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# PLANNING AND IMPLEMENTATION INITIATIVES FOR AN AFFORESTATION PROJECT IN AN ARID ENVIRONMENT, NORTHERN CHILE

**D.M. Mchaina, Ph.D., P.Eng.**

Boliden Limited
Suite 1500 West Tower
3300 Bloor Street West
Toronto, ON M8X 2X2

**G. Roman Serra**

Compaiña Minera Lomas Bayas Ltda.
Galleguillos Lorca 1610
Antofagasta, Chile

## ABSTRACT

This paper describes a community forest project located in the township of Calama, Region II, Northern Chile. The project was initiated in 1996 with a goal to create a 100 hectares of self-sustaining forested ecosystem for a valued oasis in the Atacama Desert. The objectives of the project are: to create a self-sustaining ecosystem with minimal maintenance using native plant species that are drought resistant and to undertake initiatives that will speed up natural successional changes. To meet the above objectives, a local drought-resistant species known as 'algarrobo' *(Prosopis chilensis)* was selected for the project.

The afforestation program includes key elements such as seed preparation; sowing of seeds in greenhouse containers and maintenance; land preparation; transplanting the individual seedlings into the field; and on-going field maintenance and monitoring.

## INTRODUCTION

The purpose of the project is to establish a stand of forest trees to preserve the Rio Loa oasis, improve the environment and presumably produce timber for fire wood production.

Leguminous trees of the genus *Prosopis* fmesquite) were selected for the project and they are well adapted to heat and drought stresses, and have potential for fire wood production, forage production, and increasing the fertility of soils through nitrogen fixation in arid regions. *Prosopis Chilensis* fixes nitrogen and grows well at extreme salinity. The tree normally reaches an average height of 15 metres. The roots can go as deep as 10 metres in search of underground water.

The afforestation project involves the planting of 10,000 trees covering an area of 100 hectares. Before the project was initiated the relevant stakeholders such as the National Forest Commission (CONAF) and the public were consulted for their input. CONAF reviewed the project as part of the environmental impact statement submission and strongly provided all the required support for the planning and implementation of the project. CONAF promotes afforestation programs on a large scale in these areas with the expectation of active participation by the private sector. Boliden's contribution toward the CONAF initiative is quite significant. For example, CONAF plans to plant trees in 800 hectares for the coming five years and Boliden's contribution (100 hectares) translates to approximately 12.50% of the CONAF reforestation target.

The overall objective of this project is to enhance the ecological, biological and climatic contributions through the introduction of forest resources. An increasing vegetation cover would promote and stabilize the hydrological balance in the oasis areas and maintain land quality and productivity.

Prevention of not yet degraded oasis through the introduction of environmentally sound, socially acceptable, fair and economical land use systems is critical. This will enhance the land carrying capacity and maintenance of biotic resources in fragile ecosystems. This approach establishes an ecologically-based man-made artificial ecosystem in desertified environments leading to partial amelioration of arid environments. This concept represents a continuous manipulation process, controlled by natural succession and managed by man.

The overall program has financing of U.S. $1 200 000 and has an overall duration of at least five years.

## LOCATION

The project is located in the Atacama Desert, Region II, Chile. Region II is an extremely arid area in Northern Chile and is one of the driest on the planet (some parts with no rain at all for more than 50 years). The project is specifically situated in an oasis in Calama, as shown in Figure 1. The oasis is recharged by water from the "Rio Loa" which derives its water from the so-called "Bolivian winter" in the Andean High Plateau. This area has problems of marginal productivity due to poor climatic and soil conditions.

The soils in the oasis have typical characteristics of those with a lacustran origin (stratified, moderate depth, fine texture, clays) strongly impregnated with salts (Na, Ca, Mg, K) and a flat saline hardpan or surface crust with a thickness often greater than 50 cm and of irregular micro-relief. Under the salt basin, the existence of subterranean aquifers that do not vary much in depth constitutes the main source of water for the tree plantations.

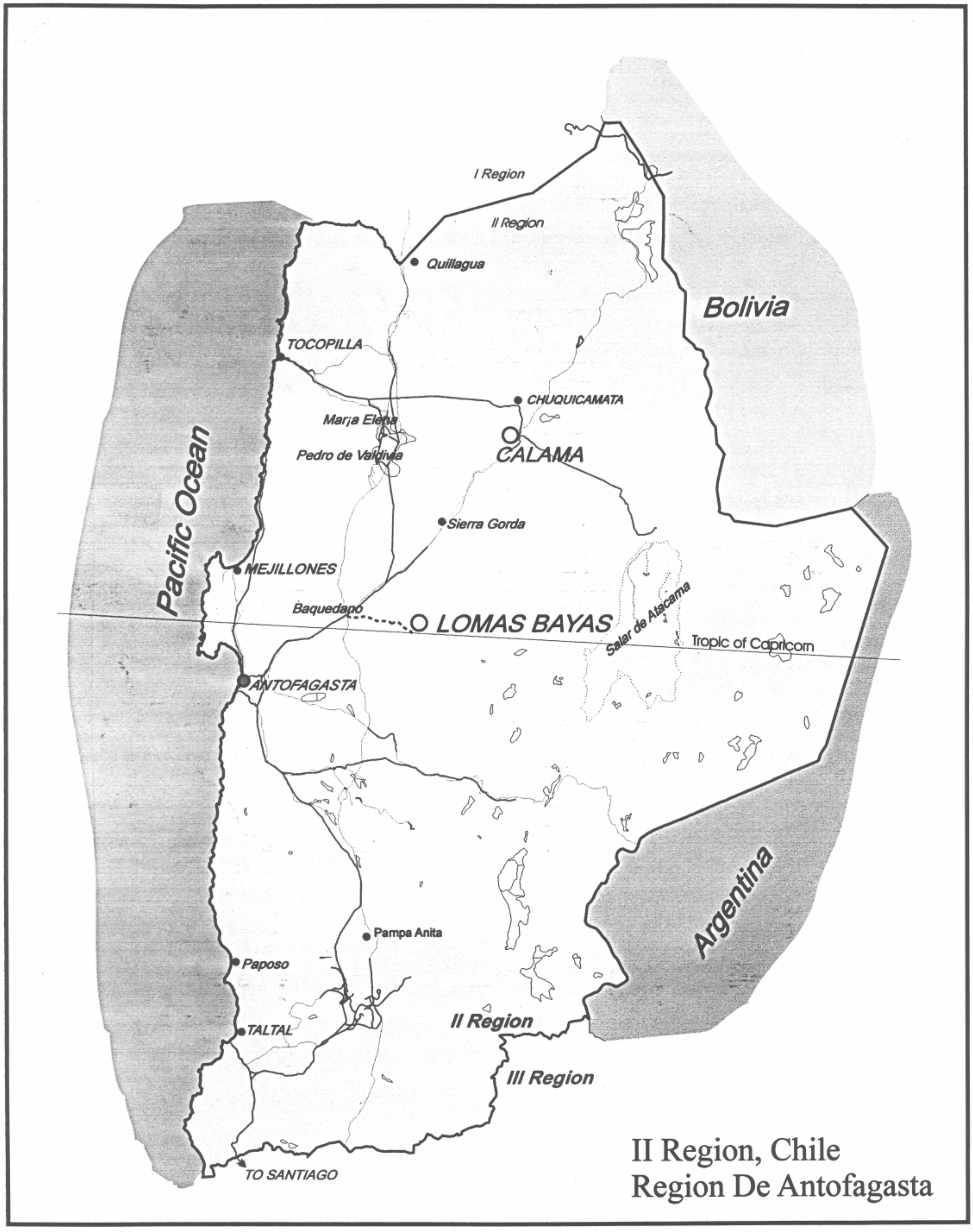


Figure 1: Project Location

## OBJECTIVES

The objectives of the program include and not limited to the following:

- Meet the Environmental Impact Assessment (EIA) commitments;
- Enhance the ecological, biological and climatic contributions through the introduction of forest resources;
- Facilitate and support the effective implementation of a demonstration forest project at a local community level with a goal for transfer of technology; and
- Contribute to the overall national forestry goals and targets.

## AFFORESTATION PROJECT BENEFITS

The benefits are many and diverse, but are all directly related to environmental protection and human use. In general, forests are known to:

- Maintain water holding capacity of the soil;
- Provide green belts for campers and hikers;
- Provide fuel wood for communities;
- Minimize soil erosion and thus conserve soil;
- Minimize particulate emission to the atmosphere and remove many pollutants from the atmosphere;
- Moderate water vapour and temperature in the surrounding area;
- Provide opportunities for recreation and habitat for wildlife where the land was completely a desert; and
- Provide shelter for livestock and wildlife.

Thus, the benefits of trees that people enjoy include aesthetic, recreation, psychological, shade, heat dissipation, blockage of glare, blockage of noise, reduction of pollutants, production of oxygen, reduction of erosion, wildlife habitat, increased property values, and increased economic stability.

Trees have great benefits but also have great costs. Tree costs include capital infrastructure investment, foregone alternative investments, installation, maintenance, management, and removal.

## AFFORESTATION PLANNING

The afforestation program was very much dependant on thorough planning together with regular consultations with CONAF. The basic principles of the program that were followed include the following.:

- Define clear objectives and goals;
- Minimize disturbance during the implementation phase;
- Allocate sufficient resources to enable the afforestation goals to be met;
- Ensure that the selected seed species is consistent with the afforestation goals and objectives;
- Develop a water management plan;
- Characterize the soils;
- Develop criteria for seed selection and procurement;
- Ensure nursery-raised seedlings quality criteria are met;
- Develop Quality Control and Quality Assurance (QC/QA) Programs for all phases of the project;
- Compliance with statutory requirements;
- Limitation of potential of pest and disease infestations by choice of resistant species and choice of chemicals with least potential negative impacts;
- Ensure site and surface preparation work meets the required standards;
- Make the workplace safe;
- Keep comprehensive and accurate records of all project activities;
- Monitor and maintain forested lands until the trees are self-sustaining; and
- Long-term land use of the forested lands.

## SPECIES CONSIDERATIONS

Tree species vary greatly in their ability to grow in different environments. The selection required consideration of the characteristics of the site, adaptation of tree species to these characteristics, the function of the tree in the area and its availability. Tree species known to adapt to desert conditions were thus considered. These tree species had to have the following characteristics:

- Drought (and cold) tolerant;
- Tolerant of low nutrient levels;
- Capable of producing self-sustaining forest cover;
- Seed availability;
- Availability of the trees in the nearby area;
- Elevation; and
- Surrounding vegetation.

Algarrobo *(Prososis* spp.) was selected particularly the *P. Chilensis.* [There are four most important types of algarrobo in the *Prososis* spp. namely, *Prososis alba, and P. Chilensis,* commonly known as white algarrobo, and *P. nigra and P. flexuosa,* known as black algarrobo]. The *P. Chilensis* is a deep-rooted woody species native to South America and has the potential to produce forage, fuel and wood, and to stabilize soil. For this reason algarrobo has become part of an agroforestal land-use system in most countries in South America. In addition, the area has few algarrobo trees scattered in the oasis. The presence of the *P. Chilensis* strongly implies that there is groundwater close enough to the surface to be used by new trees,

## ESTABLISHMENT

The following plant propagation methods were considered for the project:

- Direct sowing of seeds into the field;
- Transplanting of nursery raised seedlings;
- Transplanting of plants from natural areas; and
- Habitat transfer.

Based on the logistics and nature of the project, transplanting nursery-raised seedlings was selected. The choice depended on factors such as reliability, cost, practicability, field application, plant population and performance. The afforestation process used to implement this project is detailed in the following section.

### Seed Collection

When selecting seed sources for the project, it was important to realize that the seeds from *P. chilensis* obtain half their genetic make up from the selected mother tree and the other half from an unknown male parent. This is because most *Prososis* spp. are diploid and self-incompatible (Simpson, 1977). The resulting populations are highly polymorphic. Therefore, it is necessary to select the best mother trees from the best natural population stand based o>n their phenotypic characteristics. The seed for this project originated from natural *P. chilensis* stands in the Quillagua Valley, Northern Chile.

Fruits of *P. chilensis* were picked, cleaned and ground in a mill. Clean seeds were then obtained by sieving and floating the milled product. The seeds were then treated with a solution of Aldrin before storage to prevent pest infestation. The seeds were also scarified with 85% sulphuric acid (in a ratio of 1:2 parts seed and acid) to abrade the cuticle, and facilitate the exchange of gases and penetration of water through the single micropyle aperture of the seed. This process breaks seed dormancy by causing the colloids to rehydrate and germination begins. An alternative practice was mechanical scarification of the seeds, which was not adopted because of lack of suitable equipment.

**Nursery**

Planting of tree seedlings is recommended when seed source of desirable species is not readily available. For this project it was more practical and economical to establish plants by planting nursery raised seedlings because the particular species cannot be established in suitable numbers by direct seeding. In addition, the afforestation objective required a systematic layout of trees, as is the case in establishing a plantation.

Nursery preparation involved preparation of three seedbeds sunken 10-15 cm below ground level in the greenhouse. Two walkways separated the seedbeds.

Seeds previously treated with sulphuric acid to break dormancy were sown in black polyethylene bags containing a mixture of 50% sand, 25% local soil and 25% dehydrated animal droppings. The plastic bags were 12 cm in diameter and 30 cm long, without rips and tears but they were perforated at the base to allow drainage of water during watering. The plastic bags were then placed in seedbeds. Three to five seeds were sown in each plastic bag at a depth of 1.5 cm. Watering of the bags was done regularly to keep the soil moist to ensure germination of the seeds. Before sowing, both the seeds and the soil were treated with appropriate fungicides and pesticides to prevent soil borne pests and diseases in the early stages of seed germination and seedling development.

Once the seedlings emerged, they were hardened by reducing the frequency of watering to acclimatize them for field the conditions.

The seedlings were in the nursery for 5-6 months, until they reached a height of 8-10 cm. Root development was rapid and vigorous and care was taken to ensure that the roots did riot outgrow the plastic bag. Thinning was done when the plants were 2-2.5 cm tall. One to three vigorous, healthy and well-developed plants were left per plastic bag.

**Seedling Selection for Planting**

Seedlings for planting were selected based on seedling quality classification Criteria adopted from CONAF as detailed in Table 1.

**TABLE 1 : SEEDLING SELECTION CLASSIFICATION CRITERIA**

| Seedling Quality | Height (T) | Diameter (D) |
|---|---|---|
| | (cm) | (cm) |
| Primary | >50 | >0.80 |
| Secondary | T>40 and T<50 | D>0.50 and D<0.80 |
| Tertiary | T<40 | D<0.50 |

Based on these criteria, the best seedlings from the primary and secondary categories were selected. Seedlings in the tertiary group were either discarded or given to interested parties within the community.

**Site Preparation and Planting**

The home of the tree is the soil; thus its growth, development and productivity are partly affected by the quantity and quality of the soil. Site preparation is therefore as critical as seed selection and requires proper planning and implementation. The seedlings were planted in an area covering 100 ha. Plant spacing was 1Ox 10 m between and within rows and this translated to 100 trees per hectare. A rotary cultivator dug the planting holes of approximately 30 cm in diameter and 40 to 50 cm deep. Care was taken in the preparation of the new site and the hole to ensure the ultimate success when transplanting. The main factors considered in preparing the hole were size and depth, soil quality and drainage. Soil quality was improved by adding triple super phosphate fertilizer to each planting hole. The drainage capacity of the site was determined by drilling a hole 60cm deep and feeling it with water. The hole drained appreciably within 30 minutes indicating no drainage problem. Before planting, 90 to 100 litres of water were applied to each planting hole in order to wet the soil as far down as possible. Weed control was also done around the planting hole to minimize competition of the tree seedlings with the existing vegetation. Weed control 60 cm around the tree continued until the seedlings were tall enough to rise above the competing vegetation.

To ensure high rate of success, the seedlings needed extra tender-loving care before and especially after transplanting. This is because from the moment the seedlings were taken out of the greenhouse, they were subjected to stress. Therefore, it was important to pay attention to the details of carefully handling the seedlings to minimize stress. When planting, the seedlings were taken out of the plastic bags and put into the planting hole as quickly as possible to avoid root exposure to the sun. Approximately 2.4 hectares were planted per day.

## MANAGEMENT PROGRAM

Management of the forest included maintenance, protection and prevention of weeds, pests and diseases, irrigation, monitoring of seedlings for survival under field conditions and other unforeseen problems that arose.

### Irrigation Program

To ensure proper establishment of the plants, enough water must be given to penetrate down to the root level so that there is constant moisture around the roots. Watering is one of the major factors contributing to high planting costs in forestation projects in arid regions. One way to reduce the number of irrigations is to cut water losses due to evaporation by stretching a plastic tarp over the hole. Another way is to use drip irrigation, which makes for better water use. Drip irrigation was the preferred option in this project.

In addition to saturation irrigation of the planting hole with 90 and 100 litres of water before planting, maintenance irrigation was done at five-day intervals during the initial stages following seedling transplantation. These interval irrigations supplied 60 and 70 litres of water per plant. After the plants were established (when they began to send out new shoots), drip irrigation was used. Drip irrigation supplied approximately 27.16 litres of water per irrigation per plant.

## RESULTS

The data recorded to date indicate the following:

- Overall survival rate of better than 80% for the nursery program;
- Overall survival rate of better than 85% for the field program;
- Overall 70% of the nursery seedlings passed seedlings selection criteria for the primary and secondary quality standards;
- Irrigation schedules are consistent to projections;
- 100 ha have been planted successfully; and
- Projected growth rates have been achieved to date;

## LESSONS LEARNED

Experience gained from the afforestation planning and implementation has indicated a number of suggestions for the future projects of magnitude.

- Develop project goals and objectives right from the start;

- Ensure a project plan is in place;
- Revisit the plan on a regular basis to address new aspects;
- Ensure persons planting the seedlings are properly trained to minimize mortality;
- Ensure appropriate regulatory agencies and other stakeholders are consulted accordingly;
- Review project plan on a timely basis;
- Cross cultural and sensitivity training is important to narrow cultural differences;
- Ensure all relevant permits are in place;
- Determine post-project land use to minimize future conflicts;
- Ensure all land titles are transferred accordingly;
- Project of this nature requires total commitment on the part of the company in terms of financial resources, time and opportunity cost;
- Ensure regular communication of the progress with the local community, regulatory agencies and other stakeholders; and
- Project is a showcase in the area and can be used as an example of a successful afforestation initiative.

It takes a lot of faith to look ahead many years to grow timber for whatever end use may be. But that is what growing trees is all about. Every time a tree is planted, its care is trusted to future generations. This points out the need for the public to be better informed regarding the necessity for managing forest lands and the techniques involved. This project involved the public from the planning stage to the implementation phase. Transfer of technology components was also included in all stages of the project.

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