Conservation and Restoration of Subtropical Atlantic Forests invaded by monocarpic woody bamboo grasses

ANNUAL REPORT 2006

LÍA MONTTI

Laboratorio
de Ecología
Funcional

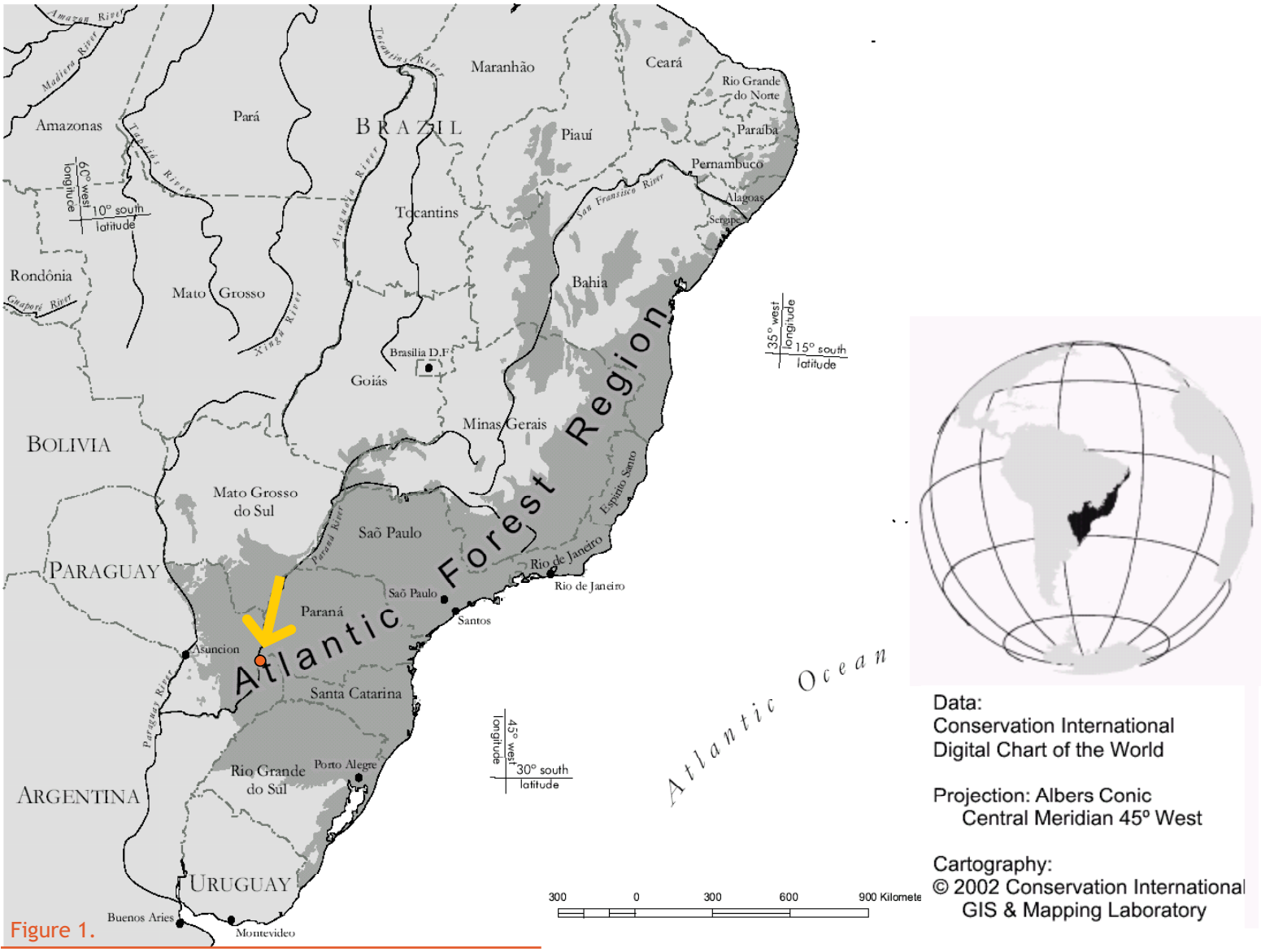


Figure 1.

Introduction

The Atlantic Forest is one of the most endangered rainforests on earth, of which remains about 7% of its original extension. Misiones Province in Argentina and neighboring areas of Brazil and Paraguay contain the "Green Corridor", the largest remnant of this forest.

This area and the rest of Atlantic Forest are rich in native bamboo species, some of which may colonize disturbed sites and become the dominant species (Judziewicz et al., 1999). Bamboos are woody grasses that have dramatic and far-reaching impacts on the diversity and productivity of the forests in which they are found (Griscom and Ashton 2003, Saha and Howe 2002).

In Argentina, woody bamboos of the genus Chusquea and Merostachys form impenetrable thickets in gaps and open canopy areas (Tabarelli and Mantovani, 2000; Campanello et al, in press). Especially the bamboo Chusquea ramosissima can be an aggressive colonizer after human disturbance. It is able to spread rapidly through leptomorph rhizomes while forming dense clumps that could inhibit tree regeneration by changing environmental conditions (Campanello et al, 2007a; Montti, unpublished data).

This project, join with my PhD thesis, tries to elucidate how biotic and abiotic factors, including bamboo colonization of the understory, affect the regeneration of tree forest species by contributing with basic information on the ecology, forest dynamics and coexistence of bamboo grasses. Also, this project intends to assess important factors that determining the invasive behaviour and success of bamboo. Field work was carried out at the Iguazú National Park, where the dominant vegetation corresponds to the semideciduous forest, commonly denominated Upper Paraná Atlantic Forest or Misiones Forest (Figure 1). The average annual precipitation is 2000 mm, evenly distributed throughout the year and the average annual temperature is 21° C. Soils belong to the order of the Ultisoles (Kandiudultes ródicos); developed from a basalt layer, they are deep to very deep, and their colour is an intense dark red (between 25YR 3/4 colour in dry and 25YR 4/6 colour in wet) (Ligier et al., 1990; Montti, in press).

The Iguazú National Park constitutes a distinct and unique protected area, not only because of the intrinsic value and beauty of its scenarios (the Iguazú falls), but also for being one of the biggest and most diverse protected areas in Argentina, that is connected to other protected areas (Urugua-í Provincial Park, located in Misiones Province and Iguaçu National Park in Brazil). However most of the native forest in Argentina, even in actual protected areas, was subjected to selective timber extraction and gaps are commonly covered by bamboo.

During the first part of this project, we studied forest structure and dynamics as affected by bamboo grasses invasion. We measured bamboo and tree seedlings and saplings abundance and growth, microclimatic conditions, nutrients, light and water availability for plants species. In order to assess factors contributing to the invasive behavior and success of bamboo we are also studying bamboo population ecology and ecophysiology.

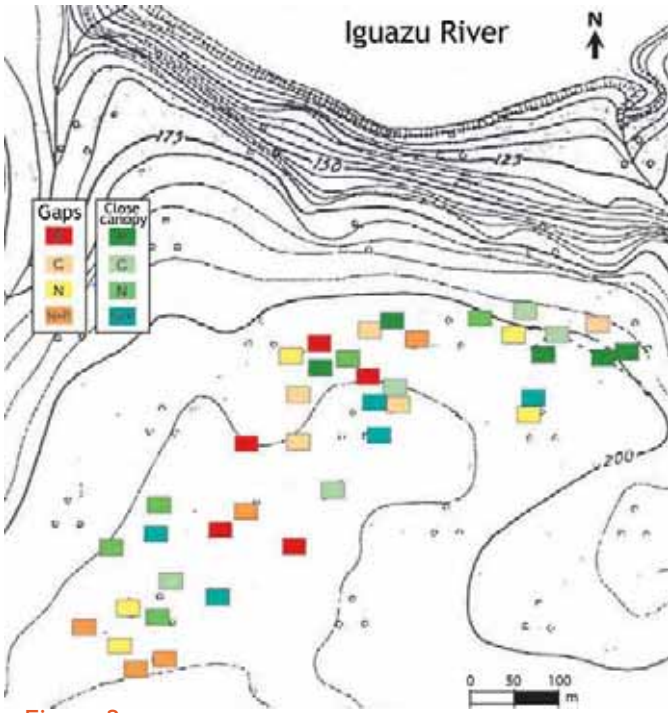


Figure 2.

We planted two bamboos species on 40 already fertilized permanent plots in the National Reserve of the Iguazú National Park (Figure 2). These plots were installed to study nutrient control over ecosystem processes and plant ecophysiology. Plots are subjected to 4 nutrient treatments (N, P, N+P, and Control) in 2 contrasting light situations in the forest environment (gaps and closed-canopy sites). During 2005-2006 we measured and harvested plants under treatments and we estimated growth rates for both bamboo species, as well as physiological and morphological characteristics of bamboo that determine their ecological success.

The objective of the second part of this project, started on October 2005, was to apply restoration techniques to a de-

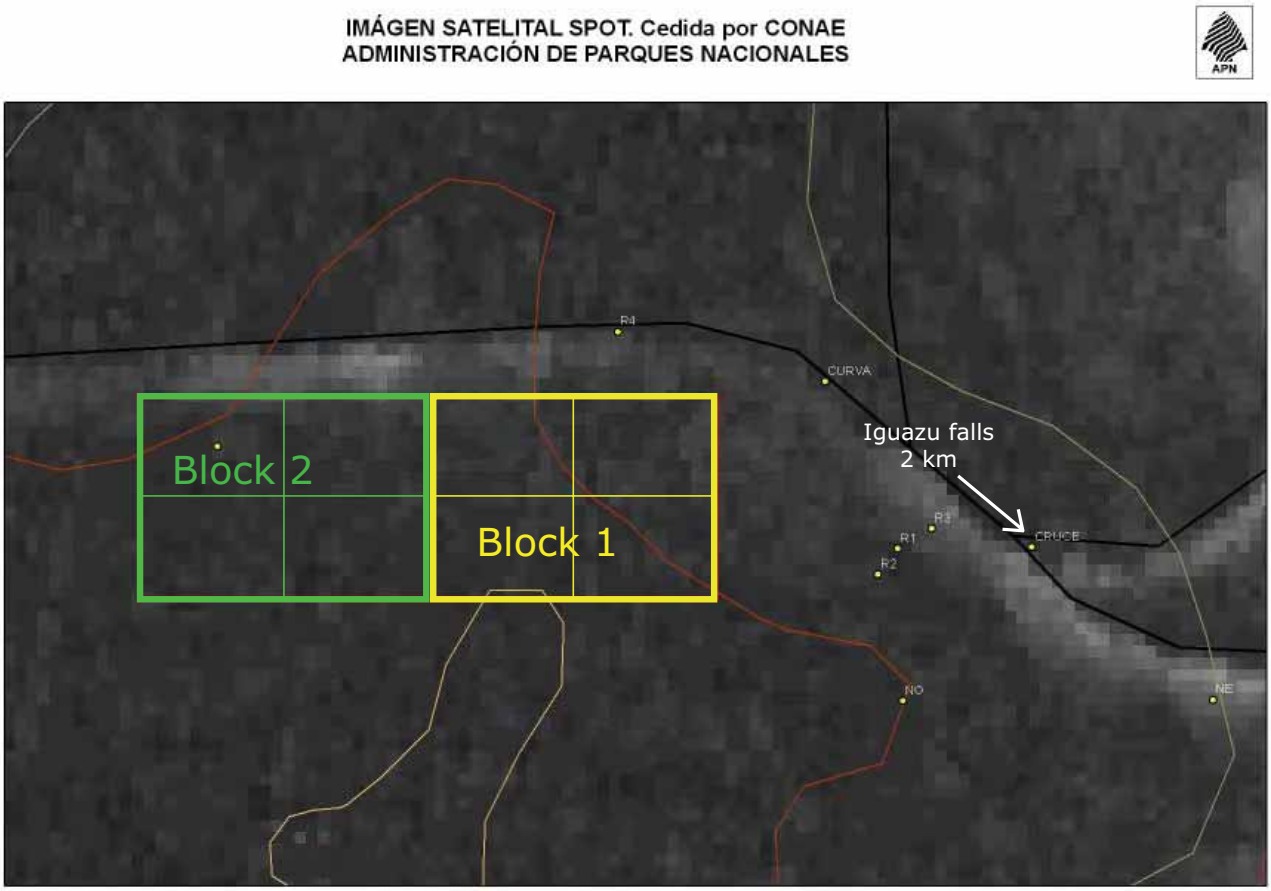


Figure 3.

graded primary forest inside the Iguazú National Park. The practices we proposed for this area were strictly based on scientific knowledge of ecosystem functioning and processes. Some of the activities involved bamboo cutting and removal from gaps, promoting sun adapted native tree species, and studying animals that may help in seed dispersal of forest species. The study area was subjected to severe selective extraction before the National Park was created 70 years ago. The restoring plots cover 4 hectares and other 4 contiguous hectares are used as control for monitoring purposes. Plots are being installed according to MAB-UNESCO program for permanent plots (Dallmeier 1992) (Figure 3).

During 2007 we will finish the restoration experience and during 2008, with the help of the National Park Administration, we are planning to implement a demonstrative and educative area in the plots. Given that this area is very accessible for people visiting the National Park (around 1 million visitors a year), this project is an excellent opportunity for interacting and developing relationships with local community throughout the region and showing scientist's work, and also for helping to recognize forest intrinsic value and promote its conservation.

The information obtained from this project joints with those of other works that we are carrying out in the same area, in order to contribute to the understanding of the Atlantic Forest dynamics and functioning. This knowledge is basic not only for the management of protected areas but also for developing strategies of sustainable use of Misiones forests.

Permanent collaborators

Dr. Guillermo Goldstein (research advisor), Dra. Paula Campanello, Dra. Susana Bravo, Dra. Genoveva Gatti and Lic. Ana Sallenave (student of University of Buenos Aires, conducts her PhD thesis in the restoration plots).

Other Staff:

Biologists, and students of different Universities from Argentina and other countries participated in the field activities of this project since 2005-2006. This experience contributed to their professional development.

Collaborators of the last year:

Larraburru Diego (forest engineer),
Villagra Mariana (biologist),
De los Santos Carolina (student of University of Misiones, she made her degree thesis in this project plot),
González Mauricio (local assistant),
Foletto Fernando (park ranger),
Camposano Mónica (pemanent assistant from Centro de Investigaciones Ecológicas Subtropicales (CIES), Iguazú National Park),
Pereyra Lorena (park ranger assistant),
Christine Scoffoni (biology student of University Paul Cezanne, France).

Institutional affiliations and collaborations

All permanent collaborators and I belong to the Laboratorio de Ecologia Funcional (Universidad de Buenos Aires) and the Argentine National Council of Scientific and Technological Research (CONICET). I am enrolled in the Doctoral program in Biological Science of Universidad de Buenos Aires (UBA). Dr. Guillermo Goldstein is the director of this research team, and he is also professor at the University of Miami. Dra Susana Bravo is professor at the Universidad de Buenos Aires and Ana Sallenave's advisor. Dra. Paula Campanello and Dra Genoveva Gatti are postdoctoral fellows of CONICET. Ana Sallenave is actually enrolled in a doctoral program at the Univesidad de Buenos Aires. Her thesis research attempts to understand the role of seed dispersal in maintaining tree species diversity using as a model the dispersal system of animal-dispersed tree species. Her study will provide complementary information to this project by contributing data on the spatial patterns of seed dispersal by animals, the mechanisms producing them and their recruitment consequences. She

has recently started fieldwork at the restoration project plots, where she is using a combination of observational and experimental methods to identify the main mammalian frugivores, determine their movement and seed deposition patterns and monitor their impact on seed germination and seedling survival in restored and control areas. From the very beginning the project has been supported by different governmental scholarships, free lodging during our work was provided by the APN and by funds from Rufford Maurice Laing Foundation. Moreover, some researchers from different institutions, as Dra Ximena Londoño (Colombian bamboo researcher), Patricio Mac Donagh (Universidad de Misiones), Dalva Ribeiro (Universidade de Brasilia) and Margarita Osterrieth (Universidad de Mar del Plata), collaborated with valuable suggestions and observations about our work.

Main Results

Between the most evident influences of the selective tree extraction are the reduction of the arboreal cover, the population diminution of timber species and a high proportion of individuals in the smaller diametrical classes. Notably, we registered big gaps invaded by Chusquea ramosissima and Merostachys clausenii. Woody bamboos are an important component of the Misiones Forest, with 6 native species: Guadua chacoensis, G. trinii, Merostachys clausenii, Colanthelia rhizanta, Chusquea ramosissima and Ch. tenella.
In the study site bamboo density was very high in forest gaps having 16,000 to 20,000 culms of Ch. ramosissima per hectare. These culms formed a dense, 2-3 meters height stratum in the understory, and the established saplings (trees more than 30 cm

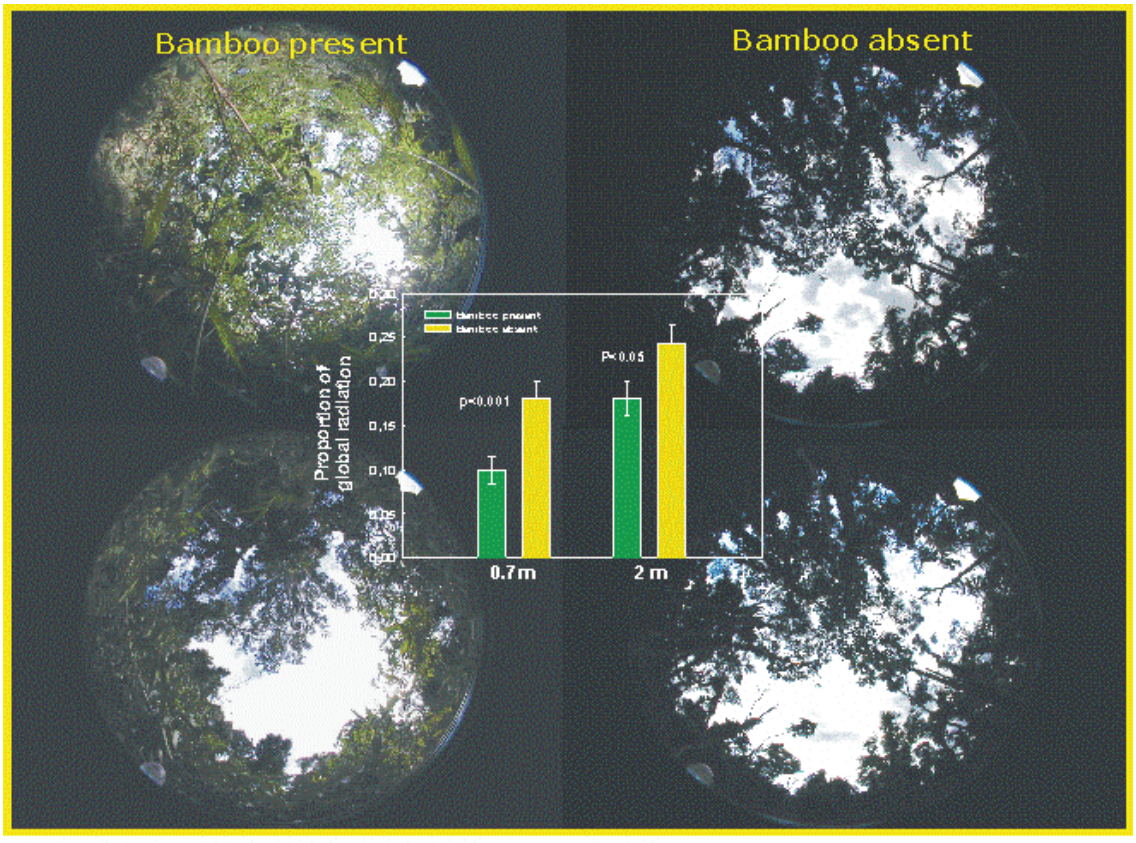
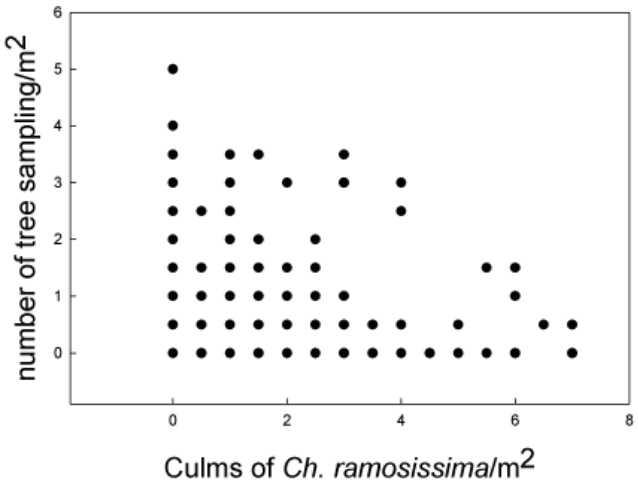


Figure 4.

Figure 5.



height and less than 10 cm of DAP) reached 16,166 individuals by hectare.

Native invasive species such as Ch. ramosissima intercept radiation in gaps reducing light availability to other plants. Its absence by artificial removal significantly increased radiation at 0.7m height above ground level (Figure 4). Also, this change affected growth, mortality, ecophysiology and diversity of tree saplings. The highest values of tree species richness and abundance were observed at 10 to 15% of total radiation and low bamboo density. The relation between Ch. ramosissima and tree sapling density is shown in Figure 5. Tree saplings were scarce at high bamboo densities. At low bamboo densities tree sapling abundance could be high or low depending on particular site conditions (i.e., tree cover, abundance of other invasive species as herbs and ferns).

Bamboo removal did not produce any changes in water and nutrient availability. Consistently with these results, nitrification, amonification and net mineralization rates were similar in sites with and without bamboo. Chusquea ramosissima aerial biomass has very low decomposition rates compared to other species abundant in the forests of Misiones (Table 1).

Table 1. Expected time (years) for 50% and 95% loss of biomass from different species and plant material.

Litter type	T_{50}%	T_{95}%
	Mean ± SE	Mean ± SE
bamboo leaves	1.05 ± 0.08	4.56 ± 0.34
bamboo branches	0.74 ± 0.08	3.23 ± 0.35
bamboo stems	0.80 ± 0.16	3.47 ± 0.45
Sorocea ilicifolia leaves (tree)	0.72 ± 0.09	3.11 ± 0.40
Arrabidaea mutabilis leaves (vine)	0.34 ± 0.02	1.50 ± 0.10

We observed that Chusquea spp. showed different morphological and spatial patterns depending on light availability. In open areas this bamboo species grows fast and occurs in big and dense clumps of low erected culms, but in shadow conditions it forms little clumps with long and thin culms. Nutrient addition did not produce significant differences in any bamboo traits. We are still analyzing the ecophysiological results and we are performing some complementary studies. Up to now, we have determined that Chusquea species, as other bamboos, are C3, light demanding and have lepthomorphic rhizomes. Its photosynthetic capacity, estimated using PPFD (Photosynthetic Photon Flux Density) was remarkably low, even under no restraining light and nutrients conditions, with values between 60 and 80 µmol m-2 s-1 PPFD (Montti, unpublished data). Bamboo's physiological studies are scarce (see Cochard et al., 1994; Lei & Koike, 1998). Nevertheless, accordingly to theses authors, our results support the idea that photosynthetic rates seem to be low in relation to the high growth rates and colonizing capacity of bamboos.

During our study we observed that Chusquea spp. photosynthetic capacity is similar to shadow tolerant tree and palm species (Gatti, 2005; Campanello et al., 2007b). Although, its high growth rate and aggressive behavior could be due to its

structural and physiological traits as determine in this project: long life-span perennial leaves, photosynthetic tissue over the culms, substances stored in lepthomorphic rhizomes, an good water transport system and an efficient repairing mechanism of embolized vessels. Based on personal observations of Chusquea spp. leaf gutation during sunset and sunrise, we propose that the main repairing mechanism could be the generation of positive root pressures. We are conducting studies to determine if this is the case.

We divided each hectare of the restoration area in 20mx20m plots in order to facilitate measuring. In all plots we identified, measured and labeled trees over 10 cm DBH (stem diameter at 1.3 m high). We put a dendrometer in each tree to measure the annual circumference increment. We established smaller plots in order to estimate bamboo and other understory

species abundance and identify new seedling and saplings over 30 cm height. Since 2006 we have been measuring solar radiation and other micro-climatic variables (temperature, water availability). All these data are been analyzed. These plots are also used by other researchers from CIES-APN (National Park Administration) in order to monitory different kinds of environments inside the Iguazú National Park.

The study area belongs to a very disturbed forest with a basal area of 14,5-24 m2/ha and 92% of trees with DBH less than 40 cm. We registered between 45 and 60 different species per hectare. The most abundant were *Nectandra megapotamica*, *Balfourodendron riedelianum*, *Guarea pohlii*, *Alchornea iricurana* and several Myrtaceae species. In table 2 we compare forest structural attributes from restored (block1) and control (block2) plots.

One remarkable consequence of this project in terms of conservation of National Protected Areas in Argentina is that the National Park Administration (APN), through an internal disposition (DRNEA N°187/05, 11/01/06), accepted active management indispensable for recovering disturbed areas and declared our project as “of importance for the Iguazú National Park research and environmental significance.”.

Table 2. Forest structural attributes from restored (block1) and control (block2) plots.

	BLOCK 2				BLOCK 1			
	Ha 1	Ha 2	Ha 3	Ha 4	Ha 1	Ha 2	Ha 3	Ha 4
Individulas > 10 cm DAP (N°/ha)	424	432	394	398	411	457	366	401
Tree species N° /Ha	50	50	45	54	58	58	51	60
Basal Area (m2/ha)	24.0	24.3	20.5	26.1	18.2	21.8	14.5	18.72
Average tree diameter (cm)	23.1	23.3	22.3	24.0	20.8	21.4	20.2	21.22
Simpson 1-D Diversity Index	0.91	0.91	0.94	0.93	0.89	0.86	0.91	0.94
Shannon Diversity Index	3.08	3.03	3.2	3.14	3.03	2.92	3.09	3.34
Shannon Maximum Index	6.05	6.07	5.98	5.99	6.02	6.12	5.90	5.99
Evenness	0.51	0.5	0.54	0.52	0.50	0.48	0.52	0.56

Works presented at Scientific Meetings related with this project during 2005-2006

Montti, L; Fernández Honaine, M; Osterrieth M.L & Graciano Ribeiro, D. Phytolith analysis of Chusquea ramosissima Lindm. (Poaceae: Bambusoideae) and associated soils. 6th International Meeting on Phytolith Research. Barcelona. 2006.

Montti, L; Campanello, P; Gatti, M.G & Goldstein G. Biología reproductiva y demografía de poblaciones de una especie leñosa de bambú monocárpico, Chusquea ramosissima, en el Bosque Atlántico Semideciduo. XXII Reunión Argentina de Ecología. Córdoba, Agosto 2006.

Gallardo, A; Montti, L; Capdet, M & Bravo, S, P. Efecto de la floración del bambú Chusquea ramosissima sobre la remoción y predación de semilla de palmito (Euterpe edulis). IX Congreso Latinoamericano de Botánica. Santo Domingo, República Dominicana, Junio 2006.

Montti, L; Goldstein, G. & Graciano Ribeiro, D. Anatomía comparada de dos especies de bambúes nativos del Bosque Atlántico. Género Chusquea (Poaceae: Bambusoideae). IX Congreso Latinoamericano de Botánica. Santo Domingo, República Dominicana, Junio 2006.

Campanello, P., Montti, L., Gatti, M.G., Bravo, S. & Goldstein G. Forest Structure and Functioning in the Semideciduous Atlantic Forest of Northen Argentina: Effects of native invasive bamboos and lianas on the tree regeneration and diversity. Understanding biodiversity loss: A Workshop on forest fragmentation in South America. San Carlos de Bariloche, Argentina, 2006.

De los Santos, C; Campanello, P; Montti, L.; Foletto, F& Larraburru, D. Estructura arbórea y presencia de lianas en dos bosques del norte de Misiones con diferente estado de conservación.12 Jornadas Técnicas, Forestales y ambientales. Eldorado Misiones, Argentina, 2006.

Montti, L.; Campanello, P.; Gatti, M.G. & G.Goldstein. Effects of Chusquea ramosissima (Poaceae: Bambusoideae) on forest structure and functioning in the Atlantic Forest of Northern Argentina. Tropical Biology and Conservation Annual Meeting. Uberlandia, Brasil, 2005

Goldstein,G; Montti, L; Campanello, P & Gatti, M.G. Dinámica poblacional y eco fisiología de bambúseas invasoras en el bosque Misionero. Reunión Internacional sobre biología y ecología de especies de bambú. IAI Course/Workshop. Universidad de Los Andes, Mérida, Venezuela, 2005.

Publications related to this project

Montti, L; Fernandez Honaine, M; Osterrieth M.L & Graciano Ribeiro, D.2007. Phytolih analysis of Chusquea ramosissima Lindm. (Poaceae: Bambusoideae) and associated soils. In press, Quaternary International

Campanello, P., M. Genoveva Gatti, Adrian Ares, L, Montti & Guillermo Goldstein.2007. Bamboos and lianas affect tree regeneration and microclimate in a Semi-deciduous Atlantic Forest. In press. Forest Ecology and Management

Campanello, P., L. Montti, M.G. Gatti y G. Goldstein. 2005. Efectos de la tala selectiva sobre la estructura y funcionamiento del bosque nativo en Misiones: desarrollo de técnicas de manejo forestal sustentable. Resumen expandido en Actas del 3er Congreso Forestal Argentino y Latinoamericano, Corrientes, Argentina, 10pp.

Montti, L., P. Campanello and G. Goldstein. Reproductive biology and demography of Chusquea ramosissima, a monocarpic woody bamboo of the Atlantic Forest (in preparation).

Lectures about this project results

2006. Las Bambúseas: Ecología y biología. Impacto sobre la dinámica de los bosques de Misiones. I Reunión de asesoramiento con el Comité Internacional de la Reserva de Biosfera Yabotí. Puerto Iguazú. Misiones

2006. Ecología y Ecofisiología de Ch. ramosissima y Ch. tenella, dos especies de bambúes leñosos de la Selva Misionera. Seminario regional: Sistemática, silvicultura, cadena reproductiva y usos del bambú. San Miguel de Tucumán. Tucumán.

2006. Restauración de la estructura arbórea en un bosque primario invadido por bambúes leñosos dentro del Parque nacional Iguazú. Centro Operativo Área Cataratas. Administración de Parques Nacionales.

2005. Impacto de lianas y Bambúseas sobre la estructura y funcionamiento de la Selva Misionera: la importancia de restaurar el bosque nativo para su conservación. Ciclo abierto de Conferencias, Centro de Investigaciones Subtropicales. Administración de Parques Nacionales. Puerto Iguazú. Misiones. Argentina.

2004. Efecto de las Bambúseas sobre la biodiversidad del bosque. Ciclo abierto de Conferencias, Centro de Investigaciones Subtropicales. Administración de Parques Nacionales. Puerto Iguazú. Misiones, Argentina.

Cited Bibliography

Campanello, P.I., M.G. Gatti, Adrian Ares, L, Montti and G. Goldstein. 2007a. Bamboos and lianas affect tree regeneration and microclimate in a Semi-deciduous Atlantic Forest. Forest Ecology and Management (in press).

Campanello, P.I., M.G. Gatti and G. Goldstein. 2007b. Coordination between water transport efficiency and photosynthetic capacity in canopy tree species under different growth irradiances. Tree Physiology (in press).

Cochard, H., F.W. Ewers and M.T. Tyree. 1994. Water relations of a tropical vine-like bamboo (Rhipidocladum racemiflorum): root pressures, vulnerability to cavitation and seasonal changes in embolism. J. Exp. Botany, 45: 1085-1089.

Gatti, M.G. 2005. Ecofisiología de una palmera arbórea (Euterpe edulis) del Bosque Atlántico: crecimiento, fotosíntesis, arquitectura hidráulica y resistencia a las bajas temperaturas. 1-163. PhD Tesis, Universidad de Buenos Aires. Buenos Aires, Argentina.

Griscom, B.W., Ashton, P.M.S., 2003. Bamboo control of forest succession: Guadua sarcocarpa in southeastern Peru. For. Ecol. Manage. 175: 445-454.

Judziewics, E. J., L. G. Clark, L. J, and M. J. Stern. 1999. American Bamboos. Smithsonian Institution Press, Washington.

Lei, T.T. and T. Koike. 1998. Functional leaf phenotypes for shaded and open environments of a dominant dwarf bamboo (Sasa senanensis) in Northern Japan. Int. J. Plant Sci., 159: 812-820.

Ligier, H. D., Matteio, H. R., Polo, H. L., Rosso, J. R., 1990. Provincia de Misiones. In: Atlas de suelos de la República Argentina, Tomo II. Secretaría de Agricultura, Ganadería y Pesca. Proyecto PNUD Arg.85/019. INTA, Centro de Investigaciones de Recursos Naturales, 111-154.

Saha, S. & Howe, H.F. 2001. The bamboo fire cycle hypotesis: a comment. The American Naturalist Vol 158. N.6.

Tabarelli, M. and W. Mantovani. 2000. Gap-phase regeneration in a tropical montane forest: the effects of gap structure and bamboo species. Plant Ecology 148: 149-155.