting a large number of species (around 80 or more species). Therefore, this group is composed of many species but with few individuals from each species, which is an essential characteristic for the restoration of the forest dynamics. Thus, this category includes the more initial species in lower proportion (pioneer and non-leafy early secondary species) and mainly the final succession species (late secondary and/or climax species), from several forms of life that will increase the perpetuation chances of the restored forest.

The planting groups were implanted as alternated line models: a filling line and a diversity line. The planting lines present spacing of 3 m between each other and of 2 m between plants in the same line (Figure 1).

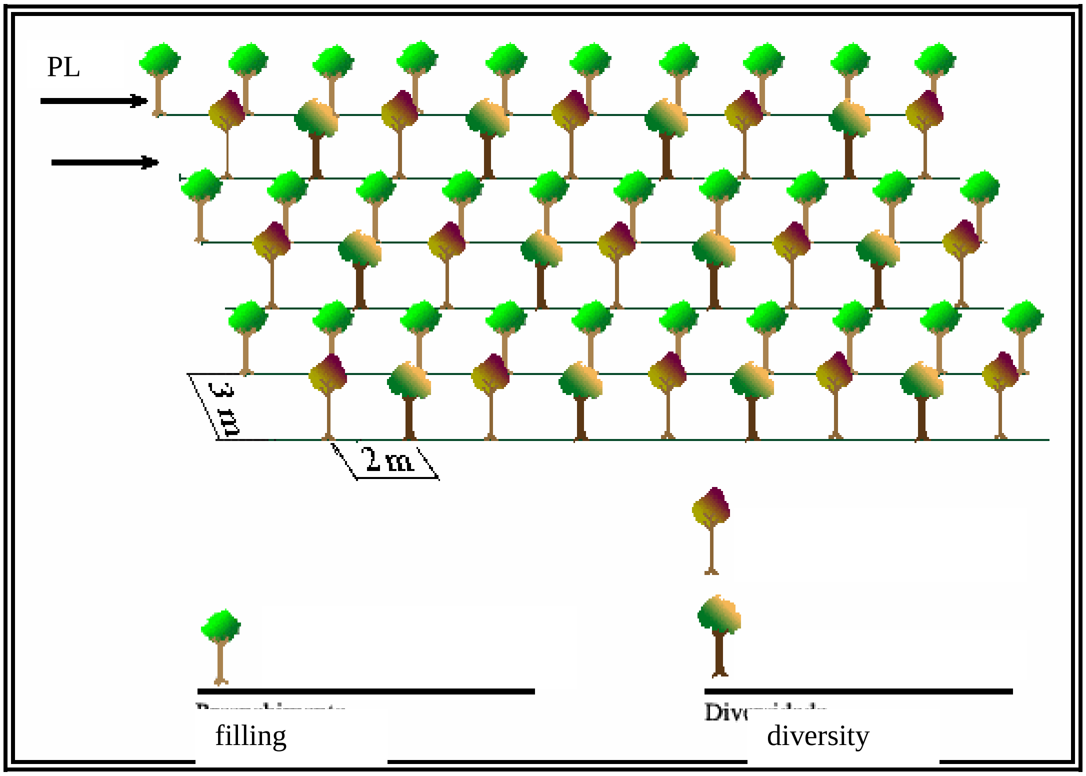

Figure 1. Schematic distribution drawing of the ecological groups in planting lines currently used by the Forest Restoration Ecology Laboratory - LERF - ESALQ/USP, a filling line and a diversity line. PL = planting line;

The maintenance practices were performed in the same way for filling and diversity lines by means of the following activities: a) crowning; b) chemical weeding; c) manuring and d) aunt control.

The canopy cover measurements were obtained through the canopy diameter and width along the planting line and performed in two different communities as follows: a measurement performed in a 1.5-year-old reforestation and another in a 2.5-year-old reforestation. The objective was to verify covering differences between filling and diversity groups in both communities.

The data collection was performed in July 2004 by means of measuring the canopies of planted individuals from each species with the aid of two tape measures, forming transects of 100 m each. The tape measures were placed on the planting lines following the land contour line. The canopies were measured through their vertical projection on the tape measure (Figures 2 and 3).

The width of canopies was obtained through the subtraction between measurements of each individual, in other words, final canopy projection on the tape measure – initial canopy projection on the tape measure ($P_2 – P_1$).

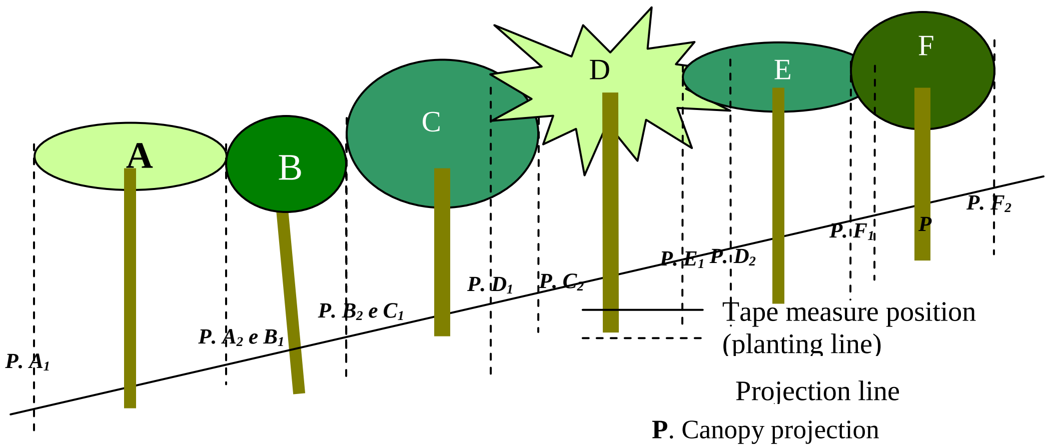

Figure 2. Scheme used in field for the measurement of canopies of arboreal individuals planted in the Intermontes Farm, Ribeirão Grande Cement Company, state of São Paulo, Brazil.

Figure 3. One of the transects where the survey was performed presenting “Filling lines” (side - P) and “Diversity line” (center - D), Intermontes Farm, Ribeirão Grande Cement Company, County of Ribeirão Grande, state of São Paulo, Brazil.

The measurements were conducted in 15 transects of 100 meters each in each line of the different planting groups. Overall, 1500 linear meters for the Filling group and over than 1500 meters for the Diversity group were sampled, summing up 3000 linear meters for each planting age sampled. Therefore, 6000 linear meters were sampled in both surveys. The initial points for the transects installation were randomly distributed throughout the reforestation area.

With data corresponding to the average canopy coverage of individuals from each group, it was possible performing a simulation with different planting models using different spacing combinations and arrangements between groups.

For the identification of species according to their botanic families, the APG II (*Angiosperm Phylogeny Group* - APG II, 2003) classification system was used.

The successional classification of the sampled species was defined by means of the concept proposed by Budowski (1965), as pioneer, early secondary, late secondary and climax, frequently used in restoration works (Gandolfi, 1991; Gandolfi et al., 1995; Gabriel, 1997; Albuquerque, 1999; Fundação Florestal, 2004).

Statistical Analysis

The analysis of variance was aimed at quantifying the effects of factors *Planting Groups* (Filling and Diversity) and *Communities* with different ages (1.5 and 2.5 years) on variables average coverage response and mortality rate.

The statistical hypotheses raised were: a) the average coverage of individuals from the Filling group should be significantly higher than species from the Diversity group; b) the mortality rate of individuals from the Diversity group should be higher than that presented by species from the Filling group, once this latter develops better under full sun.

This analysis was performed based on the Tukey Test (Hatcher, 1994) for multiple comparisons of averages from a fully randomized experiment with two factors (*Planting group and Community*)

The "*Planting group*" presents two levels: "Filling" and "Diversity", whereas factor "*Community*" presents two levels: "1.5" years and "2.5" years.

Since all two-factor levels were combined in order to generate a total of 4 groups, it was characterized as a fully randomized 2x2 factorial experiment combining.

The grouping analysis was performed in order to group species with similar canopy development characteristics and to relate them with Diversity or Filling groups. To do so, the "*Average Linkage*" (SAS Institute Inc., 1999) method was used by calculating the average distances between groups.

Only variable Average Coverage of species with at least 10 individuals that quantifies the canopy width growth was used in this study.

A significance level of 5% was considered. All analyses were performed through the SAS (SAS Institute Inc., 1999) statistical program.

Results and Discussion

Including results obtained from both communities with different planting ages, 2787 individuals belonging to 143 species and 45 families were sampled, where 35 species belonged to the Filling group and 108 species belonged to the Diversity group. Annex I presents all species from Filling and Diversity groups found in this work and specifies the planting age in which the group was found and the planting group determined by the LERF for the implantation of the project.

For the 2.5-year-old reforestation, 1283 individuals belonging to 114 species and 31 botanic families were measured, where 627 individuals and 34 families were found in the filling line and 656 individuals and 80 species in the diversity line. For the 1.5-year-old reforestation, 1504 individuals belonging to 109 species and 29 botanic families were sampled, where 735 individuals and 28 species were found in the filling line and 768 individuals and 81 species in the diversity line.

The results of mortality rate, average spacing between plants, coverage percentage in both planting groups and the difference between coverage percentages for ages of 2.5 and 1.5 years are presented in Table 1.

Table 1. Planting age, mortality rate, average spacing between plants, coverage percentage in both planting groups, difference between coverage percentages for ages of 2.5 and 1.5 years

Planting group	Planting age (years)	Number of ind. sampled	Mort. %	Average spacing (m)	Coverage * %	Coverage difference between groups %	Average coverage ** (m)
Diversity	1.5	768	18.9	2.0 x 3.0	47.0	73.6	1.13
Filling	1.5	736	14.3	2.0 x 3.0	81.6		1.94
Diversity	2.5	656	13.5	2.3 x 3.0	59.6	83.3	1.56
Filling	2.5	627	6.7	2.4 x 3.0	109.2		2.80

* Considers the sum of canopies coverage in relation to the sampled area, sometimes higher than 100%

** Considering live individuals only

Mort = mortality rate

Figure 4 presents averages and confidence intervals for average coverage between planting groups. Results show that the Filling group presented average coverage percentage significantly higher than average coverage of the Diversity group, thus fulfilling its main function in the restoration process. This occurred both for the 1.5-year-old reforestation and for the 2.5-year-old reforestation, where for the 1.5 years, the coverage difference was of 73.6% higher for the Filling group in relation to the Diversity group and for the 2.5 years, this difference reached 83.3%.

These values showed that the initial recovery of the restored area in relation to the Filling group has been fulfilled already in the 1.5-year-old reforestation and increased with the 2.5-year-old reforestation. This initial recovery will contribute for the reduction on the interference from invading species (competing herbs) and for the creation of favorable environments for the regeneration of the native vegetation due to improvements on fertility, temperature and soil humidity and to the attraction of seed-dispersing fauna due to the appearance of new habitats and food resources (Parrota, 1995, Parrota et al., 1997, Tucker and Murphy 1997, Wunderle Jr., 1997, Souza and Batista, 2004).

Results also showed that the establishment of a high number of species reveals that the function of the diversity group has been maintained, increasing the restoration chances of ecological processes and the perpetuation of the restored environment (Rodrigues and Gandolfi, 2004).

Another fact observed is that, depending on the regional climate, edaphic conditions and even on the management of the restored area, some species and hence their respective groups may behave differently (Barbosa, 2004). Table 2 shows the results obtained by Araújo et al., (2004) in the Morro Agudo region, state of São Paulo, Brazil, using the same sampling methodology in three plantings of different ages implanted with the same restoration model as that used in this work.

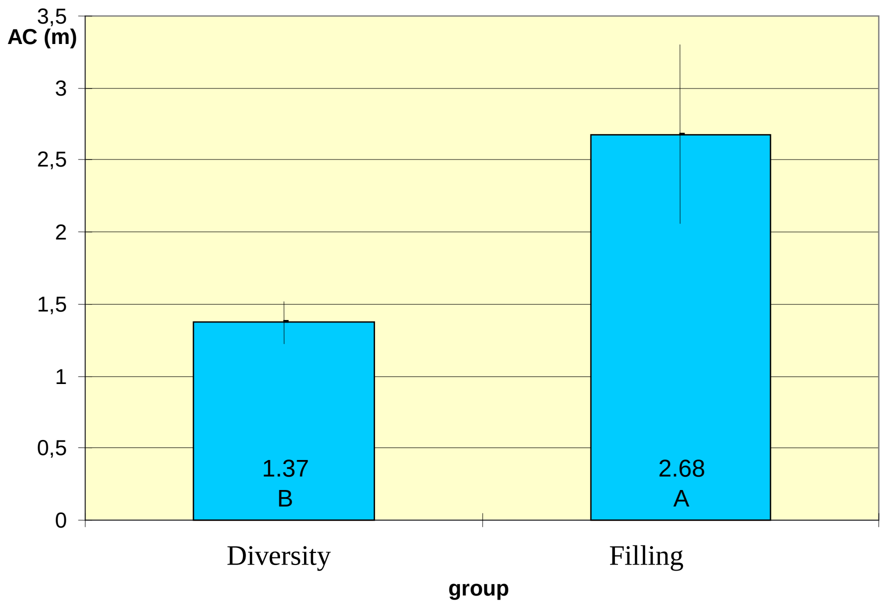

Figure 4. Average coverage (AC) of individuals from Filling and Diversity groups (Averages and confidence intervals). Bars with same letter are not different from each other through the Tukey Test or analysis of variance with significance level of 5%.

When data obtained by Araújo et al., (2004) are compared with data obtained in this work, the growth difference between planting groups attracts attention. At age of 3 years, the Filling group presents 165% of coverage, while at age of 2.5 years; coverage reaches only 109.2% in this work, presenting a difference of 51.1% between both coverages. The difference between coverage from the diversity groups is even greater: 139.2% in Morro Agudo and 59.6% in the present work, in other words, 133.6% higher in Morro Agudo.

Table 2. Planting age, mortality rate, average spacing between plants in the same planting line and coverage percentage in both planting groups for ages of 1, 2 and 3 years in Morro Agudo, state of São Paulo, Brazil

Planting group	Planting age	Average spacing (line)	Coverage %	Difference between groups %
Diversity	1	2.0 x 3.0	44.6	114.35
Filling	1	2.0 x 3.0	95.6	
Diversity	2	2.0 x 3.0	104.2	31.28
Filling	2	2.0 x 3.0	136.8	
Diversity	3	2.0 x 3.0	139.2	18.50
Filling	3	2.0 x 3.0	165.0	

Source: Araújo et al. (2004)

Differences are not so relevant when 1-year-old plantings in Morro Agudo are compared to 1.5-year-old plantings of this work. In the first year of planting, the Filling group of Morro Agudo presented 95.6% of coverage, while with 1.5 years; the coverage rate reached 81.6% in this work, difference of 17.2% between coverages. The difference between coverage from diversity groups is of 44.6% in Morro Agudo and of 47.0% in the present work, in other words, lower for Morro Agudo.

Although the areas compared did not present exactly the same age, these values probably indicate increase on the difference between planting development in both regions, especially between the first and a half year and the third year. These increases on the planting development reflect both the climatic and edaphic conditions involved in relation to the maintenance of the implanted area. The area studied in this work is located at the county of Ribeirão Grande in a cold region with subtropical climate subjected to frosts and annual average temperatures of 18 °C (Setzer, 1966) and presents not much fertile soils generally degraded by constant burns. On the other hand, the region of Morro Agudo is located at the northern state of São Paulo, with typically tropical climate with annual average temperatures of 22 °C (Setzer, 1966), where fertile latossols prevail. However, the region of Ribeirão Grande presents slight hydric deficiency during the winter, while in Morro Agudo, the dry season is well defined in this period.

Thus, we believe that the maintenance intensively performed in the first year of planting in the Intermontes Farm and the non-occurrence of frosts in the first 1.5 years after planting provided unremarkable differences between 1-year-old planting in Morro Agudo and 2.5-year-old planting in this work. On the other hand, 2.5-year-old plantings, besides being half year younger than the 3-year-old planting of Morro Agudo, strong frosts were observed in the first and second years, what certainly caused damages to planted individuals, delaying their development and increasing their mortality rate.

Still comparing regions, the change on the coverage differences between groups in the different planting ages attracts attention (Table 1 and 2). While in Morro Agudo these differences are of 114.35% in the first year, 35.5% in the second and 18.5% in the third year, in the Intermontes Farm, the difference in 1.5-year-old planting is of 73.6% and of 83.3% in the 2.5-year-old planting. These differences suggest that in the region of Morro Agudo, species from the Filling group may be creating favorable environmental conditions for the development of the Diversity group effectively from the second year on (Souza and Batista, 2004) and decreasing the coverage differences between groups. On the other hand, in the Intermontes Farm, the coverage difference between planting groups increased with the planting age, probably meaning that the Diversity group still have not found favorable conditions for its development. Thus, the use of this parameter becomes interesting for the monitoring and determination of the moment in which the maintenance of the area under restoration is abandoned.

The results corresponding to the average canopy coverage were also analyzed by species that presented more than 10 individuals sampled and provided important information on the classification of the species according to its planting group. These information allowed us evaluating if the species were classified correctly or not thought the grouping analysis results (Figure 5) in order to propose this methodology as practical evaluation and, whenever necessary, the reclassification of the species into projects using similar models.

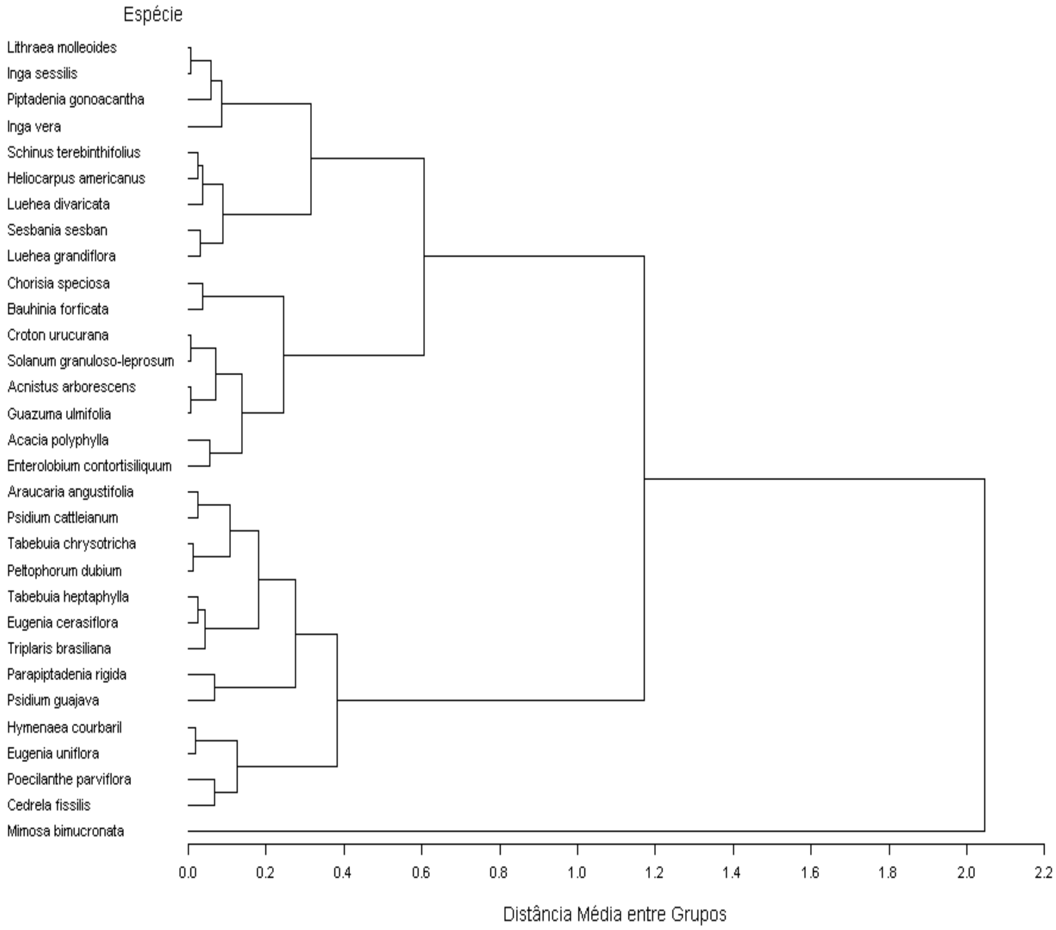

Figure 5. Dendogram of the average canopy coverage of species that presented over than 10 individuals sampled in the 2.5-year-old reforestation constructed based on the original grouping analysis (*Cluster Analysis*) with cutting point indication (0.8). Underlined species were mistakenly classified by the LERF at the planting moment. (axis x: average distance between groups)

The species composed 3 groups namely: group “A” corresponded to species from the Filling group. Within group A, it is interesting observing a subdivision in which two subgroups also presented distinct average coverages, with 2.47 m for A^1 that presented 9 species and 3.43 m for A^2 that presented 8 species. This information demonstrates the possibility of using a model to rather select species from group A^2 in the Filling line, thus increasing even more its efficiency. This may be obtained, once the average for the Filling group ($A^1 + A^2$) was of 2.8 m, about 0.63 cm less than the average obtained for subgroup A^2. In this model, although the diversity of species in the Filling group is lower, species from group A^1 could be included in the Diversity group, thus maintaining the total number of species to be planted.

In a third group, called as “C”, only species *Mimosa bimucronata* used in planting within the Filling group was observed. This species stands out in the dendogram and forms an independent group due to its high average canopy (5.38 m) in relation to all others, sometimes 47% higher than the second highest average canopy of species *Solanum granuloso-leprosum*, with 3.66 m. For this reason, one may say that this species was correctly classified within the Filling group, once this species provides shade, which is the main function of the group.

Table 3 presents the average width of canopies of species with over than 10 individuals sampled in the 2.5-year-old planting, their classification in this planting and their reclassification according to the grouping analysis.

Species as *Chorisia speciosa* A. St.-Hil. and *Lithraea molleoides* Engl., which belong to the Diversity group, *Peltophorum dubium* Taub. and *Triplaris brasiliana* Cham., which belong to the Filling group were, according to the grouping analysis, mistakenly classified by the LERF at the moment this methodology was implanted in the region.

Chorisia speciosa was planted in the diversity group and presented and average canopy width of 3.1m, which is larger than the average canopy width of species belonging to the Filling group (2.80 m). For this reason, if *Chorisia speciosa* and the other 3 species had been correctly classified in their respective planting groups, the differences of coverages between filling and diversity groups would be even greater.

In the search for diversity of plantings, some species are frequently mistakenly classified, especially due to lack of knowledge on their architectural and growth characteristics or even in relation to the response of some species to edaphic and climatic characteristics and the maintenance of the area under restoration. Barbosa (2004) reports a differentiated behavior of the same species when planted in different sites in function of the variation of some specific characteristic of the site. Different behavior may occur in function of interactions between genotype and environment, reason why the generalization of information on the behavior of species from one region to another is not recommended. However, even with some mistaken classifications, the final results presented no alterations on the functions of the filling and diversity groups.

Similarly, the group of pioneer species has been recommended in several restoration models with the main objective of providing shade (Kageyama, 1986; Kageyama et al., 1990; 1994; Barbosa, 2004; Kageyama and Gandara; 2004). However, Table 4 shows that the use of some species reported in literature as pioneer or early secondary with the objective of providing shade may not present these functions in conditions studied in this work. Among them *Peltophorum dubium* Taub., *Psidium cattleianum* and *Triplaris brasiliana* Cham. stand out. These species were identified through the grouping analysis as belonging to the Diversity group. Other native species classified as pioneer such as *Cecropia pachystachia*, *Rapanea umbellata*, *Lafoensia pacari*, *Syagrus romanzoffiana*, *Zanthoxylum riedelianum*, *Aloysia virgata*), among others may present the same behavior.

On the other hand, two species classified in literature as belonging to the late secondary group, *Chorisia speciosa* and *Inga sessilis* seemed to be good shade providers at their initial development phase.

The study performed by Barbosa et al. (1996) in restored areas using parameters such as: total height, canopy diameter, stem circumference and breast height (CAP) concluded that several pioneer species used as shade providers in fact did not have this function. The authors even proposed changes in the successional classifications of several species in function of the behavior of these parameters in field. The same was observed in the work performed by Rodrigues et al., (1999).

Table 3. Average width of the canopy projection of species sampled with more than 10 individuals in the 2.5-year-old planting; PG = planting group; F = Filling; D = Diversity; R = Reclassification (based on the grouping analysis. Figure – 5)

Family	Specie	Author	Number of repetitions	PG	R	average canopy coverage (m)
Anacardiaceae	*Lithraea molleoides*	Engl.	58	D	P	2,18
Anacardiaceae	*Schinus terebinthifolius*	Raddi	67	P	P	2,68
Araucariaceae	*Araucaria angustifolia*	Kuntze	22	D	D	1,38
Bignoniaceae	*Tabebuia chrysotricha*	(Mart. ex A. DC.) Standl.	10	D	D	1,19
Bignoniaceae	*Tabebuia heptaphylla*	(Vell.) Toledo	10	D	D	0,98
Fabaceae Caesalpinioideae	*Peltophorum dubium*	Taub.	14	P	D	1,17
Fabaceae Caesalpinioideae	*Hymenaea courbaril*	L.	23	D	D	0,77
Cercideae	*Bauhinia forficata*	Link	19	P	**P**	3,16
Euphobiaceae	*Croton urucurana*	Baill.	52	P	P	3,65
Fabaceae Faboideae	*Poecilanthe parviflora*	Benth.	11	D	D	0,61
Fabaceae Faboideae	*Sesbania sesban*	Fawc. & Rendle	54	P	P	2,76
Malvaceae	*Chorisia speciosa*	A. St.-Hil.	65	D	***P***	3,10
Malvaceae	*Guazuma ulmifolia*	Lam.	10	P	P	3,53
Malvaceae	*Heliocarpus americanus*	L.	43	P	P	2,64
Malvaceae	*Luehea divaricata*	Mart.	64	P	P	2,60
Malvaceae	*Luehea grandiflora*	Mart.	14	P	P	2,86
Meliaceae	*Cedrela fissilis*	Vell.	42	D	D	0,50
Fabaceae Mimosoideae	*Inga sessilis*	(Vell).Mart	29	P	P	2,19
Fabaceae Mimosoideae	*Inga vera*	Willd.	43	P	P	2,08
Fabaceae Mimosoideae	*Mimosa bimucronata*	(DC.) Kuntze	14	P	P	5,38
Fabaceae Mimosoideae	*Acacia polyphylla*	DC.	18	P	P	3,33
Fabaceae Mimosoideae	*Enterolobium contortisiliquum*	(Vell). Morong	13	P	P	3,42
Fabaceae Mimosoideae	*Parapiptadenia rigida*	(Benth.) Brenan	18	D	D	1,52
Fabaceae Mimosoideae	*Piptadenia gonoacantha*	(Mart.) J.F. Macbr.	24	P	P	2,28
Myrtaceae	*Eugenia cerasiflora*	Miq.	11	D	D	0,94
Myrtaceae	*Eugenia uniflora*	L.	18	D	D	0,74
Myrtaceae	*Psidium guajava*	L.	12	D	D	1,63
Myrtaceae	*Psidium cattleianum*	Sabine	19	D	D	1,34
Polygonaceae	*Triplaris brasiliana*	Cham.	17	P	***D***	1,03
Solanaceae	*Acnistus arborescens*	(L.) Schltdl	25	P	P	3,57
Solanaceae	*Solanum granuloso-leprosum*	Dunal	15	P	P	3,66

Table 4. Relation between planting groups and ecological groups (Budowski, 1965) of species with more than 10 sampled individuals

Planting group	Total of species	Pioneer	Early Secondary	Late |Secondary	Climax	N.C.
Filling	18	11	3	2	-	2
Diversity	13	3	1	7	-	2

N.C. = not classified

Thus, information on growth rate and average canopy width of species in the first years are essential for their classification within filling and diversity groups as well as the average canopy width of each planting group is important for the reevaluation of spacing and arrangement of groups under restoration activities. In this context, Figures 7, 8 and 9 present three schematic drawings using the average canopy coverages obtained by both planting groups. Based on this simulation of model containing different arrangements and spacing between planting groups, it was possible obtaining data on the total coverage and superposition of canopies (Table 5), thus allowing the proposal of planting models more efficient and hence less expensive.

Table 5. General data obtained through simulation of models containing different arrangements and spacing between planting groups using the average canopy projection diameter (Filling = 2.8;Diversity = 1.56 m) obtained in the planting of the 2.5-year-old area

Models	A	B	C
Spacing	3 x 2 m	3 x 2 m	2 x 3 m
Plants per ha	1667	1667	1667
Land coverage %	59.68	67.33	69.32
Superposition of canopies %	10.00	2.05	0.0

The results of the planting models simulation showed that the methodology employed in Model A (Table 5) used in the Intermontes Farm reforestation was less effective in terms of land coverage. Models B and C (Table 5) presented coverages significantly higher than Model A. The way groups are arranged in Model A even suggests an increment of the competition between individuals belonging to the Filling group, once their canopies presented 5.9% of superposition, characterizing competition for space and light, besides a probable competition for nutrients. According to Kageyama et al. (1990), an experiment using only initial species presented lower development of this group in relation to the use of a combination of pioneer (typical pioneer and early secondary species) and non-pioneer (late secondary and climax species).

The arrangements of groups in Models B and C (Table 5) showed the non-superposition of canopies, demonstrating a lower competition between individuals from both planting groups. This lower competition between individuals suggests that in models B and C, the size and width development of canopies could present in field, results even higher than those presented by the theoretical model. However, model B takes advantage of the mechanization between lines, once it remains 3 m wide and allows the presence of a tractor for clearing at the beginning of the reforestation process. Model C limits this mechanization to small-sized tractors.

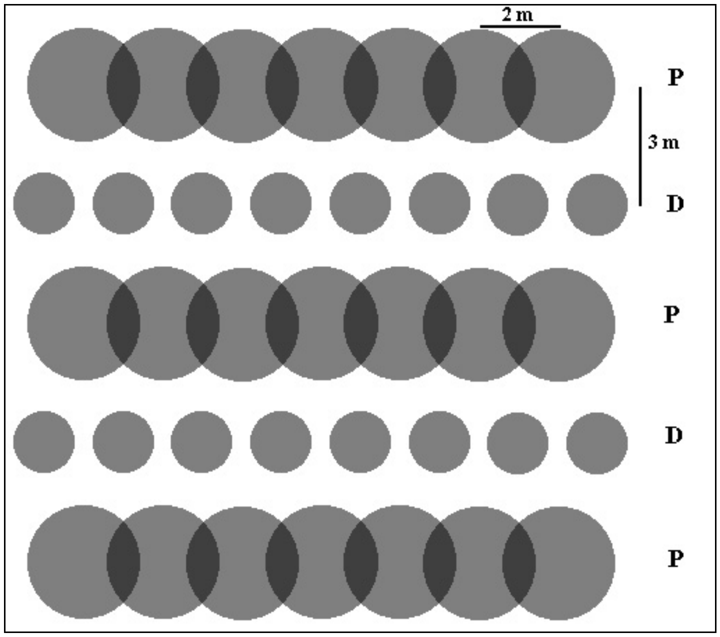

Figure 7. Model A – simulated planting situation using alternated lines of the planting groups and the average canopy projection diameter (P: Filling = 2.80; D: Diversity = 1.56 m) obtained in the planting of the 2.5-year-old area and traditional spacing of 3 between lines by 2 between plants.

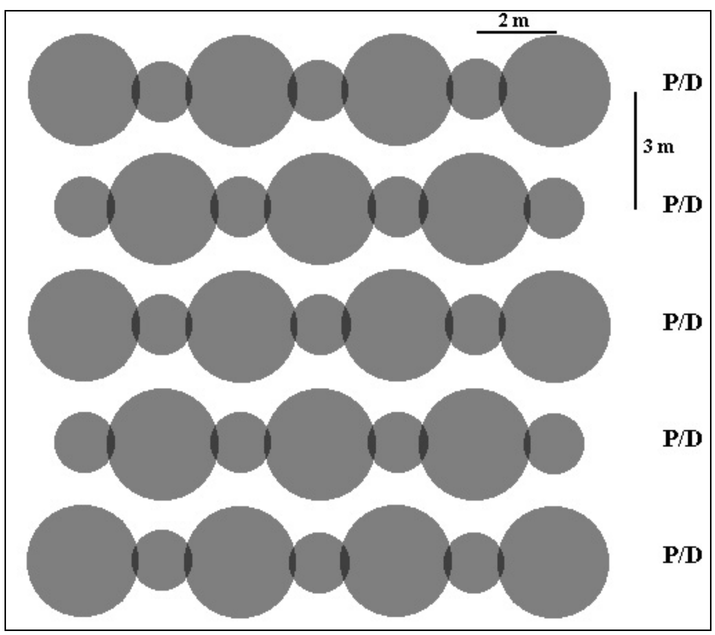

Figure 8. Model B – simulated planting situation using alternated planting groups in the same line and the average canopy projection diameter (P: Filling = 2.80; D: Diversity = 1.56 m) obtained in the planting of the 2.5-year-old area and traditional spacing of 3 between lines by 2 between plants.

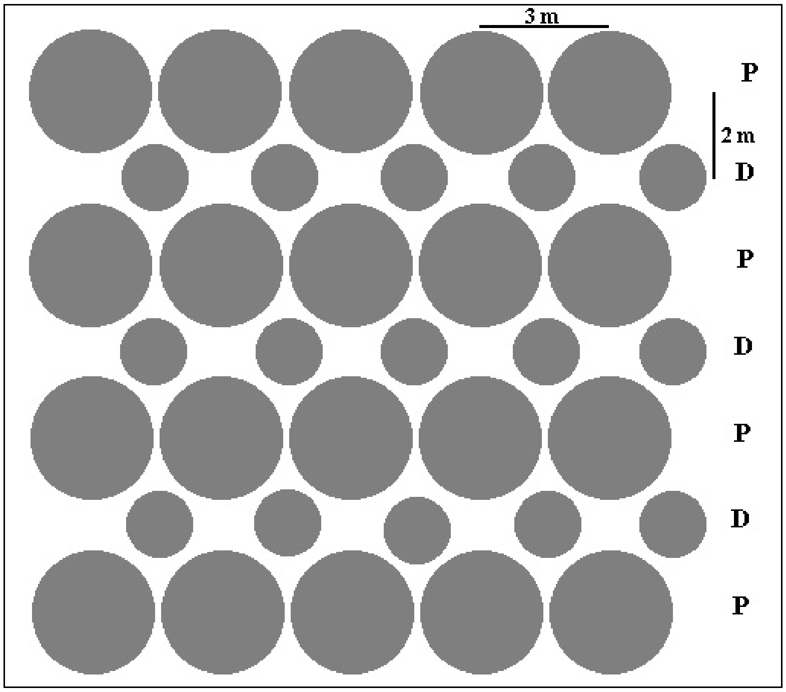

Figure 9. Model C – simulated planting situation using alternated lines of the planting groups and the average canopy projection diameter (P: Filling = 2.80; D: Diversity = 1.56 m) obtained in the planting of the 2.5-year-old area and traditional spacing of 3 between lines by 2 between plants.

Table 5. General data obtained through simulation of models containing different arrangements and spacing between planting groups using the average canopy projection diameter (Filling = 2.8;Diversity = 1.56 m) obtained in the planting of the 2.5-year-old area

Models	A	B	C
Spacing	3 x 2 m	3 x 2 m	2 x 3 m
Plants per ha	1667	1667	1667
Land coverage %	59.68	67.33	69.32
Superposition of canopies %	10.00	2.05	0.0

It is worth mentioning that if Model C had 2x2 m spacing, it would present coverage with 97.5% due to the narrowing of the spacing between lines. The Model B (2x2 spacing) would certainly present a higher implementation cost in relation to the other models due to the higher density of seedlings planted; however, it would present lower maintenance of the implanted area and compensate the initial financial investment. Another advantage presented by Model B (2x2 spacing) would be the fast creation of a favorable environment for the natural regeneration appearance, once the canopy closing will allow the increase on humidity and decrease on competition with aggressive exotic species such as brachiaria and *Panicum maximum* (Parrota, 1995; Parrota et al., 1997; Souza and Batista, 2004). The models proposed shall be tested in order to corroborate their efficiency.

Conclusions

Overall, 2787 individuals belonging to 143 species and 45 botanic families were sampled in both planting ages, where 35 species belonged to the Filling group and 108 to the Diversity group. These values showed the possibility of implementing high diversity restoration projects and the effective establishment of this high number of species, thus demonstrating that the function of the diversity group is being maintained, increasing the restoration possibilities of ecological processes and the perpetuation of the restored area, in other words, a successful initiative.

The results showed that the Filling group presented a coverage percentage significantly higher than the Diversity group and fulfilled its main function in the restoration process. This occurred both for the 1.5-year-old and for the 2.5-year-old reforestations, and for the 1.5-year-old reforestation the coverage difference was of 73.6% higher for the Filling group in relation to the Diversity group and for the 2.5-year-old reforestation, this difference was of 83.3%.

Thus, it was possible combining high diversity forest species into filling and diversity groups and obtaining a fast and effective recovering of the area under restoration, reducing the maintenance costs and increasing its success possibilities.

The methodology employed in this work to quantify the efficiency of the use of both planting groups seemed to be practical and fast for field applications, being able to be used in monitoring and evaluation activities of restoration projects, including its use by surveillance agencies.

The attainment of individual parameters made the evaluation of the specific development of each species possible and the reclassification of species into planting groups whenever necessary, what occurred with four species in the present work.

The simulation of planting models with different arrangements, spacing between plants and using average coverage parameters of individuals from both planting groups showed the possibility for the model to be improved in order to increase the area recovering efficiency through the lower competition between planted individuals. Thus, these new theoretical models shall be submitted to field tests in order to corroborate their efficiency.

Annex I

Table 1A. Species found in surveys specifying planting age and planting group (PG). P = Filling and D = Diversity. N/E = Native or Exotic. N = Native; E = Regional exotic

Family	Specie	Author	N/E	PG	Age (years)	
					1,5	2,5
Anacardiaceae	*Astronium graveolens*	Jacq.	**N**	**D**	**X**	
Anacardiaceae	*Lithraea molleoides*	(Vell.)Engl.	N	D	X	X
Anacardiaceae	*Schinus molle*	L.	E	P		X
Anacardiaceae	*Schinus terebinthifolius*	Raddi	N	P	X	X
Annonaceae	*Rollinia sericea*	(R.E.Fr.) R.E.Fr.	N	D	X	
Annonaceae	*Rollinia sylvatica*	(A. St. Hil.) Martius	N	D	X	X
Apiaceae	*Dendropanax cuneatus*	(DC.) Decne. & Planch.	N	D	X	
Apocynaceae	*Aspidosperma cylindrocarpon*	Mull.Arg	N	D	X	X
Apocynaceae	*Aspidosperma parvifolium*	A. DC.	N	D	X	
Apocynaceae	*Aspidosperma ramiflorum*	Müll. Arg.	N	D	X	X
Apocynaceae	*Aspidosperma subincanum*	Mart.	N	D	X	
Apocynaceae	*Tabernaemontana catharinensis*	A. DC.	N	D	X	X
Araucariaceae	*Araucaria angustifolia*	(Bertol.) Kuntze	N	D	X	X
Arecaceae	*Syagrus romanzoffiana*	(Cham.) Glassman	N	D	X	X
Asteraceae	*Baccharis schultzii*	Baker	N	D	X	
Asteraceae	*Gochnatia polymorpha*	(Less.)Cabrera	N	D	X	X
Bignoniaceae	*Jacaranda cuspidifolia*	Mart. ex A. DC.	E	D		X
Bignoniaceae	*Jacaranda mimosifolia*	D. Don	E	D	X	X
Bignoniaceae	*Tabebuia impetiginosa*	(Mart. ex DC.) Standl.	N	D	X	X
Bignoniaceae	*Tabebuia chrysotricha*	(Mart. ex A. DC.) Standl.	N	D	X	X
Bignoniaceae	*Tabebuia heptaphylla*	(Vell.) Toledo	N	D		X
Bixaceae	*Bixa orellana*	L.	E	D		X
Boraginaceae	*Cordia ecalyculata*	Vell.	N	D	X	X
Boraginaceae	*Cordia myxa*	L.	E	P	X	X
Boraginaceae	*Cordia trichotoma*	(Vell.) Arráb. ex Steud.	N	D	X	X
Fabaceae Caesalpinioideae	*Caesalpinia peltophoroides*	Benth.	E	D	X	X
Fabaceae Caesalpinioideae	*Cassia tora*	L.	E	D		X
Fabaceae Caesalpinioideae	*Copaifera langsdorffii*	Desf.	N	D	X	X
Fabaceae Caesalpinioideae	*Copaifera trapezifolia*	Hayne	N	D		X
Fabaceae Caesalpinioideae	*Hymenaea courbaril*	L.	N	D	X	X
Fabaceae Caesalpinioideae	*Peltophorum dubium*	Taub.	N	P	X	X
Fabaceae Caesalpinioideae	*Schizolobium parahyba*	(Vell.) S.F. Blake	N	D	X	X
Fabaceae Caesalpinioideae	*Senna alata*	(L.) Roxb.	E	P	X	X

Table 1A. Species found in surveys specifying planting age and planting group (PG).

P = Filling and D = Diversity. N/E = Native or Exotic. N = Native; E = Regional exotic (Continued)

Family	Specie	Author	N/E	PG	Age (years)	
					1,5	2,5
Fabaceae Caesalpinioideae	*Senna macranthera*	(DC. ex Collad.) H.S. Irwin & Barneby	N	P	X	X
Fabaceae Caesalpinioideae	*Senna multijuga*	(Rich.) H.S. Irwin & Barneby	N	P	X	X
Fabaceae Caesalpinioideae	*Senna pendula*	(Humb. & Bonpl. ex Willd.) H.S. Irwin & Barneby	N	D	X	X
Fabaceae Caesalpinioideae	*Pterogyne nitens*	Tul.	N	P	X	X
Cannabaceae	*Trema micrantha*	(L.) Blume	N	P	X	
Cardiopteridaceae	*Citronella paniculata*	(Mart.) R.A. Howard	N	D	X	
Celastraceae	*Maytenus robusta*	Reissek	N	D	X	
Cercideae	*Bauhinia forficata*	Mart.	N	P	X	X
Cercideae	*Bauhinia purpurea*	Wall.	E	P	X	X
Combretaceae	*Terminalia brasiliensis*	(Cambess. ex A. St.-Hil.) Eichler	N	D	X	X
Connaraceae	*Connarus regnellii*	G.Schellenb.	N	D		X
Erythroxylaceae	*Erytroxyllum* sp		N	D	X	
Euphorbiaceae	*Alchornea triplinervia*	(Spreng.) Müll. Arg.	N	P	X	X
Euphorbiaceae	*Croton lindenianus*	A. Rich.	N	P		X
Euphorbiaceae	*Croton urucurana*	Baill.	N	P	X	X
Euphorbiaceae	*Joannesia princeps*	Vell.	E	D		X
Euphorbiaceae	*Sapium glandulatum*	(Vell.) Pax	N	D		X
Euphorbiaceae	*Sebastiania serrata*	(Baill.exMüll.Arg.)Müll. Arg	N	D	X	X
Euphorbiaceae	*Croton floribundus*	Spreng.	N	P	X	X
Euphorbiaceae	*Actinostemon concolor*	(Spreng.) Müll. Arg.	N	D	X	
Fabaceae Faboideae	*Centrolobium tomentosum*	Guillemin ex Benth.	N	D	X	X
Fabaceae Faboideae	*Dalbergia frutescens*	(Vell.) Britton	N	D	X	
Fabaceae Faboideae	*Dipteryx alata*	Vogel	E	D	**X**	
Fabaceae Faboideae	*Erythrina speciosa*	Andrews	E	D	X	X
Fabaceae Faboideae	*Lonchocarpus campestris*	Mart. Ex Benth.	N	D	X	X
Fabaceae Faboideae	*Lonchocarpus muehlbergianus*	Hassl.	N	D	X	X
Fabaceae Faboideae	*Machaerium hirtum*	Stellfeld	N	**P**		X
Fabaceae Faboideae	*Machaerium nyctitans*	(Vell.)Benth.	N	D	X	X
Fabaceae Faboideae	*Machaerium paraguariense*	Hassl.	N	D	X	X

Table 1A. Species found in surveys specifying planting age and planting group (PG). P = Filling and D = Diversity. N/E = Native or Exotic. N = Native; E = Regional exotic

(Continued)

Family	Specie	Author	N/E	PG	Age (years)	
					1,5	2,5
Fabaceae Faboideae	*Machaerium stiptatum*	Pers.	N	D	X	
Fabaceae Faboideae	*Myroxylon peruiferum*	L.f.	N	D		X
Fabaceae Faboideae	*Platypodium elegans*	Vogel	E	D		X
Fabaceae Faboideae	*Poecilanthe parviflora*	Benth.	N	D	X	X
Fabaceae Faboideae	*Pterocarpus violaceus*	Vogel	N	D	X	X
Fabaceae Faboideae	*Sesbania sesban*	Fawc. & Rendle	E	P	X	X
Lamiaceae	*Aegiphila sellowiana*	Cham.	N	P	X	X
Lamiaceae	*Vitex montevidensis*	Cham.	N	D		X
Lauraceae	*Ocotea dispersa*	(Nees) Mez	N	D	X	
Lauraceae	*Cryptocarya aschersoniana*	Mez.	N	D	X	X
Lauraceae	*Nectandra leucantha*	Nees & Mart	N	D		X
Lauraceae	*Nectandra megapotamica*	(Spreng.) Mez	N	D		X
Lauraceae	*Ocotea corymbosa*	(Meisn.) Mez	N	D	X	
Lecythindaceae	*Cariniana estrellensis*	(Randdi) Kuntze	N	D	X	
Loganiaceae	*Strychnos brasiliensis*	(Spreng.) Mart.	N	D	X	X
Lythraceae	*Lafoensia glyptocarpa*	Koehne	E	D	X	X
Lythraceae	*Lafoensia pacari*	A.St.-Hil.	N	D	X	
Magnoliaceae	*Talauma obovata*	Korth.	N	D	X	
Malvaceae	*Pachira aquatica*	Aubl.	E	D		X
Malvaceae	*Bombacopsis glabra*	(Pasquale) Robyns	E	D	X	
Malvaceae	*Chorisia speciosa*	A. St.-Hil.	N	D	X	X
Malvaceae	*Guazuma ulmifolia*	Lam.	N	P	X	X
Malvaceae	*Heliocarpus americanus*	L.	N	P	X	X
Malvaceae	*Luehea divaricata*	Mart.	N	P	X	X
Malvaceae	*Luehea grandiflora*	Mart.	N	P	X	X
Meliaceae	*Cedrela fissilis*	Vell.	N	D	X	X
Fabaceae Mimosoideae	*Acacia polyphylla*	DC.	N	P	X	X
Fabaceae Mimosoideae	*Albizia hassleri*	(Chodat) Bur Kart.	E	D	X	X
Fabaceae Mimosoideae	*Albizia lebbeck*	Benth.	E	D	X	X
Fabaceae Mimosoideae	*Anadenanthera falcata*	(Benth.) Speg.	E	P		X
Fabaceae Mimosoideae	*Anadenanthera macrocarpa*	Benth.	N	P	X	X
Fabaceae Mimosoideae	*Enterolobium contortisiliquum*	(Vell). Morong	N	P	X	X
Fabaceae Mimosoideae	*Inga marginata*	Willd.	N	D	X	X

Table 1A. Species found in surveys specifying planting age and planting group (PG). P = Filling and D = Diversity. N/E = Native or Exotic. N = Native; E = Regional exotic

(Continued)

Family	Specie	Author	N/E	PG	Age (years)	
					1,5	2,5
Fabaceae Mimosoideae	*Inga sessilis*	(Vell).Mart	N	P	X	X
Fabaceae Mimosoideae	*Inga vera*	Willd.	N	P		X
Fabaceae Mimosoideae	*Leucochloron incuriale*	(Vell.) Barneby & J.W. Grimes	N	D	X	
Fabaceae Mimosoideae	*Mimosa bimucronata*	(DC.) Kuntze	E	P	X	X
Fabaceae Mimosoideae	*Mimosa scabrella*	Benth.	N	P		X
Fabaceae Mimosoideae	*Parapiptadenia rigida*	(Benth.) Brenan	N	D	X	X
Fabaceae Mimosoideae	*Piptadenia gonoacantha*	(Mart.) J.F. Macbr.	N	P	X	X
Fabaceae Mimosoideae	*Piptadenia paniculata*	Benth.	N	D	X	X
Myrsinaceae	*Rapanea ferruginea*	(Ruiz & Pav.) Mez	N	D	X	X
Myrtaceae	*Campomanesia neriiflora*	(O. Berg) Nied.	N	D	X	X
Myrtaceae	*Eugenia cerasiflora*	Miq.	N	D	X	X
Myrtaceae	*Eugenia cf bocainensis*	Mattos	N	D		X
Myrtaceae	*Eugenia florida*	D.C.	N	D		X
Myrtaceae	*Eugenia involucrata*	DC.	E	D		X
Myrtaceae	*Eugenia jambolana*	Lam.	E	D	X	
Myrtaceae	*Eugenia platysema*	O. Berg	N	D	X	X
Myrtaceae	*Eugenia pluriflora*	D.C.	N	D		X
Myrtaceae	*Eugenia pruinosa*	D. Legrand.	N	D	X	X
Myrtaceae	*Eugenia sp 1*		N	D	X	
Myrtaceae	*Eugenia uniflora*	L.	E	D	X	X
Myrtaceae	*Hexachlamys edulis*	(O. Berg) Kausel & D. Legrand	N	D	**X**	X
Myrtaceae	*Psidium cattleianum*	Sabine	N	D	X	X
Myrtaceae	*Psidium guajava*	L.	N	D	X	X
Nyctaginaceae	*Guapira opposita*	(Vell.)Reitz	N	D		X
Phytolaccaceae	*Gallesia integrifolia*	(Spreng.)Harms	E	D	X	
Phytolaccaceae	*Seguieria langsdorffii*	Moq.	N	D	X	X
Picramniaceae	*Picramnia cf parvifolia*	Engl.	N	D	X	
Piperaceae	*Piper aduncum*	L.	N	D	X	
Polygonaceae	*Triplaris brasiliana*	Cham.	E	D	X	X
Rhamnaceae	*Colubrina glandulosa*	Perkins	N	D	X	
Rosaceae	*Eriobotrya japonica*	(Thunb.) Lindl.	E	D	X	X
Rosaceae	*Prunus myrtifolia*	(L.) Urb.	N	P	X	X
Rubiaceae	*Coutarea hexandra*	(Jacq.) K. Schum.	N	D	X	X
Rubiaceae	*Randia armata*	(Sw.) DC.	N	D		X
Rutaceae	*Esenbeckia febrifuga*	(A. St. Hil.) A. Juss. ex Mart.	N	D		X
Rutaceae	*Zanthoxylum chiloperone*	Mart. ex Engl.	N	D		X
Rutaceae	*Zanthoxylum hyemale*	A.St-Hil	N	D		X
Rutaceae	*Zanthoxylum riedelianum*	Engl.	N	D	X	X

Table 1A. Species found in surveys specifying planting age and planting group (PG). P = Filling and D = Diversity. N/E = Native or Exotic. N = Native; E = Regional exotic

(Continued)

Family	Specie	Author	N/E	PG	Age (years)	
					1,5	2,5
Sapindaceae	*Cupania vernalis*	Camb.	N	D		X
Sapindaceae	*Dilodendron bipinnatum*	Radlk.	N	D		X
Sapindaceae	*Matayba elaeagnoides*	Radlk.	N	D	X	
Sapotaceae	*Chrysophyllum marginatum*	(Hook. & Arn.) Radlk.	N	D	X	X
Solanaceae	*Acnistus arborescens*	(L.) Schltdl	N	P	X	X
Solanaceae	*Solanum concinnum*	Sendtn.	N	D	X	
Solanaceae	*Solanum granuloso-leprosum*	Dunal	N	P	X	X
Urticaceae	*Cecropia pachystachya*	Trécul	N	D		X
Verbenaceae	*Aloysia virgata*	(Ruiz & Pav.) Juss.	N	P		X
Verbenaceae	*Citharexylum myrianthum*	Cham.	N	D		X

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