Multicriteria Analysis of policy alternatives for the conservation caldén forest in Córdoba, Argentina

D.S. Tello[1]; J.D. De Prada[2]; E.R. Cristeche[3]

1: Universidad Nacional de Río Cuarto, Facultad de Ciencias Económicas, Argentina, 2: Universidad Nacional de Río Cuarto, Facultad de Agronomía y Veterinaria, Argentina, 3: Instituto Nacional de Tecnología Agropecuaria, Instituto de Economía, Argenti

Corresponding author email: dtello@fce.unrc.edu.ar

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Keywords

forest policy; multiple forest use; ecosystem services

Introduction

Currently, public policies associated with regulation and conservation of the native forest have become important in the public agenda regarding their provision of ecosystem services (ES). Society is concerned about the loss of non-commercial ecosystem services (NCES) provided by the forest (MA, 2005). Besides, there is a growing concern for the increase of the income generated by commercial ecosystem services (CES) from the forest, based on the promotion of its multiple use, particularly, non-timber forest products (Živojinović et al., 2017). Currently more than 60% of the countries have some kind of national forest legislation, and most of them have updated their contents in the last 15 years (FAO, 2010).

In order to guarantee the provision of NCES and CES, and according to their degree of obligation, native forest legislation has incorporated two types of mechanisms: those of compulsory adoption and voluntary ones. Compulsory adoption mechanisms, also known as "command and control", are regulatory compliance devices that restrict or prohibit certain behaviors of the producer (Izko & Burneo, 2003). Assunção, Gandour, and Rocha (2013) analyze the effectiveness of these measures implemented to reduce deforestation in the Brazilian Amazonia and demonstrate that this not only turns out to be an effective tool, but also that the benefits of avoiding deforestation outweigh the costs of control and surveillance. Additionally, Brown et al. (2001) analyze the impact of the policy of banning deforestation in six countries of the Asia-Pacific region and conclude that bans are effective instruments but in the short term. On the other hand, the mechanisms of voluntary adoption are instruments that promote a change in producers´ behavior based on economic incentives (Rudas Lleras, 1998). Engel et al. (2008) perform a review of NCES payment schemes and compare it with command and control instruments. The authors highlight the flexibility of these instruments in contrast to command and control policies, however these mechanisms should be considered only when NCES are socially desirable, and there is a low opportunity cost.

In all the bibliography reviewed above, it is concluded that forest conservation is guaranteed if a combination of complementary policies is adopted instead of one policy in isolation. In general, producers prefer deregulation or voluntary adoption policies, while command and control policies are resisted by them (Izko & Burneo, 2003). On the contrary, command and control policies are well received by environmental organizations and society in general, while incentive policies does not usually cover social interests for their voluntary nature (Cabrol & Cáceres, 2016). In this sense, Lambin et al. (2014) analyze the effectiveness of the combination of land use policies for the conservation of natural ecosystems and their capacity to offer ES. These authors describe five instruments individually: one of restrictive nature (command and control), and four of a voluntary nature (ecocertification, denomination of origin, negotiation tables, and ES payments schemes), and then analyze the interaction between them. They conclude that the combination of restrictive and voluntary policies achieves a good effectiveness in forest conservation.

To choose a forest conservation policy it is necessary to rely on some method of decision. In general, there are two approaches: monocriterial and multicriterial (Falconi & Burbano, 2004).

In the former, cost benefit analysis (CBA) is probably the most widespread. The effects of the native forest conservation policies would be transformed into monetary values, and appealing to a private or social opportunity cost of capital, the values of the economic flow are brought up to present value through some indicator of profitability, the most widespread is the Net Present Value (Pearce, Atkinson, & Mourato, 2006). This decision rule allows choosing the alternative that generates the greatest net benefit of costs to a specific interest group or society as a whole. The advantages of this approach are: i) the decision rule is simple and easy to interpret, and ii) the monetary values obtained allow comparison with other projects or alternatives (Penna, de Prada, & Cristeche, 2011).

However, this approach has disadvantages. Simon (1979) shows that in many cases, decisions are oriented by multiple objectives (political, social, economic), usually in conflict, and that the design of alternatives and information in decision-making processes are generally incomplete. In this sense, the ABC assumes that the decision maker is rational (and optimizing), that economic efficiency is the main purpose of the social system, and that the information is complete. These principles gave the philosophical bases to multicriterial methods (Romero, 1993).

One of the most developed multicriteria approaches are the discrete methods by classification. The discrete multicriteria analysis (DMCA) allows ordering and selecting an alternative amongst several competitive ones. In the case of methods of classification, binary comparisons are made between alternatives and two indicators are elaborated. One of strength, that computes when an alternative surpasses the others in some criterion, and one of weakness, that computes when the alternative is surpassed by the other alternatives (Bernard Roy, 1991). The most widespread outranking methods are ELECTRE (Bernrd Roy & Hugonnard, 1982), and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) (J. P. Brans & Vincke, 1985). In these methods, decision makers play an important role in the application of the multicriteria approach, since they assign the importance of each criterion, the direction of the objectives, preference and indifference thresholds in the valuation of criteria (pseudo-criteria); and they adjust the model considering the preliminary results (J.-P. Brans & De Smet, 2016).

The choice of the method for the evaluation of conservation policy has been analyzed in the literature. In this sense, Saarikioski et al. (2016) compare the ABC and DMCA approach, and conclude that the second has a better performance, however, they recommend the integration of an ABC in an DMCA analysis. In this sense, the objective of this work is to design and evaluate *ex ante* alternatives for native forest conservation policies in the Caldén Biogeographic Corridor (CBC) area, in the province of Córdoba, Argentina.

Methods

The study area is the CBC (see Figure 1). In the year 2003, the province of Córdoba declared the CBC as a strategy of territorial organization and environmental conservation with an area of approximately 670.000 ha located in the southwest of the province (Decree 891, 2003). This law recognizes the need for its conservation due to its endemic and cultural importance, as well as for its protection service against water and wind erosion, as its soils are mostly fragile and easily degradable. The CBC located in the SouthWest of the General Roca Department in the province of Córdoba, Argentina; has a remnant native forest (RNF) of 77.589 ha (CNA, 2002).

In the CBC, there are five urban localities with 22,000 inhabitants and around 2,000 rural inhabitants are estimated (DGEC, 2008). There are currently around 627 farms, with production systems based on cattle farming (breeding, rearing, fattening and complete cycle) and harvesting crops (soybean, corn, sorghum, sunflower, wheat and peanuts). The use of the land is: 70% livestock and 30% agricultural. The farms with remnants of caldén forest are 215, which partially use the herbaceous stratum for livestock.

Regarding the native forest of caldén, it is characterized phytogeographically by the predominance of the caldén tree (*prosopis caldenia*), in transition with grass savannahs, dunes with sammófila vegetation and saline soils with shrubs or halophilic steppes (Cabrera, 1976).

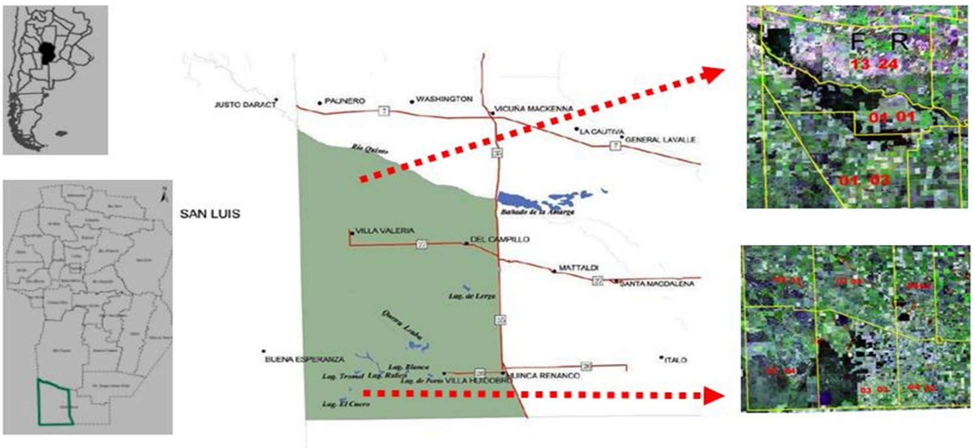

Figure 1. Biogeographic Corridor of Caldén.

Source: Own elaboration based on Rosacher (2002) and Google Earth.

In 2007, the National Law No. 26,331 of Environmental Protection of Native Forests was sanctioned. This Law established that the provinces should declare the minimum environmental protection conditions for its native forests and the ES that they provide to society. To accomplish this, it establishes a territorial ordering process in three categories: high, medium and low conservation value. In the first and second category the clearing is prohibited, and its sustainable use, tourism, forest goods collection and scientific research are allowed. Each province should define its territorial ordering according to criteria of sustainability. Besides, it includes a promotion regime by compensations for native forest NCES. The province of Córdoba in 2010 defined its territorial arrangement of native forest (Law 9814, 2010).

Identification of policies

Five policy alternatives were identified: A1) Tendency, constitutes the projection of the current producers behavior if the same policy is maintained. On the other hand, the four alternatives designed are: A2) Deregulation of Forest Conservation; A3) a Program of Extension for the Multiple Use of the Forest with Prohibition; and A4) Extension Program for the Multiple Use of the Forest; and A5) a Forest Reforestation Program with Prohibition.

A1. Tendency: constitutes the reference situation, projecting the current economic behavior of the farmers with caldén forest. The current Law on the Conservation of Native Forests (No. 26,331) constitutes the combination of a Compensation Scheme for NCES and Penalties for deforestation (PD). If the current policy is maintained, the caldén forest lands in Córdoba are considered of high or medium conservation value. Therefore, the State will annually compensate the farmers with an average amount of $ 50 ha^{-1} of forest. In addition, if a farmer performs forest clearing the penalty varies between "a minimum of five (5) and a maximum of five hundred (500) basic salaries of the rural peon for each hectare in violation" (Law 9814, 2010). The implementation of the policy covers monitoring and inspection expenses.

A2. Deregulation of forest conservation (Deregulation): it consists of eliminating legal restrictions as well as areas of the State with competence in the administration of the forest, to allow the free functioning of the market. In this way, the agricultural producer receives net benefits for the sale of goods and services in the market, and if the net agricultural and / or livestock benefits are greater than the net benefits obtained from the RNF, the farmer can deforest.

A3. Extension Program for the Multiple Use of the Forest with Prohibition (EPMUF+P): consists in adding to the Tendency alternative, an Extension Program that transfers capacities to take advantage of the multiple CES of the forest. The Extension Program helps the farmer to develop a production system integrating farm land and forest that allows the multiple use of the forest (eg. beekeeping, livestock and forestry). There is evidence that with this type of system is possible to triple the commercial benefits that are currently obtained from the forest from (Coirini & Karlin, 2011). To obtain these benefits it is necessary to make fencing and water supply investments and changes in livestock management. These private investments of $ 4,000 ha^{-1} are made by the producer and estimated at a value. For the implementation of this program, an average annual transfer of $ 1,248 ha^{-1} of forest is estimated in two years. This amount is based on a model forest program from Jujuy, Argentina (Outon, 2002).

A4. Program of Extension for multiple use of the forest (EPMUF): this alternative is similar to the previous one without Prohibition of deforestation. The farmer can sell goods and services in the Market; and if the agricultural benefits are greater than the benefits obtained from the new technological model adopted for the forest, the farmer can deforest.

A5. Program of Reforestation with Prohibition (RP+P): it consists of a Program to expand caldén native forest area through the reforestation of 36,467 hectares (equivalent to 47% of the current area of forest) in a period of 20 years. Integrates policies A1 and A3. The State jointly implements these policies: i) a one time subsidy for caldén reforestation, ii) the extension program for multiple forest use , iii) the prohibition of clearing on the current forest area, and iv) compensation for NCES. In this sense, the farmer will be prohibited from clearing RNF, but will receive a subsidy for reforestation, and a compensation for NCES provided by the forest area he currently owns and decides to reforest. The subsidy takes as reference the investment law for cultivated forests (Law 25080, 1998). In the province of Córdoba, a one time non-refundable economic contribution is paid for reforestation (plantation) of native species, of $ 9,782 per ha for farms up to 300 ha, and a payment of $ 2,445 for farms between 301 and 500 ha (SAyGP, 2015).

Policy evaluation

To evaluate the alternatives of native forest conservation policy, the DMCA Promethee I and II methods were applied (JP Brans & Vincke, 1985) integrating the results of: a) a Private cost benefit analysis (CBA); b) a contingent valuation of caldén forest ES by urban population from the study area , and c) secondary data to contemplate the social dimension. The PROMETHEE method subsumes the CBA, which is used to: a) predict the policy impact on farmers´ behavior in relation to clearing, and b) to assess the benefits obtained by the urban population from ES provided by the RNF. The Brans & de Smet procedure (2016) was used for the Promethee method; Pearce et al (2006) was used for CBA; and Bateman et al (2002) was used for the contingent valuation survey (CV).

Derivation of the criteria

Of the seven criteria, five criteria are quantified based on the farm model and two social criteria are elaborated based on secondary information and experts interviews.

C1. Private Benefits of Farmer (PBF): private benefits are measured in $ year-^{1}, are the sum of the annuities of the NPV (ANPV) calculated for a period of 20 years. To estimate this effect of the policy on the property model, a private CBA is applied considering the NPV as an indicator of profitability, considering a planning horizon of 20 years and an opportunity cost (r) of 12%. The farm model is represented by the following equation:

$$NPV_i = \left\{ \pm I_{0i} - P_{0i} + \sum_{t=1}^{20} \left[\frac{(ONB_{tij\neq n} - ONB_{tij=n} - CES_{ti})}{(1+r)^t} \right] \right\} a_{0ij=n}, \qquad \text{[Eq.1]}$$

$$ONB_i = \left[\sum_j p_j q_j s_j - c(q_j, s_j) \right] \frac{1}{\sum_j s_{ij}} \qquad \text{[Eq.2]}$$

where: I represents the investment made by the producer, measured $ ha^{-1}; P the value of the penalty, measured in $ ha^{-1}, the ONB represents the operational net benefit of the farm ($tij = n$ indicates operative net benefits from forest activities and $tij \neq n$ operative net benefits from agricultural activities), expressed in $ ha^{-1}, CES represents the compensation for forest provision of NCES, measured in $ ha^{-1}; p represents prices, $ q yields measured in kg ha^{-1}; c costs measured in \$ kg^{-1}, a the area of activities measured in ha; the subscript i represents the farm (1 to 215), the subscript t represents the time measured in years (from 0 to 20); j represents the set of productive activities of the farm, ($j = ag$ indicates the activities on the implanted crops surface, $j = n$ the activities done in the RNF).

The farm model assumes that the farmer compares the income of the RNF with respect to the income of implanted crop systems (rest of the farm) and decides to clear or conserve the forest. The private decision rule:

$$\left\{\pm I_{0i} - P_{0i} + \sum_{t=1}^{20}\left[\frac{(ONB_{tij\neq n} - ONB_{tij=n} - CES_{ti})}{(1+r)^t}\right]\right\} > 0\text{; deforest } a_{0ij=n}\text{; or} \quad \text{[Eq.3]}$$

$$\left\{\pm I_{0i} - P_{0i} + \sum_{t=1}^{20}\left[\frac{(ONB_{tij\neq n} - ONB_{tij=n} - CES_{ti})}{(1+r)^t}\right]\right\} <= 0\text{; maintain RFN.} \quad \text{[Eq.4]}$$

In A1 Tendency, the NPV (Eq. 1) of the change in land use, is considered as a farm investment, incorporating the elements of the current policy: a) one time penalty (P), and b) the annual compensation for NCES (CES). In this case, if the NPV_i is greater than zero, farmer i will clear the RNF of its farm and produce crops during the NPV analysis period (Eq.3). In contrast, if the NPV_i is less than or equal to zero, the farmer i maintains the RNF. To the extent that the present value of the flow of the income of the crops implanted does not exceed the income flow of the RNF ($ONB + CES$), the investment expenses (in this case I represents the investments for the clearing) and the penalty, there is no incentive to clearing (Eq.3).

In the case of the deregulation policy (A2), two elements are eliminated in the private cost benefits analysis: $P_0 = 0$ and CES_t=0. Therefore, it is probable that there are farmers who have an incentive to deforest, depending on the cropping and rotation systems that each farmer has on his farm.

In A3 the extension program generates a rise in caldén forest productivity. This alternative triples the $ONB_{tij=n}$ from year 3 onwards. In this case, I represents the difference between the investment expenditure for clearing (\$ 5,000 ha^{-1}) and the investments necessary to adopt the activities promoted by the extension program (\$ 4,000 ha^{-1}).

As for the A4 alternative, it improves forest productivity in a similar way to A3, but eliminates the P_0 prohibitions.

In the Reforestation Program (A5), it is considered:

$$NPVP_i = \left\{-IR_{0i} + \frac{SR_{1i}}{(1+r)} + \left[\frac{(\sum_{t=3}^{20} ONB_{tij=n} + \sum_{t=1}^{20} CES_{ti} - \sum_{t=1}^{20} ONB_{tij=ag})}{(1+r)^t}\right]\right\} a_{0ij=ag}, \quad \text{[Eq.5]}$$

where: IR is the investment in reforestation in \$ ha^{-1}, that the producer must make in the cultivated lands, SR the subsidy for reforestation in \$ ha^{-1} that the producer receives from the

State. In this alternative, the SR is received once the investment is made and the $ONB_{tij=n}$ begin at year 3.

In this sense, the PBF criterion is made explicit as an equivalent annuity ($ANPV$):

$$ANPV_i = \frac{NPVP_i r}{1-(1+r)^{-T}} \quad \text{[Eq.6]}$$

where $ANPV$ is the annuity of the NPV, of each policy alternative. The objective of this criterion is to maximize.

C2. Transfers (T): are measured \$ year^{-1}, refer to the public funds used to induce a change in farmers' behavior. The annuaties of CES, SR, extension costs (E) and prohibition expenses (M), is estimated as follows:

$$T = \frac{CES_i r}{1-(1+r)^{-T}} + \sum_i AECNR_{1i} + \frac{E_i r}{1-(1+r)^{-T}} + \frac{M_i r}{1-(1+r)^{-T}}, \quad \text{[Eq. 7]}$$

The first and second components of equation [7] are direct payments made to the producer. The third component represents a direct payment from the State to the producer during three years (it does not modify the NPV) although it provides the farmer with new know-how to modify the private ONB. The fourth component is an estimated fixed control and surveillance expense for those alternatives that include clearing prohibition. The objective of transfers' criterion is to minimize.

C3. Economic valuation of the forest by urban population (EVFUP): measured in \$ year^{-1}, computes urban population WTP for an increase in forest area or the compensation accepted for the loss of utility due to the clearing. In case the current RNF is conserved, its value is zero. The objective of this criterion is to maximize.

C4. Forest area (FA): measured in ha, is the aggregate RNF derived from the farm model after the implementation of the different policies (Eq.1). The objective for this criterion is to maximize.

C5. Employment generation (E): number of permanent employees derived from activities j in the farm i.

C6. Institutional Political Effort (IPE): qualifies the changes that must be made in the State in order to induce changes in farmers' behavior to achieve the results of the designed policy. This effort is expressed in the creation of new areas for policy management, particularly staff selection and training, interaction with the rest of the government areas and the private sector to develop control, inspection and monitoring activities.

C7. Risk of Socio-environmental Conflict (RSC): qualifies the potential conflict or resistance that an alternative can generate in certain groups. To assess this criterion, Silvetti et al. (2013) study native forest from the northwest of the province of Córdoba was considered.

In that study they identify two types of social actors in conflict regarding forest conservation policies: i) cattle farmers group motivated mainly by economic interest and opposed to any type of regulation; and ii) the environmentalist peasant group with philosophy based on forest protection highlighting its ancestral use. For the study area considered in this research, two potentially conflicting local actors were identified: i) Farmers Associations (FA) with an economic orientation intending to maintain or increase their private economic benefits and avoid regulations, and ii) the Environmental Assemblies and Collectives (EAyC) that intend to conserve or increase the forest area. The objective of this criterion is to minimize.

Farm model data

Farm component

The CBA farm model represents the individual behavior of 215 farms. Information was taken from the last National Agricultural Census database (Table 1). The implanted surface of these farms is 374,825 hectares. 98% of the RNF is used for livestock and only 1,379 hectares of forest are not used according to that source.

The technical parameters of the ONB were obtained from specialized journals (see Table 2, Table 3 and Table 4). For the estimation of commodities prices and input costs, an 2007 to 2016 average of price series were considered (SIIA, 2015; CREA, 2017). All values are expressed in Argentinian pesos (AR $) at constant 2016 prices, with an average exchange rate 2007-2016 of: AR $ 6.01 = USD 1.

To estimate the generation of employment in agricultural activities, the following were used: a) the estimated technical coefficients of 1997 argentinian input output matrix published by Visintini et al. (2007); b) a coefficient for forestry that is taken from input output matrix; and c) beekeeping coefficient taken from literature (Apícola, 2013). Regarding this information, in an average 100 ha area it is estimated 1 full time employee for agricultural and beekeeping activities, 4 employees for livestock activities and 7 employees for forestry activities (Cisneros et al., 2011).

Table 1. Identification of Farm with Caldén RNF in the south of Córdoba

Category	Farm with RNF	Farm without RNF	Total Farm
Farms (n)	215	412	627
RNF (ha)	77.589		77.589
Livestock Area (ha)	269.441	126.788	396.229
Agriculture Area (ha)	105.384	97.869	203.253
Apiculture Activity (hives)	30.474	14.788	45.262

Table 2. Economic yields and indicators of crops

Crop	Yields	Price	Cost	ONB
	kg/ha	$/kg	$/ha	$/ha
Corn	5000	1,86	5324	935
2nd Corn	4500	1,86	4643	990
Soybean	2400	3,65	3656	3630
2nd Soybean	1800	3,65	2947	2517
Sorghum	5000	1,52	2864	1670
Wheat	3000	2,36	3067	2170
Sunflower	2200	3,70	4991	2207
Peanut	1900	7,75	7913	5401

Source: Own elaboration based on technical proposals and average 2007-2016 crop yields (Margenes, 2017), except from the case of peanut taken from Bongiovanni et al. (2008).

Table 3. Stocking rate and economic indicators by type of cattle activity

Activity	Stocking Rate	Income(*)	Costs	ONB
	GLU/ha	$/ha	$/ha	$/ha
breeding with forest	0,15	445	50	422
breeding without forest	0,50	1485	286	1287
fattening with forest	0,96	4520	1211	3309
fattening without forest	1,22	5556	1267	4288
Breeding- fattening with forest	0,75	3607	1403	2337
Breeding- fattening without forest	0,98	4714	1490	3397
Full cycle cattle production with forest	0,26	1045	272	819
Full cycle cattle production without forest	0,70	2813	1060	1876

Note: (*) regarding the variety of categories grouped in each type of livestock activity, the price and quantity parameters are presented aggregated in the Income parameter. Source: Own elaboration based on technical proposals and livestock stocks 2006-2017 of the economic bulletin of INTA Anguil (INTA, 2017).

Table 4. Yields and economic indicators of the apiculture activity

Actividad	Yields	Price	Costs	ONB
	kg/ha	$/kg	$/ha	$/ha

Honey	7	27	87	100

Source: Elaborated by the authors on the basis of technical proposals 2007-2016 of INTA Anguil economic bulletin (INTA, 2017).

Economic valuation by urban population data

Based on a contingent valuation survey made to urban inhabitants from urban households of south of Córdoba a willingness to pay is estimated at $ 2,874 per hectare of increased forest (Tello, from Prada, & Cristeche, 2017).

Decision matrix and sensitivity analysis

To transform the quantitative criteria into pseudo-criteria, the preference function used is Linear with an the indifference threshold (q_j) of 10% and a preference threshold (p_j) of 90%. In the case of qualitative criteria, the preference function used was Usual (J.-P. Brans & De Smet, 2016).

To show the flexibility of the model, two simulations of the model were conducted: 1) with four theoretical weighting profiles, and 2) with the weightings given by extraregional actors in a workshop. In the first case, four contrasting decision-maker profiles were designed. The first profile balances the social, environmental and economic dimensions, and is called Sustainable Development (w_1) profile. The second is a socioeconomic profile w_2, the third is a pro-market profile w_3 and the fourth profile is preservacionist w_3. These profiles will refer to four different vectors of weighing for the criteria $w_j(FA, PBF, T, EVFUP, E, PIE, RSC)$: in the first profile was assigned a 33.3% to the environmental, economic and social dimension that were distributed equitatively among the criteria that belong to each dimension $w_1(0{,}33;\ 0{,}11;\ 0{,}11;\ 0{,}11;\ 0{,}11;\ 0{,}11;\ 0{,}11)$; in the second profile $w_2(0;\ 0;\ 0;\ 0{,}33;\ 0{,}33;\ 0;\ 0{,}33)$ 33.3% was assigned to the E, RCS and EVFUP criteria; in the third profile $w_3(0;\ 0{,}33;\ 0{,}33;\ 0;\ 0;\ 0{,}33;\ 0)$ 33.3% was assigned to the PIE, T and PBF criteria; and finally $w_4(0{,}5;\ 0;\ 0;\ 0{,}5;\ 0;\ 0;\ 0;\ 0;\ 0)$ was assigned 50% to criteria FA and VEBPU. Then, a simulation with real weightings from participants of a discrete multicriteria analysis workshop outside the study area was done. These participants had mainly an academic profile (researchers, professors and postgraduate students).

In both simulations, the one with theoreticaly designed weighting profiles and the other with actual actors weightings, a sensitivity analysis was conducted, modifying the indifference (q_J) and preference p_J thresholds of the linear preference function.

Results

1. Cost Benefit Analysis

In general terms, the combined results of the private CBA and the contingent valuation survey show a strong contrast between two groups of policy.

Table 5. Main indicators of the Cost Benefit Analysis and the Contingent Valuation Survey

Alternatives[1]	**Criteria**[2]					
	FA		***PBF***	**EVFUP**	**T**	***E***
	hectáreas	**Farm with Forest**	***$mill/year***	**$mill/year**	**$mill/year**	***quantity***
Tendency	77.589	215	4	0	5	3.080
Deregulation	52.953	103	26	-71	0	2.461
EPMUF + P	77.589	215	30	0	27	4.457
EPMUF	57.709	121	41	-57	20	3.614
RP + P	114.056	219	76	105	71	5.815

Note: [1] EPMUF+P: Extension Program for the Multiple Use of the Forest + Prohibition; RP+P: Reforestation Program + Prohibition. [2] FA: Forest area; T = transfers; PBF = private benefit of the farmer; EVFUP = economic valuation of the forest by urban population; E: Employment.

The forest area requires policies combined with prohibition, otherwise there is an incentive to clear and consequently loss of the economic value of the forest perceived by the urban population. The model predicts that the deregulation of forest conservation, is the alternative of greater incentive to clear, of the 215 farms, 103 farms decide to conserve the forest and 112 farmers decide to deforest, this implies a loss of the current forest area of approximately 34% (Table 5). With the implementation of the EPMUF program, the farms that decide to keep (121) i.e. are increased. 18 farmers refuse to deforest compared to the Deregulation alternative, however, in 94 farms the incentive to clear persists. These alternatives (Deregulation and EPMUF) generate a negative perception about the urban population and are expressed in an economic loss in terms of economic value, of approximately $ 71 and $ 57 million annually respectively. On the contrary, alternatives with prohibition generate neutral or positive values. This result shows that only with compensation for SENC, and extension of technological improvements are not sufficient to maintain the current area of the native forest, and that the key to current policy, as well as extension and reforestation programs, has been a dissuasive prohibition. In the same way, the prohibition alone would not be sufficient, given that its compliance depends on the effort made by the State, and does not itself generate a change of conscience and attitude towards the conservation of the native forest by the farmers.

On the other hand, the model estimates that the implementation of extension and reforestation programs are those of greater private benefit of the farmers. If the PBF of the alternative that would produce the largest deforestation (Deregulation) is taken as reference, the EPMUF programs with and without prohibition as well as the RP+P program (which includes the extension program) increase the private benefit that could be obtained in each farm. Similarly, the extension and reforestation programs are the alternatives that generate the most employment, with respect to the Deregulation and Tendency alternatives. This result warns how the multiple use of the forest - currently wasted by the farmer - increases the economic benefits, as well as the jobs. However, these programs generate larger transfers. In this sense, Deregulation is the best alternative, followed by the Tendency alternative that involves a low transfer.

2. Decision Matrix

In addition to the criteria presented in the previous section, consultation with public policy experts allowed the incorporation of the criteria IPE and the RSC. Conforming the consolidated decision matrix of the multicriteria decision analysis (Table 6):

Table 6. Decision matrix of policy alternatives for the conservation of the caldén forest

Alternatives	Criteria[1]						
	FA	PBF	T	EVFUP	E	PIE	RSC
	Hectáreas	$mill/año	$mill/año	$mill/año	Cantidad	Índice	Índice
Tendency	77.589	4	5	0	3.080	Low	Medium
Deregulation	52.953	26	0	-71	2.461	Very low	Very high
EPMUF+P	77.589	30	27	0	4.457	High	Low
EPMUF	57.709	41	20	-57	3.614	High	High
RP+P	114.056	76	71	105	5.815	Very high	Medium
Objective	MAX	MAX	MIN	MAX	MAX	MIN	MIN
Preference	V lineal	V lineal	V lineal	V lineal	V lineal	Usual	Usual
W	1	1	1	1	1	1	1
w normalized	14,30%	14,30%	14,30%	14,30%	14,30%	14,30%	14,30%
Range	61.103	72	71	176	3.354	4	3
Qj	6.110	7	7	18	335	Nc	Nc
Pj	54.993	65	64	158	3.019	Nc	Nc

Note: [1] PIE: Political Institutional Effort; RSC: Risk of Socio-environmental Conflict.

As can be seen in Table 6, the alternatives of lower IPE were the policies that involve the least intervention of the State, such is the case of the Deregulation and Tendency policies, while the largest IPE is in the extension and reforestation programs. In the case of RSC, the Deregulation policy was the alternative of greatest conflict since this alternative would be the one with the greatest loss of forest area and the environmental group would reject it, while the policy of greater consensus would be EPMUF+P, due to the acceptance of both farmers -the majority would not reduce their benefits, on the contrary they would increase- as well as the environmental group (I would not object because it would conserve the current forest area). Between these extremes, the rest of the alternatives are located.

In summary, the analysis of the decision matrix shows a different performance of the different policy alternatives according to the criterion considered, giving an account of the existence of conflicts between criteria:

The alternative RP+Prohibition has a high economic valuation of the urban population associated with the increase in forest area and the prohibition of clearing in the current RNF. Additionally, the greater area of forest makes it the alternative of greater employment generation. As this policy includes the extension program for the use of different forest products, it has good private profitability. The combination of a high private benefit and increased forest area causes a null socioenvironmental conflict. However, the political-institutional effort is considerable, as well as the transfers that the State must make.

The EPMUF programs with and without Prohibition from the multiple use of the forest show a good performance in the private benefits expected by the farmer, as well as in the generation of employment. The alternative combined with the prohibition avoids the loss of the current forest surface and consequently this alternative improves in terms of environmental performance and presents less socio-environmental conflict than the alternative without prohibition. However, these programs require the largest volume of transfers from the State, mainly to promote the multiple use of the forest by the farmer.

In the case of the projected current policy (Tendency) it is observed that the current implementation of compensation by ESNC is very low, and together with the low private benefit expected by the farmer in this alternative, does not cover the opportunity cost of maintaining the forest, and consequently, the incentive to deforest persists, hence the importance of prohibition. This added to a null economic value perceived by the urban population implies a low economic performance and employment generation. However, the levels of transfers are low, the socio-environmental conflict is null and the political-institutional effort is low.

With Deregulation, a forest loss of 34% of the current surface is projected, this loss of forest being negatively valued by the urban population and generating possible socio-environmental conflicts. However, this alternative has an acceptable private benefit, the absence of State transfers and a low political-institutional effort.

Preferences Test

Of the four vectors of weights considered to express different preference schemes on the identified criteria (w_1, w_2, w_3, w_4), it was found that three of them prioritize the combined policies with prohibition over the voluntary, and only one is completely different, with an ordering almost exactly inverse (Tables 7, 8, 9 and 10). Additionally, when sensitivity analysis of the preference and indifference thresholds is made, the arrangement of the alternatives is stable, with the exception of one case (Table 11).

P1. Preferences 1 (w_1): with this vector of preference, the decision maker balances the weights of the criteria of the environmental, social and economic dimensions (Table 7). The alternatives of better performance are the alternatives with Prohibition and with multiple use of the forest. With these alternatives it is not deforested (even in RP+P the forest area is increased), the biggest jobs are generated, it presents good indicators of private profitability and economic value perceived by the urban population. The worst performance alternatives are those that allow the clearing (EPMUF and Deregulation).

P2. Preferences 2 (w_2): with this vector of preference the socio-economic criteria are emphasized, economic value of the forest for the urban population, generation of employment and minimization of the risk of social conflict (Table 8). An order similar to that of w_1 is obtained. The alternatives with better performance are those that include the prohibition.

P3. Preferences 3 (w_3): in the third preference vector, the freedom of the market and the lower intervention of the State are prioritized (Table 9). Consequently, the low political implementation effort, the minimization of State transfers to the private sector and the maximization of private benefit are valued. As a result, in this case the previous orders are completely reversed. The preferred alternative is Deregulation, and on the contrary, RP+P is the worst performance alternative.

P4. Preferences 4 (w_4): with the fourth preference vector it is considered that one hectare less of forest can not be had, therefore, the forest conservation and the economic value that the urban population is assigned to the forest are determining criteria. In the same way as preferences 1 and 2, the most preferred alternatives (Table 10) are alternatives with prohibition.

Table 7. Order of policy alternatives for decision-makers with sustainable development profile (w_1)

Alternative	Net	Strength	Weakness
	Order	**Order**	**Order**
RP + P	1	1	2
EPMUF+P	2	2	1
Tendency	3	3	3
Deregulation	4	4	5
EPMUF	5	5	4

Table 8. Order of policy alternatives for decision-maker with socioeconomic profile (w_2)

Alternative	Net	Strength	Weakness
	Order	**Order**	**Order**
RP+P	1	1	1
EPMUF+P	2	2	2
Tendency	3	3	3
EPMUF	4	4	4
Deregulation	5	5	5

Table 9. Order of policy alternatives for decision maker with a pro-market profile (w_3)

Alternative	Net Order	Strength Order	Weakness Order
Deregulation	1	1	1
Tendency	2	2	3
EPMUF	3	4	2
EPMUF +P	4	5	4
RP+P	5	3	5

Table 10. Order of policy alternatives for decision maker with preservationist profile (w_4)

Alternative	Net Order	Strength Order	Weakness Order
RP+P	1	1	1
EPMUF+P	2	2	2
Tendency	3	3	3
EPMUF	4	4	4
Deregulation	5	5	5

With thresholds of preference and indifference modified to 30% and 70% respectively, a similar ordering of the alternatives was obtained, with the exception of the sustainable development profile, in which the Deregulation and EPMUF alternatives invert their order (Table 11).

Table 11. Net ordering of alternatives with different thresholds of preference and indifference

Order	**Sustainable development profile**		**Socioeconomic profile**		**Pro-market profile**		**Preservationist profile**	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**
1	RP+P	RP+P	RP+P	RP+P	Deregulation	Deregulation	RP+P	RP+P
2	EPMUF +P	EPMUF +P	EPMUF +P	EPMUF+ P	Tendency	Tendency	EPMUF+ P	EPMUF+ P

3	Tendency	Tendency	Tendency	Tendency	EPMUF	EPMUF	Tendency	Tendency
4	Deregulation	EPMUF	EPMUF	EPMUF	EPMUF+P	EPMUF+P	EPMUF	EPMUF
5	EPMUF	Deregulation	Deregulation	Deregulation	RP+P	RP+P	Deregulation	Deregulation

Note: qj and pj assume %: A) between 10% and 90%; and B) between 30% and 70% respectively.

Weighting test with Workshop

In a first statistical analysis of the weight assigned by each one of the assistants of the workshop to the criteria (Table 12). They had to give a score of 0 to 10 for each of the criteria, being 0 for the least preferred and 10 for the most preferred. It was obtained that the FA and E, have the highest weights and the smallest variabilities (Coefficient of variation 14 and 16% respectively), indicating that both criteria are very important and have been positively valued by most of the participants. For the rest of the criteria, there are significant differences in the weights, it was found that those who value the criteria with the highest weight (10) and who directly rejected criteria (0).

Table 12. Statistical analysis of the preferences of workshop participants

Statitical	PBF	T	EVFUP	FA	E	PIE	RSC
Mode	10	5	8	10	9	2	9
Minimun	2	2	0	7	6	2	0
Maximum	10	9	10	10	10	10	9
Average	7	6	6	9	8	6	6
Standar deviation	3	2	4	1	1	3	3
Coefficient of variation	47%	35%	61%	14%	16%	56%	48%

Under a frequency analysis of the net ordering of the alternatives weighted, a consensual ordering -almost by majority- with preferences in those alternatives combined with prohibition. Considering the sum of the net arrangements, for most of the participants (Table 13) we obtained: 1) RP+P, 2) EPMUF+P, 3) Tendency, 4) EPMUF, and 5) Deregulation. When the thresholds of preference (decrease to 70%) and indifference (increase to 30%) were modified (Table 14), the net ordering of the alternatives is not modified.

Table 13. Frequency of Net Ordering of each alternative $qj = 10\%$ and $pj = 90\%$

Alternative	Order				
	1	2	3	4	5
RP+P	100%	-	-	-	-
EPMUF+P	-	100%	-	-	-
Tendency	-	-	89%	11%	-
EPMUF	-	-	11%	44%	44%

Deregulation	-	-	-	44%	56%

Tabla 14. Frequency of Net Ordering of each alternative $qj = 30\%$ and $pj = 70\%$

Alternative	Order				
	1	2	3	4	5
RP+P	100 %	-	-	-	-
EPMUF+P	-	100 %	-	-	-
Tendency	-	-	78 %	22 %	-
EPMUF	-	-	22 %	78 %	-
Deregulation	-	-	-	-	100 %

Discussion

From the presented results it is possible to discuss at least three aspects.

In the CBA, the extension and reforestation programs are the best performing alternatives in terms of PBF, $EVFUP$ and E, however, they require higher transfers than the Tendency and Deregulation alternatives. This result is very important given that the policies linked to the multiple use of forests can play an important role in protecting the RBN, and at the same time, significantly increase the welfare of the community, however, these policies require large transfers from the State. This result coincides with the sustainable forest management policies of the forest in other regions of the world (X. Izko & Burneo, 2009).

In both CBA and DMCA, policies combined with prohibition over voluntary ones predominate. The profiles of decision makers designed, as well as the weights obtained in the workshop, show that incentive policies combined with restrictive policies dominate voluntary policies. This result coincides with the literature that indicates that in certain cases the combination of incentive policies with command and control policies can be effective and valued by society (Brown et al., 2001, Lambin et al., 2014).

Analyzing the alternatives individually, RP+P emerges as the best positioned alternative in at least three types of profiles that prioritize environmental and social criteria in different degrees, and Deregulation in the pro-market profile. Cisneros et al. (2011) evaluate 10 (ten) land-use alternatives for a micro-basin in southern Córdoba based on thirteen environmental, social and economic criteria based on the DMCA AHP, ELECTRE and PROMETHEE methods, finding a similar result. When social and environmental criteria are prioritized, a silvopastoral land use planning program similar to the reforestation and multiple use alternative proposed in this work is preferred. On the contrary, when economic criteria are prioritized, the Tendency situation is chosen, which resembles Deregulation because the trend situation of this work considers the absence of an effective regulation of the watershed management. Addicionally, in Abedi and Ghamgosar (2013) when evaluating 3 alternatives for the management of the native forest in the region of Guilan in Iran, on 14 criteria from an ADM ELECTRE. The results indicate that a management of forest conservation for that region is the best alternative over the commercial and recreational strategy, because the current state of the forest is degraded and it is essential to preserve the forest to improve its conservation status.

Although the results found from the weighting done in the workshop show a certain degree of consensus for a type of policies associated with greater forest conservation than the current one, it is important to note that the participants form a homogeneous group, linked to academic activities and research in the area of natural sciences. Therefore, these results could avoid the heterogeneity of actors that exist in the study area. However, the literature shows the possibility of finding consensus in actors with different preferences. Sheppar and Meitner (2005) apply PROMETHEE to evaluate the forest management of British Columbia (Canada) and find that stakeholders with different preferences (forest groups, environmental groups, owners and experts) obtain similar arrangements of policy alternatives.

Conclusions

In this work, a discrete multicriteria conceptual and mathematical model is developed, which allows incorporate the preferences of different social actors. As a result, to obtain as a result a ranking of the different policies designed, detecting possible conflicts between the social actors interested in the caldén forest. Likewise, the application of an CBA in an integrated way with the DMCA stands out; these techniques, that are usually presented as competing, are nonetheless used as complement in this work trying to preserve the advantages that both provide for policy evaluation.

The PROMETHEE turned out to be ductile to reflect the interests of the different actors when contrasting results with respect to the most desirable policy alternatives. This paper demonstrates the ability of the method to systematize the available information and to help the decision maker to compare the alternatives subject to the interest of the social actors. Additionally, this type of method offers, from successive approaches, the possibility of reaching agreements between the majorities of the actors involved without ignoring the multiple interests at stake. In the future, it is expected in the future to demonstrate this ability to discuss and define the policy addressed in this work.

It is necessary to warn the reader of some limitations of this work. The policy alternatives have been designed without including certain aspects in the environmental dimension that incorporate the state of the forest and its fragmentation, for example indicators that simulate, in a georeferenced manner, the spatial distribution of the forest surface (size of the patches), being able to estimate the provision of the odd associated SENC. Likewise, this work does not incorporate the opinion of the local actors, and possibly integrating this information it will be possible to have a more precise decision matrix. Both limitations are part of the future research agenda.

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