Native forests, wildlife and water in Central Argentina: fostering public ecological understanding and forest restoration in Argentina

Final report: Booster Rufford Small Grant for Nature Conservation
Grantee: Daniel Renison and colleagues
Institution: ONG Ecosistemas argentinos

Summary. Forests of central Argentina have experienced one of the world highest deforestation rates in the last decades. This combined with a very dry series of years has produced serious soil erosion, dust storms, low water quality and quantity, and interestingly, the first public and political debates on the conservation and restoration of our forests. In this context we were very happy to receive our booster RSG. We promoted volunteer participation in forest restoration and fostered public ecological understanding giving over 25 conferences, producing and replicating educational material like booklets, 500 copies of DVDs with local documentaries, signposts for two trails and a newly created nature reserve. We also organized a forest workshop with scientists, public and government participation, and gave three restoration ecology courses. Members of our team were also very active collaborating in writing, explaining and lobbying for a forest conservation and restoration act first promoted by Greenpeace Argentina and which will soon be voted for at a provincial level – we hope favourably. Our activities and conferences were published or broadcasted in radio and TV on numerous occasions. The booster RSG also helped to conduct applied researches in forest restoration and we published 9 scientific articles where the RSGs are of course gratefully acknowledged.

Figure 1: A portion of Los Gigantes model restoration area, Central Argentina

Winter of 1997 – almost no trees

Winter of 2007 – darker round blobs in the grassland are planted Polylepis already more than 2 m tall

Autumn of 2009 – the large non-native pine trees beside the mountain lodge are gone

Main report: Introduction

I asked for a booster RSG because present day mountain forests of Central Argentina represent less than 5 % of their previous extension and in some areas more than 90% of their biomass is composed of exotic invasive species. This combined with a very dry series of years has produced serious soil erosion, dust storms, low water quality and quantity, and interestingly, the first public and political debates on the conservation and restoration of our forests. I aimed at contributing to the restoration of the native mountain forests of Central Argentina, and hence of wildlife, water quality and other valuable ecosystem services, by promoting volunteer participation in forest restoration, fostering public ecological understanding through conferences and educational material, organizing a forest workshop with scientists, public and government participation, organizing restoration ecology courses and by conducting two applied researches with the help of local students. Teem members performed these and other activities which I detail bellow.

Volunteer participation in restoration work

We worked mainly in two restoration areas the high mountains and three areas in the low mountains. For this we organized 14 volunteer groups of 6 to 35 people which worked 1 to 5 days in planting of native tree species, collection of seeds, transplanting vegetation to erosion gullies and thus attempting to reduce soil erosion, fixing and building wire fences to exclude livestock, fixing trails, cutting non-native trees and weeds and building a second green-house for the project. We used RSG funds to buy fencing materials, crow bars, spades, fuel for transport of seedlings and volunteers. In the few dates where we needed extra help we also paid for food, lodging and buss tickets of volunteers.

Area 1. Los Gigantes (2100 m asl). Consists of a 45 ha valley located in a beautiful mountain landscape and a popular area for project volunteers which are lodged in the area for free in a mountain lodge belonging to "Club Andino Córdoba" – a mountaineering group. The area can only be accessed by walking (3-4 hours) and was extremely degraded due to a combination of short growing seasons, fragile soils and 400 years of livestock grazing. Not only the climax Polylepis forests had disappeared in the area, but over 1/3 of the soils have been lost. Since 1997 the area is part of a provincial water reserve but under private ownership (the Nores family) that gave us permission to use part of their land as a model restoration area. We fenced the valley in successive stages from years 1997 to 2006. Over the years we planted 35 000 native tree seedlings, also shrubs and grasses. Today the area has much improved (figure 1) and represents a nice example of how ecosystems can be restored if the area is managed to initiate a succession leading to forests. Due to low temperatures and short growing seasons it will take over 100 years to have a mature forest – but in the mean time many attributes of the forests are being restored, as soils get less compacted, our 12 year old trees capture water from fogs and the biota associated to forests is starting to return (wood degrading fungi and birds).

During 2009 volunteer groups fixed fences and trails, and did a lot of hard work reducing slopes of large erosion gullies and planting grasses, forbs and trees within the gully (figure 2). Los Gigantes has few alien species –however much effort was put to eliminate a few oak, pine and salix trees which were planted in the area (some by me over 25 years ago when I did not know these species could become invasive and were not good for the conservation of the local biota). Also a few non-native forbs and berries were detected and pulled out. This restoration area is now mainly in charge of team members Ricardo Suarez, Julio Dominguez and myself.

Figure 2. Planting vegetation in erosion gullies to reduce soil erosion in Los Gigantes model restoration area.

Area 2. Quebrada del Condorito Nacional Park (2000 m asl). To help forest restoration within the Nacional Park starting from the year 2004 we have planted over 6000 tree seedlings (figure 3), as always with help of volunteers and in this case the children of a near by rural school who also produce seedlings in their green house. We have set up three experimental reforestation in the area: a *Polylepis australis* provenance test, an experiment to determine cattle effects and an experiment to determine whether the inoculation of micorrhiza is useful when reforestation is done in degraded areas (in this case by fire – see appendix 1). This restoration area is now mainly in charge of team members Carla Coutsiers, Florencia Soteras and Alejandra Becerra.

Figure 3: *P. australis* seedlings transplant to Quebrada del Condorito National Park by volunteers.

Area 3 Cuesta Blanca hills (800 m asl). The Bosque Serrano is the climax vegetation of the lower Córdoba mountains. It is dryer and more diverse than the high-mountain *Polylepis* forests. Here the main conservation concerns are human ignited fires, urbanizations and invasion by non-native species. In early 2009 we fenced of 4 ha in the Dominguez ranch at 800 m asl to plant late successional trees (*Lithraea molleoides, Schinopsis marginata* and *Ruprechtia apetala*). During the dry season a very large fire which was initiated 10 km away burnt the fenced area and many hundreds of ha more. This was a rather bad start but we fixed the fences and when the rains started we planted 3000 seedlings of the three native species in a provenance experiment to determine which tree seeds give the best progeny. This restoration area is now mainly in charge of team members Romina Torres and Julio Dominguez.

Area 4 Cuesta Blanca River Nature Reserve (750 m asl). Our mountains have several very beautiful rivers which are popular summer destinations for people from the cities to picnic, swim and rest in the beaches. The high tourist pressure together with buildings, mowing of the vegetation and 4 wheel drive vehicles which can access to the very river edges are destroying the river side forests. After several years of workshops and working with authorities we cooperated in the creation of a river reserve of 10 ha and in 2009-10 we planted 120 native tree seedlings of 7 species in areas now excluded from vehicles by the communal government. The exclusion was carried on through barriers, which were constructed using the wood of invasive elm-trees. We also cut dozens of other non-native trees whose branches and stems were used to protect native seedlings from animal browsing. A group of local volunteers take turns to cooperate with the communal wardens to look after the Nature Reserve during week-ends and talk to visitors explaining the project and asking for their cooperation in the maintenance of the area. This restoration area is now mainly in charge of team members Ana Cingolani and I.

Area 5 Roadsides of Río Ceballos (900 m asl). A large road that crosses the mountains was built in 2005-2008 and authorities were planning to plant non-native trees in the roadside. We initiated negotiations to instead plant native trees and volunteer groups planted around 4000 native seedlings which are protected with branches of non-native trees extremely abundant in Río Ceballos – more than 90% of the biomass. We hope this will be a good example of how native trees can also be roadside trees. This restoration area is mainly in charge of team member Ricardo Suarez.

Environmental Education and lobbying

During 2009 the Argentine provinces had the mission of implementing at the provincial level national forest conservation and restoration act. In our province many large companies working in agriculture were very active lobbying for a law which permitted forest opening for agriculture – under the argument that our forests were so degraded there was nothing to be lost. Given only 5% of our forests are still remaining this was inadmissible to people from the provincial conservation movements and many other people including other agriculturist did not agree with further forest conversion – and much was debated on whether these forests could or could not be restored. The year 2009 also brought as a very long drought season with the first severe dust storms, extremely low water levels, severe forest fires and water pollution – and the connection between some of these disasters (i.e. dust storms) with forest loss was soon in the media. As a consequence our team members were often invited to give conferences, courses and called upon by the media – we took advantage of this, and gave over 25 conferences – mainly in schools but also at the University, to general public and in one occasion to government officials. We were out on numerous occasions on TV and radio programs, and in 3 mayor newspapers articles. Team member Ricardo Suarez has also been very active collaborating in writing, explaining and lobbying for the implementation of the local forest conservation and restoration act which will soon be voted for at a provincial level – we hope favourably. Additionally, Ricardo organized a Regional Forest and Water Workshop was held in Río Ceballos during September 17, 18 and 19. Around 150 scientists, public and government officials attended.

Our environmental education activities also included the design by Pamela Chialva of educational signposts for two trails (Los Gigantes and Cuesta Blanca) which we are now in the process setting them up at the trail (Los Gigantes) or at an earlier stage of carving and painting the signposts (Cuesta Blanca). We also paid for several signposts in the newly created river nature reserve in Cuesta Blanca.

Additionally, Ricardo Suarez gave a Reforestation course in Río Ceballos (16 hours and 40 students), and I gave four Restoration Ecology courses: In Los Molles (16 hours, 15 students), Los Gigantes (16 hours, 15 students); Córdoba city (70 hours, 18 students) and in Bariloche city (40 hours, 38 students).

Funds from the RSG were used to buy a laptop and projector and when necessary to pay for travel to the conference sites. At conferences we distributed educational material like booklets and a total of 500 copies of DVDs with 2 local documentaries about nature conservation (elaborated in previous RSGs to Luis Volkmann and me). We also bought field guides which were used by volunteers, as educational material for six trekking outings organized for all public, and also donated to schools. For organizing the workshops we pay? Phone calls and travel too many localities to invite politicians and government officials to the meeting in Río Ceballos, and for bringing well known speakers like Juan C. Chébez and Raul Montenegro. We also paid for copies of CDs with the program and food for workshop attendants. RSGs were also used to contribute to other meetings in the context of the forest conservation and restoration law by printing maps to show to our representatives in congress and other activities. Expenses of restoration courses were paid by the students (travel, food, etc.) but RSG contributed with the laptop and projector and some of the educational material.


Applied researches

Studies financed by past RSGs 1 and 2 are now being accepted and published in scientific journals, to date 9 national and international articles have been accepted or published. The RSGs are of course gratefully acknowledged in all the articles which I list bellow:

1. Renison, D., Valladares G. Martella M.B. Germination of tree seeds as affected by their passage through the Greater Rhea (*Rhea americana*) gut: Implications for forest restoration. Emu (in press).
2. Landi, M., Renison, D. 2010. Forestation with *Polylepis australis* BITT. in eroded soils of the Sierras Grandes of Córdoba: testing the use of terraces and nurse vegetation. Ecología Austral (in press).
3. Aronson, J., Blignaut, J.N., de Groot, R., Clewell, A., Lowry II, P.P., Woodworth, P., Cowling, R.M., Renison, D., Farley, J., Fontaine, C., Tongway, D., Levy, S., Milton, S.J., Rangel, O., Debrincat, B., & Birkinshaw, C. 2010. The road to sustainability must bridge three great divides. *Annals of the New York Academy of Sciences* 1185: 225–236.
4. Menoyo, E., Renison, D., Becerra, A.G. 2009. Arbuscular mycorrhizas and performance of *Polylepis australis* trees in relation to livestock density. *Forest Ecology & Management* 258: 2676–2682.
5. Aronson, J., D. Renison, O. Rangel-Ch., S. Levy-Tacher, C. Ovalle, & A. Del Pozo 2007. Restauración del Capital Natural: Sin reservas no hay bienes y servicios. *Ecosistemas* 16: 15-24.
6. Menoyo, E., Becerra, A.G., Renison, D. 2007. Mycorrhizal associations in *Polylepis* woodlands of Central Argentina. *Canadian Journal of Botany* 85: 526-531.
7. Renison, D., Cingolani, A.M., Suarez, R., Menoyo, E., Coutsiers, C., Sobral, A., Hensen, I. 2005. The restoration of degraded mountain woodlands: effects of seed provenance and microsite characteristics on *Polylepis australis* seedling survival and growth in Central Argentina. *Restoration Ecology* 13: 129-135.
8. Renison, D., Cingolani, A.M. 2002. Optimización del crecimiento del tabaquillo (*Polylepis australis*, Rosaceae): selección de las mejores plantas semilleras. *AgriScientia* 19: 63-66.

9. Renison, D., Cingolani, A.M., Suarez, R. 2002. Efectos del fuego sobre un bosquecillo de *Polylepis australis* (Rosaceae) en las montañas de Córdoba, Argentina. *Revista Chilena de Historia Natural* 75: 719-727.

The current booster RSG was used to finance two studies. The first study is of PhD student Florencia Soteras under the supervision of Alejandra Becerra who is studying whether *Polylepis australis* seedling need inoculation of micorrhiza to booster their growth. This study is explained in detail in Anex 1, and funds from RSG were used for paying for expensive soil analysis, field trips for volunteers who helped collect and transport soils and to plant the inoculated seedlings. The second study is of graduate student Tatiana Valfré who is studying the best methods to germinate seeds of *Sebastiania commersoniana* a native tree with good potential to use as ornamental and fences. This study is ongoing and funds from the RSG were used to repair and maintain our experimental germinator and associated computer, bye Petri dishes and other lab materials.

New projects derived from the RSGs and networking

The 12 years of functioning of our project – mainly financed by RSGs – besides contributing to 15 restoration areas in which I have personally been involved, has stimulated several other initiatives. (1) Pablo Friedlander and Jerónimo Segura from the locality of Los Molles since 2008 are leading a similar project to ours. This project was inspired by our restoration area in Los Gigantes and is run in a similar manner with volunteers. (2) Daniela Marina, an attendant to a Restoration Ecology course I have in 2007 decided to do a PhD study contributing to the Restoration of invaded areas of Southern Córdoba – in part inspired by the course and the restoration example in Los Gigantes. (3) Julio Dominguez since 2007 started a similar project in the mountains of northern Argentina – centered in a school and with a large environmental education component (the present booster RSG helped to finance a small part of this project – mainly travel and fencing material). (4) Romina Torres, Carla Coutsiers, Irene Lett and Paula Marcora in 2007 started several nice environmental education projects working in reforestation with school children. They have all been my students at the University and are currently doing their PhDs under my supervision. (5) Marcos Landi, who did his graduation thesis with funds from a previous RSG to myself is now seeking funds to start a big reforestation project in the locality of Tanti and has participated as a professor in several reforestation and restoration courses. All the involved people keep in touch and announce the volunteer activities in a coordinated mail system.

Annex 1. Preliminary results of research project funded by RSG

Title: Effectiveness of Arbuscular mycorrhizal fungi inoculum on *Polylepis australis* establishment in degraded areas of the highest mountains of central Argentina.

Polylepis (Rosaceae) forests are restricted to the higher mountains regions of South America from Venezuela to Argentina (Simpson 1979) and they belong to one of the most endangered ecosystems in the world (UNEP-WCMC 2004) (Fjeldså & Kessler 1996; Renison *et al.* 2002a; Enrico *et al.* 2004). *Polylepis australis* Bitt. ("tabaquillo" o "queñoa"), the southernmost specie of the genus, is endemic to central Argentina (Luti *et al.* 1979; Cabido & Acosta 1985). *P. australis* forests are restricted to rocky outcrops, where they are protected from livestock and burning (Renison *et al.* 2006; Cingolani *et al.* 2008). Consequently, woodlands restoration and conservation are urgently needed in the Sierras Grandes de Córdoba (APN 2004).

In the reclamation of degraded ecosystems is necessary to consider plant community and indigenous organisms (Wardle 2002). Arbuscular Mycorrhizal Fungi (AMF), belonging to the Phylum Glomeromycota, are one of the most important soil microorganisms due to their direct effect on plant-soil processes (Fitter *et al.* 2000; Schüβler *et al.* 2001).

AMF colonize almost the 80% of vascular plants (Smith & Read 2008; Wang & Qui 2006), and this fungi influence in soil stabilization, plant composition, ecosystem productivity, diversity and sustainability (van der Heijden *et al.* 1998).

In degraded lands, reforestation with indigenous microorganisms - such as AMF - can play an important role restoring woodlands diversity (Perry & Amaranthus 1990; Haselwandter 1997; Dobson *et al.* 1997). In Latin America, degraded land restoration projects with AMF inoculation have been conducted (Cuenca *et al.* 1998; Cuenca *et al.* 2003; Sánchez-Álvarez *et al.* 2007; White *et al.* 2008). In central Argentina mountains restorations and conservations programmes of *P. australis* woodlands are being carried out since 1997 and it is desirable to accelerate seedlings establishment and growth (Renison *et al.* 2002b, 2005).

The aim of this project was to evaluate *P. australis* establishment and growth in degraded areas of the Córdoba Mountains, inoculating the seedlings with three different inoculums (from a degraded forest, a mature forest and a grassland community).

<u>Activities carried out</u>

During autumn (May 2009) soil samples of ~ 300 g (n = 10 samples in each vegetation type) were collected to 10 cm depth at the river basin "Los Molles" (2100 m.a.s.l; 31º58'S, 64º56'W), situated in the west side of the Córdoba mountains, central Argentina (Fig. 1).

Figure 1: Degraded (a) and mature (b) *P. australis* forests and grassland community (c) in the river basin "Los Molles", central Argentina.

The following soil measurements were performed: electrical conductivity (mmhos/cm), moisture equivalent (%), extractable P (Jackson 1964), pH, organic matter (Nelson & Sommers 1982), Nitrogen (%), Carbon (%), Calcium (meq/100g), Magnesium (meq/100g), Sodium (meq/100g), Potassium (meq/100g) and Cation Exchange Capacity (Table 1).

Soils of the three vegetation types were lightly acidic, with high C and N contents and very low Cation Exchange Capacity. The levels of P were significantly different between three vegetation types ($P< 0.005$), being very low in degraded forest (DF), low in grassland community (G) and moderate in mature forest (MF). Soils of DF had the highest organic matter content and moisture equivalent.

Table 1: Soil properties of the three vegetation types (degraded forest (DF), mature forest (MF) and grassland community (G)).

Parameters [a]	DF	MF	G
C (%)	9.69 ± 0.80	7.30 ± 0.99	5.55 ± 0.36
OM (%)	16.68 ± 1.39	12.62 ± 1.71	9.53 ± 0.61
N (%)	0.81 ± 0.07	0.56 ± 0.08	0.51 ± 0.03
C/N relation	11.99 ± 0.29	13.16 ± 0.61	11.05 ± 0.26
pH 1:2.5	5.85 ± 0.09	5.90 ± 0.07	6.23 ± 0.04
ME	42.17 ± 2.88	29.79 ± 3.81	25.36 ± 1.93
EC (mmhos/cm)	0.38 ± 0.07	0.30 ± 0.05	0.28 ± 0.03
Ca (meq/100g)	18.66 ± 2.69	21.97 ± 3.11	16.53 ± 1.60
Mg (meq/100g)	2.16 ± 0.37	2.08 ± 0.35	1.48 ± 0.16
Na (meq/100g)	0.36 ± 0.05	0.18 ± 0.02	0.16 ± 0.02
K (meq/100g)	1.63 ± 0.29	0.47 ± 0.10	0.59 ± 0.06
P (p.p.m)	4.41 ± 1.87	16.87 ± 1.25	10.24 ± 0.37
CEC	0,32 ± 0,03	0,32 ± 0,04	0,23 ± 0,02

[a] Mean values of 10 samples ± standard error. C: Carbon, OM: organic matter, N: Nitrogen, C/N: Carbon/Nitrogen relation, ME: moisture equivalent, EC: electrical conductivity, Ca : Calcium, Mg : Magnesium, Na : Sodium, K : potassium, P : phosphorus, CEC: Cation Exchange Capacity.

Between February and March of 2009, *P. australis* seeds were collected in Los Gigantes (1900 m.a.s.l ; 31º82’S, 64º84’W) and put on plastic plates with sterilized soil (Fig. 2).

After four months seedlings were transplanted to black pots (19 x 9 cm in diameter). Each pot was filled approximately 5 cm from the top with sterilized soil and 25 g with the mycorrhizal inoculum (except in control pots) (Gillespie & Allen 2006). The mycorrhizal inoculum contained AMF spores (Fig. 3), infected root fragments and hyphae. Three treatments were established: degraded forest, mature forest, grassland community and control, without inoculum added (4 inoculum treatments x 60 replicates = 240 pots) (Fig. 4).

Figure 2: *P. australis* seeds were put on plastic plates with sterilized soil.

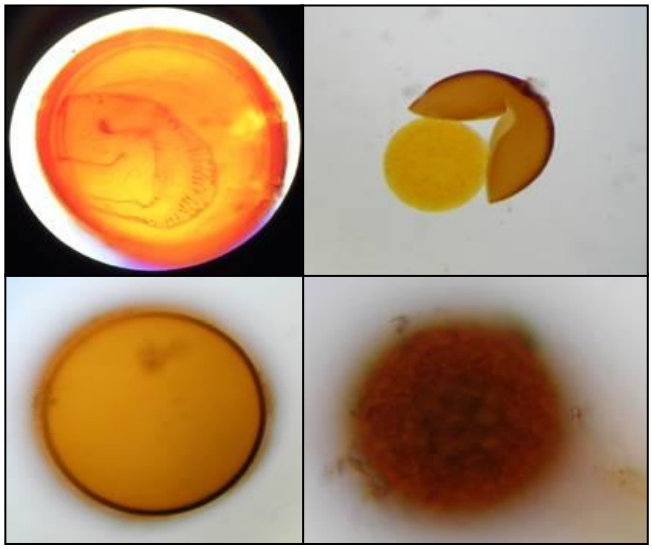

Figure 3: AMF spores found in soil inoculums collected at the river basin "Los Molles" (2100 m.a.s.l; 31º58'S, 64º56'W)

Figure 4: *P. australis* inoculation (a) and transplant to black pots of 19 x 9 cm in diameter (b).

During wet season *P. australis* seedlings were transplanted to a recently burnt site in Quebrada del Condorito National Park (Fig. 5).

Figure 5: Quebrada del Condorito National Park, site burnt in August of 2009, and measuring seedling height after planting.

Preliminary results showed that seedlings inoculated with AMF from the grassland community showed the highest growth (Fig. 6).

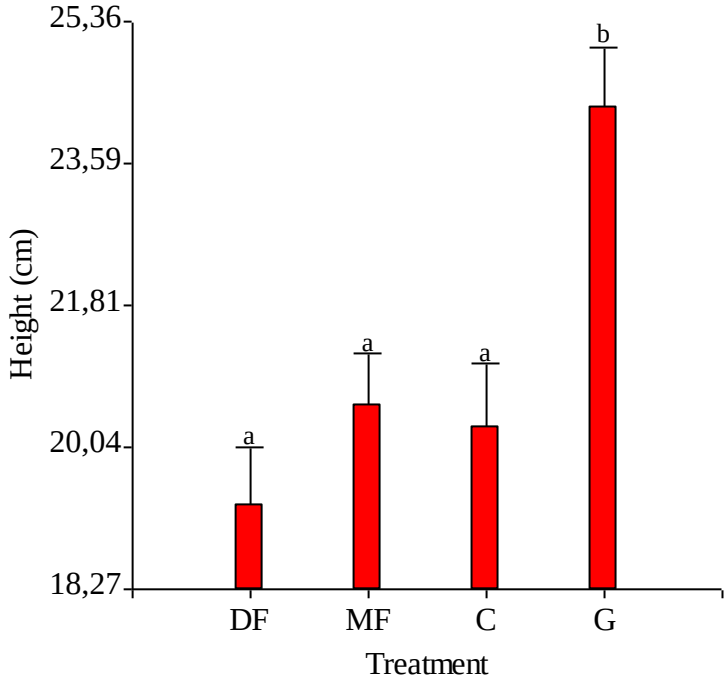

Figure 6: Height of *P. australis* seedlings inoculated with AMF from a degraded forest (DF), a mature forest (MF), a grassland community (G) and without AMF inoculum, control (C), and transplanted to Quebrada del Condorito National Park. Different letters indicate significantly differences ($p < 0,005$).

Future activities

During three consecutive years (2010-2012) after transplanting, in spring and autumn, height, survival, AMF diversity and colonization of the seedlings will be measured. We predict that the AMF inoculum from grassland community will have the highest amount of infective propagules and will promote the highest *P. australis* growth.

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