Vol.57, n.2: pp. 284-294, March-April 2014
ISSN 1516-8913 Printed in Brazil

BRAZILIAN ARCHIVES OF
BIOLOGY AND TECHNOLOGY
A N I N T E R N A T I O N A L J O U R N A L

Management of the Environmental Restoration of Degraded Areas

Izabel Cristina Leinig Araujo[1], Maurício Dziedzic[2] and Leila Teresinha Maranho[2,3*]
[1]Curso de Ciências Biológicas; Universidade Positivo; Curitiba - PR - Brasil. [2]Programa de Pós-graduação em Gestão Ambiental; Universidade Positivo; Curitiba - PR - Brasil. [3]Programa de Pós-graduação em Biotecnologia Industrial; Universidade Positivo; Curitiba - PR - Brasil

ABSTRACT

The aim of this work was to study ecotechnology for the management of degraded areas originally covered by the Atlantic Rainforest and located at the coordinates 25º31'50''S, 9º09'30''W. The area included 12 islands, each consisting of six jute bags with 20 kg of substrate (cattle manure and soil transposed from forest fragments). In six of these bags, native plants and seeds were also included. Six additional islands were selected randomly in the vicinity as the control. The process of evaluation was monitored through the chemical and granulometric soil analysis and surveys of survival, biometrics, floristic and phytosociological vegetation. An improvement in soil properties was observed where the model was implemented, which could be attributed to the substrate and re-vegetation. In the floristic and phytosociological studies, out of the 118 identified species, 65 were observed in the first floristic inventory and 86 in the second floristic inventory with similarities between the subfields of 27.69% and 11.36%, respectively. The influence of the substrate seed bank in the implemented islands was also observed. Increased diversity was only significant in the subareas with the model. It was concluded that this technology was effective in accelerating the succession and promoting the beginning of the restoration.

Key words: restoration ecology, environmental degradation, soil management, revegetation

INTRODUCTION

Since the beginning of the industrial and agricultural revolution, environmental degradation has exceeded the rate of ecological conservation (Cairns Jr. 1998). Hence, quite often the restoration of an ecosystem that has been degraded, damaged, altered or completely destroyed as a direct or indirect result of human activity is required (Society for Ecological Restoration International Science and Policy Working Group 2004). Ecological restoration is the process that promotes the recovery of an ecosystem (International Society for Ecological Restoration 2004; Koehler 2005) in order to promote the return of the biological communities to their original state (Jordan et al. 1998).

The development of a restoration model is a process of constant improvement and should consider the conditions of the region where it is deployed (Leite et al. 1994), the implementation of efficient soil management (Prober et al. 2005) and the restoration of species and communities (Palmer et al. 1997). The selection of the species for re-vegetation employs the criteria based on natural occurrence, required light and humidity, ability to adapt to depleted soils and nitrogen fixation, presence of extensive root system and production of edible fruits (Glufke 1999). The monitoring of biological indicators is the key to

*Author for correspondence: maranho@up.com.br

understanding the evolution of the restoration (Koehler 2005; Jacomel 2008). The analysis of floristic and dimensional structure of the vegetation indicates whether restoration is occurring or not (Araujo et al. 2008; Sávio and Maranho 2008).

The model implemented and evaluated in this study was based on the environmental technology developed by Kesel, Koehler & Associates (KEKO), called Revitec®. This model has already been used by these authors in the regions such as Namibia (Koehler et al. 2006a) and Spain (Koehler et al. 2004, 2006b). Revitec® is described as ideal for ecological restoration of degraded areas, stabilization of areas exposed to erosion and lost soil regeneration (Koehler et al. 2004; Koehler 2005; Koehler et al. 2006a).

The basic model in this jute study was a bag made of a biodegradable cloth, filled with substrate prepared with biotic and abiotic elements (Koehler et al. 2004). The bags protected the substrate and promoted initial erosion control (Koehler et al. 2006a) until, shortly after implantation, the vegetation created erosion barriers. The bags could be arranged linearly or in fertility islands, positioned to capture water in their particles and to disseminate their portions. In the long run, the successional process is expected to propagate (Koehler et al. 2004). This model should be efficient in all aspects of restoration of degraded areas. Furthermore, the use of sustainable and low cost resources (Araujo et al. 2008) should favor its applicability in future projects. The study described herein aimed to evaluate and implement the Revitec® ecotechnology for the restoration of degraded areas, demonstrating that adjustments were deemed necessary.

MATERIALS AND METHODS

The study area, initially degraded and eroded, was located in São José dos Pinhais, Paraná, Brazil (25º31'50"S, 49º09'30"W). There were fragments of Atlantic Rainforest adjacent to this area. According to Köppen's classification, the climate was classified as Cfb: mesothermal, humid and super humid (IAPAR, 1994). The experimental modules were composed of islands approximately 1.8 m wide and 2.0 m long and were implemented using the Revitec® model (Fig. 1A). Around this area, additional, untreated, islands of the same size were also randomly selected and monitored as control. Three sample subareas were established: subarea 1, with 6 islands with implantation of vegetation, called islands with vegetation (Fig. 1B); subarea 2, with 6 islands without the implantation of vegetation, called islands without vegetation; and subarea 3, with 6 control islands. In subareas 1 and 2, each island was composed of six jute bags filled with the substrate (Fig. 1A), which was prepared with preserved cattle manure and soil collected from the Atlantic Rainforest fragments located near the experimental area at a ratio of 1:1 (v/v). Twenty kilograms of substrate were placed in each bag (Figs. 1A and 1B).

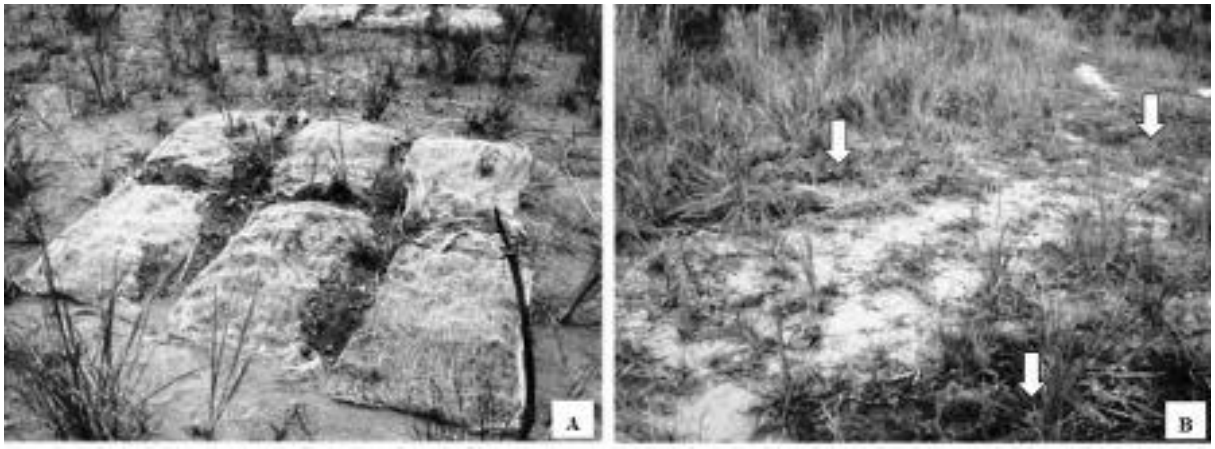

Figure 1 – The experimental modules. A) Disposition of the islands in the study area on the day of implantation. B) Island view in the 2nd month after implantation of the bags showing minimal signs of revegetation (arrows indicate boundaries).

Each island with vegetation received the bags containing the seedlings of *Mimosa scabrella* Benth. (Fabaceae) and *Sebastiania commersoniana* (Baill.) L.B.Sm. & R.J.Downs (Euphorbiaceae) provided by the Environmental Institute of Paraná (IAP). The following species, which represented the plants with pioneer ecophysiological traits collected in the surrounding areas were also sown in these islands: *Desmodium adscendens* (Sw.) DC. (Fabaceae); *Vernonia nitidula* Less., *Aspilia montevidensis* (Spreng.) Kuntze and *Bellis* sp. (Asteraceae); *Schizachyrium condensatum* Nees (Poaceae). Two months after the start of the study, *Allophylus edulis* (A. St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl. (Sapindaceae) seedlings were also planted in each island with vegetation.

Soil and substrate samples for chemical and granulometric analysis were collected at various points (arranged in a zigzag pattern) at a depth of 0-20 cm throughout the study area prior to the implementation (March 2008) and at end of the experiment (October 2008). Chemical analysis was performed by the laboratory of the Soil and Agricultural Engineering Department at the Universidade Federal do Paraná. A routine composition analysis was performed in the soil samples, including clay fraction and total nitrogen, following the method described by Pavan et al. (1992). The interpretation of the results was performed according to Lima and Sirtoli (2003). The granulometric analysis was carried out according to the Brazilian Standards (NBR) 6508 (Associação Brasileira de Normas Técnicas 1984a) and 7181 (Associação Brasileira de Normas Técnicas 1984b).

The evaluation of the survival index (SI) and biometric index (BI), defined by the height and perimeter of the plants at 15 cm from the ground, were performed monthly for the seedlings of *M. scabrella*, *S. commersoniana* and *A. edulis*. Floristic and phytosociological surveys were conducted in June and October 2008. The material was collected and herbarium specimens were prepared according to the appropriate techniques (Fidalgo and Bononi 1989). Species identification was performed based on available literature and comparison with the collection of the herbarium at the Botanical Museum in the city of Curitiba, state of Parana, Brazil. The species names and their authors were confirmed by consultation to the International Plant Names Index (IPNI).

The evaluation of the succession process was carried out through the assessment of the vegetation structure, which was estimated by the horizontal coverage of individuals of each species. The average degree of coverage for each species was determined using the scale proposed by Braun-Blanquet (1979) considering five categories: coverage between 1 and 10% (average degree of coverage of species i in plot k - gck 5%), between 10 and 25% (gck 17.5%), between 25 and 50% (gck 37.5%), between 50 and 75% (gck 62.5%), and between 75 and 100% (gck 87.5%). Estimates of the following phytosociological parameters were determined: absolute frequency (AF = 100. pi/TP), relative frequency (RF = 100. AF/ΣAF); area of the species (AC = Σgck.ap/100); margin of species in the plot (CV = 100. CA/TA) and margin on the species (RC = 100. CA/ΣCA). Where: pi = number of plots with the presence of species i; TP = total number of plots; ap = area of the plot; TA = total area sampled. The similarity index of Jaccard (Pielou 1975) was employed to estimate the similarity between the subareas. The species diversity was evaluated using the Shannon index (H') (Magurran 1989). The Anderson-Darling test was used to assess the normality of the data and Student's t-test was employed to determine whether the diversity of the subareas was significant, with a significance level of 0.05. Statistical analysis was performed using Statistica for Windows® (Statsoft 2002).

RESULTS AND DISCUSSION

It was possible to observe the emergence of seedlings in all the islands in the first visit, one month after the implementation of the study. Germination and colonization of the plants were observed throughout the duration of the study. The highest index of survival of the planted seedlings was observed in *S. commersoniana* (100%), followed by *A. edulis* (83.34%) and *M. scabrella* (16.67%). From June to August 2008, the seedlings of the three implemented species underwent growth (Table 1). This growth was more pronounced immediately after the implantation in June and October. The species of the implemented seeds were suitable for the recovery of degraded areas (Lorenzi 1998; Glufke 1999; Reis and Kageyama 2003) in the locations with unique coverage such as the Atlantic Rainforest, especially on the wet and marshy soils,

as observed by Lorenzi (1998). Observed variations in the survival index and growth rate among species were probably due to climatic conditions and characteristics of deciduous and semi-deciduous species (Lorenzi 1998).

Even during the heaviest rainfalls, the islands remained stable and maintained the vegetation. The jute bags, soil from forest fragments, manure, and re-vegetation were essential factors for soil stabilization and erosion control, providing the re-establishment of pioneer species. The ease of applicability of this environmental technology and its ability to adapt to each area and biome characteristics was observed by the use of low cost jute bags and soil and seeds collected in the area's own surroundings.

The jute bags as well as the soil transposed from the forest fragments, preserved cattle manure and re-vegetation were essential factors for soil stabilization and containment of erosion, allowing the restoration of pioneer species, and therefore, the acceleration of ecological succession. Other experiments using the Revitec® model highlighted the importance of these aspects in the context of restoration (Kesel et al. 1999; Koehler et al. 2004; Koehler 2005; Jacomel and Maranho 2005; Koehler et al. 2006a; 2006b; Jacomel 2008).

Table 1 – Height and perimeter of the seedlings of species implanted during 2008, the latter measured at 15 cm from the ground level.

Species	**Parameters**	**Evaluations**			
Ratings (average in cm)		**April/08**	**May/08**	**June/08**	**October/08**
Mimosa scabrella Benth.	Height	30.00	35.00	38.00	75.00
	Perimeter	1.10	1.00	1.20	2.40
Sebastiania commersoniana	Height	35.50	36.50	37.75	40.00
	Perimeter	1.00	1.00	1.17	1.12
Allophylus edulis	Height	-	31.20	28.80	29.20
	Perimeter	-	0.98	1.24	1.06

The presence of the model in the islands and the arrangement of the bags proved to be suitable for the study area, although other authors (Koehler et al. 2004; 2006a) suggested that the bags could be accommodated in different ways such as in a linear or circular fashion. Reis et al. (2007) found that the arrangement of the islands allowed the formation of a center of diversity and the occurrence of natural regeneration in the rest of the area following the characteristic succession stages.

During the study, 118 species were grown in the three subareas. In the first floristic survey conducted in June 2008, there were 65 species, 50 of which belonged to 42 genera, distributed in 16 families, and 15 were not identified (Table 2). The Asteraceae family presented the most representative flora with 20 species, about 31% of the total, followed by Poaceae (8), Fabaceae (4) and Solanaceae (3). In subarea 1, the most representative species was *Bulbostylis capillaris* (L.) Kunth ex C.B.Clarke with a coverage of 22.86%. This species also had the greatest coverage in subarea 2 (23.53%). In subarea 3, the most representative species were *S. angustifolium* Reinw. ex de Vriese and Poaceae 1, with coverage of 11.54% each.

On the second survey, in October 2008, 86 species were found, 70 of which belonged to 55 genera distributed in 18 families, and 16 were not identified (Table 2). The Asteraceae was dominant then, with 21 species, accounting for 24.42% of the total, followed by Poaceae (8), Fabaceae (7) and Rubiaceae (4). In subarea 1, the most representative species were *B. capillaris* (L.) Kunth ex C.B.Clarke and *B. decurrens* (Vell.) Stellf. with coverage of 26.19% each. The widest coverage in subarea 2, with 19.9%, was also by the species *B. capillaris* (L.) Kunth ex C.B.Clarke. In subarea 3, *S. angustifolium* Reinw. ex de Vriese was the most representative species, with a coverage of 57.89%.

The floristic and phytosociological surveys were essential for the analysis of species diversity in each area and also to assess the potential of the environmental technology used in accelerating the succession process. Many authors emphasize the importance of these surveys for the restoration of degraded areas (Moore et al. 1970; Wikum and Shanholtz 1978; Lamb 1998).

Table 2 - Floristic composition and phytosociological structure in the three subareas (subarea 1, with implantation of vegetation; subarea 2, without implantation of vegetation; and subarea 3, control) during 2008. RC: relative coverage; AC: average coverage.

Species	Subarea 1				Subarea 2				Subarea 3			
	June		October		June		October		June		October	
	RC	AC	RC	AC	RC	AC	RC	AC	RC	AC	RC	AC
Achyrocline satureioides (Lam.) DC.	0.00	0.00	-	-	0.00	0.00	0.00	0.00	-	-	0.00	0.00
Aeschynomene falcata (Poir.) DC.	-	-	-	-	-	-	-	-	-	-	0.00	0.00
Allophylus edulis (A. St.-Hil., A. Juss. & Cambess.) Hieron. ex Niederl.	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	-
Andropogon leucostachyus Kunth	-	-	4.76	5.00	-	-	-	-	-	-	0.00	0.00
Aspilia montevidensis (Spreng.) Kuntze	0.00	0.00	0.00	0.00	-	-	3.51	5.00	0.00	0.00	10.53	5.00
Axonopus compressus (Sw.) P. Beauv.	0.00	0.00	0.00	0.00	0.00	0.00	3.51	5.00	0.00	0.00	-	-
Baccharis vulneraria Baker	0.00	5.00	-	-	19.61	17.50	-	-	-	-	-	-
Baccharis axillaris DC.	-	-	-	-	-	-	-	-	0.00	0.00	-	-
Baccharis caprariifolia DC.	-	-	-	-	-	-	0.00	0.00	-	-	0.00	0.00
Baccharis dracunculifolia DC.	0.00	0.00	0.00	0.00	-	-	0.00	0.00	-	-	-	-
Baccharis erioclada DC.	-	-	-	0.69	-	-	-	-	0.00	0.00	0.00	0.00
Baccharis megapotamica Spreng.	-	-	4.76	5.00	-	-	-	-	-	-	-	-
Baccharis pauciflosculosa DC.	0.00	0.00	-	-	-	-	-	-	-	-	-	-
Baccharis schultzii Baker	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Baccharis semiserrata DC.	-	-	-	-	-	-	0.00	0.00	-	-	-	-
Baccharis spicata Hieron.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Baccharis trimera (Less.) DC.	0.00	0.00	0.00	0.00	0.00	0.00	7.02	5.00	0.00	0.00	0.00	5.00
Baccharis uncinella DC.	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	-
Baccharis decurrens (Vell.) Stellf.	17.14	17.50	26.19	37.50	0.00	5.00	10.53	5.00	0.00	0.00	10.53	5.00
Bulbostylis capillaris (L.) Kunth ex C.B.Clarke	22.86	17.50	26.19	17.50	23.53	17.50	19.30	17.50	3.85	5.00	10.53	5.00
Calamagrostis viridiflavescens Steud.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Campovassouria cruciata (Vell.) R.M.King & H.Rob.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Chromolaena ascendens (Sch.Bip. ex Baker) R.M.King & H.Rob.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Commelinaceae 1*	0.00	5.00	0.00	0.00	0.00	5.00	0.00	0.00	-	-	0.00	0.00
Conyza bonariensis (L.) Cronquist	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
Coronopus didymus (L.) Sm.	0.00	0.00	-	-	0.00	0.00	-	-	-	-	-	-
Crotalaria hilariana Benth.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Croton pallidus Müll.Arg..	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-
Cyperus surinamensis Rottb.	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-
Desmodium sp.	0.00	0.00	4.76	5.00	0.00	5.00	3.51	5.00	0.00	0.00	0.00	0.00
Dichondra microcalyx (Hallier f.) Fabris	0.00	0.00	-	-	0.00	0.00	-	-	-	-	-	-
Disynaphia ligulifolia (Hook. & Arn.) R.M. King & H. Rob.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00
Eragrostis ciliaris Kunth	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-
Eriosema crinitum Benth.	-	-	0.00	0.00	-	-	-	-	-	-	0.00	0.00
Erythroxylum deciduum A.St.-Hil.	-	-	-	-	-	-	-	-	-	-	0.00	0.00
Fabaceae 1*	-	-	0.00	5.00	-	-	-	-	0.00	0.00	-	-
Fabaceae 2*	-	-	-	-	-	-	-	-	-	-	0.00	0.00
Facelis retusa (Lam.) Sch.Bip.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Fimbristylis autumnalis (Willd.) Roem. & Schult.	0.00	0.00	-	-	-	-	-	-	-	-	-	-

(Cont. ...)

(Cont. Table 2)

Species	Subarea 1				Subarea 2				Subarea 3			
	June		October		June		October		June		October	
	RC	AC	RC	AC	RC	AC	RC	AC	RC	AC	RC	AC
Galium hypocarpium (L.) Fosberg	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-
Gnaphalium purpureum L.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	-	-
Gnaphalium spicatum Lam.	0.00	0.00	-	-	-	-	-	-	-	-	-	-
Hybanthus parviflorus (L.f.) Baill.	-	-	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-
Hypochaeris brasiliensis (Less.) Benth. & Hook.f. ex Griseb.	0.00	0.00	-	-	0.00	0.00	-	-	0.00	0.00	-	-
Hypochaeris radicata L.	-	-	-	-	-	-	0.00	0.00	-	-	0.00	0.00
Ipomoea indivisa Hallier f.	5.71	5.00	-	-	11.76	5.00	-	-	-	-	0.00	0.00
Juncus micranthus Desv.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-
Juncus microcephalus Kunth	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Lactuca scariola L.	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-
Lolium multiflorum Lam.	5.71	5.00	4.76	5.00	0.00	5.00	7.02	5.00	0.00	0.00	-	-
Lycopodiella caroliniana (L.) Pic.Serm.	-	-	-	-	-	-	-	-	0.00	0.00	-	-
Mikania micrantha Kunth	-	-	0.00	5.00	-	-	7.02	5.00	-	-	-	-
Mimosa daleoides Benth.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Mimosa scabrella Benth.	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	-
Mitracarpus hirtus (Sw.) DC.	-	-	-	-	-	-	0.00	0.00	-	-	-	-
Noticastrum calvatum (Baker) Cuatrec.	0.00	0.00	-	-	0.00	0.00	-	-	0.00	0.00	-	-
Panicum helobium Mez ex Henrard	-	-	4.76	5.00	-	-	10.53	5.00	-	-	0.00	0.00
Panicum repens L.	0.00	0.00	0.00	0.00	-	-	-	-	-	-	0.00	0.00
Panicum sp.1*	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-
Panicum sp.2*	0.00	0.00	-	-	0.00	0.00	-	-	11.54	5.00	-	-
Paspalum urvillei Steud.	0.00	0.00	4.76	5.00	0.00	0.00	0.00	5.00	0.00	0.00	-	-
Paronychia camphorosmoides Cambess.	-	-	0.00	0.00	0.00	0.00	3.51	5.00	-	-	-	-
Paronychia communis Cambess.	-	-	-	-	0.00	0.00	-	-	-	-	-	-
Petunia regnellii R.E.Fr.	0.00	5.00	-	-	0.00	5.00	-	-	-	-	-	-
Petunia sp.*	-	-	4.76	5.00	-	-	7.02	5.00	-	-	-	-
Plantago guilleminiana Decne.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Polygala pulchella A.St.-Hil.	-	-	0.00	0.00	-	-	-	-	-	-	0.00	0.00
Polygonum aviculare L.	-	-	0.00	0.00	-	-	0.00	5.00	-	-	-	-
Richardia brasiliensis Gomes	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Richardia humistrata Steud.	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Saccharum angustifolium Rein w. ex de Vriese	0.00	5.00	9.52	5.00	0.00	5.00	3.51	5.00	11.54	5.00	57.89	17.50
Schizachyrium condensatum Nees	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.85	5.00	10.53	5.00
Sebastiania commersoniana (Baill.) L.B.Sm. & R.J.Downs	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	-
Senecio brasiliensis Less.	0.00	0.00	0.00	0.00	-	-	-	-	-	-	-	-
Sisyrinchium micranthum Cav.	-	-	0.00	0.00	-	-	0.00	0.00	-	-	0.00	0.00
Sisyrinchium vaginatum Spreng.	-	-	0.00	0.00	-	-	3.51	5.00	-	-	-	-
Solanum americanum Mill.	-	-	-	-	0.00	0.00	0.00	0.00	-	-	-	-
Solanum sisymbriifolium Lam.	-	-	-	-	0.00	0.00	0.00	5.00	-	-	-	-
Solidago chilensis Meyen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sonchus asper (L.) Hill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	-	-	-
Sonchus oleraceus L.	0.00	0.00	-	-	0.00	0.00	-	-	-	-	0.00	0.00
sp. 1*	5.71	5.00	0.00	0.00	0.00	0.00	-	-	-	-	-	-
sp. 2*	-	-	-	-	-	-	-	-	0.00	0.00	-	-
sp. 3*	0.00	0.00	-	-	0.00	0.00	-	-	-	-	-	-
sp. 4*	-	-	-	-	0.00	0.00	-	-	-	-	-	-
sp. 5*	-	-	-	-	0.00	0.00	-	-	-	-	-	-
sp. 6*	0.00	0.00	-	-	0.00	0.00	-	-	-	-	-	-
sp. 7*	-	-	-	-	0.00	0.00	-	-	-	-	-	-
sp. 8*	-	-	-	-	0.00	0.00	-	-	-	-	-	-

(Cont. ...)

(Cont. Table 2)

Species	Subarea 1				Subarea 2				Subarea 3			
	June		October		June		October		June		October	
	RC	AC	RC	AC	RC	AC	RC	AC	RC	AC	RC	AC
sp. 9*	0.00	0.00	-	-	-	-	-	-	-	-	-	-
sp. 10	0.00	0.00	-	-	-	-	-	-	-	-	-	-
sp. 11*	0.00	0.00	-	-	0.00	0.00	-	-	-	-	-	-
sp. 12*	-	-	-	-	0.00	0.00	-	-	-	-	-	-
sp. 13*	0.00	0.00	-	-	-	-	-	-	0.00	0.00	-	-
sp. 14*	-	-	-	-	-	-	-	-	0.00	0.00	-	-
sp. 15*	-	-	-	-	-	-	-	-	0.00	0.00	-	-
sp. 16*	-	-	4.76	5.00	-	-	10.53	5.00	-	-	-	-
sp. 17*	-	-	0.00	0.00	-	-	-	-	-	-	-	-
sp. 18*	-	-	0.00	0.00	-	-	-	-	-	-	-	-
sp. 19*	-	-	0.00	0.00	-	-	-	-	-	-	-	-
sp. 20*	-	-	0.00	0.00	-	-	-	-	-	-	-	-
sp. 21*	-	-	0.00	0.00	-	-	-	-	-	-	-	-
sp. 22*	-	-	-	-	-	-	0.00	0.00	-	-	-	-
sp. 23*	-	-	-	-	-	-	0.00	0.00	-	-	-	-
sp. 24*	-	-	-	-	-	-	0.00	0.00	-	-	-	-
sp. 25*	-	-	-	-	-	-	0.00	0.00	-	-	-	-
sp. 26*	-	-	-	-	-	-	0.00	0.00	-	-	-	-
sp. 27*	-	-	-	-	-	-	0.00	0.00	-	-	-	-
sp. 28*	-	-	-	-	-	-	0.00	0.00	-	-	-	-
Stipa sp.*	-	-	0.00	0.00	-	-	-	-	-	-	-	-
Taraxacum officinale F.H.Wigg.	0.00	0.00	-	-	-	-	-	-	-	-	-	-
Trifolium repens L.	-	-	-	-	0.00	0.00	-	-	-	-	-	-
Veronica arvensis L.	-	-	0.00	0.00					-	-	-	-
Vernonia nitidula Less.	-	-	0.00	0.00	-	-	0.00	0.00	-	-	-	-
Veronica persica Poir.	0.00	0.00	-	-	0.00	0.00	-	-	-	-	-	-
No species	37.14	37.50	0.00	-	4.72	33.33	1.85	0.00	7.59	80.70	7.32	62.50
Total	**100**	**107.5**	**100**	**147.5**	**100**	**107.5**	**100**	**120**	**100**	**107.5**	**100**	**105**

The biggest floristic representativeness of the Asteraceae and Poaceae was also observed in the studies of seed banks of the forest fragments in the state of São Paulo (Baider et al. 2001) and in the application of the Revitec® model in the degraded pastures in the state of Paraná, Brazil (Jacomel 2008). *Bulbostylis capillaris* (L.) Kunth ex C.B.Clarke was the most prevalent in the subareas where the model was implemented, possibly because of the seed bank. There was high germination of this species in the soil collected in forest fragments that was deposited near the study area. This species was identified in a floristic survey carried out in the urban area of Curitiba, PR and reported as an Atlantic Rainforest native (Biondi and Pedrosa-Macedo 2008). According to Viani and Rodrigues (2009) and Mackenzie and Naeth (2010), salvaged soils could harbor appropriate plant species to develop diverse ecosystems. Baider et al. (2001), Reis et al. (2007) and Schorn et al. (2010) reported that the seed bank allowed recolonization with the seeds and other propagules of pioneer plant species.

Rodrigues et al. (2010) observed that the use of seed banks transposition in forest restoration projects demonstrated to be a viable alternative to stimulate forest succession in degraded areas. However, Baider et al. (2001) suggested that the seed bank alone was not sufficient for restoration, indicating that it was necessary that the seeds were derived from other sources, since frequently the bank did not store in the soil seeds of medium and large woody species, which were tolerant to the shade. In this context, the importance of planting seeds and seedlings of species characteristic of the surrounding forest fragments was evident.

The Shannon index (H') revealed that the highest species diversity was observed in October/2008 in Subarea 1 (1.76 nats/ind.) and Subarea 2 (1.66 nats/ind.). In the control area (Subarea 3), the Shannon index (H') was 1.37 nats/ind. in October/2008. A higher diversity of species was observed in the area where the model was implemented with vegetation (Fig. 2). Significant differences were observed in the Shannon indices (H') for the subareas 1 and 2 between the first (June 2008) and the second assessment (Oct. 2008).

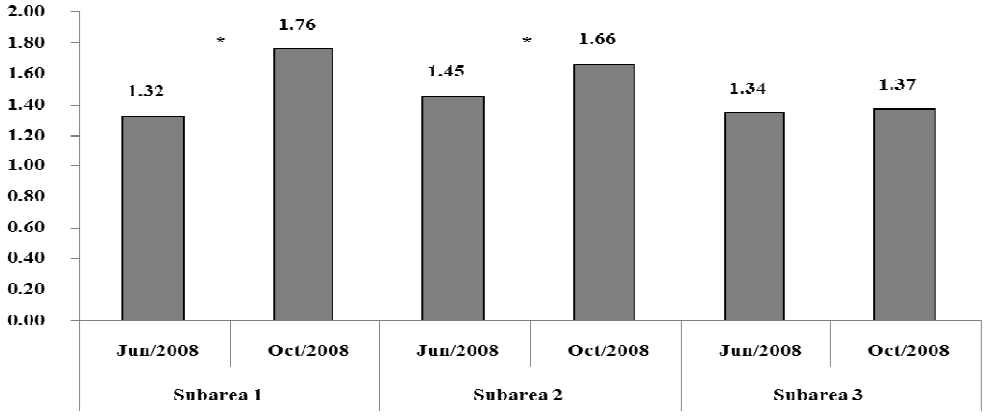

Figure 2 - Shannon index of diversity in the three studied subareas; * $p<0.05$ denotes significant difference at 5% between Jun/2008 and Oct/2008.

Comparison of the physical and chemical properties of the soil before and after the implementation of the restoration model and between subareas showed improvement of chemical and textural properties. The chemical nature of the soil and substrate (SB) (Table 3) was altered with the implementation of the model. The pH tended to increase in the subareas where the model was implemented, particularly with vegetation. The same was observed for saturation (V%), amount of phosphorus and organic C.

Table 3 - Composition of substrate, degraded soil and soil from three subareas (subarea 1, with implantation of vegetation; subarea 2, without implantation of vegetation; and subarea 3, control).

	pH	**Al^{3+}**	**$H^{+}+Al^{+3}$**	**Ca^{2+}**	**Mg^{2+}**	**K+**	**T**	**P**	**C**	**m**	**Clay**	**N total**
Soil*	$CaCl_2$			cmolc.dm^{-3}				mg.dm^{-3}	g.dm^{-3}	%	g.kg^{-1}	g.kg^{-1}
SB	4.20	5.90	16.30	13.00	4.50	0.40	34.20	10.10	7.50	25.00	400.00	2.00
DS	VL	H	-	VH	VH	H	VH	H	B	-	-	-
A1	5.40	0.00	4.60	4.60	3.10	1.11	18.51	262.50	52.20	0.00	475.00	3.50
	L	VL	-	H	VH	VH	VH	VH	VH	-	-	-
A2	4.70	0.70	7.20	7.20	2.60	2.60	19.05	175.00	34.70	6.00	475.00	3.30
	VL	M	-	VH	VH	VH	VH	VH	VH	-	-	-
A3	4.20	3.80	12.10	12.10	3.30	3.30	30.83	10.40	12.40	17.00	425.00	1.30
	VL	H	-	VH	VH	VH	VH	H	M	-	-	-

*SB = substrate; DS = degraded soil; A1 = soil subarea 1; A2 = soil subarea 2; A3 = soil subarea 3. Data interpreted according to Lima and Sirtoli (2003). Where: VL = very low; L = low; M = medium; H = high; VH = very high.

The soil pH, which varied between 5.0 and 7.0 in the study area where the vegetation was implemented, provided a higher range of phosphorus availability (P) for the plants. The pH values observed in the same area prior to the deployment (DS) made this compound remain insoluble (Raij 1991). Moreover, at such low pH values, most of the aluminum was soluble and could cause extreme nutrient deficiency or toxicity to the plants (Delhaize and Ryan 1995; Kochian 1995). The aluminum excess in the soil prevents the development of the root system (Ryan et al. 1993; Delhaize and Ryan 1995; Kochian 1995), resulting in decreased absorption of water and nutrients. A high content of aluminum (m%) and ion exchange capacity (T) were observed in the DS and A3. The highest content of total N was observed in the substrate, followed by A1 and A2. The proportion of clay increased after implantation, being similar in A1 and A2.

Table 4 shows the granulometry results, with the highest percentages of fine sand, silt and clay (material passing the 2.00 mm sieve) observed in the substrate and in the soil where the model was applied. While in subarea 3, the amount of material passing the 0.075 mm sieve was 26.51%,

this value reached 65.41% for the substrate and 51.09% for the soil from subarea 2. The highest percentage of medium sand (0.25-0.5 mm) was also observed in SB, A1 and A2. The soil collected before the implementation (degraded soil – DS) showed 11.68% for the equivalent parameter (material passing the 0.075 mm sieve), while the substrate and soil A1 had values above 21%. The largest proportion of coarse sand and gravel (0.5-2.0 mm) was observed in soil A3.

The application of preserved cattle manure contributed to the improvement of the soil´s chemical conditions and the results corroborated the studies that evaluated the aspects of fertilization (Ceretta et al. 2003; Favaretto et al. 2003). Experiments with the use of cattle manure showed changes in the levels of C, Mg, K and P (Favaretto et al. 2003).

Table 4 - Granulometric composition of the degraded soil and soil from three subareas (subarea 1, with implantation of vegetation; subarea 2, without implantation of vegetation; and subarea 3, control).

Screening	Sieve (mm)	Nº	Passing mass (%)					Accumulated Mass (%)				
			DS	SB	A1	A2	A3	DS	SB	A1	A2	A3
THICK (76 mm > ∅ > 2.0 mm	4.800	4	0.89	1.92	1.84	1.14	4.96	99.11	98.08	98.16	98.86	95.04
	2.000	10	2.37	3.95	4.88	3.42	7.34	97.63	96.05	95.12	96.58	92.66
	1.200	16	3.79	4.82	5.47	5.62	5.70	96.21	95.18	94.53	94.38	94.30
	0.600	30	8.61	14.17	16.17	14.50	11.98	91.39	85.83	83.83	85.50	88.02
THICK (2.0 mm > ∅ > 0.075 mm	0.420	40	11.68	21.41	21.17	18.42	14.24	88.32	78.59	78.83	81.58	85.76
	0.250	60	17.44	37.43	36.94	35.15	20.04	82.56	62.57	63.06	64.85	79.96
	0.150	100	22.72	52.27	49.10	49.19	25.54	77.28	47.73	50.90	50.81	74.46
	0.075	200	29.33	65.41	50.41	51.09	26.51	70.67	34.59	49.59	48.91	73.49

*Percentages of dry mass. DS = degraded soil; SB = substrate; A1 = soil subarea 1; A2 = soil subarea 2; A3 = soil subarea 3.

Studies on the application of swine manure showed an increase in organic C, total N, P, Mg and Ca and a decrease of Al and K (Ceretta et al. 2003). Another important factor in the edaphic changes was the re-vegetation since the soil in the area where the vegetation was implemented revealed better conditions than the soil of the area with only the substrate and jute bags. Studies using the Revitec® model also showed improvement of the soil´s chemical properties due to re-vegetation and the use of substrate consisting of preserved cattle manure (Jacomel and Maranho 2005; Jacomel 2008).

CONCLUSION

The Revitec® model has a low cost of implementation and promoted the containment of erosion, stabilization of soil, and increased availability of nutrients in the soil. Floristic analysis showed that the restoration attained its purpose of accelerating the succession process. The use of native species selected in the vicinity of the study area, as well as the implementation of soil obtained from nearby forest fragments, would allow the adaptation of this technology to any biome. The application of the model could be recommended in restoration projects since it demonstrated to be sustainable and efficient.

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Received: November 09, 2012;
Accepted: December 23, 2013.