The Rufford Small Grants Foundation Final Report

Ecological parameters related to the regeneration of Chilean palm forests (*Jubaea chilensis (Mol.) Baillon)* in the Region of Valparaíso – Chile

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Plan Nacional de Conservación
de la Palma Chilena

Operational context

Antecedents

Image 1. The harvest of fruits for sale is a common practice in all the palm forests. In the picture, the nails are inserted in the stalk to climb the apical part.

Jubaea chilensis (Mol.) Baillon, is the world's second southernmost palm, endemic from Chile and it is the only species of its genus. In days gone by, the Chilean palm covered 600 km of the country forming several plant units. Varied anthropogenic interventions have caused fragmentation of the palm population, decrease of seed bank and decline of juvenile individuals.

Nowadays, few places in Chile can be considered as palm forests, due to the shortage of its population, which do not exceed 65.000 specimens. Three of the four Chilean palm forests can be found in the region of Valparaíso, including the largest one with age heterogeneity — it was here where the project was carried out. According to the Chilean legislation and the IUCN classification (2008), *J. chilensis* is in vulnerable conservation status; it is protected of any anthropogenic action that could directly interfere in the development of the species or in the place where they grow. Due to the continuous decrease on the number of individuals, in 2006 the National Plan for the Conservation and Recovery of the Chilean palm was created. This project is sponsored by this National Plan.

Area of study

The Project was developed in two locations: The area of "Ocoa" of "La Campana" National Park (6354847 N 305001 E, WGS 84 - 19 H) and the area of the ravine "El Quiteño" in "El Salto" palm forest Nature Sanctuary (6339189 N 265030 E, WGS 84 - 19 H). The first and main one is located in the province of "Hijuelas" in the region of Valparaíso, Chile. It is located in a mediterranean semi-arid sector (Hajek, 1991) and it stands out from the rest for averaging the highest annual temperatures because of the prevailing suntrap hillsides (of north or northwest exposition) and big plains at the bottom of the mountain ridges that surround it.

Due to these characteristics, most common plant associations include xerophytes, such as, "*Puya*" genus and "Quiscos" (*Echinopsis chiloensis*); sclerophylls as the "Quillay" (*Quillaja saponaria*) or "Litre" (*Lithrea caustica*) in hillsides; "Peumo" (*Cryptocarya alba*) and "Boldo" (*Peumus boldus*) at the bottom of the dampest ravines (Elortegui & Moreira, 2002). Amongst these associations palms grow, which are characterized by its height, above 5 metres (an average height for tree species).

Image 2. Work team at the entrance of "La Campana" National Park.

Image 3. Chilean palm specimens stand out for its height.

The second area is located in the province of Valparaíso, in the region that has the same name in Chile. The third palm forest of the country can be found in this area and it is possible to find around 7.000 specimens of Chilean palm. One of the significant differences respecting the Ocoa sector is its proximity to the sea, which provides a constant humidity during the year, despite the fact that is located in the same mediterranean, semi-arid area. This humidity condenses into mist because of the closed basin, which contributes to plant formations where arborescent phanerophytes such as "Peumo", "Boldo" or "Lilén" (*Azara celastrina*) predominate. As a result of several fires in the area (Flores & Aguirre, 2008), It is possible to see dominance of "Quila" (*Chusquea cumminguii*) and "Tevo" (*Retanilla trinervia*) towards the

Image 4. The ravine "El Quiteño" has very closed basins with hillsides of steep slopes.

steep hillside (all slopes above the 45°). The ravine "El Quiteño" was used only as comparison, when necessary.

Methodology and results per objective

Objective 1. To assess the effect of geomorphology on the area of study. This is about the natural regeneration of the Chilean palm.

Two geomorphologic factors were assessed: Orientation (exposure) and slope of hillsides. Firstly, exposure was categorized by the cardinal points and the simple combination of each one of them, giving eight categories. Additionally, an extra category was added for flat places named "non-exposure". On the other hand, the slope was categorized in three groups, according to the following table:

Category	Measurement
Low	1° to 20° of inclination
Medium	21° to 40° of inclination
High	41° to 90° of inclination

To these two factors, a third one was added, which is not geomorphologic; however, it was possible to define it with simple land observations: Phanerophytes vegetation cover—mainly trees and bushes higher than two metres high. The cover was classified as follows:

Category	Measurement	Symbol
Low	Less than 25% of the quadrant covered by phanerophytes specimens	↓
Medium	Between 25% and 49% of the quadrant covered by phanerophytes specimens	1/2
High	50% or more of the quadrant covered by phanerophytes specimens	↑

Slope	0-20			21-40			41-85		
Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North									
Northeast									
East									
Southeast									
South									
Southwest									
West									
Northwest									
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Table I. Matrix table of the project.

Slope	0-20			21-40			41-85		
Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North	3	0	18	0	3	3	4	3	6
Northeast	6	7	0	0	2	7	0	3	9
East	8	0	3	4	8	2	1	0	16
Southeast	0	0	5	0	11	4	0	0	3
South	0	0	5	0	1	3	0	2	4
Southwest	0	0	2	0	0	17	1	4	12
West	3	2	15	0	0	3	8	2	5
Northwest	6	5	12	0	0	6	12	1	0
---	0	1	15	-	-	-	-	-	-

Table II. "Ocoa" regenerations count.

A matrix table was built with these three factors. This was used to set sampling points for the implementation of remaining methodology considered in the research. Five regeneration censuses were conducted for each box once the matrix table was built. Censuses were done in plots of 25 m^2 (5x5 metres) and a recount of the total regenerations found of the Chilean palms was made in them. The concept of regeneration used in this project is the one defined by Michea (1988) , which is: Simple leaf. This methodology was applied during spring and summer (October to March). Nevertheless, observations of regeneration were made during autumn and winter as well.

The result analysis demonstrates that the greater amount of regenerations was detected in areas with a high (or even medium) vegetation cover. Regardless of the hillsides inclination; it shows a clear tendency towards plain sectors. Vis-à-vis the exposure, the regenerations are

Image 5. A simple leaf individual, regeneration of Chilean palm.

gathered together in north, west, north-west and south-west hillsides.

Chilean palm fruits have a higher germination rate in areas of high coverage, where temperatures are lower and humidity is higher. During the regeneration age, vegetal cover is needed by the seedling for its growth. It continues with the appearance of the first compound leaves. After approximately 15 years, the infantile individual has generated enough leaves and has reached an average diameter of 3 metres which leads to its height growth emerging from the surrounding vegetation. Once this period is over, the plant has many possibilities to survive because of its great resistance to adverse environmental factors—it is even able to resist forest fires.

Slope	0-20			21-40			41-85		
Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North	0	0	0	0	0	0	0	0	0
Northeast	2	0	0	0	0	0	0	0	0
East	0	0	0	0	0	0	0	1	3
Southeast	0	0	0	0	0	0	0	0	0
South	0	0	0	0	1	0	0	1	0
Southwest	0	0	0	0	0	0	0	0	1
West	0	1	0	0	0	0	0	0	0
Northwest	0	0	0	0	0	0	1	1	0
---	0	1	1	-	-	-	-	-	-

Table III. "El Quiteño" regenerations count.

On the other hand, the observations made at the ravine "El Quiteño" in "El Salto" palm forest Nature Sanctuary show a shortage of regeneration age individuals. According to a simple proportion, in "Ocoa" every adult palm collaborates with 0.004 regenerations, whereas in "El Quiteño", they just collaborate with 0.002. In addition, a clear relation cannot be seen between the studied factors and regenerative ability of the Chilean palm. This is because the sector of "El Salto" is likely to be altered by anthropogenic factors;

as it is a private sector and within its goals preservation, conservation and sustainability are not included, different from "La Campana" National Park. It is also a reduced and fragmented area ("El Quiteño", 166 ha), which increases the effects of external interventions. In conclusion, although places with similar characteristics that would allow regeneration growth (adequate vegetal cover and high humidity) as the ones observed in "Ocoa" can be found in "El Salto", there are human factors that collaborate with the regenerations reduction:

a) The regimen of intentional fires suffered by the Sanctuary, which victimize vegetal shrub species and eliminate herbaceous species, where stratum regenerations can be found.

b) The annual and non-sustainable extraction of fruits for its illegal sale.

Objective 2. To assess the effect of floristic composition on the natural regeneration of the Chilean palm.

The floristic composition was defined through the phytosociologic methodology of Zurich-Montpellier school during spring 2010 (September to November); key season for flowering of many plants and the appearance of many therophytes and geophytes. A maximum of 10 plots of sampling of an area of 25 m^2 (quadrants of 5x5 metres) by box of the matrix table were made. In each one of them, the name of the vegetal species of all stratums and its abundance were recorded. It was estimated in the coverage that the species occupies in the plot according to the following table:

Abundance	Species coverage in the quadrant
R	One individual in the quadrant with a coverage < 5%
+	From 2 to 25 individuals with a coverage < 5%
1	From 26 to 60 individuals with a coverage < 5%
2	Any number of individuals with a coverage between 5% and 25%
3	Any number of individuals with a coverage between 26% and 50%
4	Any number of individuals with a coverage between 51% and 75%
5	Any number of individuals with a coverage between 76% and 100%

These data were analyzed in a phytosociologic table to know the most important vegetal species, according to Importance Value.

Species	Relative frequency	Relative coverage	Importance Value
Cryptocarya alba	8,26	13,84	22,10
Lithrea caustica	10,57	11,32	21,89
Jubaea chilensis	7,68	11,80	19,49
Acacia caven	6,24	8,26	14,51
Aristeguietia salvia	8,74	5,42	14,16
Colliguaja odorifera	6,44	6,71	13,14
Retanilla trinervia	5,96	6,12	12,07

Table IV: Results of flora in "La Campana" National Park.

Species	Relative frequency	Relative coverage	Importance Value
Nassella chilensis	4,62	8,68	13,31
Chusquea cumingii	3,47	6,78	10,5
Retanilla trinervia	3,66	5,70	9,36
Jubaea chilensis	2,50	6,38	8,88
Euphorbia peplus	4,05	2,99	7,03
Cryptocarya alba	2,50	3,80	6,30
Dichondra sericea	3,08	2,17	5,25

Table V: Results of flora in "El Salto" palm forest Nature Sanctuary.

Even though the Importance Value for each species is not comparable between different places where the methodology was applied, it does allow tabulating the most important species of each area. While this process is being carried out and both tables are being compared according to the found species, many elements can be highlighted:

- *Jubaea chilensis* is the species that characterizes both areas as expected and observed in field. All ages of the Chilean palm were considered on the methodology; however, in both places the palm stands out for its high relative cover rather than its abundance. This demonstrates the predominance of juvenile and adult ages rather than regenerations and infantile (of low coverage).

- The most important species of the "Ocoa" sector of "La Campana" National Park are two sclerophyllous plants of grate size that provide great coverage to the substrate. This is extremely important for the preferential characteristics of the regenerations mentioned in the Objetive 1. Additionally, it has to be mentioned that *Cryptocarya alba* can be found mainly on hillsides of south and west exposition (even at the bottom of a ravine), whereas *Lithrea caustica* shows a preference for hillsides located in the north and east (mainly of medium and high inclination), which provides high vegetal coverage in the entire studied sector. Nevertheless, vegetal coverage is not the only limiting factor of the Chilean palm natural regeneration. In the other case, the ravine "El Quiteño" is dominated by short herbaceous and shrub species (no more of 2 m height). This contributes with little presence of Chilean palm regenerations. Moreover, according to the field observations, it is not possible to find any vegetal coverage under *Chusquea cuminguii* y *Retanilla trinervia*—two of the most important species.

- According to Flores & Aguirre (2008), the vegetal composition of the "El Salto" forest palm National Park shows a degraded ecosystem by the several fires and the high

anthropogenic presence in the area. The dominance of *Nassella chilensis* and *C. cuminguii* and the presence in the importance table of an introduced species, *Euphorbia peplus* are an evidence of the aforementioned phenomenon. This means that in an area with higher protection, as "La Campana" National Park, the fruits and subsequent renewable of the Chilean palm are protected. While the anthropogenic interventions in "El Salto" palm forest Nature Sanctuary helps with the disappearance of type species of this plant formation.

Objective 3. To assess the existent ecological interrelation between micro mammals and sapling of the Chilean Palm.

To study the interrelation between micro mammals and samplings of the Chilean palm, captures with standard size Sherman tramps baited with oat were carried out. All this was done in capture periods of three weeks for each season in order to sample all the defined areas by the matrix table. Captured rodents were properly branded and registered in a data base to be subsequently released.

Image 6. Carrying out micro mammals protocol with Sherman tramps.

Slope	0-20	21-40	41-85

Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North	RR	OD			TE	OD RN RR OL			
Northeast	OD	OD			OD	RN			RR
East					OD		OD		
Southeast			RR				OD		AL
South					AL		OL OD		
Southwest				OD	AL			AL OL	RR OL
West			OL OD RR	RR	OD OL AO PD		RR	RR AO	PD
Northwest	OD		RN		PD			OD	
---	OD AO TE OL	OL	RR OL	-	-	-	-	-	-

Table VI: Results of fauna in "La Campana" National Park.

Slope	0-20			21-40			41-85		
Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North	AL MM							AL	
Northeast					AO			RR	
East							AL		
Southeast									
South								AL RR TE	
Southwest							RR	TE AL	TE AL
West		AL	AO				AL		TE AL AO
Northwest			TE AL RR					TE AO	AL TE AO
---	AL AO	AL AO	TE	-	-	-	-	-	-

Table VII: Results of fauna in "El Salto" palm forest Nature Sanctuary.

Legend		
Code	**Scientific name**	**Common name**
AL	*Abrothrix longipillis*	Long-haired field mouse
AO	*Abrothrix olivaceus*	Olivaceous field mouse
MM	*Mus musculus*	Common house mouse
OD	*Octodon degus*	Fence degu
OL	*Oligoryzomys longicaudatus*	Long-tailed rice mice
PD	*Phyllotis darwini*	Darwin's leaf-eared mouse
RN	*Rattus norvegicus*	Norway rat
RR	*Rattus rattus*	Black rat
TE	*Thylamys elegans*	Llaca mouse-opossum

Image 7. *Phyllotis darwini*, Darwin's leaf-eared mouse.

The exclusive species found at "La Campana" National Park correspond to *Octodon degus*, *Rattus norvegicus*, *Oligoryzomys longicaudatus* and *Phyllotis darwini.* The most abundant species was *O. degus*, followed by *O. longicaudatus.* One of the most common shrubland sclerophyllous, xerophillous and steppe hawthorn rodents is the *O. degus.* It is very dependent to environment alteration degree. This explains its absence at "El Salto" palm forest Nature Sanctuary. Sunny, well-drained and humidity free places are preferred by this species, different from places where regenerations of Chilean palms can be found, which are humid and with high vegetal cover. This indicates that rodents go there only to feed themselves with palm fruits. *O. longicaudatus* is considered versatile in its habitat election—it goes from wooded to ecotonal sectors between forests and bushy zones. Even though humid areas, where regenerations can be found, are preferred, its diet is granivorous (small seeds) during driest periods; flowers, foliage and arthropods during humid periods.

On the other hand, in *Mus musculus* was only found in "El Salto" palm forest Nature Sanctuary. This indicates certain degree of alteration of this sector, since this introduced species is considered plague. This plague is distributed along all the regions of Chile associated to town planning; however, it can be found in natural environments, always close to human settlement and dumps. The most abundant species of this sector was *A. longipillis*, followed by *T. elegans*—first described for this area. The former one inhabits a wide range of ecosystems:

Grasslands, shrubland, forests, rocky places and pastureland. This species has a continuous activity, day and night; higher in summer, declining in autumn and disappearing in winter.

A. longipillis is known to be an omnivorous for the central zone sclerophyllous shrubland and Chile's southern temperate hygrophila forest. Other components of its diet are: Arthropods (16%), seeds (11%), insect larvae (10%) and fruits (5%). *T. elegans* is a marsupial species. In areas of dense vegetation (as "El Salto" palm forest), the density of the species is higher than in opened areas. Research show that there is a higher abundance of this species in spring, whereas in summer, autumn and winter there is a decrease. This suggests that dynamic population is ruled by intraspecific competition (food and/or territory).

Image 8. First time detected, *T. elegans* in "El Salto" palm forest.

Image 9. *Abrothrix logipillis*, long-haired field mouse.

According to the statistical analysis (Pearson product-moment correlation coefficient and Covariance) used to relate the number of regenerations and micro mammal's fauna. The results show:

- "La Campana" National Park shows a tendency to a negative relationship (r_{xy} = -0.115), as well as "El Salto" palm forest, but with higher magnitude (r_{xy} = -0.456); taking into account the analysis in terms of diversity and the counting of all detected micro mammal species by

sector. This can be caused by the few regenerations presence in the sector. Therefore, as one variable increases, the other decreases; in other words, the increase of the richness of micro mammals associated to the area where palm regenerations can be found decreases the number of regenerations. Most of these micro mammals are omnivorous or herbivorous, so palm seeds are considered in its diet creating a direct relationship between palms and them.

- A negative tendency can be observed (r_{xy} = -0.253) by linking regenerations with the presence or absence of *Octodon degus* in "La Campana" National Park. The higher presence of fence *degu* in the palm surroundings, the lower amount of regenerations.

Image 10. *Octodon degus*, a common micro mammal in Chilean palm forests.

It is important to clarify that even though the rates show a negative relationship between degus and the regenerations, it does not mean that this species is negatively affecting or altering in way to reduce palm renewable, since there are places where regenerations were found as well as fences degus. Nevertheless, the rate shows that in the proximities of the palms there are less regenerations, probably because fence degus move the fruit away or/and eat it.

On the other hand, there are some research that show *O. degus* individuals keep a natural balance with the Chilean palm, so the species cannot be wiped out, despite of the high diet preference—estimated in more than 95% of preference of the Chilean palm fruits.

In non-published research, it is mentioned that the influence of *O. degus* could be positive because they transport the fruits to their burrows (that can be 30 metres radius), where excellent conditions can be found—humidity, temperature, among others. This would allow the germination of them, keeping the population stocks of palm regenerations.

Although the anthropogenic factors were indirectly detected through this research, they were identified as the main problem for the alteration of natural renewal of Chilean palm. These factors act, in many ways, decreasing the bank seed or eliminating infantile individuals. The result of this action is due to the decrease of fruit stock for rodents, such as fence degu, whose food is few fruits that can be collected.

Objective 4. To assess the effect of the physic-chemical parameters of the ground on the regeneration of the Chilean palm.

Image 11. Soil thermometer (measurement range: -10 to 200°C).

As it was stated on the basic Final Report, only the ground temperature was measured. The field protocol consisted in the temperature measurement of the substratum shade using a ground thermometer (measurement range: -10 to 200°C) in 50 points of each matrix table box. The data for each box were averaged out.

These data has not been analysed, due to the lack of information of the resting ground parameters that were not measured.

Following tables shows the final data:

Summer

Slope	0-20			21-40			41-85		
Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North	38,3	30,6	22,8	17,2	19,4	19,4	21,0		14,8
Northeast	35,9	31,6	22,8	24,5	19,7	22,1	18,6	20,5	22,4
East		23,6	19,0				17,0		19,5
Southeast			22,6					17,5	
South			20,8						22,2
Southwest	16,4			17,0			16,2	16,7	16,2
West	33,5	22,7	20,2	34,8	35,1	18,5	29,6	20,5	19,8
Northwest	24,4	23,5	22,7	17,5	28,9	20,5	16,1		14,6
---	41,0	38,2	22,6	-	-	-	-	-	-

Autumn

Slope	0-20			21-40			41-85		
Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North	11	9,5	10	13	18	12	14	11	9,6
Northeast	14	12	11	13	12	12	17	12	11
East	12	11	12	14	10	11	17	15	12
Southeast			9,7		11		8,9	9	12
South				9,5	9,7	9	10	9,6	12
Southwest			9,4	9,5	11	11	8,9	18	11
West	16	9,9	10	11	14	8,8	14	12	10
Northwest	13	10	11	9,2	11	12	12	11	11
---	15	11	12	-	-	-	-	-	-

Winter

Slope	0-20			21-40			41-85		
Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North	17	9,7	8,6	14	16	8,1	18	11	10
Northeast	12	8,9	7,9	17	13	8,6	13	12	9,9
East			8,4	14	14	8,4	13	10	7,4
Southeast	13	11		7,4	8,1	7,9	7,9	12	7,9
South	14		6,5	12	7,8	9,3	11	9,3	7,7
Southwest	12	9,1	7,1	16	9,2	8,2	9,4	9,4	9,3
West	9,3	13	7,2	17	9,2	8	8,9	9,5	8
Northwest	12	11	6,8	21	14	9,1	18	16	11
---	8,3	7	7,6	-	-	-	-	-	-

Spring									
Slope	0-20			21-40			41-85		
Vegetal cover	↓	1/2	↑	↓	1/2	↑	↓	1/2	↑
North	26	27	24	27	22	14	27	21	23
Northeast	28	25	17	28	24	18	33	23	17
East	33	21	17	29	27	18	28	26	16
Southeast	21	25	16	26	16	15	19	16	16
South	26	23	18	18	27	20	21	18	20
Southwest	27	26	16	21	20	13	25	14	20
West	23	17	26	29	17	15	20	25	16
Northwest	31	25	25	28	19	24	34	24	21
---	26	29	21	-	-	-	-	-	-

Looking ahead

In the context of this research, the most urgent is to complement the information related to ground parameters, for example, pH and texture of the ground. Once the information in field is gathered together, the objective assessment is going to be carried out to see how these parameters affect the natural regeneration of the Chilean palm.

In the medium-term, conservation measures of the species, orientated to the environment where it grew, are pursued, in order to avoid the disappearance of the few palm forests that are left in Chile. In this way, the genetic resource would be naturally kept and would not be modified in relation to the human, since the current measures just consider fruit germination and its future plantation in protected areas: gardens, parks or even houses—not necessarily where Chilean palms can be found. On the other hand, the creation of mitigation measures of the anthropogenic impacts that affect the ecosystem, where sclerophylle forests associated with the Chilean palm live, is needed, carrying out an accurate management of the territory.

In the long-term, there is the idea of starting courses, seminars or workshops to collaborate with the environmental education in the communities which are directly related to palm forest

sectors. The aim is to teach them about the importance of the conservation and care of unique places in the world, as the Chilean palm forests are.

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