The Rufford Foundation
Final Report

Congratulations on the completion of your project that was supported by The Rufford Foundation.

We ask all grant recipients to complete a Final Report Form that helps us to gauge the success of our grant giving. The Final Report must be sent in **word format** and not PDF format or any other format. We understand that projects often do not follow the predicted course but knowledge of your experiences is valuable to us and others who may be undertaking similar work. Please be as honest as you can in answering the questions – remember that negative experiences are just as valuable as positive ones if they help others to learn from them.

Please complete the form in English and be as clear and concise as you can. Please note that the information may be edited for clarity. We will ask for further information if required. If you have any other materials produced by the project, particularly a few relevant photographs, please send these to us separately.

Please submit your final report to jane@rufford.org.

Thank you for your help.

Josh Cole, Grants Director

Grant Recipient Details	
Your name	Iglesias Aimé Lucila
Project title	Climate variability as a driver of pine invasion: Potential management tools at an initial invasion stage in north-western Patagonia
RSG reference	25441-1
Reporting period	June 2018 – June 2019
Amount of grant	4990
Your email address	iglesias.aime@comahue-conicet.gob.ar
Date of this report	20 August 2019

1. Please indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Develop a field experiment to evaluate the responses of pine establishment and early performance to temperature and moisture variability				I was able to conduct the field experiment.
Evaluate seedling emergence, and seedling and sapling survival				I measured seedling emergence and survival of *Pinus contorta* and *Pinus ponderosa* during a full growing season. I obtained relevant results from this experiment (point 3)(Figure 1)
Evaluate the final aerial biomass and final height and diameter to assess establishment success and early performance in all four treatments				I measured the aerial and root biomass of the surviving saplings, I didn't find any relationship between treatment and these traits.
sample invasion areas next to pine plantations				I was able to sample 20 sites, distributed in the provinces of Rio Negro and Neuquen.
assess attributes of selected trees (height, diameter at breast height and at ground height, and cone presence)				I assessed these attributes at each sample site, but until now I didn't analyse these data. (Figure 2 and 3)
Obtain stem disk samples or tree-ring cores for each tree, and determine year of establishment.				I collected almost 1800 stem disks, currently, I dried and sanded these disks. (Figure 2)
Evaluate climatic variability effects on tree encroachment.				I need data from the stem disks to achieve this objective.
Communicate the results of this project to the scientific community				I presented our research project to university students, professors and researchers during a conference at the National University of Comahue. I

				also shared some of the findings of this project in two international scientific meetings: Valdivia (Chile) and Ushuaia (Argentina).
Presentation of results to the local communities				We provided the result of the experiment and discuss the invasion of pines in natural areas to land owners and managers, as well as the importance of manage invasion in these areas. I plan to hold a workshop with the owners of the fields for the next spring in order to tell them about the results obtained and thus be able to discuss possible management strategies related to the project. I will also participate in August 2019 in the "Open INIBIOMA" where the primary schools of the city participate and there are activities and games on the different topics worked in the institute.
Publish the results of this project in a peer-reviewed international journal and in a local journal				We need the full data and the analyses data about these objectives.

2. Please explain any unforeseen difficulties that arose during the project and how these were tackled (if relevant).

During August 2018 there was a significant currency devaluation in Argentina (nearly 35%), as result, this generated an increase of the values compared to the initially presented budget, particularly, of the main materials used for the open top chamber and chainsaw, as well as all the materials budgeted, like fuel, travel and the cost/payment of the assistants.

I also had to include rodent enclosures as an additional cost to prevent seed predation as well as a fence to prevent the entry of large animals (hares, cows, deer, and wild pig) in order to protect the establishment's experiment. This situation led us to decide to reduce the number of sites sampled in the field, due to a combination of the difficulty of accessing the sites and the lack of budget to complete the expected number. Also, to reduce costs I decided not to buy materials as Garmin GPS, such as clinometer, and drilling materials, and temperature sensors were provided by colleagues in the laboratory.

The difficulty of access the site generated a delay in processing the tree samples and consequently in the analysis of results regarding the relationship between successful establishment and growth and climatic variability over time.

I also had to incorporate expenses due to the fact that I consider it very important that the field assistants have life insurance, as well as a higher amount due to the physical capabilities required to perform the work with a chainsaw. This implied that in order to assess some of the sites I had to be accompanied by two assistants. In addition, I had to ask for help in the collection of the samples of the experiment as well as in the processing of those samples (roots and aerial parts), and in the sanding of stem disk sample.

I have considered to use a small portion of the grant in fuel and field assistant, to evaluate the reinvasion of *Pinus contorta* and *Pinus ponderosa* in post-extraction areas with varying degrees of prior invasion. These areas had different degrees of invasion (575 to 14500 ind/ha) of *P. ponderosa* and *P. contorta* and during the years 2014-2015 they were entirely thinned in a 20 x 20 plot. Considering it important to take advantage of this experimental situation at a landscape scale in order to evaluate the reinvasion state after 5 years. The removal of invasive individuals and the subsequent recolonisation or restoration of native vegetation are the main objectives in the management of areas invaded by exotic conifers. The management of the invasion of exotic conifers, mainly species of the genus *Pinus*, is a challenge little explored in the Patagonian region. For this purpose, during the summer of 2018-2019 I studied the total reinvasion density, age, reproductive stage, total biomass, and the presence and identity of both native and exotic herbaceous and shrub species.

3. Briefly describe the three most important outcomes of your project.

1. Our study provides significant insight regarding the effects of climate change in emerged seedling and survival of invasive pine species, specifically *Pinus contorta* and *P. ponderosa*. Currently *P. contorta* is the most invasive pine species in Patagonia, in Argentina it represents less than 10% of the plantations. However, in a climate change scenario the main species *P. ponderosa* with 90% of the plantations could increase its invasiveness and become a concerning scenario.
2. We found greater survival *of P. ponderosa* compared to *P. contorta* in all treatments. These results suggest a higher resistance of *P. ponderosa* to an increase in temperature, which may be associated to a higher invasion potential in the context of climate change. *P. ponderosa* in Patagonia is the dominant forest plantation and is the main species used for new plantations, currently *P. ponderosa* presents only local invasion foci, and it is not considered an invasive species. These results should be considered when increasing the control of areas adjacent to forestations and when continuing with the installation of new areas forested with this species.
3. *Pinus contorta* is one of the main species planted in the region and is considered one of the most invasive species in the world. The results obtained in the experiment show us that *Pinus contorta* could compensate for its low survival with a high seeding emergence independent of the climatic characteristics of the season. This species presented a high seedling emergence independently of treatments, but the survival at the end of the season was low in all treatments. This should result in an increased control of

the invaded areas since the climate would not generate a restriction on the expansion of the invaded areas.

4. Briefly describe the involvement of local communities and how they have benefitted from the project (if relevant).

I tried to increase the involvement of the local and regional community in this project and I have had many successes:

When I developed the fieldwork I had interacted with and involved the owners and managers and their concern about the invasion of pines in natural areas, as well as the importance of management and control of these areas. I am planning to complete sample analysis and data analysis by next spring in order to hold a workshop with the owners of the fields to inform them about the results obtained in full and thus be able to discuss possible management strategies related to the project.

In November 2018 I presented preliminary results in the Joint Conference on Forests and Water 2018, which was a joint meeting of II Congreso Latinoamericano Bosques y Agua and V IUFRO Conference on Forests and Water in a Changing Environment (www.forestsandwater2018.cl) in Valdivia, Chile. I presented the project "Establecimiento de especies forestales invasoras en un contexto de cambio climático" explaining the objectives and preliminary results from experiment regarding the responses of pine establishment and early performance to temperature and moisture variability.

In April 2019 I presented results about re-invasion of *Pinus contorta* and *Pinus ponderosa* in post-removal areas with different degrees of the previous invasion in the scientific meeting "IV Jornadas Forestales de Patagonia Sur y IV Congreso Internacional Agroforestal Patagónico" (https://www.jfps-ciap2019.com/). In this meeting, members of the Ministry of Agroindustry from Argentina expressed their interest in the results obtained, as well as their intention to continue working together in the project.

Also, in May 2019, I presented my research project to assess the invasive capacity of *P. ponderosa* and *P. contorta* in a context of climate change at a seminar at the National University of Comahue. The audience of this conference were mainly students, professors, and researchers from the University. Again, I received very valuable feedback on my research.

I will also contribute in the "Open INIBIOMA" in August 2019 where the primary schools of the city participate and there are activities and games related to the different topics worked in the institute. In this case we will teach the students on the growth differences between native and exotic species as well as the differences between native forests and exotic forests, so that children and teachers have knowledge about the differences between native and exotic species, learn how in this region the trees show the years they have and how an exotic species grows and

reproduces before the natives, generating awareness about the use of exotic and invasive species.

5. Are there any plans to continue this work?

We are highly motivated by the future plans of this work, focused on different aspects of pine invasions. As the most relevant next step, we are planning to experimentally evaluate the mechanisms by which non-native invasive microbial communities may favour or hinder the invasion of non-native pine species under a climate change scenario. Pines are an ideal system to study this, as they are obligate symbionts with ectomycorrhizal fungi (EMF), and without them, their invasion is hindered. EMF provide nutrients, water, and defence against pathogens to their plant hosts. As both pines and EMF disperse independently, and many EMF species have highly resistant propagules, fungal symbionts are able to convert native communities into vulnerable sites for pine invasion, with negative impacts above and below ground. This set of complex interactions may vary in a climate change context.

Recent evidence shows that the invasion of microbial taxa adapted to harsh conditions may provide additional tolerance to plant populations facing these conditions. It could be expected that the invasion of pine associated EMF may potentiate their invasion due to an increased tolerance to changes in temperature and humidity. Specifically, we will ask: is ectomycorrhizal colonization of pine-trees favoured under conditions that simulate climate change? If so, which EMF species are involved? In turn, is plant performance optimised due to this higher colonisation under climate change conditions? For this purpose, we plan to carry out complementary studies of establishment, survival, and growth of pine species, both in growth chambers with controlled conditions and in the field using the open top chambers (OTC) obtained by this subsidy. This combined experimental approach would allow us to capture the possible variations in EMF community due to different forms of pines root colonization (i.e. spore colonization favoured in the growth chamber and mycelia colonisation considered in the field). Different temperatures and water regimes will be addressed to evaluate differential responses in the establishment and growth of pines and their colonisation by EMF. Paired with that, and taking advantage of the experience of our group in pine-EMF co-invasion, we will be able to know the identity of EMF species colonising pines roots by means of simple fungal DNA analysis techniques. This will allow us to evaluate possible changes in EMF species composition due to variations in temperature and water availability.

We believe that these studies complement and provide the information needed to establish strategies to manage the invasion of exotic conifers at a regional scale in the context of climate change. Moreover, the proposed approach provides relevant information for predicting the directions of conifer invasions in Patagonia region and in other areas of the world where climate change projections generate changes in temperatures and average rainfall. The results obtained in the current project need to be complemented in order to establish what would be the responses of invasive pine species to climatic conditions considering their interaction

with belowground biota. Combining two different aspects of global change: climate change and invasive species, and with a focus on plants below-ground interactions, this work may contribute to the understanding of how microbial interactions may potentially exacerbate or mitigate challenges to plant populations caused by climate change.

6. How do you plan to share the results of your work with others?

Outreach: Together with the "Laboratorio de Investigación en Ecología de Bosques" I will conduct outreach activities in local communities where adults and children can participate. Also, I am planning for the next spring to hold a workshop with the owners of the fields in order to inform them about the results obtained in full and thus be able to discuss possible management strategies related to the project.

Scientific dissemination: results will be presented in other national and international conferences. I expect to publish at least three papers in peer-reviewed journals and in a regional journal, as the Journal of Patagonia Andina forestal (http://patagoniaandinaforestal.blogspot.com/p/revista-produccion-forestal-nro.html), which is a space for the dissemination of information and forestry activities in the Andean Patagonia Region.

I expect to publish the results of this work in three different papers in peer-reviewed: one focusing on the invasive capacity of coniferous species in a context of climate change, using the results of the field experiment, a second one regarding the relationship between climatic variation and successful establishment and growth of invasive exotic conifers, and the third focusing on the management and reinvasion of exotic conifers in the region.

Scientific network: During the development of this project I have shared my objectives, questions, and results with researchers from other parts of the country and the world interested in this problem, researchers working on similar problems in countries such as Chile and South Africa. As well as researchers who work in the areas of native distribution of these species but who recognise as a problem on a global scale that needs to be further investigated in depth. These interactions have allowed me and will allow me to discuss the results of my work and generate a greater spread of the results obtained in other regions working on this problem.

7. Timescale: Over what period was The Rufford Foundation grant used? How does this compare to the anticipated or actual length of the project?

The grant was used over a period of a bit more than 1 year. The main part of the equipment was bought in July and August 2018. Field work was conducted between November 2018 and May 2019. Principal part of laboratory work was conducted from June to August 2019. The whole project started on July 2018 and will last till October, November 2019, when I plan to end the analysis and present the results to local community and the owners and managers interested. Compared to the expected schedule the project will be extended for approximately 4 additional

months, due to the analysis of dendrochronological samples and the corresponding analysis of data and dissemination of results.

8. Budget: Please provide a breakdown of budgeted versus actual expenditure and the reasons for any differences. All figures should be in £ sterling, indicating the local exchange rate used.

Item	Budgeted Amount	Actual Amount	Difference	Comments
Fuel (field truck)	420	486	+66	The devaluation of the Argentinian Peso generated an increase in the fuel cost
Food for fieldwork 30d x 3 £	90	200	+110	The increase in food value for devaluation was sharp, and also in some case implicate food for 3 people.
Field assistant (£40 per day for 30 days)	1200	1430	+230	Field work includes assistance with experiments, field work and preparation of materials for the experiment (fence and rodent enclosure), as well as sample processing.
insurance for field assistants six months	0	100	+100	The use of a chainsaw implies a risk inherent to the use and it was, therefore, necessary to incorporate this item.
Field truck and chainsaw maintenance	0	200	+200	The field truck had a mechanical issue during the summer, and we had to fix it to carry on with the fieldwork. And the chainsaw needs maintenance for field use.
Open Top Chamber - 3mm-Plexiglass Acrylic Sheets (LEXAN® Plazit, 2UV-protected polycarbonate) (x20)	560	1784	+1224	The devaluation in Argentina generated a very sharp increase in this item. At the same time, we had not contemplated in the budget the transport from the capital (Buenos Aires) to Bariloche as well as the cuts of each panel.
Tools and materials (plastic flagging tape, plastic band seals, straw and wooden mounts for cores, tubes,	150	96	-54	It was not necessary to use materials for the cores because there were few samples of this type, and I had some materials

wire)				for this.
Extra supplies (sharpie, paper tapes, Insulating tapes, pencils, plastic boxes, paper bags)		90	+90	We had not considered the need for various field materials for marking, transport, and preservation of samples.
Fence		180	+180	Was necessary to build a fence to protect the experiment since the field has the presence of hares, exotic deer, and raise cattle and sheep, which could damage the OTC as well as consume the plants.
Rodent enclosure		170	+170	To prevent rodents from consuming the seeds at the site of the experiment we had to build enclosures using a metallic mesh.
Pine Seeds and saplings	80	50	-30	Reducing the number of replicas and seedlings used for each replica the cost of this item was lower.
Sandpaper sheets and belts	80	50	-30	A co-worker shared several of the sandpapers with me so it was not necessary to buy all of them.
Curve Pruning saw and machete tool	18	20	+2	
HUSQVARNA 440 15" 40.9cc X-Torq Petrol Chainsaw	293	410	+117	We changed brand and model for cost reasons and characteristics such as weight and the presence of official distributors in Bariloche, we select Chainsaw Stihl MS 210.
Safety and accessories supplies for the use of the chainsaw (gloves, glasses, oil, Sharpening set, etc.)		100	+100	We considered buying these supplements that had not been budgeted.
Metric Fabric Diameter Tape (x2)	64		-64	These materials have been provided by colleagues
iButton Hygrochron Temperature/Humidity Logger (x10)	1050		-1050	
Haglöf EC II-D Electronic Clinometers	182		-182	
Haglöf Replacement Steel Bit, 2-Thread, 400mm (x1)	165		-165	

Haglöf Borer 5.15mm 2 Thread, 400mm (10-100-1027) (x2)	412		-412	
Garmin GPSMAP 64s GPS	226		-226	
National Bank commission and taxes	0	33.5	+33.5	
Total	**4990**	**5400**	**400**	We spent more than estimated in the initial budget, which we explain in detail on the budget comments under point 2. We supplement these additional expenses with external funding as my salary.
Currency exchange rate fluctuate during these years (July 2018 – Jun 2019): ARS$ 36 = £1 (July 2018), ARS$ 48 = £1 (November 2018), ARS$ 56 = £1 (July 2019).				

9. Looking ahead, what do you feel are the important next steps?

The next most important step is to achieve the unfinished objectives, finalise the analysis of dendrochronological samples and be able to know if there is a relationship between the establishment and growth and climate variations over time. We hope that these results give us some pattern that provides us with tools to develop predictive models. The set of the obtained results could allow to generate greater conscience and interest in carrying out practices of management and control of the invaded areas. In turn, in the region are developing various projects for the use of forest waste, which would be of great importance for the management of invaded areas and the use of these wastes in the generation of biofuels (pellets), which are currently at an initial stage of development in the region https://maderamen.com.ar/desarrollo-forestal/2019/04/22/biocombustibles-solidos-forestal-en-patagonia/. Also as next steps we prioritise the publication of the results in peer-reviewed journal and in the organisation of a workshop with those interested in the problem in order to share management strategies, and that the government institutions linked to forestry promote and support with incentives the control of these areas.

10. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did The Rufford Foundation receive any publicity during the course of your work?

I used The Rufford Foundation logo when I presented results at the Joint Conference on Forests and Water 2018, which was a joint meeting of II Congreso Latinoamericano Bosques y Agua and V IUFRO Conference on Forests and Water in a Changing Environment in Valdivia, Chile. I also used the logo in the international Congress "IV Jornadas Forestales de Patagonia Sur y IV Congreso Internacional Agroforestal Patagónico" in Ushuaia (Argentina). I also included the logo on my presentation at the seminar in the National University of Comahue. Finally, I will use the logo in INIBIOMA ABIERTO, and we will use the logo in the future

workshop we will organize with forestry local stakeholders from north Patagonia and on the manuscripts that I will write.

11. Please provide a full list of all the members of your team and briefly what was their role in the project.

Lic. Aimé Lucila Iglesias (INIBIOMA-UNCOMA-CONICET): Main leader of the project and doctoral researcher. I designed the project, performed experimental and fieldwork, also I working in the data analysis and writing of main reports.

Dr. Juan Paritsis (INIBIOMA-UNCOMA-CONICET): Researcher-Advisor. He helped to design the main project, particularly in aspects related to the development of the field experiment, as well as the selection of sampling sites and the development of the correct methodologies, and also in the discussion and interpretation of the results obtained.

Dr. Martín Andrés Nuñez (INIBIOMA-UNCOMA-CONICET): Researcher-Advisor. He helped to design the main project, particularly as regards assistance with aspects related to the conceptual framework and he provided me part of the equipment used for the experiment. He also contributed in the discussion and interpretation of the results obtained.

Pablo Alvear (INIBIOMA-CONICET) Technicians. He helped with fieldwork and field experiment.

Mariano Cruz Costa, Lucas Velez Ponce and **Ismael Pazos Gonzales** (freelance Technicians) they helped in field work, particularly in stem disk collection, and sanded steam disk. Dra. Priscila Edwards helped me on roots and aerial biomass processing.

12. Any other comments?

Yes, we would like to thank the Rufford Foundation for the grant received, as it was fundamental for accomplishing the project objectives with sound scientific bases. Without the support from the Rufford Foundation, we would not have been able to achieve our objectives. Another important point is that Argentina is currently witnessing one of the most profound economic crisis in the last decades, that is particularly affecting the scientific and conservation sector due to the political measures implemented to solve this crisis and, because of that, getting funding for scientific projects has become a real challenge. We believe that the Rufford Foundation plays a very important role funding research in developing countries, where research is most needed and economic resources are usually scarce. I hope to apply again for a RSG in the near future.

Figure 1. Experiment to evaluate the responses of pine establishment and early performance to temperature and moisture variability, seedling emerged of *Pinus ponderosa* and *P. contorta* in field experiment, and *Pinus contorta* sapling.

Figure 2. Field work to evaluate effects of climatic variability on tree invasion.

Figure 3: Invaded areas next to pine plantation.