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Sustainable Forest Management of the Native Forest, Application for a Nothofagus Forest in Southern Chile

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Abstract: A sustainable forest management of native forests with the raulí tree (*Nothofagus Alpina* (Poepp. & Endl.) Oerst.)), was developed. Based on its profitability, under sustainable management terms, we conclude that raulí is more profitable for native woodlands than livestock, which is currently the principal use for lands and the main cause of the destruction of native forests. The estimation of profitability is based on how much a well-managed raulí tree is worth it. From the current price of 3000 CLP per board foot for standing raulí, every growing centimeter for a tree smaller than 30 cm dbh has a value of less than 1000 CLP. In contrast, every increasing centimeter of a tree bigger than 50 cm dbh has a value of more than 3000 CLP. Considering a model for an irregular high mount, with six classes of ages (every 10 cm), a harvest diameter of 60 cm dbh for which the raulí tree only occupies 30 m^2 of basal area and the rest of the area occupied with other species it is possible to estimate a sustainable annual income which is about double the yearly income that a farmer receives with sheep or cows on the same land.

Key words: sustainable management, native forest management, Nothofagus Alpina

1. Introduction

The effect of human progress on the deterioration of the environment is a relevant issue for different production models. Farming production starts with the destruction of the natural ecosystem and replacing it with an artificial ecosystem of higher production for man. The current dilemma is whether to preserve a low productivity nature (low for modern human needs) or replace it with a high productivity ecosystem [1-2]. Which is not a minor dilemma.

The Chilean population increases by one million inhabitants every six years [3] (over the world, there are one billion more people every 13 years [4]). The challenge the Chilean economy faces is feeding, providing housing and energy, and providing quality of life to one million more people every six years, without losing the quality of life for previous inhabitants. The dilemma between nature conservation and development has formerly been a critical driver for the forestry public policies and forestry industry [5, 7-8].

Sustainable management of native forest looks for a third alternative that breaks through this dilemma. The challenge is to build a forest management model that allows taking better advantage of the natural productivity of the forest, without losing its natural character and condition. Certainly, the type of forest that presents the greatest chances of success to take on this challenge in Chile is the roble-raulí-coihue forests [9, 10]. This is due to its natural conditions, location, and for the value of raulí (*Nothofagus Alpina* (Poepp. & Endl.) Oerst.)) wood [11-13].

With its rich forest resources, Chile has background in terms of forest management. Between 1862 and 1965 chilean regulation aimed at forest protection which have no real effect in its management, but in 1965 a new gobernance is established, and by 1972 the creation of the National Forest Corporation (CONAF) started the administration of these resources, and in

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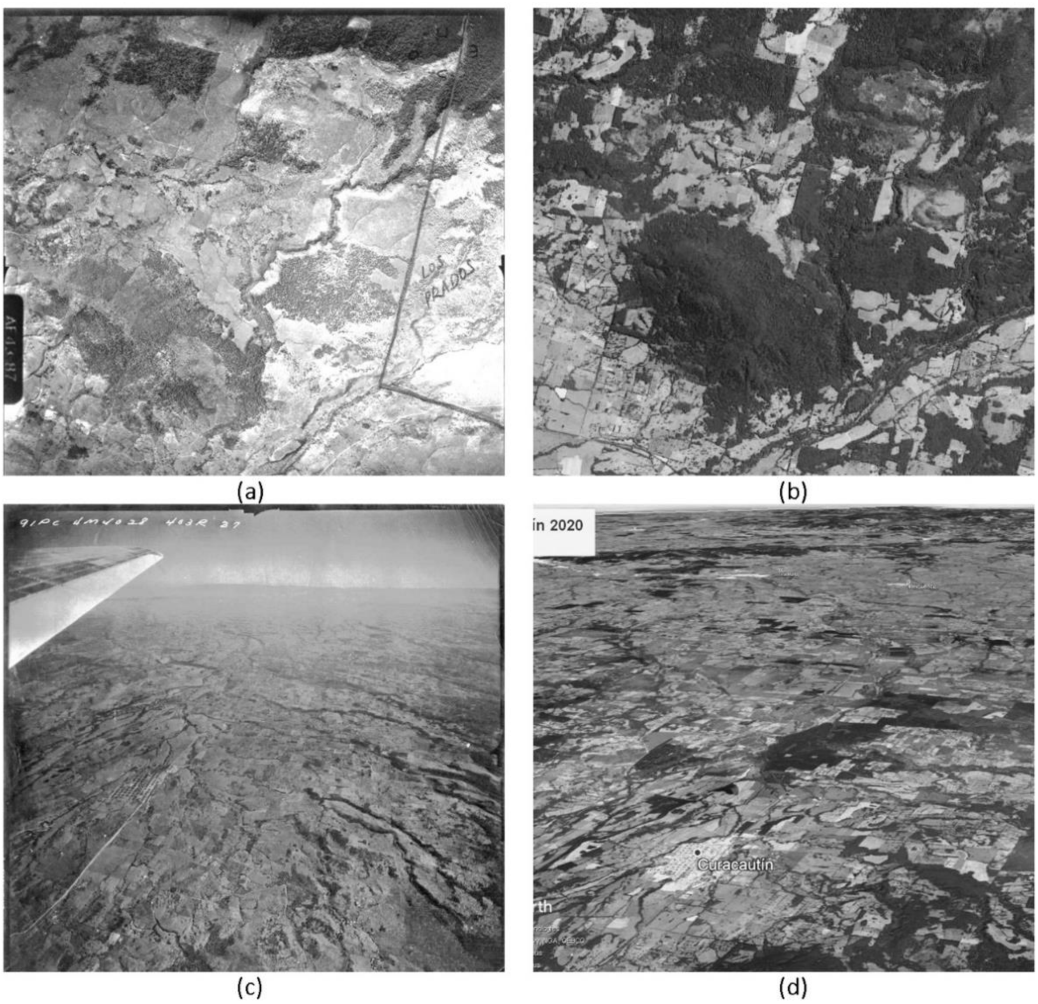
2009 is enforced the Law of promotion of sustainable forest management. Despite these efforts from public policy, there are still several challenges to develop models that are appropriately embraced by farmers, while presenting a solution to sustainable development dilemmas.

2. Material and Methods

This article is based on field research, via the author's everyday work with native forest owners. Data and information are based on interviews and conversations with forest owners, as well as field research, evaluating the effect of intervention in these forests.

The investigation was carried out in the Curacautín Commune, about 700 kilometers south of Santiago, in the Andean piedmont. The Curacautín Commune is more than 50% covered in by natural forests, in the highest parts by araucaria tree forests (*Araucaria araucana* (Molina) K. Koch), and below that by Nothofagus deciduous forests. For this reason, Curacautín had an important forestry industry, which mostly broke down in the 60s due to the depletion of these forests. History of Curacautín is an example of unsustainable development. The bankruptcy of the forestry industry allowed a significant natural recovery of these forests over the last 50 yearsThis recovery can be seen by comparing the aerial pictures from 1944, 1960, and 1990 with current satellite pictures from Google Earth® (Fig. 1).



(a) Aerial photo east of the city of Curacautín year 1960 (b) Aerial photo east of the city of Curacautín year 2020
(c) Aerial photo city of Curacautín year 1960 (d) Aerial photo city of Curacautín year 2020

Fig. 1 Aerial photos of the zone under study.

About ten years ago a new type of portable sawmill appeared in the zone; the development of horizontal bandsaw technologies allowed for better use in thinner trees. The low cost of this technology (between US $5,000 and $15,000 for sawmills with production in the range of 2000-4000 board foot) helped become so that there are now more than 30 of this type of sawmills in Curacautin. The technology created a new and significant demand for raulí wood, which significantly increased the pressure to use these forests. The increasing demand came from small entrepreneurs, leading to a "perfect competition" scenario, which brought up the value of a board foot of raulí standing to 350 CLP (US$ 0.5 per board foot of timber). This price significantly raised the value of the larger specimens of the raulí tree, as seen in Table 1. In this article, we describe this new socio-economic process and explore alternatives for sustainable development in harmony with nature.

3. Results and Discussion

3.1 What is the Value of a Raulí Tree?

In order to estimate the standing value of a raulí tree, taper tables were used, resulting in a calculated diameter of 4, 8, and 12 meters high. Then, the amount sawn wood per 12 feet sections was estimated through the timber rule of Casimiro Donat [6]. The results are shown in Table 1.

Table 1 shows that the value for a 20 cm diameter tree is 2,240 CLP, while in the range from 20 to 30 cm value is multiplied by 6, obtaining a product with a higher value (considering 300 CLP per board foot). A rauli tree with a 40 cm dbh has a value of 35,064 CLP, a 60 cm dbh reaches a value of 83,000 CLP, and a 80 cm dbh has a value of 152,000 CLP.

Table 1 Value of a raulí tree (Nothofagus alpine) according to size.

DBH	**H**	**V**	firewood	DT1	DT2	DT3	CDt1	CDt2	CDt3	total	**$ [CLP]**	CLP/cm.
10	19	0,07	0.1								**562**	56
20	23	0.29	0.5								**2,240**	168
30	25	0.69	1.1	25	23		25	21		46	**13,788**	971
40	27	1.27	1.9	34	31	28	47	38	31	117	**35,064**	1,844
50	28	2.04	3.1	44	39	36	76	62	51	189	**56,619**	2,623
60	28	3.00	4.6	53	48	43	111	91	75	278	**83,331**	2,671
70	29	4.14	6.4	62	56	51	154	126	105	384	**115,183**	3,185
80	29	5.47	8.4	71	64	59	203	166	139	507	**152,197**	3,701
90	29	6.98	10.7	80	73	67	258	211	178	647	**194,218**	4,202
100	29	8.68	13.4	90	81	74	321	263	222	806	**241,668**	4,745

DBH: diameter at brest heigh; H = height in meters; V = volume in m^3; firewood in stereo cubic meters;
DT1: trunk diameter at 4 meters; DT2: at 8 meters, DT3: at 12 meters
CDt1 = board foot of the first piece according to Casimiro Donat's timber rule; CDt2: the same at 8 meters.
Total = total inches of wood per tree
CLP = value in pesos of the tree according to the number of inches it yields, base price $ 3,000 inch
CLP/cm. = value of the additional centimeter of growth in diameter

This way, a forest owner, who sells ten trees of 60 centimeters in diameter per year could earn one million CLP, which is a growth rate of 2,600 CLP per cm. This relationship is essential when assuming this challenge since longer rotations are suitable with a model of sustainable management. However, a commonly observed behavior is cutting down a raulí when it reaches 40 cm, which is done to replace the tree with smaller ones that will grow at a rate of 56 CLP per cm.

Field work in the form of interviews with owners provides further information about current practices, where the waiting time appears to be a key factor in the decision for harvesting. This, combined with clearcutting, generates an unsustainable model based on short waiting times and the total deterioration of the ecosystem, starting from zero every time.

For the proposed model the waiting time is ten years, since there is no clearcut. The model considers partial extractions with cutting cycles that are only a fraction of the rotation. The basis is that native forest, unlike a plantation, does not require a start from clearcut, since the forest already exists. Thus, the economic cycle begins with the harvest, and not with the development of the forest.

Raulí tree result suitable for a management model of this type because their development requires a protective canopy. When one raulí is planted under a canopy, with cup coverage of about 50%, fast growth is obtained, both in height and in diameter: one meter per year in height, one centimeter per year in diameter. In contrast, raulí trees planted in meadows without a canopy of protection have minor growth and also damage from the sun is observed.

A raulí tree is easy to plant if the right technique and plants are used. Some examples of good practices for planting have been observed in fieldwork. Fig. 2 shows an example of this with a photo of a 7-year-old raulí plantation under a canopy using 2-meter-tall bare-root plants, obtained from the forest's peal. In case of the showed picture, about 60 trees were planted per hectare, with a survival exceeding 90%.

3.2 Theoretical Model of Management of an Irregular Raulí Forest

Table 2 represents a model of forest management for an irregular raulí tree forest with six classes of ages, defined by diameter in this case [14]. The accompanying species are not directly considered in this simulation. However, they are indirectly considered when modeling with only 30 m^2 of basal area and leaving at least 10 m^2 as an additional area for other species. This way, we have a forest with 344 raulí trees per hectare, that occupy a basal area of 30

Fig. 2 Raulí forest with proposed model management.

m^2/hectare, 5 m^2 for each diameter or age class, plus an indefinite number of trees of other native species.

Raulí has an excellent response to silvicultural interventions through a good forestry growth of one cm dbh per year (up to 1.4 cm). These results are valid, at least in the proper places of Curacautín, where high site index is observed. Therefore, considering a rotation of 60 years and cutting cycles of ten years, harvesting could be done every ten years. The data is shown in table 2, in the column tagged “harvest”, for 18 trees with 60 cm dbh, and a value per tree of 83,331 CLP, which gives us a total of 1,473,607 CLP. For the case of the 50 cm dbh class, this would be thinned by extracting eight trees with a total value of 440,546 CLP, the same for classes of 40 cm dbh and 30 cm dbh, extracting 14 and 31 trees respectively.

The result is a total extraction of 71 trees with a value of 2.84 million CLP as standing value, without considering selling the remains of the tree for firewood, and a residual forest of 273 raulí trees and the accompanying trees. To this value, we subtract the cost of planting about 120 trees per hectare to rebuild the first diameter class again.

For an owner of 20 hectares of raulí forest under this management scheme, 2 hectares per year should be intervened, obtaining an annual income of around 5.7 million CLP, or 284,000 CLP/hectare/year. This income doubles the annual income of cattle production, which is the alternative use and requires the removal of the native forest.

Table 2 Management moder for multi-age raulí tree forest (values per hectarea)

BA/clase	**species**	**DBH [cm]**	**H [m]**	F	**V [m^3]**	harvest	$ [CLP]
5.0	rauli	**10**	19	100	7.3		
5.0	rauli	**20**	23	90	29.1		
5.0	rauli	**30**	25	71	48.8	31	426,710
5.0	rauli	**40**	26	40	50.6	14	502,252
5.0	rauli	**50**	27	25	52.0	8	440,546
5.0	rauli	**60**	28	18	53.0	18	1,473,607
30				344	241	71	**2,843,115**

Rows: Classes of ages for multi-age forest management model
BA/clase: Base área per age class
DBH: upper limit for diameter per age class
H: Height in meters
F: Number of tres per age class
V: Volume in m^3 per age class
Harvest: number of tres for harvesting per age class
$: Harvest value per age class

4. Conclusion

With this management model for an irregular forest with six classes of tree ages, a local owner of a native obtains a sustained annual income of 284,000 CLP per hectare per year, considering the value of standing timber, which can last for an indefinite time. For the estimation of these values, local prices for wood trade were considered.

The management model considers ten years cycles for timber harvesting. This way, an owner of a typical land of 40 hectares will intervene in the forest every four years, which means an intensity of 25%. Furthermore, the cycle will be complete after ten years, starting again with the first 4 hectares by the year 11.

The final income could be even higher, as the estimation consider only the value of the logs sold as sawn timber. However, since the firewood market in southern Chile is relevant (with more of 80% of the population in the zone using firewood as a main in-house heating resource), farmers could also sell, from the same harvest, firewood. There is no precise estimation about the amount of firewood obtained from raulí tree, but we have observed at least 20 steres per hectare, with a trade market value of 5,000 CLP per stere, with could add up 100,000 CLP per hectare.

Another highlight is that this income is achieved without an added value due to any industrial process, and just with a high-value tree, with fine wood appreciated in the market.

When relatively soft interventions are carried out in the forest, like this 25% cases, the impacts for ecosystems are of little significance, allowing a fast recovery. In the same way, environmental services from the forest, as regulation for water cycles (which are becoming critical on climate change scenarios), as well as nutrient availability on the soil, oxygen regulation, carbon fixation, between other, keep working for the 75% of the forest remaining without intervention.

Moreover, as there is always some part of the forest remaining with no alteration, allowing the housing of large native trees, which are responsible for keeping biodiversity, especially locally protected birds species as woodpecker (*Campephilus magellanicus*), parrot species, diurnal and nocturnal birds of prey, as well as epiphytic and fungal flora which maintain their habitat.

Finally, another indirect benefit is the use of a Chilean government bond for sustainable native forest management. This bond considers a one time amount of until 470,000 CLP per hectare and also considers technical support, whose main barrier for it application is lack of information about sustainable management applications for the native forest.

So we can conclude that there is a model which is both the most profitable alternative (compared with other local land use as cattle ranching) and a sustainable alternative, maintains the increasingly valued conditions of biodiversity.

Since all the conclusions are based on information observed from fieldwork, which has been documented in this work, the presented model requires further development based on a classic theoretical model of an irregular forest. Future research could be refined through future systematization and documentation of the next findings.

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