Characterization and Proposition of Silvicultural Treatments for a Plantation of Tamarugo (*Prosopis tamarugo*) in the Atacama Desert, Chile.

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ABSTRACT

One of the biggest natural resource conservation problems present in non-developed countries is the insufficient rural developing. By looking for goods and services, a rising number of rural communities have no other option than to use up the vegetation in huge surfaces, producing acceleration in the desertification processes. The rural communities responsible of this environmental damage often know the situation that they provoke, looking powerless the decreasing food and fuel shortage.

In 1970, the Chilean Government established about 5,000 hectares of tamarugo (*Prosopis tamarugo*), close to San Pedro de Atacama town, located in the Atacama Desert, at the north part of Chile. The zone is characterized by its poor soils and the absent of rain during the whole year. Because of some causes, there is a remaining of about 800 hectares as a whole, and the biggest plantation has about 535 hectares, which is fundamental for the surviving of many people (animals, fuel, and tourism, among others).

This plantation was characterized in this study, founding some places with very good trees, as well as others with suppressed ones. These differences could be due to soil characteristics, according to the soil analysis. The study proposed some silvicultural treatments with the objective of optimizing the resource, assuring it to the future communities.

INTRODUCTION

One of the characteristics of the North of Chile is its extended area, almost completely constituted by poor soils and a climate extremely dry, making practically impossible the growing of woody plants. Thanks to the presence of the Pacific' anticyclone, and the La Costa mountain range, the Atacama Dessert is considered the most arid in the world.

Nevertheless, the *Prosopis* genus, that is represented (without considering shrubs and herbs) by trees that can reach 20 meters in height and over a meter in diameter, is characterized principally because is in places so dry that hardly can survive other species. It can even grow very fast in salty or unfertile soils. Besides, not only supports long drought periods, but also produces abundant fruits in these periods.

The tree species of this genus that had been adapted to such environment should be considered exceptional, and their presence is possible due to underground water, and a high night relative humidity in some places. Those forests contrast strongly with the surroundings sterile in vegetation.

Like this, in the San Pedro de Atacama County (II Region of Chile), specifically in the Tambillo sector, there is a 535 hectare tamarugo (*Prosopis tamarugo*) plantation, established by CORFO (Production Foment Corporation) in 1970, today under the direction of CONAF (Forestry National Corporation).

The species is an endemic and not well known species. It is ignored when it appeared and dispersed. It grows during the whole year, reaching a maximum in the blooming period (between August and November). It is unknown its productive life, but it starts between the 7th and 8th year, which makes it a very attractive investment.

In an area so big like the Atacama Desert, a plantation like this is fundamental for many families, all poor in resources. Tamarugo is used, among other things, for forage and the only one woody fuel resource. Even though there had been some treatments applied to the Tambillo plantation, all of them hadn't had as an objective the optimization of the resource' efficiency to the local community, but had had as an objective the habilitation of camping areas (tourism).

That is why this study pretended to characterize the Tambillo plantation, and to propose some silvicultural treatments with the objective of increasing the benefit of the people that use it.

STUDY AREA

The plantation is located 27 km from San Pedro de Atacama, a small touristy town, and 11 km from Toconao. Both are part of the San Pedro de Atacama County, part of the II Region of Chile (Atacama Desert).

METHODOLOGY

CONAF divided the plantation in 10 sub-areas, according to the density and the size of the trees. Because each sub-area is homogeneous, it was established just one sampling plot in each one. The plot was established first in the plane, and the in the field by using a global position system (GPS). The plot consisted in an 85 m side square (containing 5 rows and 5 columns, if there was 0% mortality, because the original density was 15x15 m). The sampling point was considered the center of the plot.

Once the plot was established, for each tree were measured some variables, like height (with Haga gun), number of shoot, diameter of the thicker and thinner shoot, canopy diameter (north-south, and east-west), canopy length, and ramification height.

It was made a soil analysis by two samples, in the best developed sub-area, and in the worth one. The samples were taken at 60 cm, and like this there was no influence of the salty crust of the salar. Like this, it was analyzed the nitrogen content, as well as phosphorus and potassium, together with the pH, bore, electric conductivity, and the organic material.

The data obtained were useful for having a clear idea of the general site conditions, and the tree characteristics of each sub-area.

In each tree plot, and around the plantation, was sampled the accompanied vegetation, by using an ecologic variables form. It was also listed the animal species that use the plantation, by observation, as well as by information recollected from the people around the place.

It was also characterized the treatments applied in the past to the plantation. The characterization was made based in the intensity of the treatment applied. It was not measured a possible reaction of the trees because the intervention was very recent.

It was possible to have a meeting with the people that use the plantation, knowing what those people want about the future of the plantation (uses and production).

Finally, with the characteristics of the plantation obtained in the field itself, was possible to determine the actual architecture of the trees. Such architecture, complemented with the information obtained from the users of Tambillo, plus similar studies made in the Pampa del Tamarugal (located in the extreme north of the Atacama desert, with 20,000 hectares of tamarugo), were useful for proposing of some silvicultural treatments, with the objective of doing a process of transformation in the handling structure, and to create certain goal architectures according to uses, and like this to increase the benefits of the community in the short, medium, and long term.

RESULTS AND DISCUSSION

1. Characterization of the trees

There were bent trunks through out side the whole, looking for light. This situation brings as a direct consequence, a difficult commercialization of the wood, due to the presence of defects in the straightness of themselves.

Canopy diameter was bigger in the north-south direction, than in the east-west one. This phenomenon is because of the inclination of the sun through the north, making the tree to receive more light in that part of the canopy, developing this segment more than the rest of the canopy, accompanied also with more fruit production.

Even though all the sub-areas have the same age, it was observed considerable differences in diameter, height, and the density. Such differences haven’t been deeply studied, but the causes could be due soil characteristics, salt excesses in the water table, deepness of the water table, genetic characteristics, or the presence of a hardpan.

Without considering the size, the trees have the same architecture, which consists basically in trees formed by branches in all directions and dense canopies (see Figure 1). This is because Tambillo practically hasn’t been affected by any silvicultural treatments, and like this every tree and every branch grows looking for light.

There were different wither statuses among the sub-areas. This phenomenon in some cases reaches 80% of the canopies, and is because in some places is that much the salt in the soil that, with the passing of the years, the salt itself has saturated the conduct elements of the roots, bringing as a consequence the withering of the foliage.

The Table 1 shows some silvicultural antecedents for each sub-area, with the average values of certain attributes measured in the field, with the objective of giving a clearest idea of the silvicultural situation of the trees of each sub-area.

About the sub-areas, each one has its own density and dasometric characteristics, but the most representative differences are among sub-areas 4 (the best developed), 8 (the worth developed), and the rest as a whole.

2. Soil analysis

According to the soil analysis, the development differences between the 4th and the 8th sub-area are related to the salt content (electric conductivity) that those soils have. The interpretation of these results is exposed in the Table 2.

The soluble salts make that the soils available water decrease by adding osmotic pressure to the total tension that those soils have. When it exceeds certain values (like the case of sub-area 8) there is a decrease in the growth.

3. Characterization of the accompanied vegetation

By using a random sampling in and around the plantation, it was possible to conclude that Tambillo has the following species:

- *Distichlis* sp.
- *Ephedra breana* Phil.
- *Acantholippia deserticola* (Phil.) Mold.
- *Tiquilia paronichioides* (Phil.) Richard
- *Atriplex atacamensis* Phil.

4. Animal species

According to the people that use the plantation, and by direct observation, it was possible to conclude that the animal species present in Tambillo are sheep, donkeys, llamas, and goats.

5. Characterization of the past treatments

The objective of the intervention was to improve the tourist conditions in Tambillo, giving a rest shady area.

Some trees were just pruned (Figure 2), while others were besides thinned (Figure 2). In the thinning were extracted an average of two trees per hole, which gave firewood and, with the pruning, shade in an absolute arid place. There are absolutely no withering problems after the pruning.

As a result from the treatments, there are tree groups compound by high canopies and well differenced from the trunks, separated in average almost two meters from the ground, which makes impossible the direct animal feeding, even though the animal could eat the hay deposited underneath the canopy, once it is formed.

6. Treatments proposition

Following are exposed the treatments to apply in Tambillo in order to increase the productivity of the plantation, and the benefit of its users.

Forestation

It would be convenient to reforest the 5,000 hectares, and like this to continue the initial project. It would be necessary to establish 176 hectares per year (70 trees per hectare), in order to satisfy 2,821 m^3 as an annual demand (Charcoal, fire wood, and parquet).

Pruning

In arid lands, the objective of the pruning is focused principally to optimize the forage production toward the increasing of the fructification. Five types of pruning are proposed:

- Recuperation pruning: consists in the extraction of the dead branches with the objective of giving more light to the rest of the branches.
- Formation pruning: increments the fruit production concentrating the phloem in a low and illuminated number of branches, giving a better fruit quality.
- Maintaining pruning: the interior non-fruit branches, together with the branches that grow through the interior of the tree, are eliminated.
- Sanity pruning: it was observed a parasite attack in the whole plantation.
- Clear pruning: it is cleared the base of the tree in order to facilitate the animal foraging under the tree.

Thinning

The higher increment invariables like diameter, basal area, height, volume, and canopy diameter, is obtained in tamarugo by extracting 50% of the existent biomass. It will be necessary to execu te thinning at the 15^{th}, 30^{th}, and 40^{th} year, considering a 50 year rotation age. Like this, the thinning will be applied at hole level, and when a tree is straight, it will be designated to high quality saw wood production, extracting the rest of the trees in that specific hole. In such situations, it will be necessary an extra pruning in order to increase the wood quality. The trees with a high wither level, must be completely cut, and like this the tree will sprout again vigorously.

In summary, the final architecture of the trees would be, after pruning and thinning, like the one shown by the Figure 3 (forage production) and Figure 4 (high quality saw wood production).

CONCLUSIONS

- Most of the plantation was in an acceptable surviving state, considering the extreme climatic conditions in which it was established.
- The wither conditions of the plantation were, in general, in a low amount.
- The plantation had sectors with great develop state (sub-area 4), like others with a deplorable state (sub-area 8). It is possible that such differences were due environmental factors like the soil composition, among others.
- In general, the canopy diameters were greater in the orientation north-south, than in the east-west one.
- The silvicultural treatments applied in the past consisted basically in prunes and thinning.

- Tambillo is constituted by trees of similar architectures. By applying silvicultural treatments it is proposed to reach certain final architectures, depending on the production objectives.
- Several actions are proposed to apply in Tambillo, in predetermined sectors:
    - Forestation of the surroundings of the plantation, in order to satisfy the necessities and demands of charcoal, fire wood, and parquet confection. Is proposed an annual forestation of 176 hectares, satisfying like this an annual demand of 2,821 m^3 of wood.
    - A combination of prunes with the objective of improving the forage capacities, the wither conditions, and the pest attack.
    - A 50% basal area thinning.
    - When the straight characteristics are good enough, certain trees will be designated exclusively to high quality wood saw wood production. Otherwise the objective will be forage and wood production.

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Table 1. Average attributes per sub-area.

Sub-area N°°	1	2	3	4	5	6	7	8	9	10
N° trees/sub-area	11	12	15	25	17	22	24	21	13	16
Bigger diameter (cm)	23.7	35.29	32.9	28.27	27.59	19.95	25.5	16.38	27.08	22.75
Lower diameter (cm)	12.5	15.45	14.51	15.13	15.05	11.22	13.63	8.25	14.77	11.44
Average diameter (cm)	18.3	27.23	23.71	21.7	21.32	16.35	20.23	15.57	20.92	17.09
Height (m)	8.66	10.19	9.32	10.08	9.47	7.48	7.77	5.45	10.58	7.69
Canopy diameter (N-S) (m)	10.58	12.45	12.08	9.18	9.44	7.07	8.35	6.47	12.22	8.02
Canopy diameter (E-O) (m)	10.8	12.3	12.36	7.89	8.91	6.65	7.78	5.37	10.68	7.79

Table 2. Soil analysis results interpretation.

Analysis type	Sub-area 4	Sub-area 8
Nitrogen	Low level	Very high level
Phosphorus	Low level	Medium level
Potassium	Very high level	Very high level
Ph	Moderately alkaline	Moderately alkaline
Electric conductivity	Lightly salty	Strongly salty
Organic material	Very low level	Very low level
Bore	Very high level	Very high level

Figure 1. Typical architecture of the trees

Figure 2. Forage production architecture without thinning

Figure 3: Forage production architecture, thinned.

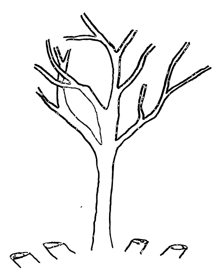

Figure 4: High quality saw wood production architecture.