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Atlantic Forest restoration in the buffer area of Iguazú National Park (Misiones, Argentina)

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Summary

The Atlantic Forest is one of the most biologically diverse as well as enormously endangered rainforests on Earth. Recovering forest cover will be one of the greatest challenges to ensure biodiversity conservation and the maintenance of ecological services in this forest. High human activity has caused only 7% of the original forest-cover to remain as a highly fragmented landscape. This ecoregion has the largest remaining forest blocks, still containing top predators such as harpy eagles and jaguars. An ecoregional planning process (biodiversity vision) developed by WWF indicates that protecting and ensuring connectivity between the larger forest remnants will enable rural communities to conserve biodiversity and ensure ecological services. Nowadays, these fragments are not effectively connected yet.

Misiones Province, in Argentina, has the largest forest remnants, covering water courses and river basin heads. Many of these remnants are found in protected areas — Iguazu National Park and the Urugua-í and Foerster provincial parks — however connectivity between them is far being achieved yet. The challenge for this area is to stop deforestation and forest degradation, and to increase connectivity between forest remnants while improving the living standard of local people, thus providing them with new sustainable economic alternatives.

The purpose of this project is to: a) evaluate the ecological and economic efficiency of different forest restoration techniques, b) develop a model of recovery of the forest productivity based on the sustainable use of palmito (*Euterpe edulis*) and the yerba mate (*Ilex paraguariensis*). These native species represent an important economic resource for local people, and through the implementation of objectives 1 and 2, they are the chance c) to restore surface areas of forests in a key sector for conservation, contributing to re-establish the connectivity between patches, d) to adjust a monitoring method that may be applied in great restored areas in the region, and will be needed when implementing landscape scale restoration.

The development of this project began at the end of 2001. During the first five years, a tree nursery was built and restoration-rehabilitation experiments were set up in the buffer area of the Iguazú National Park (province of Misiones, Argentina). These experiments have generated extensive data on native tree regeneration dynamics (saplings mortality rates in plantations, grass effect, species growth rate and biomass production, etc).

During 2006 we developed research activities and training sessions for local people. We monitored previously installed trials and analysed the results obtained up to then, which allowed for the assessment and adjustment of the various on-going models. This year we started working on a monitoring methodology for larger scale restorations, combining field information with that obtained from satellite images. We need to find out biomass production and its spatial distribution, therefore,

secondary forests with different abandonment ages (chronosequences) are sampled. We evaluate the relationship between the response from remote sensing data versus biomass values of primary and secondary succession forests.

We have continued developing small scale training activities with groups of local inhabitants and students, teaching them different activities involved in forest restoration and rehabilitation. We have also published the technical and scientific data generated up to now through different channels (governmental institutions, workshops, scientific meetings and books). Both training people in different social roles as well as advertising it are necessary strategies for people to appropriate the information generated and to apply it in their plots of lands or farms thus advancing the restoration process.

On the other hand, we have began working on a project together with a cooperative of yerba-mate small producers who are interested in applying in their farms the production-restoration models assessed in previous years. We have carried out a series of meetings and workshops with this producers' group to discuss various aspects regarding forest and farmland general management. We have now set some objectives and tasks to be developed in the following months.

In the next stage of the project, it is our purpose to combine the results of their previous (and of further) research with activities aimed at training larger groups of local producers and technicians in the restoration process and the recovery of forest productivity. Thus we expect to achieve the required local capacity to increase the scale of such processes as forest restoration and rehabilitation, therefore contributing to their conservation.

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1. Introduction

Recovering forest cover has become one of the greatest challenges to ensure biodiversity conservation and the maintenance of ecological services in the Atlantic Forest. This is one of the most biologically diverse as well as greatly endangered rainforests on Earth. High human activity has caused only 7% of the original forest-cover to remain in a highly fragmented landscape (Holz y Placci, 2003). The south-western portion of the Atlantic Forest constitutes the Upper Parana Atlantic Forest ecoregion extending along south-west Brazil to eastern Paraguay and the Misiones Province in north-east Argentina (Figures 1 and 2). This ecoregion has the largest remaining forest blocks, still containing top predators such as harpy eagles and jaguars.

An ecoregional planning process (biodiversity vision) developed by WWF indicates that protecting and ensuring connectivity among the larger forest remnants will enable the conservation of biodiversity and the ecological services to rural communities (DiBitetti et al., 2003). But today, these fragments are not effectively connected yet.

The north of Misiones is critical for maintaining the connectivity of forest cover among four key parks, Iguaçu National Park in Brazil, Iguazu National Park in Argentina (both Heritage Sites protecting the world famous Iguazu Falls), and the Urugua-í and Foerster Provincial parks in Argentina.

The challenge for this area is to stop deforestation and forest degradation, and to increase connectivity between forest remnants while improving the living standard of local people, thus providing them with new sustainable economic alternatives.

The implementation of forest landscape restoration will require an adequate legal and political framework and also the development of inexpensive methods for forest restoration as well as viable forest-friendly economic activities and benefits that make restoration and conservation more attractive to landowners.

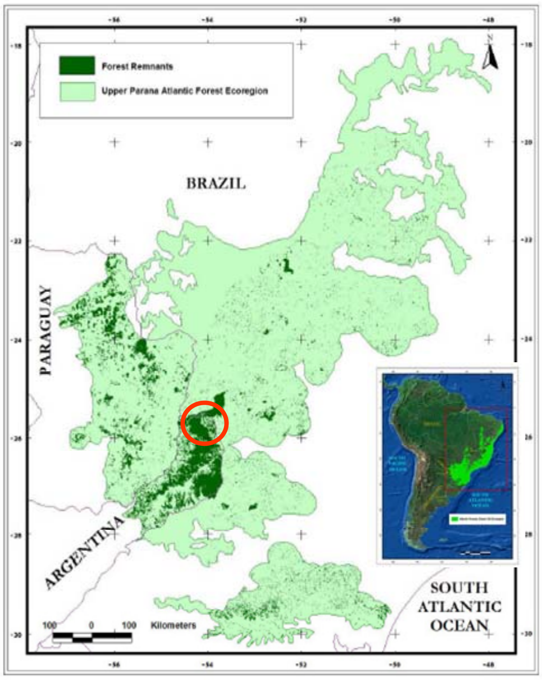

Figure 1. Original cover of Upper Paraná Atlantic Forest, current remnants and study area.

1.1. Relevance of this study for the conservation of protected areas of the Ecoregion

The information on natural regeneration and the development of cheaper and more environmentally efficient restoration technique could be used for:

- ***Forest restoration*****:** In the Andresito area, it is necessary to create biological corridors to favour the interconnection among large forest patches. The information provided by this study will answer such questions as: **a-** How do different factors influence on forest regeneration?, **b-** Which are the most appropriate groups of species to be used in restoration?, **c-** Which is the growth speed of each species and its response to different factors?, **d-** Is it necessary to eliminate grass and carry out soil compaction to plant native trees in the area to be restored? Or, in similar situations, is the influence of grasses not so important as to invest in their removal?, **e-** According to the history of use of the area to be restored, which is the most adequate restoration strategy to be used?, etc.

- ***Management of secondary forests:*** When forests are generated with productive purposes (in this case, plantations of native trees), is it truly important to know the time the system takes to reach a determined structure and wood production (standing biomass) and the growth rhythm for the different species. The information on such aspects provided by this project could be used: **a)** to design afforestation plans with native species, to commercialize wood (exotic species are currently planted in the province of Misiones) and for firewood, a resource that is getting scarcer in the study area, b**)** to manage and preserve secondary forests.

2. Objectives

The purpose of this project is to:
a- evaluate the ecological and economic efficiency of different forest restoration techniques.
b- develop a recovery model of forest productivity based on the sustainable use of palmito (*Euterpe edulis*) and the yerba mate (*Ilex paraguariensis*). These native species represent an important economic resource for local people.
c- through the implementation of objectives 1 and 2, to restore surface areas of forests in a key sector for conservation, contributing to re-establish the connectivity among patches.
d- adjust a monitoring method that may be applied in great restored areas in the region, which will be needed when implementing landscape scale restoration.

The specific objectives are: 1) To analyze the capacity of different native tree species to be used in restoration works, 2) To train local people to work in different activities involved in forest restoration and rehabilitation.

Once different restoration methodologies have been tested and adjusted, these will be available to be applied in larger areas.

3. Team

The researchers involved in this proposal have worked in the region on a variety of projects dealing with the dynamics of subtropical forests and their sustainable use.

- *Silvia Holz* - She is a Post-doctoral researcher at Buenos Aires University; widely experienced in fieldwork ecology and the conservation of subtropical forests. She has developed and cooperated on research projects dealing with the dynamics of forest regeneration and restoration in Argentina and Mexico. She has taught at secondary schools, colleges and universities. Her present interest lies with understanding the regional and local dynamics of forests affected by different uses of the soil in

Misiones, with a view to submitting criteria on their sustainable conservation, restoration and use in rural economy regions.

- *Verónica Guerrero Borges*- An Assistant Professor at the University of La Plata (province of Buenos Aires). She is currently studying for her MSc degree at the University of La Plata. She has been working on Landscape Ecology in the north of the province of Misiones for the last five years. In her MSc thesis she is developing a design of forest landscape for Andresito using a multicriteria-model.

- *Verónica Scalerandi*- She is an agronomic engineer and has specialized in rural development. She is currently studying for her MSc degree at the University of Misiones. Her Thesis deals with different social aspects of rural communities in Misiones. She has worked in the Province of Misiones for four years, and has participated in various rural development projects.

- *Anahi Flenck.* She is currently studying for her Biology degree at the University of Misiones. She has collaborated in different research projects in Misiones. She has worked in various research studies in Misiones and other provinces, and has done extensive general fieldwork. In the last years she has intensely collaborated with the field work and general organization of this project.

- *Bernardo Holzman*. He is currently studying for his Biology degree at the University of Misiones. He is a park ranger and has worked in several protected areas of the province. He has worked in various research studies in Misiones and other provinces, and is widely experienced in general fieldwork. In the last years he has intensely collaborated with this project.

4. Study area

The areas where the project is developed, Andresito and Eldorado (Figure 2), are located in the north of the province of Misiones (Argentina) and have been identified as a key area for conservation. Fieldwork was carried out in local farms belonging to different families of producers, whose authorization allowed us to use their land for experimental trials.

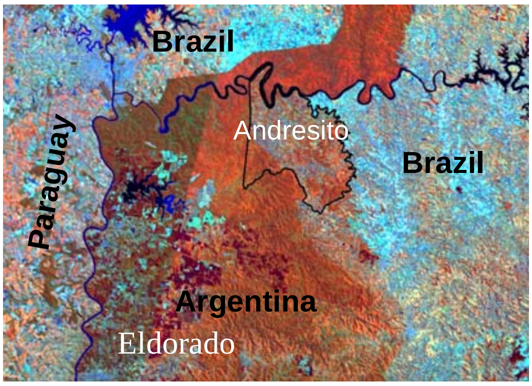

Figure 2. Satellite image of study area

5. Summary of completed activities and results (2002- 2005)

Below there is a summary description of the activities carried out in previous years and their results. A detailed report on them may be found in the Final Technical Reports RSG - 2003 and 2005.

5.1. Activities

5.1.1. Construction of a tree nursery

A tree nursery for the production native species saplings used in restoration treatments was built in a farm located in the bottleneck area of the Iguazú National Park.

5.1.2. Setting up of restoration treatments

The areas formerly covered by forests, deforested and used for different types of activities (grazing, agriculture, wood extraction, etc.) are again invaded by forests if these activities are abandoned. However, in areas where the system is significantly degraded, the recovery process may be extremely slow or inhibited (Aide et al., 1995). The key question for the people who work in forest restoration is how to "accelerate" this process.

There are different tools to stimulate regeneration (Holz y Placci, 2005). The elimination of "barriers" and the use of "facilitating species" for regeneration is a potential tool to use in field recovery (Ferretti, 2003). As forest recovery accelerates, an increase in the productive capacity of these sites will result in an economic benefit to their owners (since this shortens the time to start using the field for the extraction of palm hearts, firewood, or wood).

In farming systems, the presence of pastures, soil compaction, herbivores and the lack of seed dispersion have been identified as the more important barriers for tree establishment (Guevara et al., 1986; Purata, 1986; Holl, 1999; Peterson and Haines, 2000; Zimmerman et al., 2000). On the other hand, certain factors as it may be the presence of fauna attracting sources, which favour the establishment of seed dispersing animals, facilitate sapling establishment (Peterson and Haines, 2000; Slocum, 2000; Wunderle, 1998; Holl, 2002). Restoration treatments are based on manipulation of factors which ease or impair the regeneration of native tree species. The manipulation of these factors will allow to accelerate the process of natural regeneration of the system and the growth of transplanted saplings.

Although restoration began years ago in the ecoregion (Kageyama y Gándara, 2000), there are still many questions to be answered regarding some factors and processes involved in restoration and rehabilitation of forests. Treatments of "yerba mate" monocultures ("yerbales"), cattle-raising lands and degraded forests have been carried out to obtain information on the factors and processes which influence restoration and rehabilitation of the forest. Up to now, experimental trials have been carried out in three types of systems:

1) Abandoned grazing lands.
2) Forest edges invaded by native invasive species (bamboos and other species).
3) "Yerba mate" plantations.

5.1.2.1. Restoration of forests in abandoned grazing lands (Since 2002)

We are testing restoration designs in which we have eliminated "barriers" for regeneration (compaction and pastures). In the treated parcels we have planted native species saplings (Figure 3).

The **objectives** of these treatments are 1) To analyze how much forest regeneration is influenced by the presence of pastures and soil compaction and to evaluate if it is really convenient (at an economic and ecological level) to eliminate them before planting, 2) To analyze the mechanisms in which these "barriers" act to limit the system regeneration.

Figure 3. a) Sapling plantation in 2002, b) The same site three years after plantation (right) and cattle pasture (left).

5.1.2.2. Plantations of native tree species in "yerba mate" monocultures (Since 2003)

"Yerba mate" is currently cultivated as a monoculture. Formerly, this tree species formed dense patches within the jungle, which disappeared due to their overexploitation (Devoto y Rotkugel, 1936). Therefore, this is a species that can develop under the shade of other species. Since yerba mate production is one of the most important activities in the region, native tree plantations on yerba mate fields would allow:

- an increase in the profits of yerba mate fields, since yerba mate production is complemented with wood and firewood production;
- a larger native forest cover.
- the improvement of soil quality (increasing organic matter and nutrients principally)

We carried out plantations with native species plantations inside yerba mate fields, with the **objectives** of 1) evaluating native species growth and survival in these systems; 2) assessing the effect of these plantations on yerba mate production; 3) identifying and evaluating cost and benefits regarding the application of this model.

5.1.2.3. Rehabilitation of degraded forest edges

The borders of forest fragments are generally invaded by native invasive species, as "tala" (*Celtis sp),* or bamboos, which impair regeneration, stressing "the border effect", mainly tree felling. When restoration models are posed it is important to manage the borders, not only to decrease the border effect in the same patch, but also to decrease the "tala" effect on the "matrix".

Taking into account that the surface of forest edges is very important in the study area, and that edges are considered to be unproductive, clearing invading species may be an interesting method to increase profitability at the edges:

- since this improves natural regeneration (mainly palmetto regeneration, a species marketed by local farmers)
- and different crops which allow for a certain shadow percentage (such as yerba mate or pineapple) may be grown.

5.1.2.3.1.Plantations of "yerba mate" (Ilex paraguariensis) in degraded forest edges (since 2003)

Trials were settled at forest edges, where "tala" were cleared and yerba mate crops planted (Figure 4).

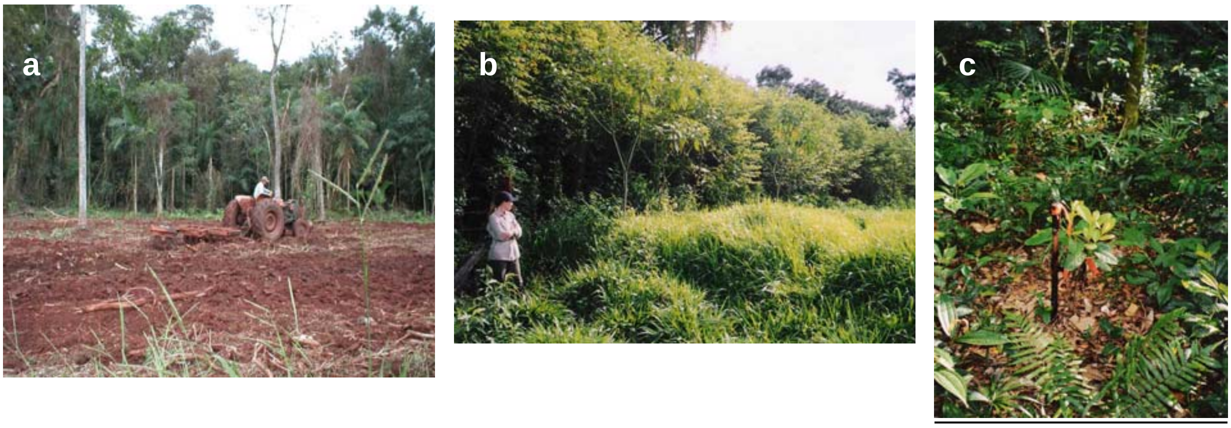

Figure 4. a) Raking forest edges where the "tala" was eliminated in 2003, b) Natural regeneration in the same edge, 1 year after treatment was carried out, c) Sapling of yerba mate growing on this edge .

The **objectives** of these treatments are 1) To evaluate the production of "yerba" in cleared edges and in sectors under forested cover, 2) To evaluate the efficiency of the "tala" elimination method, 3) To analyze natural regeneration in forest edges.

5.1.2.3.2. Rehabilitation of palm heart (Euterpe edulis) populations in degraded forests edges (Since 2004)

Trials were set up at forest edges, where bamboos were cleared (Figure 5). The **objectives** of these treatments are: 1) To evaluate the effectivity of the bamboo elimination method, 2) To analyze natural regeneration in forest edges, 3) To evaluate the need to plant palm seeds to increase density at the rehabilitated forest edges or whether natural regeneration for this species will ensure a large hearts of palms production.

Figure 5. Clearing bamboos (*Chusquea ramosissima*) in forest edges in Andresito (North of Misiones province).

*5.1.2.4. Restoration of forests in abandoned grazing land**s** (Since 2005)*

We applied restoration treatments to abandoned cattle fields in which we had initially eliminated grasses (identified as barrier for regeneration). Moreover, high densities of rapid growth pioneer species and native trees were planted (Figure 6). These species are functioning as regeneration "facilitators": as they grow quickly they produce shadow and so they decrease grass cover, facilitating, in this way, regeneration of other tree species (Holz y Placci, 2006).

Grasses were periodically eliminated through manual methods in treatments applied in 2002 to abandoned cattle fields (See 5.1.2.1). In these new treatments, grasses will be eliminated using pioneer species of rapid growth (facilitator species), which will decrease maintenance costs (manual elimination of grasses) of restored areas.

The **objectives** of these treatments are: 1) to evaluate which density of pioneer species is more efficient (at an economical and ecological level) to inhibit the development of grasses and to stimulate natural regeneration in abandoned cattle fields, 2) to evaluate if it is necessary to initially eliminate grasses when high densities of rapid growth pioneer species are planted.

Rapid growth native tree species were used, some of which are economically important for local farmers. These treatments will allow to obtain complementary information to studies already initiated in 2002.

Figure 6. Sapling plantation in abandoned cattle raising fields in Eldorado (North of Misiones province).

5.1.3. Monitoring

Two kinds of monitoring have been employed:

<u>Intensive Monitoring:</u> in each plot, growth of – planted and naturally established native species— saplings was measured (height and diameter at base: DAB) (Figure 7). Soil samples were obtained to determine moist, apparent density and nutrient content.

<u>Quick Monitoring:</u> in which we went round every treatment, taking photographs and writing down general facts on the evolution of each plot. These rounds have occurred about every couple of months and will be continued with the same regularity.

5.1.4. Data analysis

The data obtained through the monitoring was analyzed using data manning techniques, parametric and non-parametric statistical methods.

Figure 7. Monitoring of native seedlings on yerba mate plantations, a) *Maclura tinctoria* is 1.10 m tall, 1 year after it was planted, b) *Ocotea puberula* is 3 m tall, 3 years after it was planted.

5.1.5. Treatment upkeep

In treatments with grass removal, weeding was done by hand with machete in all the plot and by hoeing around each sapling (within a radius of 30 cm around each individual). Clean-ups were carried out periodically as demanded by grass growth.

5.1.6. Training of local people in different activities involved in restoration and rehabilitation of forests

Local producers of Andresito and Eldorado were trained in the production of native species saplings and plantations. Other local people, who were specially hired for this area, were trained in the installation of treatments and their monitoring.

5.1.7. Sharing information

a) The information generated by this project is reaching producers of the area by means of printed material and orally through meetings with local producers (Figure 8, a).

b) We have been participating in local workshops (organized by WWF and FVSA) to analyze conservation strategies for the region (Figura 8, b y c).

c) Part of the information generated in the first years of the project was also shared in the “World Conference on Ecological Restoration”, organized by Society for Ecological Restoration in September 2005 in Zaragoza (Spain). The trip and participation in this meeting was funded by WWF International. The following studies were presented:

√ Holz, S. and G. Placci. "Up scaling restoration in highly populated environments" (In: "*Simposium Forest Restoration in Latin America: Experiences and opportunities*").

√ Guerrero Borges, V.; Holz, S. and G. Placci. "Landscape design as a tool for strategic planning for forest landscape restoration" (In: "*Symposium WWF experiences in forest landscape restoration*").

Figure 8. a) Meeting with local producers, b y c) workshops (organized by WWF and FVSA) to analyze conservation strategies for the region.

5.2. Results

5.2.1. Survival and growth of planted saplings in abandoned cattle breeding fields

To identify groups of species with better abilities in different field situations a survival analysis of saplings was carried out, and we were able to identify groups of species that survived better to different field situations (Figure 9). Most species showed a high survival rate (between 75% and 100%) and mid survival rates (between 25 and 50 %), and a lower number of species showed low survival rates (between 25 and 50 %). Only *Euterpe edulis* showed very low survival rates (lower than 25%). Estimates on the growth of each species were also carried out during the first plantation year. According to data, the native species used in these treatments were classified into groups. This identification into species groups according to different ecological features is a useful tool in forest restoration. Species selection must be done bearing in mind not only their ecological features but also the environmental characteristics for each place and the restoration objectives.

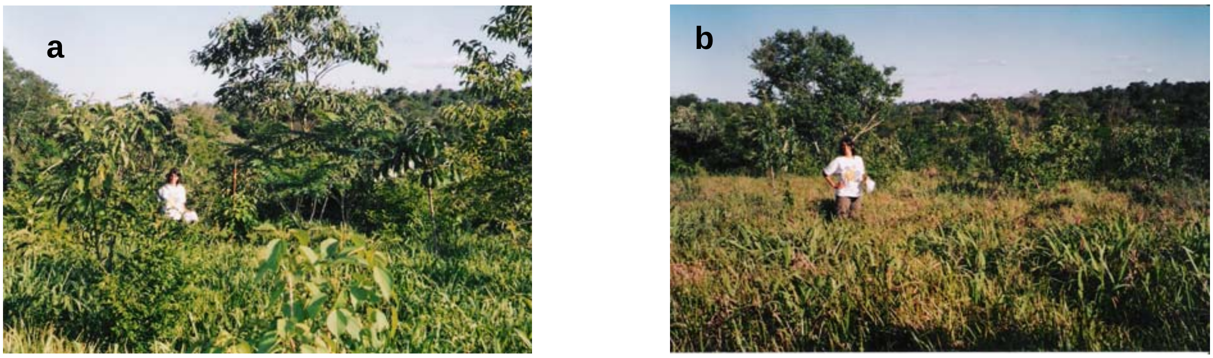

Figure 9. Plots with different treatments, 2005: a) Plot with saplings planted in 2002, b) Plot without saplings planted in 2002.

5.2.1.1. Soil characteristics

We take soil samples of each treatment and nearby forests to analyze: soil density, C, N and organic matter. The objective of these analyses was to evaluate if there are differences in these variables between treatments.

Density for soil samples in the treatments where compression was removed and in treatments with non-removal of compression was higher than for those samples obtained in nearby forests. However such differences are not statistically significant (Kruskal Wallis, H= 3.47, p= 0.17). As for soil moist, no statistically significant differences were recorded among treatments (Kruskal Wallis, H= 2.07, p= 0.4). Content of organic matter was higher in the first soil centimetres in all treatments as well as in forest samples. Values recorded for each treatment showed ample variation. No statistically significant differences were recorded for treatments (Kruskal Wallis, H= 6.75, p= 0.14). Possibly we have been unable to detect differences between treatments on any analyzed variable due to the high variation recorded between samples of a same treatment. Most probably it will be necessary to increase the number of samples so as to find differences between treatments.

5.2.2. Plantations of native tree species in "yerba mate" monocultures

Quick monitoring showed that even if there had been considerable mortality, sapling mortality had mainly occurred during yerba mate harvesting and because of weeding. In 2004 all treatments were planted anew, to make up for dead saplings thus maintaining the initial density of the treatments.
As in the grazing land plantation, saplings that were smaller in size when planted, died in larger quantities. Some saplings deemed dead during quick monitoring, later sprouted new shoots and continued growing.

5.2.3. Rehabilitation of degraded forest edges

The areas where the Tala was eliminated were speedily colonized by native trees of rapid growth (*Trema micrantha* and *Solanum verbascifolium* principally) (Figure 5,b). Recent monitoring has evidenced a great number of saplings of other species of native trees growing in these places.

Tala removal with bulldozer and rake has proved efficient, since the place was not invaded again and few tala saplings have been found. However, given the invading capacity of this species, we should wait longer to ascertain whether or not this cleaning method is efficient in the long term.

Yerba mate saplings planted during these treatments evidenced high mortality rates. This high mortality is mainly attributed to the strong drought towards the end of spring in 2003 and the summer of 2004. Surviving Yerba saplings have grown slowly and have larger and thicker leaves than those of the species in traditional open-air single crops (Figure 5, c).

The edges where lianas and bamboos were cleared have not regenerated up to date. During quick monitoring, a very important increase in natural regeneration of sapling natives trees was observed.

5.2.4. Cost analysis

Based on the tests set up, costs were worked out for the different treatments. The calculated sums correspond to the ones a local producer would have to afford if they wanted to set up these kind of plantations on their own land. Even if the weeding method used in the treatments (hand weeding by machete and hoeing around each sapling) was effective, it was also very expensive. Therefore we must keep on developing weeding techniques at lower costs (such as using quick-growing species for shadowing), a key point when it comes to restorations in these systems, mainly if we consider larger scale plantations.

Table 1. Description of the costs of setting up different treatments in Northern Misiones. *Weeding must be carried out throughout the first 2 or 3 years after planting, until saplings are higher than the grass.

Activity	Detail	Cost (US$)
a) Plantantions of natives tree species in abandoned grazing lands		
Generation of saplings (Ha/ year)	1660 stem/ Ha	334.23
Plantation cost (Ha/ year)		90.54
Weeding* (Ha/ year)		241.61
b) **Plantations of native tree species in "yerba mate" monocultures**		
Generation of saplings (Ha/ year)	400 stem/ Ha	80.54
Plantation cost (Ha/ year)		43.62
Weeding* (Ha/ year)		241.61
c) "Yerba mate" plantations in degraded forest edges		
Plantation set up (Ha/ year)	800 stem/ Ha	355.7
Weeding (Ha/ year)		479.87
d) Rehabilitation of palm heart populations in degraded forests edges		
Plantation set up (Ha/ year)		40.27
Weeding (Ha/ year)		33.56

5.2.5. Training of local people in different activities involved in restoration and rehabilitation of forests

a) Andresito producers keep growing saplings of native species for their own farms and for trade. On the other hand, through the management of local NGOs, they have agreed to selling their "yerba" production to an American company which deals in organic "yerba" generated under forest. This implies a markedly increase in their profits, since profits from the production and selling of organic "yerba" will be three times higher per ton than current earnings. From the conservational point of view, this initiative is very important since trees of native species will be planted inside the "yerba mate" monocultures, i.e., they will contribute to increase the forest surface area.

b) Producers from a tree nursery in Eldorado have started working on the project. These producers are devoted to the growth of saplings of exotic species. Nowadays they are being trained in the production of native species saplings.

6. Activities and results 2006

6.1. Activities developed

6.1.1. Research activities

6.1.1.1. Monitoring and upkeep of restoration treatments

We have continued assessment on the present treatments by means of two types of monitoring: Intensive Monitoring and Quick Monitoring (see 5.1.3.). The information thus obtained has allowed for a) a continuous analysis of the mechanisms through which different factors influence restoration and rehabilitation of the forest and b) new adjustments to both technical and economic aspects of restoration-production models proposed for this area. Weeding, bamboo, and liana clean-ups were also continued for the upkeep of the different treatments.

6.1.1.2. Growth estimates for different species of native trees

The restoration tests that have been set up are providing information as regards the growth of native species within the first plantation years. Adult individuals growing outside the forest whose age was known were measured so as to estimate growth in adult stages.

Adult trees growing under different farming systems, whose age may be provided by their owners, were selected. The following data was recorded about each individual: classification according to its species, diameter at breast-height (dbh) and height. A number of individuals of each species and age range was selected in order to obtain good growth estimates. The information generated by these measurements and supplementary data obtained on specialized bibliography, enabled the adjustment of growth curves for different species of native trees.

6.1.1.3 .Adjusting a monitoring method that may be applied great restored areas in the region

In order to evaluate the evolution of great restored areas, a method must be adjusted to each region. These methods have scarcely been developed for subtropical areas. Adjusting monitoring methods requires some basic information such as data on aerial biomass production at different regeneration stages of the vegetation. Hence, aerial biomass estimates will be based on a) field measurements, b) satellite images.

a) Secondary forests with different abandonment ages (chronosequences) were selected for vegetation sampling. On each selected site, vegetation censuses were carried out, by means of 10x100m transects, subdivided into 5x5 subparcels to calculate frequency and regeneration measurements. Preferential sampling was used to establish the transects in the patches and a systematic one to set the regeneration subparcels (Gauch, 1982; Matteucci y Colma, 1982). A total of 17 censuses were carried out, in which the individuals of tree species were identified and measured taking into account three size categories, which were defined according to the results of previous tasks completed in the area (Holz et al., 2001; Holz y Placci, 2003). Adult individuals were measured all along the transect and its species, height and DBH were recorded. Individuals in the youth category were measured in 16 (5 x 5 m) subparcels, recording DBH and height for each one. Whereas the saplings were measured in 8 (5 x 5 m) subparcels, recording each one's height. For each census, density of individuals and basal area were worked out. From these data, aerial biomass for each site was obtained and biomass production was calculated as a function of the forest age. Dry weight of trees was calculated by means of the specific regression equation proposed by Brown and Lugo (1992) for subtropical forests.

b) We have evaluated the relationship between the response from remote sensing data versus biomass values of primary and secondary succession forests. We compared regrowth stand age, biomass and structural variables of ground data with satellite data, following the methodology proposed by other authors (Neeff T. et al, 2006; Steininger M. K., 2000).

Data are obtained through the interpretation and digital processing of the six spectral bands (bands 1, 2, 3, 4, 5, and 7) at 30 m. resolution 2004 Landsat ETM satellite images. These were referenced by means of geographical coordinates for land trails and points marked with a GPS and translated into the Gauss Kruger projections system. These coordinates enabled the positioning of the exact point for each sampled site and the drawing of surrounding paths and roads. Satellite images are being interpreted with Erdas 8.5 software

6.1.2. Working with local farmers cooperatives

6.1.2.1. Meetings with members of Cooperativa Yerbatera Yapeyú

The cooperative was first contacted through the *Land Restoration and Conservation Program of the Agriculture and Production Ministry of Misiones Province*, which had been working for two years with producers groups in the region on a proposal for agroecological farm management. Meetings involving different members of the Cooperative and the Program were carried out to deal with various topics related to farm management. In this way, several opportunities for joint work were identified and dates were set for the hands-on workshops described below.

6.1.2.2. First workshop

Participants:
- Members of the board of directors of *Cooperative Yerbatera Yapeyú*, as well as some of its members.
- Officials of the *Land Restoration and Conservation Program of the Agricultural and Production Ministry of Misiones Province*.
- Members of the *Atlantic Forest restoration in the buffer area of Iguazú National Park Project*.

Workshop **objectives**: a) To make a participatory diagnosis of the main problems for the cooperative and its member producers, b) To relate and arrange in order of importance the different problems, c) To discuss which activities would be needed to solve each problem and how these could be carried out, d) To set an initial plan of action.

This workshop was organised and coordinated together with the *Land Restoration and Conservation Program*. The methodology consisted in problem brainstorming (with cards); these problems were then sorted out into a hierarchical order and then according to common causes. (Geilfus, 1997; Margoluis y Salafsky, 1998).

6.1.2.3. Visits to farms

Some member producers of the cooperative are implementing agroecological management in their farms, using native tree species. These farms were visited to obtain firsthand knowledge of the producers' experiences. The visits contributed to an initial diagnosis on how agroecological management is being implemented in the studied area and to the selection of the most appropriate farms for further rounds and discussions with different groups of producers.

6.1.2.4. Second workshop

Participants:
- Producers from the *Municipality of Guaraní* and *Montecarlo*.
- Producers of the *Cooperative Yerbatera Yapeyú*.
- Members of the *Restoration and Conservation Program for the Agricultural and Production Ministry of Misiones Province.*
- Members of the *Atlantic Forest restoration in the buffer area of Iguazú National Park Project*.

Workshop **objectives**: a) Getting to know the experiences of different producers working on agroecological management in their farms with native tree species, b) Discussing the advantages and disadvantages for several management systems, c) Based on the discussions of this and the previous workshop, identifying the main lines for work.

This, as the previous workshop, was also organised and coordinated together with the Land Restoration and Conservation Program (Figure 10). The following activities were carried out using a methodology of participatory diagnosis, with 3 groups of 12 producers each:
1) Field round.
2) Visualization technique (drawings) to refer to the experience: adapting for this situation such tools as "natural resources and land use map" and "walkabout and cross-section diagram" (Geilfus, 1997).
3) Building of an Advantages and Disadvantages Matrix incorporating the visited productive system. (adapted from Geilfus, 1997).
4) Summary on the work of all the groups and joint drawing of a plan of action for the future.

6.1.3. Work agreements with several social groups

a) Meetings were carried out with officials of the *Ecology, Renewable Natural Resources and Tourism Ministry of Misiones Province*, members of the project *Atlantic Forest restoration in the buffer area of Iguazú National Park* and members of the board of directors of the *Cooperativa Yerbatera Yapeyú*. The talk focused on the objectives and activities being developed under this project and how such governmental institution could support it. The Ministry officials committed themselves to supporting the group of producers involved in the Project, on the tasks oriented to planting native trees and seeking funds.

b) The *Land Restoration and Conservation Ministry for the Agricultural and Production Ministry of Misiones Province* agreed to continue developing joint strategies to achieve the rehabilitation and restoration of forests within the productive systems. As part of this agreement the Land Project supplies human resources, vehicles, consumables and equipment.

c) Meetings were held with the Coordinator of the *Regional Programme of Assistance to the Yerba-mate Producers* (*PRASY* - Programa Regional de Asistencia al Sector Yerbatero), funded by the National Institute of Yerba Mate (*INYM*- Instituto Nacional de la Yerba Mate). The purpose was to discuss possible work agreements for the following months.

Figure 10. Group work and lunchtime, during the second workshop.

6.1.4. Students and local people training.

We have continued developing small scale training activities with groups of local inhabitants and students, teaching them different activities involved in forest restoration and rehabilitation (Figure 11).

Figure 11. Training people on native tree plantations and monitoring activities.

6.1.5. Sharing information

Both training people in different social roles as well as making this known are necessary strategies for producers to appropriate the information generated and to apply it to their plots of lands or farms thus advancing the restoration process. The information generated during 2006 as well as that from previous years, was shared through:

a) Printed material and orally in meetings with social groups: where the activities and their results were presented adjusted to the needs of the groups they were aimed at. These data were presented to the members of *Organic Agriculture Net*, *Ecology and Natural Resources Ministry of Misiones Province*, *Cooperative Yerbatera Yapeyú* and other local producers.

b) Participation in local workshops (See 6.4.2 y 6.4.4)

c) Publications in books and scientific conferences:

- Guerrero Borges, V.; Holz, S. y L. G. Placci. 2006. Secondary forest of Northern Misiones: involving factors on floristic patterns generation. XXII Argentina Ecology Meeting, Córdoba, Argentina.

- Holz, S. y L. G. Placci. 2006. Historical use effect on secondary forest regeneration in Northern Misiones. XXII Argentina Ecology Meeting, Córdoba, Argentina.

- Holz, S. y G. Placci. In press. The challenges of restoration in highly populated environments: a multidisciplinary approach in Misiones. In: J.M. Rey-Benayas, N. Ramirez-Marcial y M. Gonzalez-Espinosa (Eds). Forest Restoration in Latin America. Mundi-prensa, México.

d) Postgraduate Teaching

- Holz, S. 2006. Forest restoration in Misiones Province. Seminars delivered as part of the postgraduate course, "Ecological restoration" at *Colegio de la Frontera Sur (ECOSUR), Unidad de San Cristóbal de las Casas*, Chiapas, Mexico.

6.2. Results

6.2.1. Research

6.2.1.1. The effect of grasses on the survival and growth of native tree seedlings

Results obtained through intensive monitoring in the set trials at abandoned grazing fields show the negative effect of grass on seedlings survival may be of different intensity according to the dominant grass type in the matrix (Figure 12). On the studied sites, on the parcels dominated by *Urochloa decumbens* and *Urochloa brizantha* - both exotic species, identified as invaders - saplings survival was lower than on parcels covered mainly by *Axonopus compressus* and *Paspalum urvillei.*

On the other hand, species are affected by grass in different degrees: on the parcels dominated by signal grass, all species were much affected; whereas on the other parcels, it was observed that the survival of the pioneer species *Solanm verbascifolium* was higher compared to species of later successional stages *Peltophorum dubium* and *Balfourodendron riedelianum;* and survival of *Luehea divaricata* (intermediate successional stages) was higher than that of the pioneer species *Trema micrantha*. These results show no general survival pattern for the species as a function of the ecological group and a survival gradient may not be predicted: pioneer > secondary initial > late secondary for every situation.

As regards growth, results showed that the presence of grass affected negatively tree saplings growth, which coincides with other authors' findings (Holl, 2000). However, it did not influence the *T. micrantha* as much as other species (Figure 13; Tables 2 and 3). Trials reflect “net” effect of grass competence, but certainly do not reflect the “interference” mechanisms (such as, shadowing, nutrients limitation, allelopathy, etc.) But looking at studies carried out in other areas, these results would mainly explain competence between grass and saplings, for nutrients (Buschbacher et al., 1988; Nepstad, et al., 1990; Reiners et al., 1994), and for water (Ashton et al., 1998).

a) b)

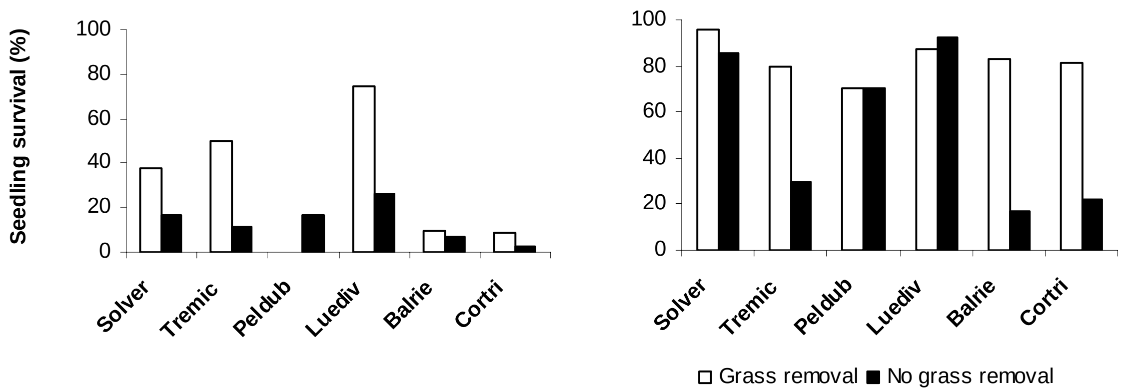

Figure 12. Survival of native seedlings in plots dominated by *U. decumbens* and *U. brizantha* (a) and in plots dominated by *A. compressus* and *P. urvillei* (b), in cattle breeding fields in the North of Misiones. Abbreviations correspond to the first three letters of the genre and the species: Solver = *S. verbascifolium*, Peldub = *P. dubium*, Balrie = *B. riedelianum*, Tremic = *T. micrantha*, Luediv = *L. divaricata*.

a)

b)

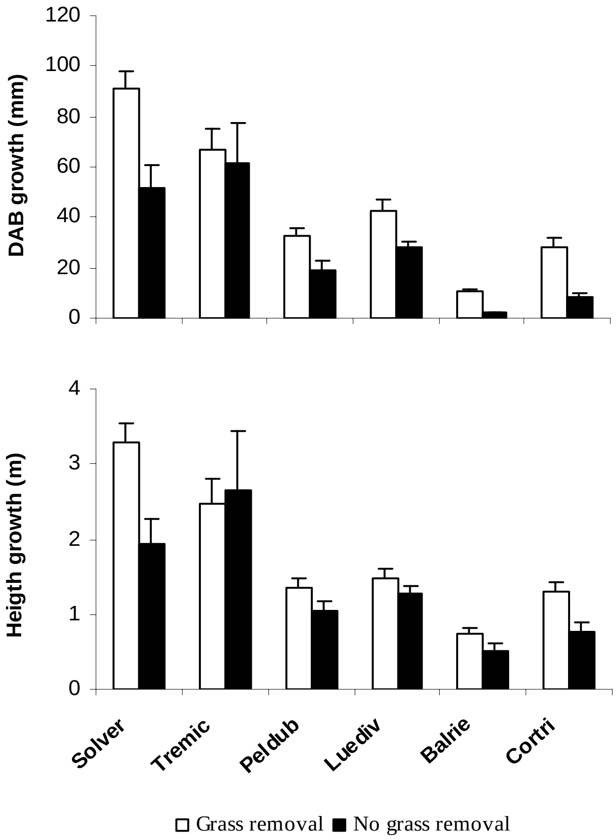

Figure 13. Average growth for diameter at base, DAB (a) and height (b) for each analysed species, in the treatments with and without weeding in cattle breeding fields in Northern Misiones. Bars indicate standard error. Abbreviations correspond to the first three letters of the genre and the species: Solver = *S. verbascifolium*, Tremic = *T. micrantha*, Peldub = *P. dubium*, Luediv = *L. divaricata*, Balrie = *B. riedelianum*.

As regards growth for ecological groups, it was greater in pioneer species than in late species, despite the presence or absence of grass, which concurs with findings in other areas (Kageyama et al., 1992; Kageyama y Gandara, 2000; Souza y Valió, 2003). A growth gradient may be predicted: pioneer > secondary initial > late secondary, for systems dominated by native grasses.

Table 2. Values for the media and standard error (between brackets) of DAB (mm) and height (m) saplings growth for each species in the treatments with weeding (LP) and without weeding (P). n_1 y n_2= number of individuals in LP and P respectively; W = Wilcoxon statistics; p= probability level.

Especies	n_1	n_2	**LP**	**P**	*W*	*p*
			DAB growth (mm)			
Solanum verbascifolium	23	18	91,18 (6,57)	51,94 (8,98)	249	< 0,01
Trema micrantha	14	5	66,57 (8,71)	61,22 (16,41)	44	0,62
Peltophorum dubium	13	13	32,59 (3,02)	19,18 (3,48)	228	< 0,01
Luehea divaricata	21	22	42,57 (4,78)	27,85 (2,54)	567	0,01
Balfourodendron riedelianum	20	5	10,82 (0,73)	2,02 (0,62)	16	< 0,01
Cordia trichotoma	29	8	28,46 (3,78)	8,34 (1,59)	55	< 0,01
			Heigth growth (m)			
Solanum verbascifolium	23	18	3,29 (0,24)	1,94 (0,34)	266,5	< 0,01
Trema micrantha	14	5	2,46 (0,34)	2,65 (0,79)	50	0,99
Peltophorum dubium	13	13	1,34 (0,15)	1,04 (0,13)	204	0,14
Luehea divaricata	21	22	1,49 (0,12)	1,27 (0,1)	510	0,24
Balfourodendron riedelianum	20	5	0,75 (0,06)	0,51 (0,11)	39,5	0,08
Cordia trichotoma	29	8	1,3 (0,13)	0,77 (0,11)	94,5	0,03

Table 3. Results for the Kruskal-Wallis test and the multiple comparisons between sample pairs, taking into account saplings DAB and height for the different species, in plots dominated by *A. compressus* and *P. urvillei* in grazing fields in Northern Misiones. Abbreviations correspond to the first three letters of the genre and the species: Solver = *S. verbascifolium*, Peldub = *P. dubium*, Balrie = *B. riedelianum*, Tremic = *T. micrantha*, Luediv = *L. divaricata*. In block type in the bottom corner are the probability values of the non-weeding treatment and at the top corner, those corresponding to weeding treatments. H = Kruskal-Wallis statistics; p = probability level.

Especies	Solver	*Tremic*	*Peldub*	*Luediv*	*Balrie*	*Cortri*	*H*	*p*
		DAB growth						
Solver		*0,17*	< 0,001	< 0,001	< 0,001	< 0,001	80,36	< 0,001
Tremic	**0,48**		0,03	*0,09*	< 0,001	< 0,001		
Peldub	**0,01**	**0,03**		0,49	< 0,001	0,3		
Luediv	**0,21**	**0,13**	**0,16**		< 0,001	0,04		
Balrie	**< 0,001**	**< 0,001**	**0,01**	**< 0,001**		< 0,001		
Cortri	**< 0,001**	**< 0,001**	**0,08**	**< 0,001**	**0,38**		**34,94**	**< 0,001**
		Heigth growth						
Solver		0,18	< 0,001	< 0,001	< 0,001	< 0,001	61,31	< 0,001
Tremic	**0,52**		0,03	0,06	< 0,001	< 0,001		
Peldub	**0,04**	**0,04**		0,62	0,01	0,65		
Luediv	**0,37**	**0,22**	**0,2**		< 0,001	0,25		
Balrie	**< 0,001**	**< 0,001**	**0,09**	**0,01**		0,01		
Cortri	**0,01**	**0,01**	**0,33**	**0,03**	**0,42**		**19,48**	**< 0,001**

6.2.1.2. Selection of most appropriate native species to be used in plantations

Through intensive monitoring in the trial parcels set in 2002 in the abandoned grazing field (See 5.1.2.1) survival and growth for different species of saplings was estimated along the first three plantation years (Figure 14). These estimates took into account the plots which were periodically weeded out, since as it was stated above, grasses affect saplings negatively and should therefore be cleared out in future plantations. Said estimates, together with those for growth and wood density contributed to species selection for future plantations aimed at producing firewood and timber (Figure 15).

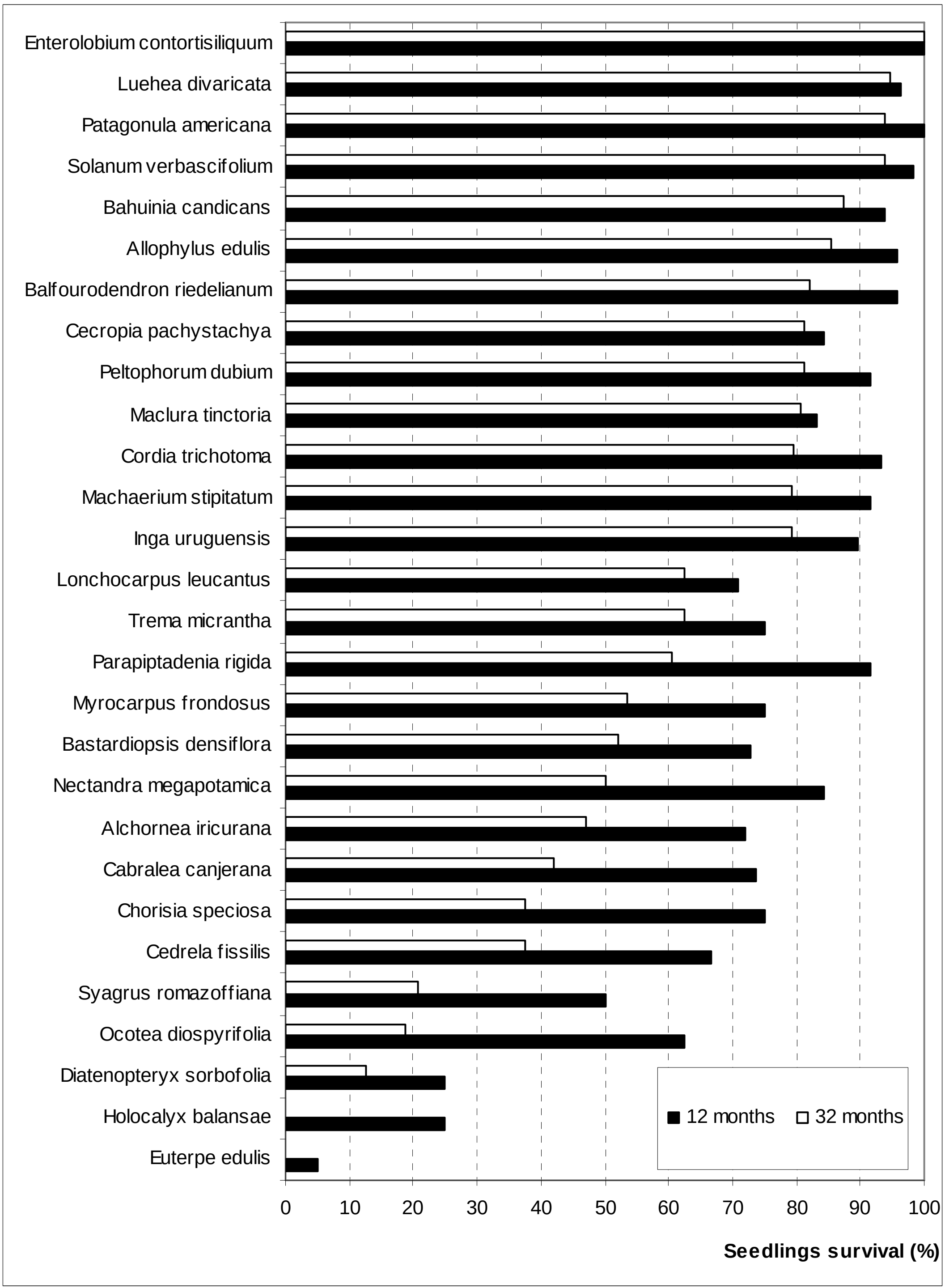

Figure 14. Survival of seedlings planted in plots with grass removal, in the first year (black bars) and on the 32nd month (black bars) from plantation date, in the abandoned cattle breeding fields in the North of Misiones.

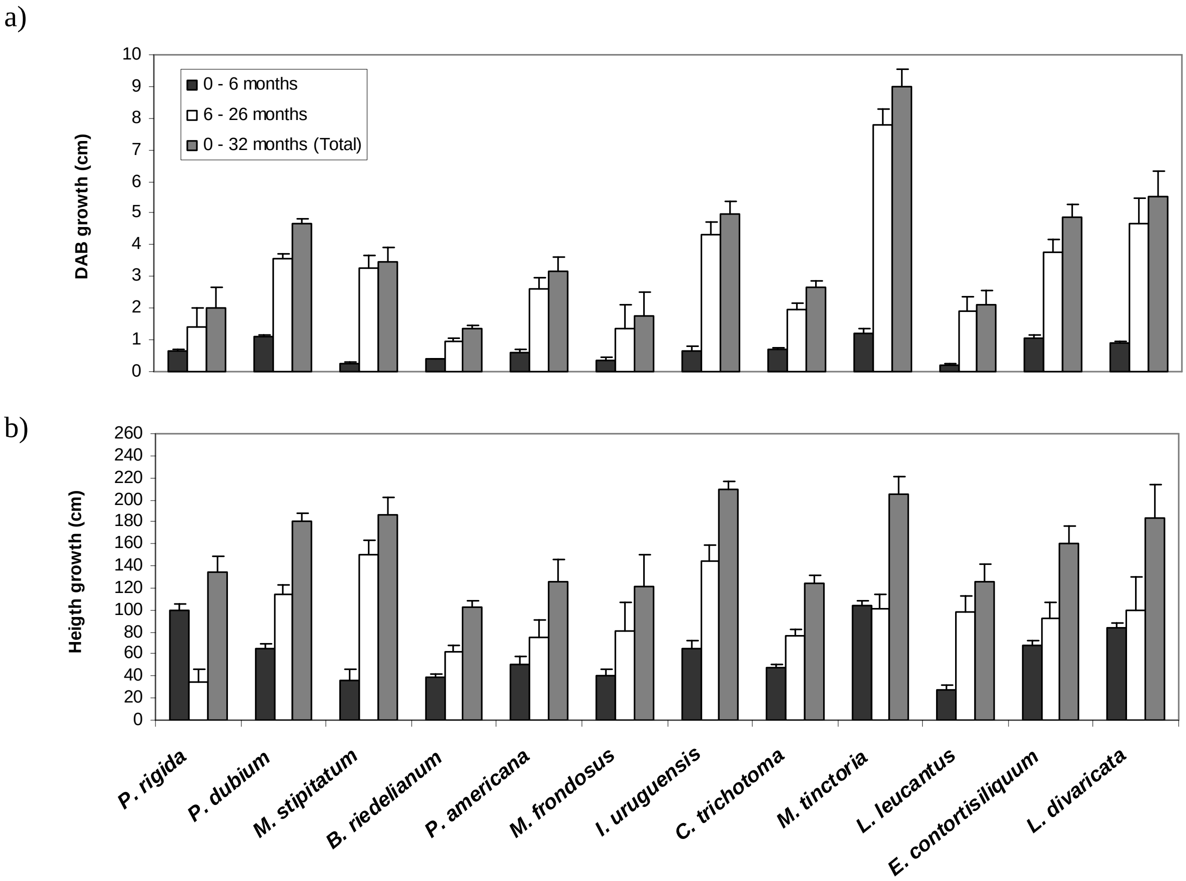

Figure 15. Growth of seedlings planted in the abandoned cattle breeding fields in the North of Misiones. a) Growth in diameter at base (DAB), b) Growth in height.

6.2.1.3. Growth and biomass production estimates in plantations

Based on these field measurements, growth curves for different species were estimated. This information was used to estimate biomass production in mixed native tree plantations, combining different species (Figure 16). Such information will be of use to design plantations for the production of firewood and timber.

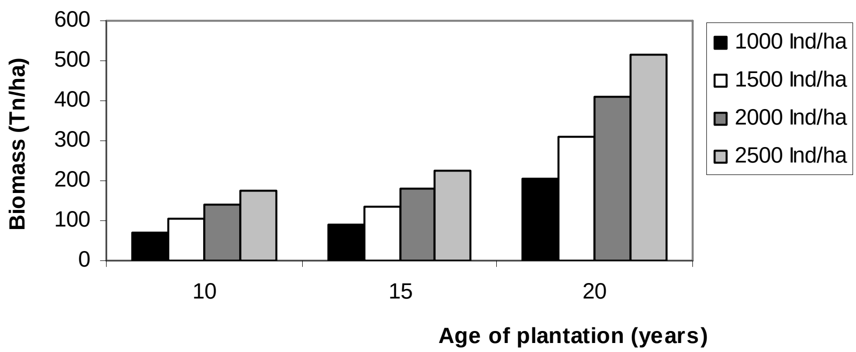

Figure 16. Biomass production along time, in native tree plantations of different density. For these estimates a mixed group of species made up of *Luehea divaricata*, *Patagonula americana*, *parapiptadenia rigida*, *Myrocarpus frondosus*, *Cordia trichotoma*, *Inga uruguensis* and *Helietta apiculata* planted in similar proportions was taken into account.

6.2.1.4. Biomass production from natural regeneration in secondary forest

Density, basal area and aboveground biomass increased rapidly during the first 20 years (Figure 17). If we compare our results with those described in other studies in the ecoregion (Holz et al., 2001; Stutz de Ortega, 1987), after 20-30 years of natural regeneration the structural characteristic of secondary forest studied are similar to those of the older forest.

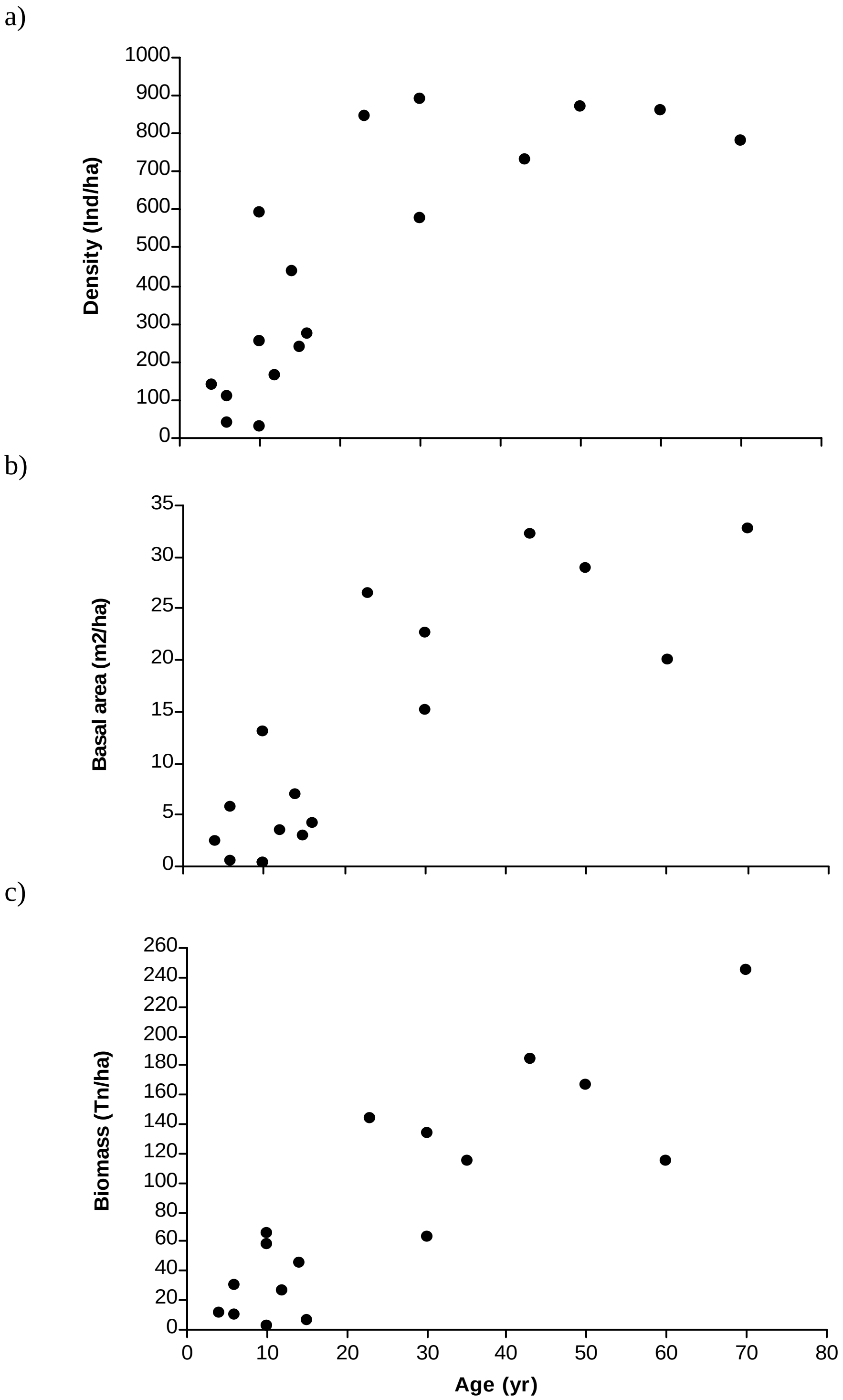

Figure 17. Relation between time since abandonment and forest characteristics (density, basal area and biomass production) in abandoned fields (young secondary forest) in the North of Misiones.

Such rapid recovery of structural parameters has been recorded in various studies carried out in tropical secondary forests (Saldariaga et al., 1988; Denslow y Guzman, 2000; Peña-Claros, 2003; Muñiz-Castro et al., 2006). Several authors have pointed out that in secondary forests vegetation picks up fast and the nutrients it feeds on are soon returned to the land through leaves falling and decomposing, which makes them highly productive systems (Brown y Lugo, 1990; Feldpausch et al., 2004).

Management in early stages of natural regeneration in secondary forests would be an effective and economic way of restoring slightly degraded areas, with a good bank of seeds in the soil and near forest remnants. However, even these relatively intact systems should be monitored periodically to evaluate the need to carry out enrichment in plantations.

6.2.2. Working with local farmers cooperatives

6.2.2.1. First workshop

As a result of this workshop, a conceptual model for the problems of yerba-mate producers was obtained. The said model helped identify the most important problems producers face nowadays: a) land degrading in yerba-mate plantations, b) lack of firewood for home use and to dry the yerba, c) few technical and financial resources to improve their farms management. Diverse causal factors and potential actions to either solve or lessen the effects of these problems were discussed.

In this first workshop an initial plan of action was agreed and drawn, allotting activities to each of the groups involved and corresponding deadlines. These activities were aimed at the design of a joint work Project.

6.2.2.2. Second workshop

A farm was visited which the owners manage in an agro-ecological fashion, and several related aspects were discussed. Advantages and disadvantages for implementing this type of management were identified along with the chances for its development.

Figure 18. Visit to an agro-ecological farm in Eldorado Department.

The plan of action agreed to in the previous workshop was adjusted and outlines for further work were drawn. (Figure 19)

1. Training in integral and agroecological management of yerba-mate plantations.
2. Design of a self-sufficient supply system of firewood for the cooperative drier.
3. Training in the generation of native species saplings in tree-nursery and management of native tree plantations.
4. Economic, social, environmental and productive assessment of the different models and management systems proposed.
5. Setting a monitoring plan for each of the planned tasks.

It was agreed that in future meetings specific objectives, aims, tasks, deadlines will be set and monitoring will be designed for each task and each plan of action.

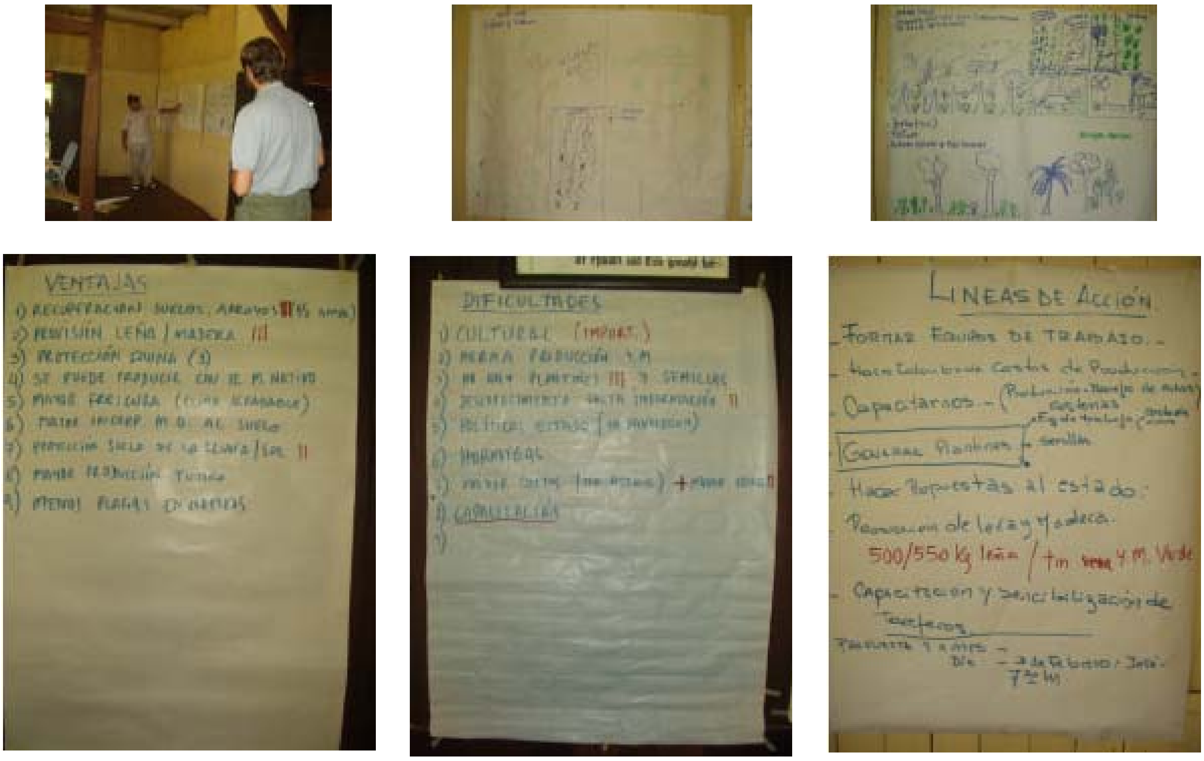

Figure 19. Graphic analysis of the problems tackled in the second workshop.

7. Financial report 2006

A summary of the money spent with the funds provided by Rufford Foundation in 2006 is shown below.

Specification	Amount granted by Rufford Foundation (£)
Materials	1448,09
Sharing information	1261,13
Technical service	4142,29
Transport	2340,84
Living expenses	413,61
Comunications	168,50
Others	212,33
Total	**9986,79**

8. Aknowledgements

This project is developed thanks to the support of the following people and institutions:

- The Rufford Foundation (UK)
- World Wildlife Fund (WWF)
- Education for Nature Program (WWF-EFN).
- Fundación Vida Silvestre Argentina (FVSA).
- Subtropical Ecological Researches Center, National Parks (Centro de Investigaciones Ecológicas Subtropicales, CIES, Parques Nacionales).
- Universidad de Buenos Aires (UBA).
- Universidad de La Plata (ULP)
- Andresito and Eldorado farmers (Misiones, Argentina).
- Students and biologists who collaborate in the field work.
- National rangers and rangers of the province of Misiones.

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