Economic Analysis of Afforestation Projects for Carbon Sequestration A Case Study in Patagonia, Argentina

M. Sc. Thesis

“International Agribusiness”

Faculty of Agricultural Sciences

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Accomplished at the Institute of Agricultural Economics

Göttingen March, 2004

Dedicated with love
to Mariana
and my Family.

Acknowledgements

I would like to express my gratitude to Dr. R. Olschewski, for his scientific guidance, constant support and patience. Also, to Prof. S. von Cramon for his flexibility.

I am indebted to Dr. G. Loguercio, my local supervisor, for providing important data, guidance and permanent encouragement. As well as, to R. Manfredi for his comments and data in economic issues and S. Antequera for his assistance.

Many thanks to F. Carabelli for support me and encourage me to apply to this M. Sc. Programme. Moreover, I would like to thank to C. Baroli for his advice.

Unfortunately, it is impossible to acknowledge all the individuals who have helped me, but special appreciation goes to the staff of CIEFAP for providing technical information, good fellowship, and the facilities to develop my fieldwork. Specially, I thank to A. Jovanoswki, D. Lencinas, and D. Martinez. And also, to G. De Maria and the GIS' staff of the DGByP for supplying important data. Furthermore, H. Colomb, A. Diaz, O. Knollseissen, F. Momberg, W. Schmid, A. Tarullo, R. and S. Whewell provided invaluable information about forest management costs. Moreover, my gratitude goes to N. Castillo from Argentina Climate Change Office and to the real estate experts from Esquel for their attention.

I thank to J. Budde from the Institute of Agricultural Economics for his support on software facilities. Also, to B. Brümmer for his software recommendation and T. von Bernard for his English corrections and useful comments.

I am indebted to B. Locatelli from CATIE and C. Forner from UNCCC for theirs very useful explanations and comments about diverse CDM topics.

I am thankful to the Deutsche Akademische Austauschdienst (DAAD), Prof. J. Diaz and Prof. M. Zeller for give me the opportunity of studying and living in Chile and Germany. Also, I appreciate the support of the M.I.A. staff.

Last, but not least, I would like to express my gratitude to my wife, Mariana, for her love, care and company in this adventure; and to my family for their unconditional encourage and love.

Gustavo M. Salvador

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List of abbreviations

AAUs	Assigned Amount of Units
CDM	Clean Development Mechanism
CERs or CER	Certified Emission Reductions
CIEFAP	Patagonian Andes Forest Research and Extension Centre
CO_2	Carbon dioxide
DGByP	Dirección General de Bosques y Parques
EAI	Expected Annual Income
ERs	Emission Reductions
ERUs	Emission Reduction Units
ET	Emission Trading
EU ETS	European Union Emission Trading Scheme
F – S	Farmer without state subsidies scenario
F + S	Farmer with state subsidies scenario
GHG	Greenhouse gases
GTZ	German Technical Cooperation
ha	Hectare
i	Discount rate
I - S	Investor without state subsidies scenario
I + S	Investor with state subsidies scenario
IETA	International Emission Trading Association
INTA	Instituto Nacional de Tecnología Agropecuaria
JI	Joint Implementation
KP	Kyoto Protocol
LCER	Long-term Certified Emission Reductions
LULUCF	Land Use, Land Use Change and Forestry
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
PCF	Prototype Carbon Fund
PV	Present Value
SAGPyA	Secretaria de Agricultura, Ganadería, Pesca y Alimentación
t CO_2	Metric tonne of carbon dioxide
t/ha	Metric tonne per hectare
TCER	Temporary Certified Emission Reductions
UNFCCC	United Nations Framework Convention on Climate Change
$	Argentinean Pesos

SUMMARY

The mitigation of global warming in a cost-efficient way is one of the global action priorities. Clean Development Mechanisms of the Kyoto Protocol could mitigate the climate change and to benefit local communities as well. However, given the current uncertainty about carbon prices for temporary credits and the high level of transaction costs, CDM forestry projects of small scale could be unfeasible.

This study aims to determine the cost and profitability of sequestering CO_2 in *Pinus ponderosa* plantations on average to high quality sites in the South of Argentina. The number of certified emission reductions (CERs) to be issued is estimated using temporary credits (TCER) and long-term credits (LCER). Furthermore, critic points - for different variables - are calculated as the values where the revenues from sales of CERs cover the transaction costs.

Results show that the conjoint production –timber plus CER sales- increases projects profitability compared to timber production alone. Different accounting approaches used have almost the same performance, even though, the major difference is originate in the cash flow payment distribution. Under an average scenario (8,2 €/CER, i=8%), the minimum size achieved for profitable projects is 200 ha or 220 ha using the TCER or LCER approach respectively. Furthermore, comparative advantages are found in the costs of sequestering carbon dioxide by Ponderosa pine plantations in Patagonia. The present value of carbon sequestration costs is 5,3 \$/t CO_2, and the CERs production costs is 6,2 \$/ TCER and 8,3 \$/ LCER, always in present value.

Using a local financial scheme to prepare project portfolios could be a possible alternative to cope with project scale. As the area has a strong impact on the project profitability; these could be carried out by the association of small farmers or investors. Consequently, both the risk and the project benefits would be shared among the participants and the attractiveness of the project increased. Therefore, small scale CDM afforestation projects in Patagonia under the scenarios assumed would not only be feasible but also advantageous.

Resumen

La mitigación del calentamiento global en forma eficiente es una de las prioridades de las acciones a escala mundial. Los Mecanismos de Desarrollo Limpio (MDL) del Protocolo de Kioto podrían mitigar el cambio climático y a su vez beneficiar a las comunidades locales. Sin embargo, dada la actual incertidumbre sobre el precio del CO_2 para créditos temporales y el alto nivel de costos de transacción, proyectos MDL de pequeña escala podrían no ser factibles.

Este estudio aspira a determinar el costo y la rentabilidad de secuestrar carbono por medio de plantaciones de *Pinus ponderosa* en sitios de calidad medio-alta en el sur de Argentina. La cantidad de certificados de reducción de emisiones (CERs) expedidos se estimó utilizando el método de los créditos temporales (TCER) y el método de créditos a largo plazo (LCER). Por otra parte, los puntos críticos del proyecto para distintas variables, se calcularon como los valores a partir de los cuales los ingresos obtenidos por la venta de CERs cubren los costos de transacción.

Los resultados muestran que la producción conjunta - madera y CERs - incrementa la rentabilidad del proyecto comparada con la producción de madera únicamente. Ambos métodos de contabilizar carbono han demostrado casi el mismo funcionamiento, sin embargo, la mayor diferencia surge en la distribución de los pagos en el flujo neto efectivo. Bajo un escenario medio (8,2 €/CER, i=8%), la superficie mínima obtenida para proyectos rentables es de 200 ha usando el método TCER, o 220 ha aplicando el método LCER. Por otra parte, se encontraron ventajas comparativas en el costo de fijación de CO_2 a través de plantaciones de pino ponderosa en Patagonia. El valor presente del costo de secuestro de CO_2 es 5,3 \$/t CO_2, y el costo de producción de CERs es 6,2 \$/TCER y 8,3 \$/LCER, siempre a valor presente.

El uso de un esquema de financiamiento local para desarrollar carteras de proyectos podría ser una posible alternativa para reducir el problema de escala de los mismos. Como la escala tiene un fuerte impacto sobre la rentabilidad de los proyectos, éstos podrían ser llevados a cabo por medio de la asociación de pequeños productores e inversores. En consecuencia, tanto los riesgos como los beneficios del proyecto serían compartidos entre sus participantes y el atractivo del mismo se vería incrementado. Por lo tanto, bajo los escenarios asumidos, pequeños proyectos de forestación en el marco de los MDL en Patagonia no solo serían viables sino que también ventajosos.

1. INTRODUCTION

Global Warming is one of the environmental problems that human beings have to solve to avoid negative impacts on the life of present and future generations. The climate change issue could affect every aspect of human endeavour, particularly economic activities (OECD, 1991).

The reduction of greenhouse gas emissions in a cost-efficient way is widely accepted and a global action priority. In the United Nations Framework Convention on Climate Change (UNFCCC) in 1997, the Kyoto Protocol (KP) was designed to address a solution to climate change. The goal of the Protocol is to reduce the aggregate emissions of a cluster of 39 countries (mentioned in Annex B of the KP) by 5,2 % below their 1990 levels in the commitment period 2008-2012 (Art. 3, UNFCCC, 1998).

In this context, the Clean Development Mechanism (CDM) came into being as one of the flexible mechanisms defined in Kyoto. The CDM allows Annex B[1] countries to offset part of their domestic greenhouse gas emissions in order to achieve the reduction target agreed in the Protocol. A new spectre of opportunities has been opened to forestry projects. Investments from industrialised countries in carbon sequestration projects by afforesting and reforesting in developing countries might be encouraged.

Although the Kyoto Protocol has been ratified by 120 countries, they are responsible of only 44,2 % of 1990 CO_2 emissions (UNFCCC, 2004). Due to a required minimum of 55 %, this is not enough and thus cannot enter into force. Now, the World is waiting for the Russian Federation's signature to fulfil this prerequisite and the Protocol will finally be ratified.

Nonetheless, world institutions, governments and private companies have already started with initiatives and negotiations. The World Bank's Prototype Carbon Fund, the Dutch CERUPT programme, the EU CO_2 Emissions Trading Scheme, and many other businesses around the world are becoming more and more actives (IETA, 2003, CDMWatch, 2003 and Point Carbon, 2003).

[1] Annex B are the 39 emission-capped countries listed in Annex B of the Kyoto Protocol.

The global carbon market has traded around 70 million tonnes (Mt) of CO_2 in 2003, up from 30 Mt from 2002 and 13 Mt in 2001 (Point Carbon, 2003). Similarly, the database of Carbon Point gives information on about 600 transactions that have taken place since 1996, amounting to 420 Mt of CO_2 (IETA, 2003). In a conservative forecast, Jotzo & Michaelowa (2001) estimated that the total after-tax revenue from CDM projects would be US$ 1,3 billion over the first commitment period assuming a price of 0,90 US$/ tCO_2.

Taking all mentioned into consideration Argentina's Forestry Sector has developed enormous expectations in the evolution of this mechanism as it may help to increase the current economic activity in rural areas. As an example, Patagonia where this research has taken place, has 2,250,000 million hectares suitable for forest and there are only around 53.000 hectares planted (CIEFAP, INTA, GTZ, 1997).

However, afforestation and deforestation represent major and dramatic transformations in the land use pattern throughout the world. These frequently controversial changes are often presented as a confrontation between economic forces on the one hand and social and environmental forces on the other (Price, 1989). Nonetheless, forestry projects based on sustainable criteria, could be a partial solution not only for environmental problems - around 84% of the surface of Patagonia have moderate to very severe degrees of desertification (del Valle *et al.*, 1997) - but also to promoting employment opportunities in rural areas. Therefore, afforestation projects could improve the standard of living of the people by increasing income.

The main concern on forestry activities to mitigate the climate change is the probable low costs of carbon sequestration. Nevertheless, important economic issues related with CDM projects like the value of Certified Emission Reductions (CERs), transaction costs, and accounting methods could be decisive when assessing forestry projects feasibility. For instance, many different positions and interpretations were up when considering the accounting method for carbon storage in CDM projects (IPCC, 2000). Consequently, these mentioned economic concerns will have a strong impact on project viability and on the scale at which it might benefit from the CDM. Moreover, the scale will have impacts not only on local livelihoods, biological diversity and the local environmental but also on the supply of timber products on local, and even world markets (Orlando *et al*., 2002 cited by Locatelli & Pedroni, 2003).

Kyoto Protocol could present a good opportunity for developing countries to attract foreign investment in sustainable forestry, land restoration, as well as energy efficiency and renewable-energy projects. Hence, evaluating the economic costs associated with the options that would mitigate the long-term increase in CO_2 becomes essential. As it is also crucial understanding how the carbon credit market works. Therefore, the Patagonian forestry sector should take into consideration to develop the necessary knowledge to offer a competitive “product”.

1.1 Problem definition

Unplanned land use, lack of adequate environmental policies, low level of diversification in the traditional production, among other causes, have had a severe impact on natural resources in the Patagonia Area in Argentina. From the environmental perspective, these result in soil degradation, soil erosion, desertification, biodiversity loss and deforestation. From the socio-economic point of view, the outcome is unemployment and migration from rural to peri-urban areas.

Afforestation activities may be both an additional source of income for Patagonian farmers, and a partial solution for the problems described above. Still, the annual rate of afforestation is low as small farmers seem to be risk averse avoiding long term investment and changes on the traditional production.

Selling CO_2 credits from plantations appears to be a possibility for increasing the profitability of afforestation projects, and thus, to increase their economic attractiveness (Loguercio, 2002). But, the price of CERs, rises in transaction costs, and carbon accounting rules will determinate who will be the beneficiary from the CDM forestry projects (Locatelli & Pedroni, 2003).

Under this framework, this research intents to evaluate different economic scenarios for CDM afforestation projects in Patagonia in order to offer an instrument of analysis to decision makers.

1.2 Hypothesis and objectives of research

The hypothesis of this study is that given the current uncertainty about carbon prices for temporary credits and the high level of transaction costs, CDM forestry projects of small scale will be unfeasible in Patagonia. In order to proof this hypothesis the research objectives are the following:

- (I) Analyse the effect of different accounting methods to calculate carbon credits for CDM forestry projects.
- (II) Calculate the minimum area at which CDM forestry project could be feasible considering different scenarios.
- (III) Estimate the cost of carbon sequestration for ponderosa pine (*Pinus ponderosa*) plantations.
- (IV) Investigate the profitability sensitiveness of ponderosa pine plantations in different scenarios.

2. LITERATURE REVIEW

The literature review is divided in three sections. The first one contains the basic knowledge to understand how the emission reduction market works, who are the current buyers and sellers, and how the carbon price trend is. Later, the second part includes the rules and modalities of CDM projects, and it is emphasized on accounting methods for carbon storage and transaction costs. The last, the third section describes briefly the results of previous researches about profitability of afforestation projects and carbon sequestration costs.

2.1 CDM market characteristics

2.1.1 Global carbon dioxide market

The Kyoto Protocol has established different mechanisms for Annex B countries in order to meet their emission reduction obligations. The Protocol's main features include:

- Domestic action to tackle gas emissions below business us usual
- Investing in Joint Implementation projects (JI). This mechanism generates ERUs[2] and they can be transferred from one Annex B country to another.
- Investing in developing countries under Clean Development Mechanism (CDM). This mechanism generates CERs[3].
- Buying emission credits AAUs[4] (hot air)[5] from other Annex B country under Emissions Trading.

Different authors have calculated the amount of emission reduction required globally in the first commitment of the Kyoto Protocol (KP). The estimations vary among each others, for example, Jotzo & Michaelowa (2001) using PET[6] modelling pointed out that

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[2] ERUs (emission reduction units).
[3] CERs (certified emission reduction).
[4] AAUs mean 'assigned amount units'. It is the total amount of GHG that each Annex B country is allowed to emit during the first commitment period o the Kyoto Protocol.
[5] Hot air: Excess permits that have occurred due to economic collapse or declined production for reasons not directly related to international efforts to curb emissions.
[6] PET Model: it is essentially a supply/demand model for the single commodity 'carbon emission credits'. It assumes that the credits will be traded in a perfect international market. The model finds the equilibrium distribution of abatement between countries and the international trade flows (Jotzo & Michaelowa, 2001).

under standard assumptions one third of effective emission reduction requirements would be met through CDM projects with a total of 296 Mt CO_2 per year. The total emission reduction required and the main features are shown below in Table 1. Moreover under conservative assumptions a work done by ELAC[7] estimated, that a reduction between 1800 to 3600 Mt CO_2 /year will be required globally to fulfil the first KP commitment, and about 290 to 660 Mt CO_2 /year will be achieved through flexible mechanisms (IETA, 2003).

Table 1. Market shares of different mechanisms to meet Annex B Kyoto Protocol commitments

Mechanism	Mt CO_2 /year.	Share in market
CDM	296	32 %
Domestic abatement in net buying countries (Annex B OECD countries except United States)	149	16 %
Joint Implementation in EIT[8] countries	78	8 %
Sales of AAUs by EIT countries (hot air)	400	43 %
Total	923	100 %

Source: (Jotzo & Michaelowa, 2001)

On the demand side, the key factors that have influenced on the CDM market are: a) lower business-us-usual[9] emissions growth in Annex B countries, b) higher supply of surplus emission quota (hot air) from EIT[8] countries, and c) crediting under Article 3.4 sequestration in agricultural soils (Jotzo & Michaelowa, 2001, Vrolijk & Niles, 2002).

Under the 'Bonn agreement', Annex B countries can use CERs from sequestration or sink projects under CDM up to a maximum of 1 % of their base year emissions in each year of the commitment period. However, the EU ETS [10] has cut back the quantitative limit of credits from JI and CDM projects and has also restricted the amount of hot air. Thus, only projects that prove additionallity will be allowed (Environmental Finance, 2003).

[7] ELAC "Oportunidades para America Latina y el Caribe dentro del MDL"(2001) cited by Reis M., in IETA, 2003.

[8] EIT are countries with economies in transition, i.e. the Central and East European countries, Russia, and the former republics of the Soviet Union.

[9] Business-us-usual is a baseline scenario in the absence of changes in current policies, economies and technology.

[10] EU ETS (European Union Emission Trading Scheme)

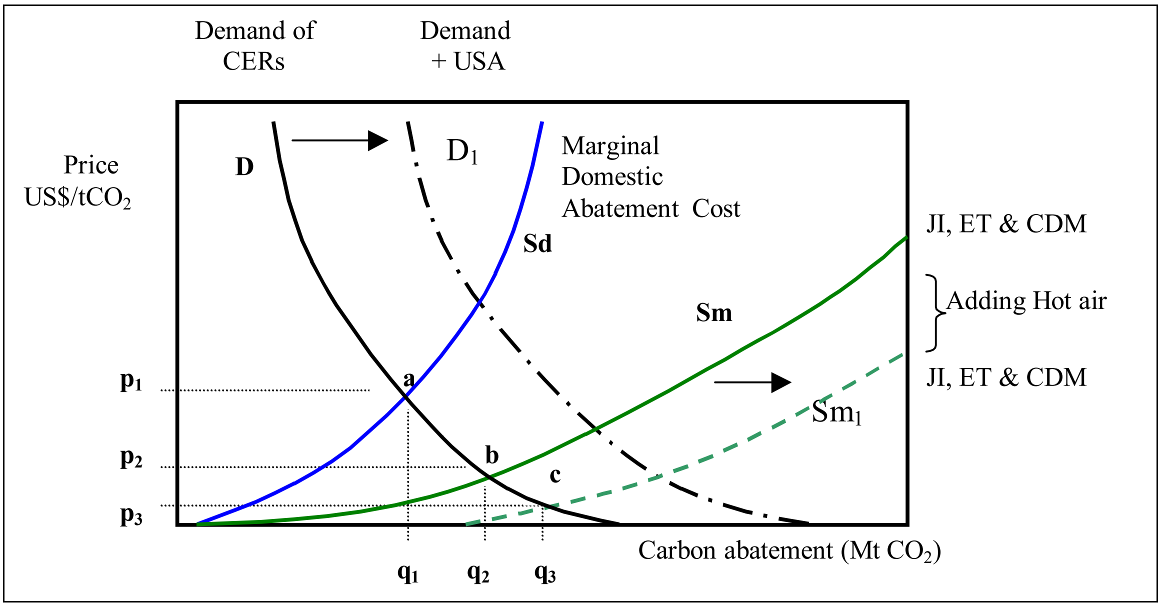
But none of these factors would be a threat to a viable and sizeable CDM only if the United States would participate in the KP (Jotzo & Michaelowa, 2001).

On the supply side fuel efficiency and fuel switching projects (e.g. reduction of gas flaring, reduction of transport losses) tend to offer the largest potential abatement in the energy sector at a low cost. Countries where the major energy users (power plants, heavy industry, etc.) are relatively inefficient and countries that use coal for their energy needs have the greatest potential for large and cheap CDM projects (Jotzo & Michaelowa, 2001).

Other factors that could influence the supply side are the transaction costs that arise (Cacho et al. 2002) especially in small-scale projects, and the quality of the project design. For instance in June 2003, the Executive Board of the UNCCC has rejected 13 out of 14 CDM projects due to their non-additionallity. Therefore, the supply could be restricted in the short-middle term.

Main factors of the carbon market equilibrium are summarised in Figure 1. The demand curve of CERs (D) would move to the right (D_1) if USA ratify the KP, meaning an increase in both the amount of credits demanded and therefore the price of CERs. Whereas, a left shift of the demand curve would occur if, for instance, business-us-usual emissions decrease in Annex B countries. Yet, the supply curve depends on the availability and costs of relevant technologies and resources endowments (Cacho et al., 2002). For example, the price of CERs (p1) would be reached at the equilibrium point (a) when only domestic abatement of atmospheric carbon (Sd) is used to achieve the commitments. If flexible mechanisms[11] are applied, the supply curve (Sd) would move to the right (Sm) and consequently the equilibrium price would decrease to p2. When hot air enters into consideration, the credits' supply would increase as the curve (Sm) shifts to the right (Sm_1) reaching a new equilibrium point (c) with a price decrease. Instead if the transaction costs increase, the amount of potential projects as well as the credits supply would be reduced. Therefore the curve (Sm) would move to the left and hence the price of CERs would increase.

Figure 1. Supply and demand curves in the global carbon market under different scenarios.



2.1.1.1 Potential sellers

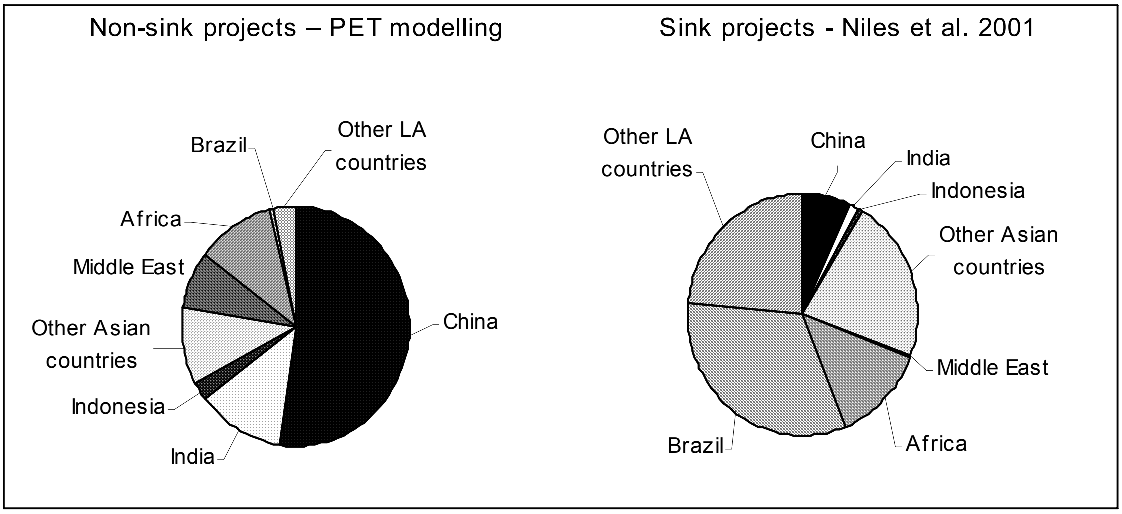
When studying the carbon market, two of the main points are to determine which the potential GHG reduction of the developing countries is and which Annex B countries are interested in.

According to Jotzo & Michaelowa (2001) China is projected to attract around half of the total CDM volume; India and Indonesia are also projected to attract a significant share of CDM projects (see Figure 2). Middle East and Africa is estimated to generate CERs from gas flaring projects. And, Latin American countries' options for low-cost and large-scale CDM projects in the energy sector are scarce.

On the other hand, sink projects developed in countries with previous experience could have advantages at least for the in the first commitment period. This means that the regions in a more favorable position would be Latin America -especially Brazil-, Southeast Asia and China. Figure 2 shows the main potential suppliers of sink and non-sink projects.

[11] JI (Joint Implementation), CDM (Clean Development Mechanisms) and ET (Emission Trading).

Figure 2. Distribution of potential suppliers of sink and non-sink CDM projects



Source: data extracted from (Jotzo & Michaelowa, 2001).

In an expert poll conducted by Point Carbon (2002) the factors that determine the attractiveness of a CDM host country were: a) government's attitude towards CDM, b) investment climate, and c) techno-economic potential. The experts agreed that capturing methane gas from mines, landfills and pipelines seemed to be the most attractive and cheapest CDM projects. The experts suggested that the more promising countries to CDM projects were China, Brazil, Costa Rica, Mexico, South Korea and Chile.

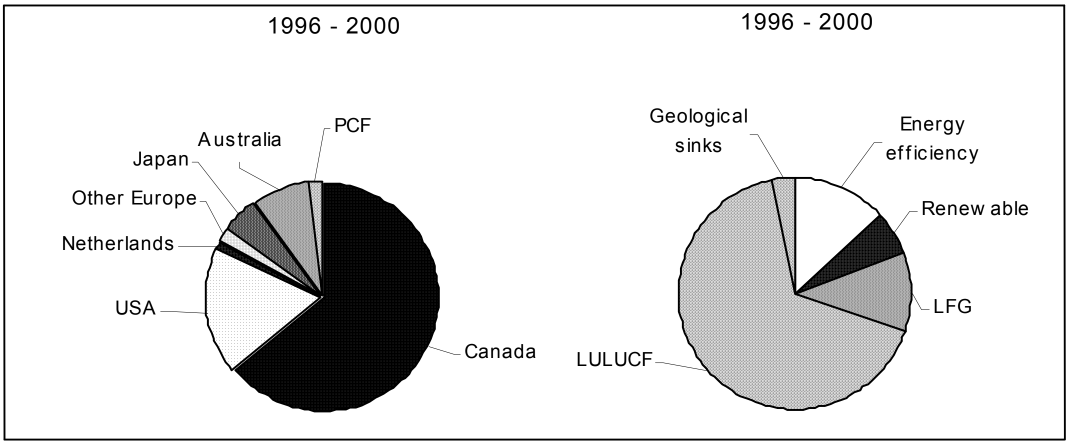
2.1.1.2 Potential buyers

Nowadays the GHG market is in its early stage of development, nevertheless, there are same fragmented markets emerging: UK Carbon Trust, EU ETS, Canadian system, Danish CO_2 Quota Act, etc. Governments promote them as a response to private sector concerns about costs of compliance with carbon constrains. However, there are many differences among them and has produced a fragmented global GHG market that consists of several independent sub-markets (IETA, 2003).

According to Lecocq & Capoor (2002), in the middle of the 90 private-sector entities were the most active buyer of candidate CERs and ERUs. Canada, USA , Australia and Japan were the most active buyers as they invested in LULUCF[12] sector (65% of total volume) and energy efficiency projects (12 %). Many of the ER projects were located in

Canada and the United States (IETA, 2003). Most important buyers and kind of project bought for the period 1996 - 2000 can be seen in Figure 3.

Figure 3. Main buyers and type of projects financed from 1996 to 2000



Source: (Lecocq & Capoor, 2002)

Then governmental and quasi-governmental entities such as the World Bank's Prototype Carbon Fund (PCF) or Government of the Netherlands (CERUPT) appeared as the most active buyers besides the older players (Lecocq & Capoor, 2002; IETA, 2003). The major investments were in renewable energies (23% of total volume) and energy efficiency projects (16 %), instead the LULUCF sector was reduced to just 12% of the total volume transacted (Lecocq & Capoor, 2002). Latin America, Central and Eastern Europe have emerged as common locations for projects involved in trade and few trades have involved ERs generated in Africa (IETA, 2003).

As a final point and regarding the project's scale, a share of 65% of them came from sizes ranging from 10,000 tCO_2 to 1,000.000 tCO_2, but only meant 16 % of the total transaction volume (Lecocq & Capoor, 2002).

[12] LULUCF (Land Use, Land Use Change and Forestry): this sector was included under the Kyoto Protocol to take into consideration certain human-induced activities that remove GHG from the atmosphere.

2.1.2 Latin American perspective

Latin America (LA) has a great potential for CDM projects. Until now, it has concentrated 71% of the GHG reductions and it has developed 21 out of 37 CDM projects (IETA, 2003). Their country distribution includes 6 projects in Brazil, 6 projects in Costa Rica, 3 projects in Panama, and individual projects in Bolivia, Chile, Colombia, Nicaragua and Peru (see Appendix I). The average emission reduction per project is around 2 M t/CO_2, and the average carbon price ranges between 3 – 4 US$/ t/$CO_2$. The Crediting period was 20 years for the PCF and 10 years for CERUPT (IETA, 2003).

According to Grütter (2002) the export volume projected for LA will reach around 110-180 M tCO_2/year with expected annual export revenues of 200-800 million US$. Its participation will be larger than Asian countries, especially China and India due to the fact that they will not be able to fully exploit their potential.

LA countries also tend to be favored by US investors and have already gained strong experience with GHG trading in several countries. Likewise, they have also been able to attract some special deals such as the GHG fund for Andean countries managed by the CAF[13] (Grütter, 2002). Similarly, many agreements have been signed in order to promote purchasing of GHG emission reduction, e.g. agreement CAF–the Netherlands, agreement the Netherlands–Costa Rica, and many others bilateral agreements.

In the particular case of Argentina, Grütter (2002) estimated an export volume of 15 to 29 M tCO_2/year. It implies an export revenue range of 25 to 127 million US$/year and a profit of around 9 to 62 million US$/year.

2.1.3 Carbon price trends

Carbon prices are volatile and depend on the quality of the certificates. The information is dispersed and uncompleted, although same consultant firms have been developed trends and they are those used for the present research.

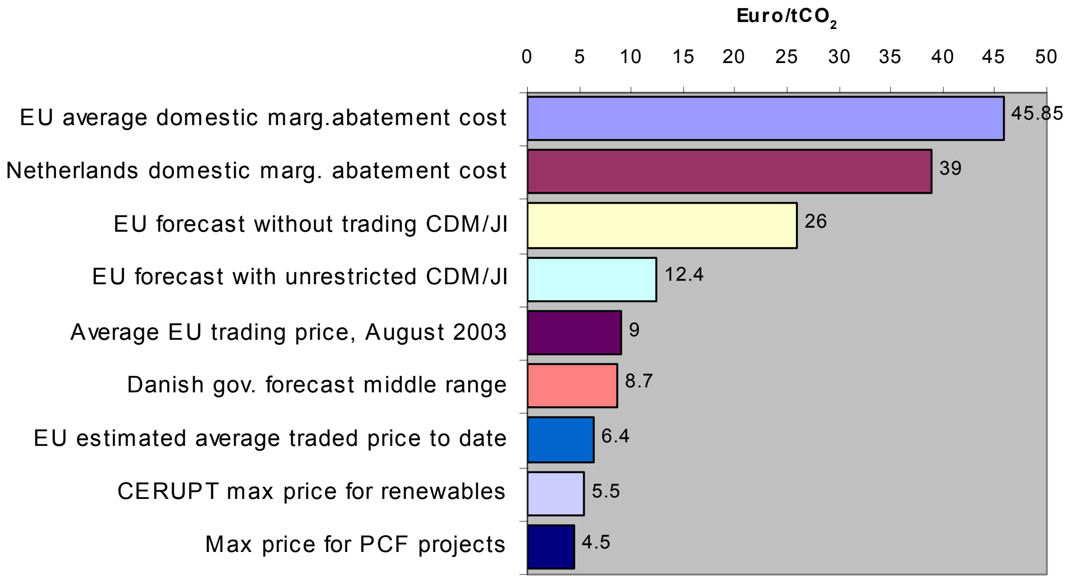
Emission reductions (ERs) that would disqualify for international recognition as permits have been traded for around 0,60 to 1,50 US$/ t$CO_2$. However ERs that could be

[13] CAF (Corporacion Andina de Fomento) is the largest development bank in South America.

candidate for CERs/ERUs have been traded for prices around 1,65 to 8,0 US$/ tCO_2 , with most occurring between 3 and 5 US$/ tCO_2 (IETA, 2003).

Obviously, carbon credits prices will affect the income generated by projects under the KP and therefore are one of the determinants on project's profitability. Some organizations like CDMWatch argue that the carbon market is a 'buyers market'. They pointed that buyer countries can benefit more than seller countries when comparing the price paid for CERs with the domestic abatement costs. The criticism of CDMWachers is that the result of a very low price for CERs reduces the chances of a project to contribute to sustainable development (CDMWatcher, 2003). Figure 4 illustrates a comparison of abatement costs, carbon prices and price forecasts.

Figure 4. Comparison between abatement costs in €/t CO_2, carbon prices paid and carbon price forecasts



(Source: IETA, 2003)

Experts from Point Carbon analyzed two scenarios of carbon prices for the first commitment (IETA, 2003): on the one hand, where the EU ETS (including EU15, EU candidates and Norway/Switzerland) operates in isolation from the Kyoto market (including Japan, Canada, Russia and New Zealand), on the other hand, a scenario where all Annex I countries less the U.S., Australia and Ukraine take part in a scheme for international emissions trading. They concluded that to fulfill the first commitment period, carbon prices might not be much lower for the first than for the second scenario.

This is mainly because the demand of credits from the EU Member States (EU15) would be almost balanced by the potential supply of excess allowances from the EU candidates. At present, they perceived the second mentioned scenario as the 'most likely' to occur, i.e., international emissions trading among all Annex I countries less the U.S., Australia and Ukraine, and updated estimation of carbon prices in 2010 to be 8,2 €/tCO_2, with low 4,2 €/tCO_2 (25th percentile) and high 11,4 €/tCO_2 (75th percentile)[14].

In addition, Appendix II illustrates figures of ERs volumes and prices in different projects. It includes those conducted by the World Bank's Prototype Carbon Fund and the Government of the Netherlands, as well as an example of recent trades by private buyers.

2.2 Modalities and rules of CDM projects

Modalities and rules of CDM will also have an important impact on the feasibility of the projects and therefore on whom is going to get the benefit from them (Locatelli & Pedroni, 2003).

In order to understand how the CDM project cycle works seems essential to be familiar with some technical definitions. For that reason, a brief summary will be presented. Later on, the review will be focused on two key factors that could affect any CDM forestry project: the accounting approach to address non-permanence of carbon credits and the transaction costs.

2.2.1 Definitions

The CDM Executive Board is the organization in charge of the final approval on the CDM projects. A diagram to comprehend the project flow is sketched in Appendix III.

Some rules, methodologies and procedures are still under discussion. However, a brief explanation of the main points and actualized definitions after the COP-9[15] (UNFCCC, 2003) is the following:

[14] In the original document prices are in US Dollars (9,9 USD/tCO_2, with low 5,0 USD/tCO_2 and high 13,7 USD/tCO_2).

[15] Conference of the Parties (COP) is the supreme body of the UNFCCC. The last took place in December 2003 in Milan (Italy).

a) Only areas that were not forest on 31st December 1989 are likely to meet the CDM definitions of afforestation or reforestation.

b) Carbon pools are aboveground biomass, below-ground biomass, litter, dead wood and soil organic carbon.

c) The project boundary is the geographic limits of the afforestation/reforestation project. It may contain more than one discrete area of land.

d) The 'baseline net GHG removals by sinks' is the sum of the changes in carbon stocks in the carbon pools within de project boundary that would have occurred in absence of the CDM project.

e) Projects must account for potential leakage. Leakage is the unplanned, indirect emissions of CO_2 which occur outside the boundary, attributable to the project activities.

f) Net anthropogenic GHG removals by sinks is the sum of verifiable changes in carbon stocks in the carbon pools within the project boundary minus the baseline minus leakage.

g) Temporary CERs (TCER) is a CER issued for afforestation/reforestation project activity under CDM which expires at the end of the commitment period following the one during which it was issued. Instead, Long Term CERs (LCER) is a CER that expires at the end of the crediting period for which it was issued.

h) Small-scale afforestation and reforestation project activities under CDM are those that are expected to result in net anthropogenic GHG by sinks of less than 8 kilotons of C02 per year and are developed or implemented by low-income communities as determinate by the host Party.

i) Projects must result in real, measurable and long-term emission reductions, as certified by a third party agency called 'Operational Entities'.

j) Emission reductions or sequestration must be additional to any that would occur without the project. This additionallity is assessed by comparing the carbon stocks and flows of the project activities with the baseline.

k) Projects must be in line with sustainable development objectives, as defined by the host country.

l) The crediting period shall begin at the start of the afforestation/reforestation project activity. The period shall be either a maximum of 20 years that may be renewed at most two times, or a maximum of 30 years.

m) The initial verification and certification may be undertaken at any time selected by the project participants. Thereafter, verification/certification shall be carry out every 5 years until the end of the crediting period.

2.2.2 Addressing non-permanence of afforestation projects

Carbon storage in forests is not permanent because it is released into the atmosphere through respiration, decomposition, digestion, fire, etc. Non-Annex B countries do not have quantified emission limitations and reduction commitments, and as a consequence carbon storage in specific forestry project must be assumed to be non-permanent (Ellis, 2001 cited by Locatelli & Pedroni, 2003). Instead, emission reductions achieved through CDM in energy sector projects as well as in forestry projects in Annex B countries are considered to be permanent.

In order to address non-permanence of forestry projects different accounting approaches were designed. These methods have been summarised and discussed by IPCC (2000), Marland et al. (2001), Locatelli & Pedroni (2003), among others. At this time, the main accounting methods evaluated in the literature were 'Ton-year accounting', 'Equivalence-adjusted average carbon storage (ACS)' and 'Temporary crediting'. The least risky method for the climate is 'Ton-year approach' (Locatelli & Pedroni, 2003), but it produces credits very slowly, and thus is unattractive for projects. The 'Equivalence-adjusted method' appears to be more advantageous for projects because it is credited very early. However, credits are awarded for the amount of carbon that will be stored in average during the whole project duration, and thus it is highly risky for the climate. Lastly, 'Temporary crediting method' assigns a lifetime to the credits, and thus it takes into account the finite period that carbon can be stored in forests (Chomitz, 2000). Hence, it arises to be the most auspicious approach not only for the climate but also for the project profitability (Locatelli & Pedroni, 2003).

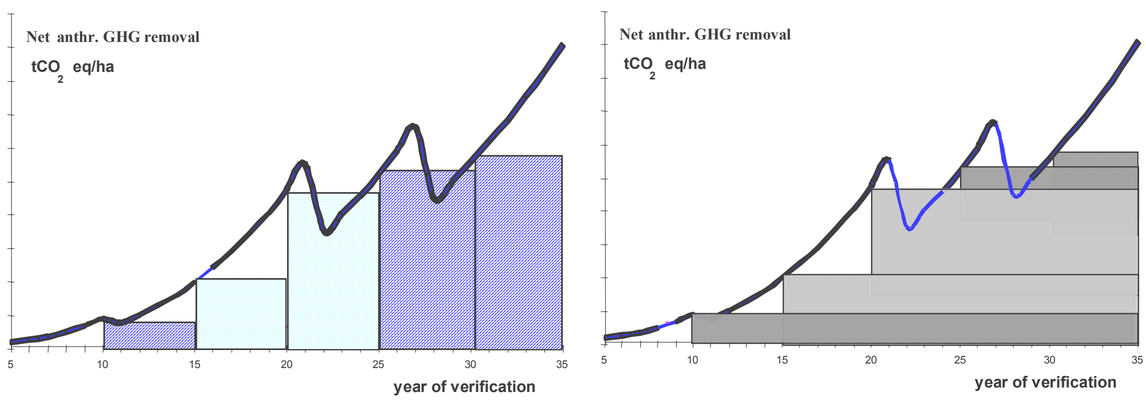
In the recent COP-9 decisions on carbon accounting rules have been taken. According to the last conference, the project participants shall select one of the following accounting rules in order to address non-permanence of an afforestation/reforestation project and it shall remain fixed for the crediting period (UNFCCC, 2003):

a) Issuance of TCERs for net anthropogenic GHG removals by sinks achieved by the project activity since the project start. The TCERs expires at the end of the commitment period following the one during which it was issued and may not be carried over to a subsequent commitment period (see Figure 5a).

b) Issuance of LCERs for net anthropogenic GHG removals by sinks achieved by the project activity under each verification period. The LCER expires at the end of the crediting period for which it was issued (see Figure 5b). However, there is to take into account that if the net anthropogenic GHG removals have decreased, an equivalent quantity of LCERs shall be replaced for the country's buyer. For each buyer the amount to be replaced will be proportional to the quantity of LCERs bought. To replace an LCER, a Party shall transfer one AAU, CER, ERU or LCER from the same project activity to the LCER replacement account for the current commitment period.

Figure 5. Examples of issuance: TCERs (a) and LCERs (b) on a curve of net anthropogenic GHG removal by sinks (carbon stock-curve discounted baseline and leakage). Beginning of the certification is year 10.

a) b)



(Source: own interpretation)

Different accounting approaches have an impact on the profitability of a CDM project, but also on the minimum area that would provide a benefit from the flexible mechanisms of PK. For instance, the model of Locatelli and Pedroni (2003) suggests that under current carbon prices and average transaction costs small-scale project (<500 hectares) are excluded from the CDM, no matter which accounting methods is used[16].

2.2.3 Transaction costs

Transaction costs are, using Coase's (1937) definition[17], costs that arise from initiating and completing transactions. They include not only those related to finding partners, holding negotiations, consulting with lawyers or other experts, monitoring agreements, etc., but also the opportunity costs, like time or resources loss.

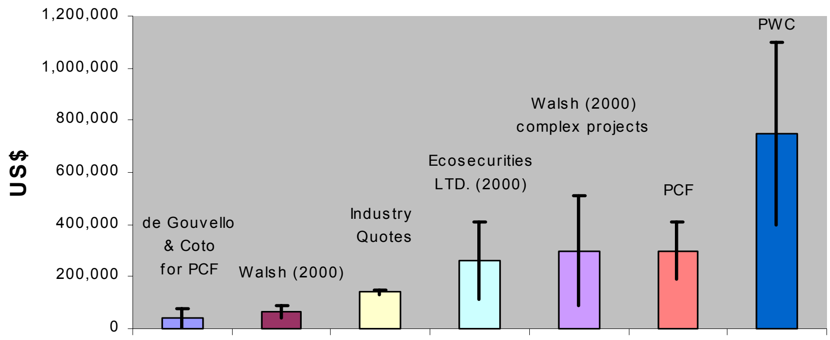
In the global carbon market, transaction costs raise the costs of the project participants and thereby decrease the trading volume or even discourage some transactions. Moreover, transaction costs reduce the attractiveness of the Kyoto Mechanisms when compared to domestic abatement options. Especially CDM project-based mechanisms and JI are likely to entail considerable costs of baseline development, verification and certification (Michaelowa & Stronzik, 2002).

Transaction costs are also function of other variables like project scale and level of fragmentation of land property. If property rights are not clear, it might be required to spend additional time and money on bureaucratic activities (Benitez, 2003). Gouvello & Coto (2002) analyzed the transaction cost in CDM projects taking into account the scale of the projects. They estimated that for small-scale projects and simplified CDM procedures transaction costs are smaller than 90,000 US$ (rural energy project). For the case of normal CDM procedures costs may vary within the range of 90,000 to 1,100.000 US$. Fichtner et al. (2003) found that transaction costs for JI range from 7% up to more than 100% of the production costs with 80% of the projects lying between 14 and 89%. Furthermore, they indicate the existence of economies of scale.

Figure 6 resumes the transaction costs of CDM project for small and normal procedures. Likewise, the maximum and minimum values were drawn.

[16] LCERs were not taken account because they appeared later.
[17] Cited by Michaelowa & Stronzik, 2002

Figure 6. Maximum, minimum, and average transaction costs of CDM projects.



(Source: Gouvello & Coto, 2002)

In addition, transaction costs will occur at different stages in the project cycle. In economic terms, they could be defined as fixed and variable costs (Milne, 1999). According to Michaelowa & Stronzik (2002) three stages can be identified: 1) pre-implementation; 2) implementation and 3) trading. Transaction cost components for CDM projects are resumed on Table 2 and it can also be seen a rough cost estimation for each component according to the international literature. A brief description of the components can be found in Appendix IV.

Table 2. Range and average of transaction cost components in a CDM project - values in €-

	Component	Range Costs (€/project)	Average Costs
Pre-Implementation Costs	Search costs & project design	2000 a 25000 [a]	13500
	Baseline determination	19200 a 24000 [b]	21600
	Monitoring plan	8000 a 16000 [b]	12000
	Approval & Validation costs	5000 a 40000 [c]	22500
	Registration fee	4350 a 26000 [d]	15000
	Share of proceeds	2% CER [d]	2% CER
	Administration costs	3% CER [e]	3% CER [e]
Implementation Costs	Monitoring costs	2000 a 10000 [f]	6000
	Verification costs	5000 a 17000 [b]	11000
	Certification costs	s/d [g]	s/d
	Enforcement costs	15000 a 25000 [b]	2% CER [e]
	Risk mitigation	1 a 3 % CER [b]	2% CER
Trading	Transfer costs	5- 7% CER [h]	6% CER
	Registration costs	0 [i]	0

Sources: Label components were taken from Michaelowa & Stronzik (2002). a) Lecocq & Capoor –PCF- (2002) but discounting baseline cost; b) Ecosecurities (2002); c) DEA (2002); d) UNFCCC (2002); e) own assumption; f) Pedroni & Locatelli (2003); g) data not available; h) Michaelowa & Stronzik (2002); i) Climate Change Office, Argentina (pers. comm.)

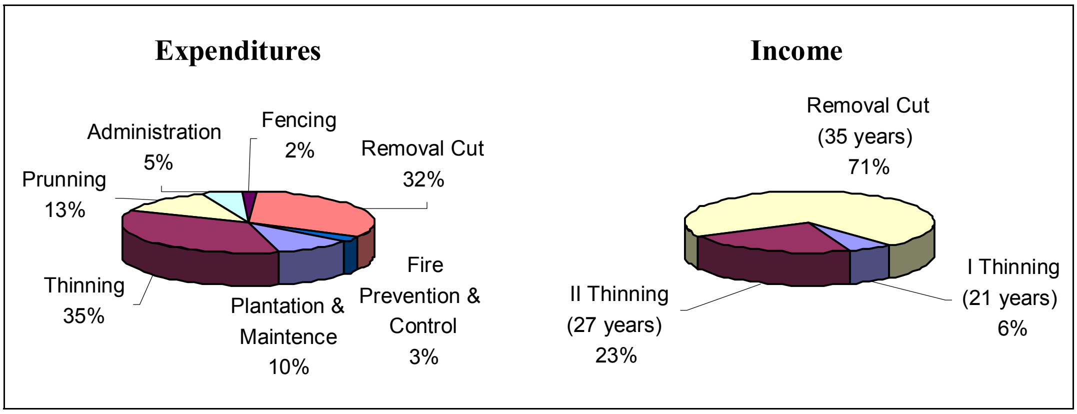
2.3 Carbon sequestration costs in forest

2.3.1 Profitability and costs of afforestation projects in Patagonia

The profitability of afforestation projects in Patagonia is mainly related to the site quality and the intensity of the forest management system. Given the same site quality the more intensive the management the higher the profitability. As well as assuming the same intensity of the forest management system, the better site quality the higher the profitability. To illustrate this point, if a discount rate of 7% is considered, the soil expectation value (SEV) is negative for less suitable soils regardless the forest management system applied. Whereas, intensive forest management either in very-apt sites or apt sites is economically viable and also the most stable system according to sensitivity analysis (Laclau et al., 2002).

The relative importance of the costs during the whole forest cycle is not only connected with the amount invested, but also with the particular moment when the investment is produced. For instance, planting costs are the most significant expenditures in the investment plan (Laclau et al., 2002). Manfredi (1999) estimate for an afforestation project in Patagonia that the total capitalized expenditure would be around 4,450 \$/ha and the total capitalized income close to 24,500 \$/ha[18]. The distribution of expenditures and incomes according to the project activities can be observed in Figure 7.

Figure 7. Distribution of capitalized expenditures and income in an afforestation project - turnover 35 years- in Patagonia



(Source: Manfredi, 1999)

[18] Computed in Argentine pesos (1\$=1US\$) at 8% interest rate.

Studies made for Patagonia have shown that the profitability of pine plantations varies significantly. For instance, Urzúa (1991) and Enricci (1994) estimated a net present value (NPV) of 448 and 442 $/ha[19] respectively. Manfredi (1999) got that the NPV range from 567 $/ha to 1243 $/ha taking into account different economic scenarios. Diaz (1997) calculated a NPV of 907 $/ha[20]. Laclau et al. (2002) determined that the SEV vary from 1198 to –128 $/ha[21] for very suitable to low suitable soils under intensive forest management.

Later, other analyses started to consider the environmental service of sequestering carbon dioxide. Sedjo[22] (1999) computed a NPV of –419 to -546 $/ha considering only to sale timber products but when taking into account carbon credits plus timber products sales the NPV raised from 48 to 99 $/ha. De Koning et al. (2002) pointed out that pine plantations had negative NPV[23] even in the best ecological sites, and thus, financial compensation is required for switching from pasture to forestry. Laclau et al. (2003) estimated that the NPV was negative in suitable and less suitable soils but it became positive in very suitable sites. In addition, when carbon credits were accounted, the NPV[24] changed from –72 to 282 $/ha for suitable soils. Loguercio (2002) calculated the additional income generated by sequestering carbon in Patagonia comparing three accounting methods: ton-year approach, average carbon storage and temporary credits. The NPV[25] reached was US$ 191, US$ 64, and US$ 553 respectively.

The differences between the economic analyses mentioned above could be found in different assumptions as: input and output prices, yields, rotation periods, discount rates, opportunity costs, among others.

2.3.2 Carbon sequestration costs

Sinks in forest plantations appear to be an economically and environmentally alternative for removing CO_2 from the atmosphere. Different authors from all around the world have estimated the cost of carbon sequestration using not only diverse tree species, but also distinct economic assumptions and methodologies.

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[19] NPV calculated in Argentine pesos (1$=1US$), using a rotation of 35 years and a discount rate of 6 %.
[20] NPV estimated in Argentine pesos (1$=1US$), managing a rotation of 35 years and a disc. rate of 8 %.
[21] SEV computed in Argentine pesos (1$=1US$), with a discount rate of 7 %.
[22] Running a rotation of 36 and 27 years, and 20 $/t CO_2. NPV computed in Argentine pesos (1$=1US$).
[23] Calculating a rotation of 23, 32 and 48 years. NPV accounted in Arg. pesos (1$=1US$) and i=7%.
[24] Estimating in Argentine pesos (1$=1US$) at 5% discount rate.

Huang et al. (2003) calculated the cost of sequestering carbon in green ash plantations in Mississippi. This calculation was performed by dividing the present value of all forest management costs by the total number of tons of carbon stored. The cost to store a ton of carbon ranged from a low of US$ 6,05 to a high of US$ 16,46.

Similarly, Castro Salazar (1999), computed the 'marginal costs' per ton of carbon sequestered in Costa Rica using the carbon estimates per year, the opportunity costs of the land, and a 5% discount rate for both capital and carbon. His calculation reached that 50% of the carbon potentially sequestered costs were less than US$ 12 per ton and that 90% of its costs less than US$ 50 per ton. The rising marginal cost was associated to the increasing opportunity costs of the more valuable land, as well as the decreasing carbon yields in some parcels due to lower productivity of the determinate zones.

On the other hand, according to de Koning et al. (2002) the cost of carbon sequestration can be defined as the minimum financial compensation a landowner has to receive, for changing for instance from pasture to forestry, for sequestration purposes. Hence, the NPV of forest plus the PV of carbon credits has to be at least equal to the NPV of pasture. For plantations in Ecuador they found that the minimum price is about US$ 4-6 /tCO_2 for 30 year projects. Meanwhile in Argentina, for Ponderosa pine they got compensation prices from 1 to 15 $/t$CO_2$ for 30 year projects from high to less suitable sites respectively.

In Patagonia, de Konnig et al. (2002) concluded that without payment for carbon sequestration, forest projects are not competitive compared to cattle ranging in the majority of cases analyzed. When a sensitivity analysis was carried out over changes in interest rate, price of wood, milk or meat, figures suggested that in most cases farmers would not switch to a forestry alternative. Therefore, it would confirm the additional nature of pine plantation projects, which is a requisite for the Kyoto Protocol.

Finally, the prices mentioned above were calculated based on the former Dollar-Peso-Parity. Nonetheless, from December 2001 Argentina has performed a significant devaluation of its currency (around 75%). Consequently, the values of the compensation prices computed by using the new exchange rate are approximately 75% lower than their values estimated at Dollar-Peso-Parity (de Koning et al., 2002).

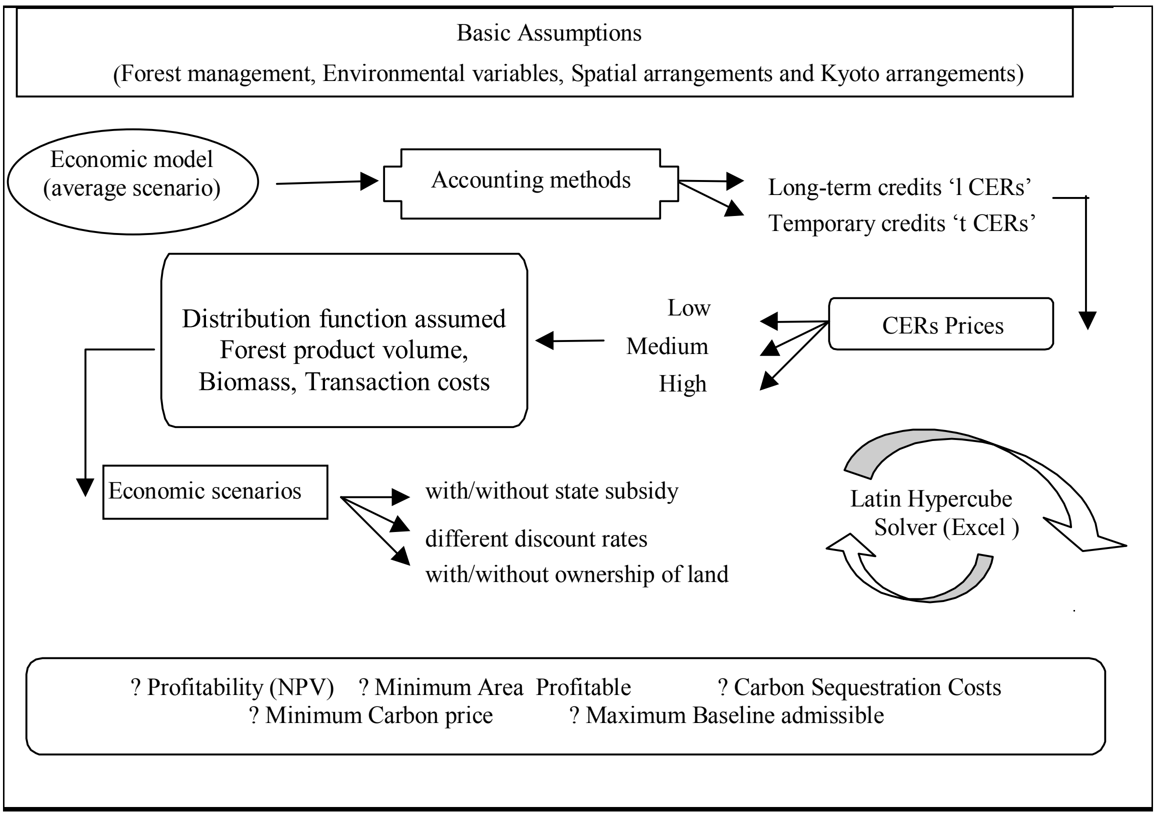
[25] Utilising a carbon price of US$ 10 t/ CO_2 and discounted at 8 %. But, it does not consider trans. costs.

3. MATERIALS AND METHODS

Firstly, this chapter describes the main characteristics of the research area and the data sources and processing. Later, a description of the technical and economic assumptions and methods is given.

The profitability for Ponderosa pine afforestation on average to high quality sites in Patagonia was calculated based on an economic model and for diverse scenarios. The conceptual framework of this research is outlined in Figure 8. Different aspects as accounting approach for Certified Emission Reductions, CERs prices, and transaction cost levels were taken into account. Furthermore, a set of assumptions on forest management, environmental variables, economic procedures, and Kyoto arrangements were considered for carrying out the study. In addition, critic points of a project assessment like the minimum profitable project area, the maximum baseline level, the minimum carbon price and carbon sequestration costs were calculated.

Figure 8. Conceptual framework of the research.

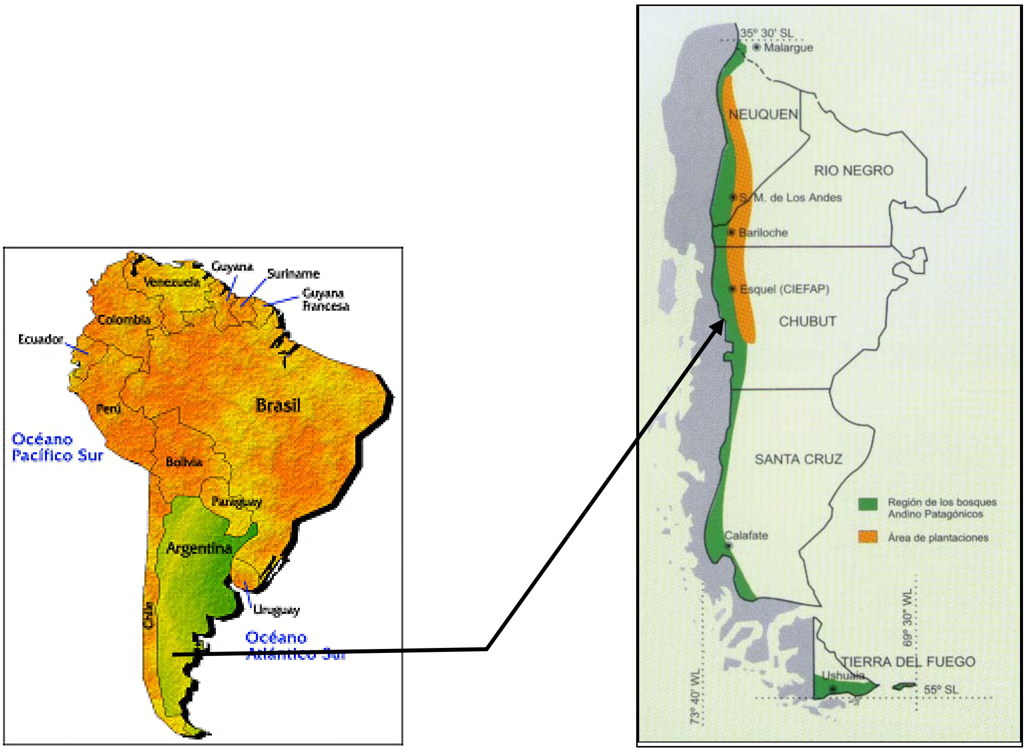


3.1 Study area

This study was carried out in the South of Argentina, more exactly in the city of Esquel and its surroundings, Chubut Province, all places in Patagonia Region.

Argentina's total area is around 2,780,400 km^2 with a population of 37,9 millions people and a 55% living under the national poverty line. The urban population represents 88% of the total population and the adult literacy rate is 97%. The GDP[26] is about 102 US$ billions and the GNI[27] per capita is almost 4,100 US$. The structure of the economy[28] is conformed by agriculture (10%), industry (41%), services (49%) and the importation of goods and services is close to (6%) (World Bank, 2003).

Figure 9: Map of the research area. Forest Region in Patagonia



[26] Gross Domestic Product
[27] Gross National Income
[28] It was estimated as a percentage of GDP.

3.1.1 Environment characteristics of the Andean Patagonia

Soils have developed over volcanic ash deposits, with moderate to high allophone content. The landscape is characterized by slopes with native forest, valleys and lakes in the western area, and plateaus, and natural grasslands to the east (SAGPyA, 2001).

The altitude where the afforestation take place range from 200 to 900 m above sea level and receiving precipitation between 500 to 1,500 mm per year. The rains decrease abruptly from west to east and are concentrated mostly in winter. While there is no water deficit in the western area, the east part bordering the steppe has water deficits up to 300 mm during the dry season (SAGPyA, 2001).

Overgrazing, fires and dry year cycles have caused scarce regeneration of the native forest, leaving lands with a disperse vegetation and soils exposed to erosion. This situation reduces the capacity for livestock production (SAGPyA, 2001). Roughly, 25% of the land in Patagonia has severe grade of desertification (INTA, 1995; PROSA, 1988, cited by Naumann, 1999). Nevertheless, in the area of research most of these degraded sites can be suitable to conifer afforestation.

3.1.2 Patagonia forestry sector features

Patagonia has 2,3 million ha of native forest where 90% is protected forest and only 10% can be used for commercial purposes (SAGPyA, 2001). *Nothofagus pumilio* so called "Lenga" is the specie with the largest distribution.

In addition, Patagonian Andes has more than two millions of hectares of suitable soil to be afforested with plantations (see Table 3). This area is found from the 37° to 44° South parallels and from the isohyet of 500 mm in the East to the Andean-Patagonian native forest in the West. The area is seen as a narrow strip of 750 km long and 40 km wide along the Andes (CIEFAP, GTZ, INTA, 1997).

Up to now, there are 53,000 ha of pine plantations in Neuquén, Río Negro and Chubut Provinces representing roughly only 3% of the total suitable potential area to be afforested. According to the SAGPyA (2001[29]) the annual forest-planting rate is about 3,300 ha/year in Neuquén, 750 ha/year in Río Negro and 2,500 ha/year in Chubut.

[29] Using data from the Forest Province Services to the year 1997.

Table 3. Distribution of suitable forest soils by Province and quality.

Province	Land Suitability classified in each Province according to mean annual increment [m3/ha/year]			
	Moderately suitable 12 to 18 *	Suitable 19 to 21*	Very suitable 22 to 25*	Total
Neuquén	600,000	500,000	150,000	1,250,000 ha
Río Negro	60,000	80,000	60,000	200,000 ha
Chubut	70,000	430,000	300,000	800,000 ha
Total	730,000 (32%)	1010 (45%)	510,000 (23%)	2,250,000 ha

Source: (CIEFAP & GTZ & INTA, 1997)
(* Mean annual increment measured in m3/ha/year and estimated to *Pinus ponderosa*)

The specie most utilized is *Pinus ponderosa* - around 75% of current plantations – and it is planted in the drier sites. The remaining 25% is mainly *Pseudotsuga menziesii* and *Pinus contorta*. The former is planted in the most humid sites and the latter in less fertile and dry soils (SAGPyA, 2001).

The land ownership of forest soils is characterised by private property (70 %), and are extensively used for ranching activities focus on sheep breeding. The rest of the land, about 30 %, is state owned and in many cases occupied by precarious tenants. These lands are now subjected to provincial programs of territorial domain regulation (CIEFAP, GTZ, INTA, 1997).

The land property regimes present differences between the provinces, for example, around 40 to 50% of the property of suitable land in Neuquén and Río Negro are state owned. Instead, in Chubut most forest suitable lands are privately owned (90 %). In addition, the farm size in areas of forest soils in Chubut Province is characterized by 60% of the farmers with less than 500 ha, 24% have between 500 to 5000, 8% have between 5,000 to 10,000 ha and 8% have more than 10,000 ha (SAGPyA, 2001).

Around 50 sawmills commercialize forest products from planted forest. They utilize approximately 60,000 m3/year of roundwood. The sawnwood is sold locally or at Atlantic coast cities. Furthermore, resale of pine from the Northeast of Argentina and importation of native timber from Chile is usually used (SAGPyA, 2001).

3.2 Data collection

3.2.1 Data source

Management costs are incurred for establishing, maintaining, and harvesting the stand of trees. In this study, all data for calculating current management costs mainly comes from two sources: interviews to forest experts and forest services suppliers, and from secondary information. It includes relevant previous researches in the area of study and also workshop reports.

Seven forest service suppliers and two forest producers were interviewed and researchers from the CIEFAP (Patagonia Andes Forest Research and Extension Center) as well as from the DGByP (Dirección General de Bosques y Parques de la Provincia del Chubut) were consulted in different topics. In addition, some spreadsheets developed by CIEFAP were actualized, modified and adjusted according to the objectives of this research.

On the other hand, information on Certified Emission Reductions, transaction costs, carbon prices, and methodologies and procedures were achieved from the international literature, Web sites, as well as from personal communication with local and international experts.

3.2.2 Interview characteristics

The main goal of the interviews was to determinate the current costs, yields and problems that service suppliers and producers had when developing afforestation projects. The questions were addressed to find the real figures for cost of plantation, cultural care, pruning, and thinning. Likewise, information about yield, timing, internal organization and number of employees for different activities were gathered. Nevertheless, there was not enough information available about the second and third pruning, as well as the second thinning and the final cut. This is because the area of research has most of plantations in their earlier stages of growth and consequently most of the service providers are working in plantations.

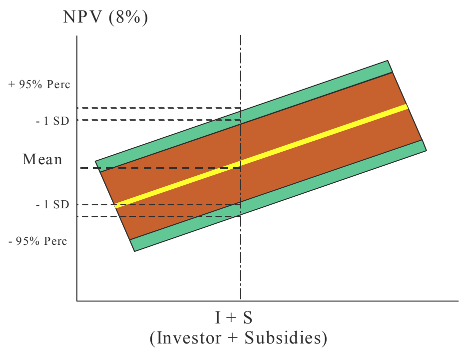
In order to solve the lack of information mentioned above the results of two recent workshops carried out in El Bolsón (Rio Negro Prov.) and San Martin de los Andes (Neuquén Prov.) were used. During these meetings, technicians, service suppliers and producers had estimated the cost of diverse forest management activities. Besides, information from previous researches was incorporated into the analysis apart from the experiences of different specialists.

3.3 Data processing

An economic model was developed in order to analyze an average situation of a forest production system. The information achieved was processed using Microsoft Excel spreadsheet, 'Solver' function of Microsoft Excel and @RISK software.

The Excel's Solver function allows searching through a number of plausible solutions until it finds the optimal solution. This function was used to calculate the maximum baseline level, the minimum carbon price and the minimum profitable area of forest project as will be explain later. @RISK software uses a quantitative method that seeks to determine the outcomes of a decision situation as a probability distribution. For the simulations Risk Analysis utilizes Latin Hypercube sampling. Simulation refers to a method whereby the distribution of possible outcomes is generated by letting a computer recalculate a worksheet over and over again, each time using different randomly selected sets of values for the probability distributions (Guide to using @RISK, 2002).

Figure 10. Example of a graphic outcome using @RISK software.



The interpretation of the figure above is as follow: the narrower the band, the less the uncertainty about the profit estimates. Conversely, the wider the band the greater the possible profit variance and therefore the greater the risk. The center line represents the trend of mean values across the range. The two outer bands above the mean are 1 standard deviation above the mean and the 95th percentile. The two outer bands below the mean are one standard deviation below the mean and the 5th percentile.

3.4 Forestry analysis

3.4.1 Silvicultural analysis and management

The economic analysis was based on a *Pinus ponderosa* plantation growing on sites of average to high quality soils. The management model was developed by Gonda (2001) and it is presented below in Table 4. Planting is done manually with a shovel at a density of 1100 plants/ha. Three pruning are considered, the first one is done over the whole plantation in order to decrease the fire risk during the dry seasons. The objective of the second and third pruning is to produce clearwood. Moreover, three thinnings are planned for the production of sawmill-quality timber. The first one does not produce commercial products unlike the second and third thinning. The final cut is assumed at the year 35th on about 200 plants/ha.

Table 4. Silvicultural management plan of Ponderosa pine to produce sawmill-quality timber and clear products on average to high quality soils in Patagonia Andes Region.

Concept	Year	Number plants/ha	Mean Height (m)	DBH (cm)	Basal area m2/ha	S. T. Vol (m3/ha)	H. T. Vol (m3/ha)
Plantation	1	1100	-	-	-	-	-
1°Pruning	10	900	3,5	8	4,5	-	-
1° Non-commercial Thinning	10						
before		900	3,5	8	4,5	-	-
after		600	3,7	8,5	3,4	7,7	
2° Pruning	12	600	4,8	12,4	7,2	17,1	-
3° Pruning	15	600	6,6	18	15,3	44,4	-
1° Commercial Thinning	21						
before		600	10,1	29,2	40,2	164,6	-
after		330	10,5	31,4	25,5	108,1	56,5
2° Commercial Thinning	27						
before		330	14,1	40,9	43,3	240,8	-
after		200	16,0	41,7	27,3	171,5	69,3
Final Cut	35	200	19,4	54,4	46,5	350,4	350,4

DBH = diameter breast height in cm. S. T. Vol = stand total volume without bark in m3/ha. H. T. Vol = harvested total volume without bark in m3/ha.. Source: Gonda, 2001.

3.4.2 Forest products

The method used for estimating forest products was the same applied by Manfredi (1999) in a previous research in Patagonia. However, different categories of timber products were chosen and set according to the price differentiation achieves in the current market. The prices of roundwood were taken from the Misiones Province market (Northeast of Argentina) due to its more developed market (see the log prices in Appendix V).

In order to compute the volume for each forest product per hectare, firstly the diameter and height of the average tree per hectare was determined. The data was taken from the silvicultural management model of Gonda (2001). Secondly, using the model developed by Cailliez (1980) (cited by Letourneau, 1996) and adjusted to local plantations by Letourneau[30] (1996) the volume of the average tree was estimated. Lastly, the volume of the roundwood products was computed on a Microsoft Excel spreadsheet trying to maximize the volume of the product of highest value. The results are shown in the Table 5.

Table 5. Volume per hectare and per plant (in brackets) of forest products obtained from Ponderosa pine afforestation in Patagonia.

Products	1° Non-comm. Thinning m^3/ha (m^3/pl)	1° Commercial Thinning m^3/ha (m^3/pl)	2° Commercial Thinning m^3/ha (m^3/pl)	Final Cut m^3/ha (m^3/pl)	Total m^3/ha
Post (p.f. 8 cm, L. 2,5 m)	-	7,8 (0.029)	4,5 (0.035)	-	12,3
Round wood 3rd (p.f. 15-25 cm, L 3,60-6,0 m)	-	52,1 (0.193)	31,6 (0.243)	25,8 (0.129)	109,5
Round wood 2nd (p.f. 25-30 cm, L 3,60-6,0 m)	-	-	-	59,4 (0.297)	59,4
Round wood 1st (p.f. >30 cm, L 3,60-6,0 m)	-	-	64,3 (0.495)	131 (0.655)	195,3
Pruned wood (p.f. > 45 cm, L 4,0 m)	-	-	-	197 (0.985)	197
Pulp (p.f. 5-11cm)	-	-	-	3,3 (0.017)	3,3
Total -m^3/ha-	-	59,9	100,4	416,5	576,8

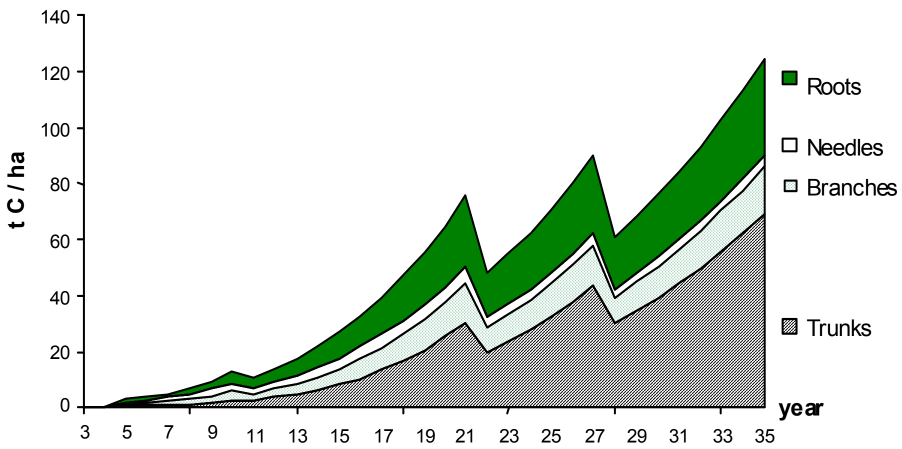
(p.f.= smallest diameter; L= long)

[30] The model adjusted was:
d=(1,378-5,372 x (h/Htot) + 22,114 x $(h/Htot)^2$ - 46,881 x $(h/Htot)^3$ + 45,2124 x $(h/Htot)^4$ - 16,440 x $(h/Htot)^5$) x dbh
Where: d=diameter estimated in cm; h=height at the diameter estimated in m; Htot= total height of the tree in m; dbh= diameter breast height in cm

3.4.3 Biomass and carbon sequestration

Biomass in pine afforestation was estimated with specific allometric equations developed by CIEFAP with co-operation of the Forest Management Institute from Universidad Austral de Chile (Loguercio et al., unpublished). The stock of carbon sequestered by a ponderosa pine plantation with a management plan of 35 years is around 124 ton of carbon[31] per hectare (t C/ ha). It means a mean value of 3,5 t C/ha/year (Loguercio, 2002). This value includes the carbon fixed in trunks, branches, needles and roots of the trees (see Figure 10). Carbon in the soil is not considered. According to Buduba et al. (2002) there are no significant changes in the carbon content of the soil, at least during the first plantation cycle. Multiplying the amount of carbon sequestered by ~ 3,667[32] the changes in carbon stocks measured in ton of carbon dioxide (t CO_2) is reached. Hence, it results in 455 t CO_2 / ha or 13 t CO_2 / ha / year.

Figure 11. Carbon sequestration in trunks, branches, needles and roots of Ponderosa pine plantation –35 years project- in Patagonia.



Source: Loguercio (2002)

The picks in the curve of carbon sequestration at the years 10, 21 and 27 shown the thinnings planned in the silvicultural scheme. Hence, the number of trees per hectare is reduced and therefore the stock of carbon as well.

[31] It assumes that the amount of carbon is 50% of the biomass dry weight (IPCC, 2000).
[32] The coefficient 3,667 ~ 44/12 is the ratio between the molecular CO_2 weight and the atomic C weight.

3.4.4 Baseline assumptions

The sum of the changes in carbon stocks in the carbon pools that would occur in absence of the CDM project were taken from preliminary results for the area of study. The carbon pools calculated included aboveground biomass and belowground biomass of herbs and shrubs. Nevertheless, neither litter nor dead wood was considered in the calculation. The preliminary results are illustrated in the Table 6.

Table 6. Biomass of different types of vegetation in forest suitable areas in Patagonia

Types of vegetation	Biomass (t / ha)
1. Herb-steppe, sub-shrub-steppe and shrub/herb-steppe with less than 20% shrub cover.	3 to 13
2. Herb-steppe and shrub/herb-steppe with shrub cover between 20% to 50%.	12 to 18
3. Herb/shrub-steppe and shrub-steppe	15 to 23
4. Shrub highest than 1 m.	> 19

(Source: Loguercio & Antequera, 2004 –preliminary results-)

Based on the data mentioned above, an average scenario was set in order to assess the projects. The baseline was estimated on an area with vegetation type 2 because it is the most representative case in sites with suitable land for afforestation. The changes on the stock of carbon pools in absence of the project were assumed to be from 12 t C/ha to 18 t C/ha in 35 years. Therefore, the changes on the carbon stock were assumed as 0,31 t CO_2/ha/year (Loguercio, pers. comm.).

3.5 Arrangements and assumptions

3.5.1 CDM arrangements

3.5.1.1 Transaction costs

The transaction costs used were taken from the international literature as described in Table 2. Average values were utilized for the whole components except for the *baseline determination costs* and *monitoring costs*. They were estimated using local costs. The assumption was that the countries would make use of their comparative advantages in order to decrease transaction costs and increase the profitability and attractiveness of the projects.

Baseline determination and monitoring costs vary according the scale of the project. Their costs were estimated based on local experience and thus, a methodology and procedure have to be set. Geo-referencing, land zoning, and biomass inventory of shrubs, herbs and small roots, have been associated to the baseline determination. Furthermore, geo-referencing, land zoning, and biomass inventory of trees have been taken into account when estimating monitoring costs. It is important to emphasize that the methodology chosen is only one of the possible options and more experience is required to develop the optimal procedure. A diagram of the methodology used can be found in Appendix VI.

The cost determination included for example: fieldwork and laboratory days, salaries to assistants and professionals, mobility costs, accommodation and food cost, administration costs, depreciation of instruments and capital costs.

3.5.1.2 Carbon prices

The scenarios regarding carbon prices were those determined by Point Carbon experts (IETA, 2003). The price for the year 2010 is predicted to be in the medium scenario about 8,2 USD/tCO_2, with low 4,2 USD/tCO_2 (25th percentile) and high 11,4 USD/tCO_2 (75th percentile).

Nevertheless, different experts inferred that the price of non-permanent credits will be lower than permanent credits (Locatelli & Pedroni, 2003; Point Carbon, 2004). The real value of non-permanent carbon credits depends on two parameteres: a) future carbon price expectations and b) the investor's discount rate (Dutschke and Schlamadinger, 2003). According to the approach of Locatelli & Pedroni (2003) to calculate the price of 'TCERs', from the economic standpoint the buyer has at least two alternatives: a) to look for a permanent credit (CER) at the time "t1"or b) to buy a temporary credit (TCER) at the time "t1" and when its lifetime is finished to buy a CER. If the result of both options is the same then the equations should be as following:

$$\left.\begin{aligned} &\text{(I) } Alternative\ a = \$\ CER_{t1} \\ &\text{(II) } Alternative\ b = \$\ TCER_{t1} + \frac{\$\ CER_{t2}}{(1+i)^{lifetime\ of\ credits}} \end{aligned}\right\} \text{Wherefore, if (I) = (II)}$$

$$\text{(III)}\ \$\ TCER = \$\ CER_{t1} - \frac{\$\ CER_{t2}}{(1+i)^{\text{lifetime of credits}}}$$

Where $\$\ CER_{t1}$ and $\$\ CER_{t2}$ is the current price and future price for permanent credits respectively; $\$\ TCER$ is the price estimated for non-permanent credits ('TCERs'or 'LCERs'), and i is the discount rate of the project. The prices $\$\ CER_{t1}$ and $\$\ CER_{t2}$ were assumed to be equal. For the 'TCERs' the lifetime of credits was 5 years (commitment period). In addition, for 'LCERs' the lifetime of credits was the difference between the lifetime of the crediting period and the year of issuance of the credits.

3.5.1.3 Calculation of CERs

The design of the financing procedure influences the project cash flow, thus, it impacts on the profitability and attractiveness for landowners and investors (de Koning et al., 2002). The amount of certified emission reductions (CERs) was calculated using the 'temporary approach' and 'long-term approach' (UNFCCC, 2003). In addition, a financing procedure was decided in order to compare both accounting approaches. The criteria chosen were the following:

a) The quantity of temporary credits (TCER) and long-term credits (LCER) generated in a verification year 't' was calculated as:

$$\text{(IV)}\ TCER_t = \text{Sum of changes on stocks of carbon pools}_{(tn - to)} - BL - L$$

$$\text{(V)}\ LCER_t = \text{Sum of changes on stocks of carbon pools}_{(tn - tn-1)} - BL - L$$

$$\text{(VI)}\ Baseline = \text{Sum of changes on stocks of carbon pools in absence of the project}$$

TCER: t CO_2/ha
LCER: t CO_2/ha
Changes stock (t CO_2/ha)
BL: Baseline (t CO_2/ha)
L: Leakage (t CO_2/ha)

b) Indirect emissions of CO_2 which occur outside the boundary attributable to the project activities (leakage) are assumed to be zero.

c) If the amount of 'LCERs' in a verification year 't' is smaller than the quantity issued in the previous commitment, it implies that the net anthropogenic GHG removals have decreased. Therefore, the countries Annex B involved in the project shall replace an equivalent quantity of 'LCERs'.

d) The crediting period last 35 years according to the forest management developed by Gonda (2001) and it starts jointly with the afforestation project activities.

e) The initial verification and certification may be undertaken at any time selected by the project participants (UNFCCC, 2003). Therefore, the current research assumes that the first verification/certification will be accomplished when the revenues generated by selling CERs are larger than the transaction cost. For instance, in year 5 revenues and costs are compared. If the revenues achieved are smaller than the transaction costs, the year 10 is evaluated. The same analysis is carried out at year 10, 15, and so on, until the revenues reached are larger than the transaction costs. At this time, the first verification/certification will be started.

f) Verification/certification will be carried out every 5 years until the end of the crediting period.

3.5.1.4 Project area

The profitability of forestry projects can be associated to, among others, the scale of the project. In order to isolate the effect of the project area size in the profitability calculation a scenario of comparison had to be set.

According to the UNFCCC (2003b) 'Small-scale afforestation project activities' are those that are expected to result in net anthropogenic GHG by sinks of less than 8 kilotons of CO_2 per year. Therefore, if a baseline of 11 t CO_2/ha is assumed and the total stock of carbon sequestered by a ponderosa pine plantation[33] is around 455 t CO_2/ha (Loguercio, 2002), the upper bound for small-scale afforestation projects is approximately 630 ha. In order to simplify the calculations an area of 600 ha was considered. The following formula was used to get this value:

(VII) $$\text{Maximum area} = \frac{8000 \text{ t CO2/ year}}{(455 \text{ t CO2/ha} - 11 \text{ t CO2/ha}) / 35 \text{ year}}$$

[33] It is for a turnover of 35 years on average to high quality sites in Patagonia.

3.5.2 Economic assumptions

3.5.2.1 Decision maker scenarios

Many economic actors may be interested in CDM afforestation projects as well as many arrangements between them could be done. The project participants could be both small or big landowners who want to diversify their incomes; also local or international companies which want to reduce their emissions or even to sell CERs; association; co-operatives, and so forth. Also, the ownership of the production factors could be integrated, rented or mixed.

Nonetheless, in order to simplify the scenarios, the economic analysis was performed from four points of view. Firstly, the farmer and the investor perspectives are being regarded. The farmer is considered as landowner; and the investor perspective includes the land purchase for establishing an afforestation project and the land resale after its final felling.

Secondly, scenarios with and without state subsidies were analyzed. According to the Law 25,080[34], current state subsidies are higher when the area afforested is up to 300 hectare per year. Thus, a total area of 600 ha was assumed as a joint project between two or more farmers or investors.

3.5.2.2 Discount rate and inflation

Revenues and costs are generated at different points along the lifetime of the project. Hence, in order to compare them it is necessary to discount them to a base period. The discount rate is important because it not only influences the economic feasibility of resource investments but also the intertemporal use of natural and environmental resources (Prato, 1998). As pointed out by several authors (e.g. Samuelson, 1976; Price, 1989; Prato, 1998; Baca Urbina, 2000; Olschewski, 2001) there are diverse approaches or arguments when choosing the appropriate discount rate.

For instance, the individual time of preference approach is used when those are more incline to an early rather than late consumption due to future uncertainty (Price, 1989). The opportunity cost rate viewpoint is concentrated on the possibilities to facilitate consumption in the future by sacrificing today's consumption. In addition, the synthetic

[34] Law N 25.080 "Inversiones para Bosques Cultivados, Resolución 22/01". Argentina.

discount rate argument proposes to use a combined rate of time preference rate and opportunity cost rate that considers consumption as well as investment aspects (Olschewski, 2001).

Samuelson (1976) argues that sometimes forest economists fight against high discount rates because the positive interest rate is the enemy of long-lived investment projects. Nevertheless, from the perspective of a social time preference, long-term reduction in carbon dioxide emissions and global warming should have a low discount rate because it benefits the future generation at the expenses of the current generation (Prato, 1998).

So, which is the appropriate discount rate? Prato (1998) pointed out that when a household maximizes his utility under budget constraint, the marginal rate of time preference equals the market interest rate. As well as, in production equilibrium, the marginal cost of capital equals the market interest rate. Therefore, the marginal rate of time preference and the marginal opportunity cost rate equal the market interest rate. This assumption was made in the present study. Furthermore, if real prices are considered in the calculations the interest rate must to be calculated in real terms too (Samuelson, 1976; Chacon Contreras, 1995; Olschewski, 2001).

However, in the reality it is usual to calculate using three interest rates. The first one is the average interest rate for savings offered by the banking sector in Argentina (self-financed scenario), it is around 7,8 %[35]. The second scenario uses the interest rate imputed when getting a credit offered by the National Bank, which is close to 16%[36] (externally-financed scenario). The third interest rate is the mean of the before mentioned scenarios. Moreover, the inflation rate during 2003 was approximately 3,7%[37]. Hence, the real interest rate (i_r) has to be computed for the different scenarios applying the following formula:

(VIII) $i_r = (i_n - f) / (1 + f)$ → where: i_n is the nominal interest rate and f is the rate of inflation

[35] Annual Nominal Rate from Banco Nacion, Banco Chubut and Banco BandSud.
[36] For long term credits to agriculture sector in Banco Nacion Argentina.
[37] INDEC (Instituto Nacional de Estadisticas y Censos).

3.5.2.3 Opportunity costs

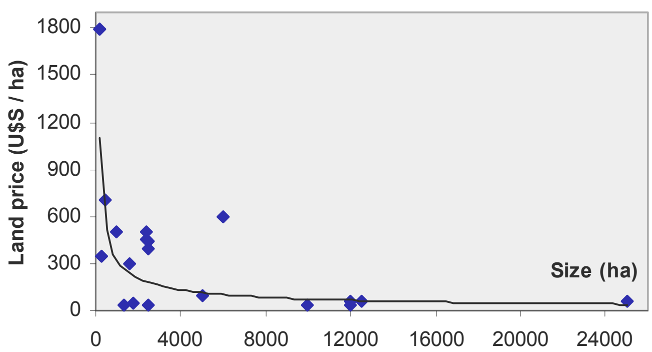
Opportunity costs are the revenues forgone when a factor of production is withdrawn or withheld from an alternative course of action (Price, 1989).

On the one hand, the revenue forgone by the farmer is either to sell the land and get an annual rent from the bank or to continue with the traditional productions – keeping sheep and cows -. The land market in Patagonia is growing strongly and it appears to be an attractive option. Nevertheless, cultural aspects, risk perception, as well as tastes and preferences of local people may emerge as barriers to sell the land. Therefore, the second option was selected. The opportunity costs assumed was 8 $/ha/year based on Laclau et al. (2003). On the other hand, from the investor perspective, the opportunity cost of investment is expressed in the rate at which benefits and costs are discounted when calculating the NPV (Gittinger, 1982). Hence, only the purchase and the resale values of the land are taken into account at the beginning and at the end of the project.

3.5.2.4 Land price

Land prices vary according to the province, area, lot size, accessibility, tourist attractiveness, potential production, facilities, etc. According to the real estate experts interviewed, the price for properties over 1,000 ha on areas suitable for afforestation is about 100 US$/ha but there is a shortage of supply. On the other hand, the supply increases for properties over 1,500 to 25,000 ha valued in 50 US$/ha and located in areas suitable for breeding sheep. Moreover, prices for properties over 150 to 1,500 ha range between US$ 300 to US$ 1,800 per hectare in the areas with tourist attractiveness. Therefore, the land price assumed in this study was 300 $/ha (approx. 100 US$/ha). Later on other prices are considered in the sensitivity analysis.

Figure 12. Land price for properties in the NW of Chubut according to the interviews.



3.5.3 Risk assumptions

Risk derives from the inability to see the exactly result of an event into the future, thus, risky variables can be described through probability distributions. Therefore, when simulations are carried out, for each iteration a new randomly selected value is chosen for each risky variable, and the results are calculated. By doing this, the simulation includes the effects of all possible future values, instead of a single projection (Guide to using @RISK, 2002).

Consequently, normal distributions were assumed for determined variables. The outcome is that profitability indicators were expressed as a range of possible values, instead of just a single one. The variables selected were: a) volume of forest products achieved, b) total carbon stocked per year, and c) transaction costs. The variables a) and b) were assumed to have a 10 % of coefficient of variation (CV). Variable c) was assumed to have a CV equal to 25 % owing to the transaction costs were considered more uncertain than the other variables.

3.6 Economic calculations

3.6.1 Profitability indicators

The profitability indicators utilized were the net present value (NPV) and the equivalent annual income (EAI). The former was chosen because it is one of the most widely used and reliable measures of an investment's viability. It is based on the following suppositions: intermediate returns are reinvested, future prices and costs are assumed to be the same as current values and the proper discount rate is selected (Ghebremichael et al., 1996).
The latter is the annual payment amount that will just pay off the NPV of an asset during its lifetime. It is useful for comparing forestry investments with projects that generate annual returns, such as agricultural practices (Ghebremichael et al., 1996). The equations used were:

$$\text{(IX)} \qquad NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+i)\, t}$$

$$\text{(X)} \qquad EAI = NPV * \frac{i(1+i)^T}{[(1+i)^T - 1]}$$

Where: B_t and C_t are the benefits and cost respectively produced in year *t.* The rotation age in years is *T* and the discount rate is *i*. The same formulas were used to calculate the profitability of timber sales and the timber plus CERs sales.

3.6.2 Critic points

The main variables that affect the profitability of CDM afforestation projects were estimated. The critic points selected were: the minimum profitable area, the maximum baseline level, and the minimum CER price.

The minimum scale of a project was determined as the area at which the present value (PV) of transaction costs would be equal to the present value of the revenues from CERs sales (Locatelli & Pedroni, 2003). Therefore, the minimum profitable project area is the size where the NPV becomes zero. The same criteria were applied to estimate the maximum baseline level and the minimum carbon price at which projects are profitable. The equation applied was the following:

$$\text{(XI)} \quad PV\ \ Transaction\ costs = PV\ Revenues\ from\ CERs\ sales \quad \rightarrow \quad NPV_{(CERs\ sales)} = 0$$

3.6.3 Carbon sequestration costs

The average cost of sequestering a ton of carbon dioxide (\$/t CO_2) was performed by dividing the present value of all forest management costs per hectare (\$/ha) by the total amount of carbon stored per hectare afforested (t CO_2/ha) (Huang et al., 2003).

$$\text{(XII)} \quad \text{Average Carbon Sequestration Cost} = \frac{\text{Present Value Forest Management Costs / ha}}{\text{Carbon Stored / ha}}$$

While the average cost of generating a certificate emission reduction (\$/ TCER or \$/ LCER) was computed via the ratio between the present value of all forest management costs (\$/ha) plus the present value of transaction costs (\$/ha) divided by the total amount of certificate emission reduction issues during the whole project (TCER/ha or LCER/ha). It is mentioned as CERs production costs.

$$\text{(XIII)} \quad \text{TCER Production Costs} = \frac{\text{PV Forest Management Costs / ha + PV Transaction Costs / ha}}{\text{TCERs issued / ha}}$$

$$\text{(XIV)} \quad \text{LCER Production Costs} = \frac{\text{PV Forest Management Costs / ha + PV Transaction Costs / ha}}{\text{LCERs issued / ha}}$$

3.7 Materials and methods' summary

The economic analysis for ponderosa pine plantations in suitable soils in Patagonia was performed based on the features and assumptions illustrated in Table 7. Timber sales and CERs sales were taken into account. Moreover, additional information is shown in Appendix VII and VIII for 600 ha project area.

Table 7. Summary of features and assumptions used in the current research.

Parameter	Value
Forest Management	Pinus ponderosa planted in suitable soils for afforestation. Planting 1100 plants/ha, Three pruning until around 5 m high and three intermediate thinning. Final cut 200 plants/ha at 35 years old.
Project area	600 ha
Accounting methods	Temporary CERs and Long term CERs
CER prices	4,2 €/t CO_2; 8,2 €/t CO_2 and 11,4 €/t CO_2
Crediting period	35 years (Verification interval every 5 years)
First certification	When the income generated by CERs sales is larger than transaction costs
Biomass	128 t C/ha
Baseline	0,086 t C/ha/year
Leakage	Zero (assumed value)
Transaction costs	Baseline determination and Monitoring were calculated locally. Others fixed and variable costs were taken from the literature.
Scenarios	Decision maker (farmer versus investor) Subsidies from the National State (with and without)
Distribution assumed	Normal Distr. for Biomass, Forest products, Transaction costs
Sampling method for simulations	Latin Hypercube (2000 iterations)
Opportunity costs	8 $/ha/year (farmer scenario)
Land price	300 $/ha
Discount rate	8 % (average scenario)
Economic indicators	NPV and EAI (calculated in Argentine Pesos before taxes)
Exchange rate	1 € (Euro) = 1,20 US$ = 3,60 $ (Argentinean Pesos at January 2004)

4. RESULTS

4.1 Profitability of Ponderosa pine afforestation based on timber sales

Two main sources of income for pine afforestation were studied: income income from timber plus 'TCER' sales, and income from timber plus 'LCER' sales. Hence, the profitability of afforestation projects by timber sales was estimated in order to be the baseline scenario of comparison.

Moreover, four scenarios were analysed: a) investor with state subsidies (I+S); b) investor without state subsidies (I-S); c) farmer with state subsidies (F+S); and d) farmer without state subsidies (F-S). The results achieved for ponderosa pine afforestation on average to high quality sites and turnover of 35 years were the following:

a. The NPV with a discount rate of 8% was positive for every scenario considered. These imply that the benefits generated by the project exceed the costs and even the opportunity costs. Therefore, the project is advantageous and recommendable.

b. The NPV mean was 796 $/ha for (F+S), 609 $/ha for (I+S), 326 $/ha for (F-S), and 139 $/ha for (I-S). The standard deviation[38] was 130 $/ha for each scenario considered (Figure 13).

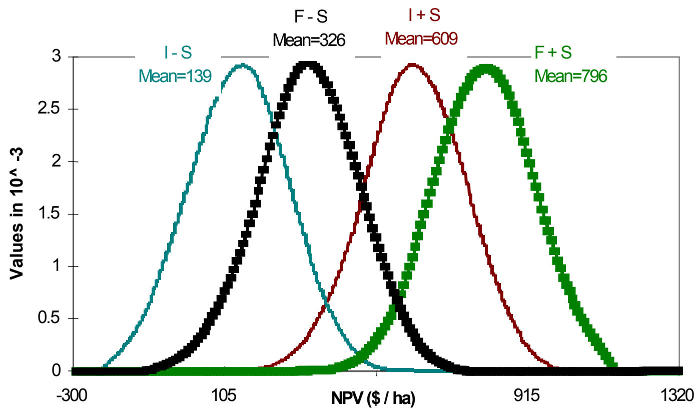
c. Similarly, the EAI was 68 $/ha/year for (F+S), 52 $/ha/year for (I+S), 28 $/ha/year for (F-S), and 12 $/ha for (I-S). Furthermore, the standard deviation was 11 $/ha in every case.

d. Therefore, the scenarios with subsidies and without land expenses have been the most profitable alternatives.

e. For the farmer, both profitability indicators increased more than two times when state subsidies were accounted. Similarly for the investor, the increment in the NPV and EAI was more than four times. These show the important role of subsidies at the beginning of the projects to improve their profitability.

[38] It appears due to a normal distribution for the volume of forest products achieved along the project was assumed in order to run Latin Hypercube simulations.

Figure 13. Profitability distributions of Ponderosa pine afforestation based on timber product sales when different scenarios are considered with 8% discount rate.



4.2 Certified emission reduction analysis

The reference scenario (profitability of timber production) was compared with projects that include CERs sales in order to analyze its impact on the project profitability. Therefore, the first step was to estimate the amount of CERs generated by ponderosa pine plantations on average to high quality sites in Patagonia. This was done using the 'temporary CER' and 'long-term CER' approaches. The first certification/verification was set at year 5 and afterwards every five years until the end of the project.

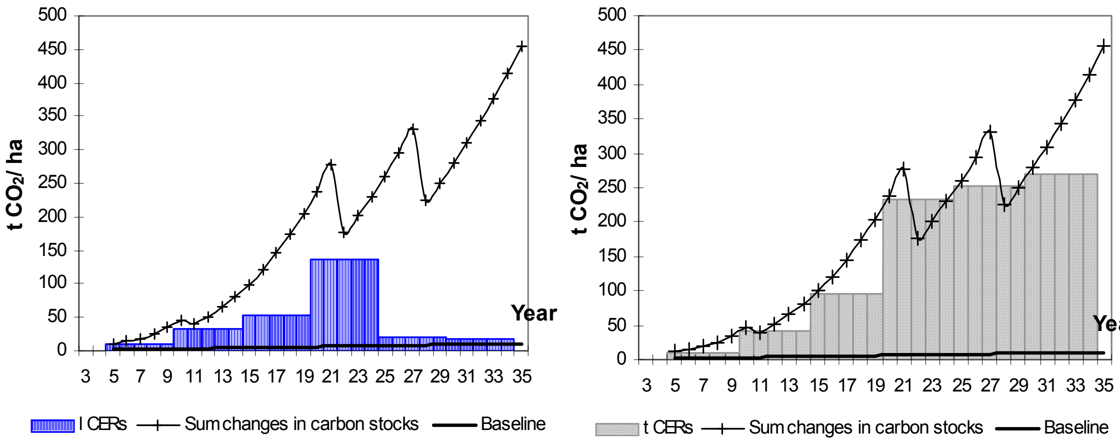
As shown in Table 8, the temporary CER approach produced 902 t CO_2 issued at the 5th, 10th, 15th, 20th, 25th, and 30th year. The maximum amount of credits was about 270 t CO_2 reached at 30th year. On the other hand, the long-term approach generated 270 t CO_2 at, 5th, 10th, 15th, 20th, 25th, and 30th year (see Figure 14). The maximum amount of credits was about 137 t CO_2 reached at the year 20. In addition, in every certification period the net anthropogenic GHG removals by sinks have increased, therefore a replacement of LCER would be not required.

The changes on the carbon pools stocks in absence of the project (baseline) were assumed as 0,17 t C/ha/year (0,31 t CO_2/ha/year).

Table 8. Amount of TCER and LCER generated in a ponderosa pine plantation with turnover of 35 years in sites of average to high quality soils.

Year	Sum of changes in carbon stocks [t CO_2]	Baseline [t CO_2]	TCER [t CO_2]	LCER [t CO_2]
1	0	0.31		
2	0	0.62		
3	0	0.93		
4	0	1.24		
5	11.2	1.57	9.6	9.6
6	14.0	1.89		
7	18.7	2.20		
8	25.4	2.51		
9	34.3	2.83		
10	45.7	3.14	42.6	33
11	39.9	3.46		
12	51.4	3.77		
13	65.0	4.09		
14	81.1	4.40		
15	99.7	4.71	95	52.4
16	121.1	5.03		
17	145.4	5.34		
18	173.0	5.66		
19	204.0	5.97		
20	238.6	6.29	232.3	137.3
21	277.0	6.60		
22	175.8	6.91		
23	201.6	7.23		
24	229.9	7.54		
25	260.8	7.86	253	20.7
26	294.6	8.17		
27	331.4	8.49		
28	225.0	8.80		
29	251.1	9.11		
30	279.3	9.43	269.9	16.9
31	309.7	9.74		
32	342.3	10.06		
33	377.3	10.37		
34	414.8	10.69		
35	454.9	11.00		
Total	455	33.6	902	270

Figure 14. Curve of carbon sequestration in a pine plantation and comparison of certified emission reductions generated with 'LCER' (left) and 'TCER' (right) approach.



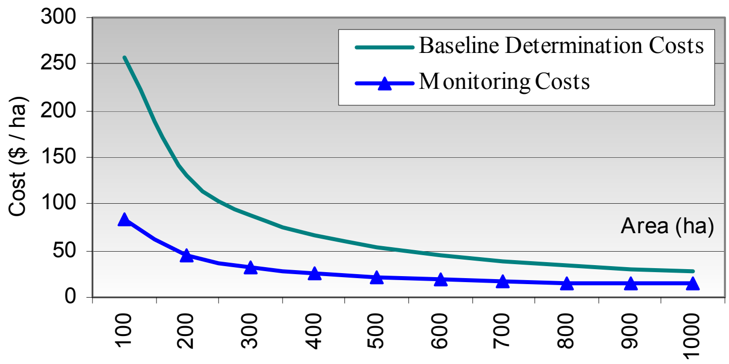
4.3 Transaction costs

The benefits generated by CERs sales will be affected by transaction costs. The transaction costs are composed of fixed and variables costs. Costs related with search and project design, baseline determination, monitoring plan, approval and validation of the project, and registration fee were all considered as fixed costs per project. Variable cost as share of proceeds, administrative cost, enforcement costs, risk mitigation, and transfer costs were assumed as 15 % of the amount of credits issued. Monitoring as well as verification costs were associated with the number of verification periods of the project.

Therefore, transaction costs were associated not only with the amount of CERs produced, the accounting approach applied and the price of the CERs, but also with the methodology and technology utilised, local input prices, and the size of the project. An example for 600 ha project area is shown in Appendix VII.

As previously explained, baseline determination costs and monitoring costs were calculated based on the current technology and expertise used for this kind of activities in the area of research. The result is illustrated in Figure 15.

Figure 15. Baseline determination costs and monitoring costs for different scale of projects estimated in Patagonia.

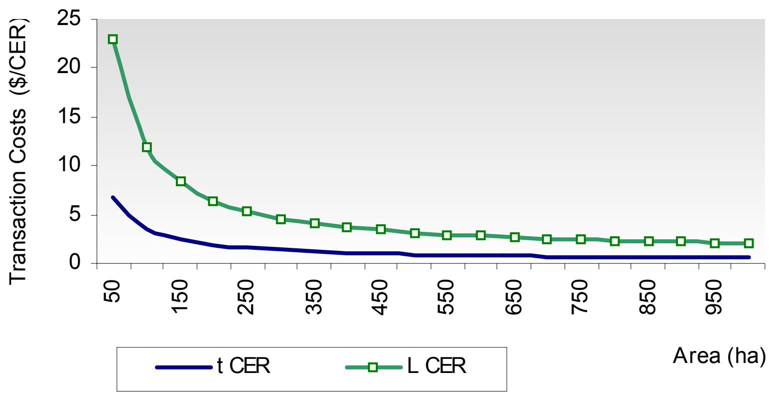


Under the range of areas assessed, the larger the project the smaller the costs per hectare. This is because those fixed costs accounted per hectare for the baseline determination and monitoring (for example geo-referencing, land zoning) became lower as the scale enlarged. For instance, the baseline determination costs estimated in Patagonia were around 88 $/ha for a project of 300 ha, but if the scale increase to 600 ha the costs decrease to 45 $/ha. The same could be seen for the monitoring costs, they were close to 32 $/ha for 300 ha and 19 $/ha for 600 ha.

The transaction costs occurred, as expected, at different times along the project life and needed to be discounted. The present value of the transaction costs per unit of CER produced was higher when the credits were issued through the 'LCER' approach. The reason for this was a smaller denominator (amount of credits) when calculated by this method compared to the TCER approach. These differences became smaller, however, when the project size increased. As expected in both accounting methods, the bigger the project area the smaller the unitary transaction costs (Figure 16).

For an afforestation project of 300 ha, the present value[39] of transaction costs were close to 1,4 $ per 'TCER' issued and 4,6 $ per 'LCER' issued. If these values were analysed per hectare, the would be 1263 $/ha using the 'TCER' approach and 1242 $/ha applying 'LCER' method. However, if the project size would increase to 600 ha, the present value of transaction costs would decrease by 43% and 39% respectively.

Figure 16. Present value of unitary transaction costs ($/CER) utilising 'TCER' and 'LCER' approaches for different plantation project sizes (i = 8%, 8,2 €/ CER).



4.4 Effect of accounting methods

The long-term and the temporary approach seem to have their advantages and disadvantages. The credits issued by the long-term method (LCERs) could have a higher price than the temporary credits (TCERs). For instance, if the expected price of permanent credits is 8,2 €/ t CO_2 (IETA, 2003) after applying the equation (III) with 8% discount rate, the result would be a price of 2,6 €/ t CO_2 for 'TCERs' and 7,6 €/ t CO_2 for 'LCERs' (lifetime 30 years). However, according to the approach of Locatelli & Pedroni (2003) the price of LCERs would decrease as the lifetime of the credit becomes shorter.

In addition, the amount of temporary credits generated would be larger (more than three times) than the amount of long term credits issued (see Table 8). Therefore, the effects

[39] It was discounted at 8% and the CER price used was 8,2 euro/ t CER.

of different accounting methods to calculate carbon credits in CDM forestry projects have to be analysed from different perspectives. In this research the analysis was carried out via four criteria:

- the impact on economic indicators (NPV & EAI) compared with the alternative "timber production".
- the effect on the cash flow
- the maximum baseline level admissible
- the minimum carbon price admissible

Firstly, the results either taking **NPV** or **EAI** showed that the most profitable scenario was timber products plus TCER sales, and the second best was the alternative timber products plus LCER sales. However, the difference in the results when comparing both approaches was smaller than 2,5 %.

The profitability of afforestation taken into account TCER sales, with 8% discount rate and considering the current state subsidies, was about 14% larger for the farmer (1561 ± 245 \$/ha) than for the investor (1373 ± 245 \$/ha). Similar results were obtain for the situation without subsidies, the NPV was almost 21% larger for the farmer (1090 ± 245 \$/ha) than for the investor (903 ± 245 \$/ha). The figures are represented in Table 9.

Table 9. Economic indicators for a pine afforestation in Patagonia under different scenarios of decision maker and sources of income (600 ha project area, i = 8% and 8,2 €/t CO_2).

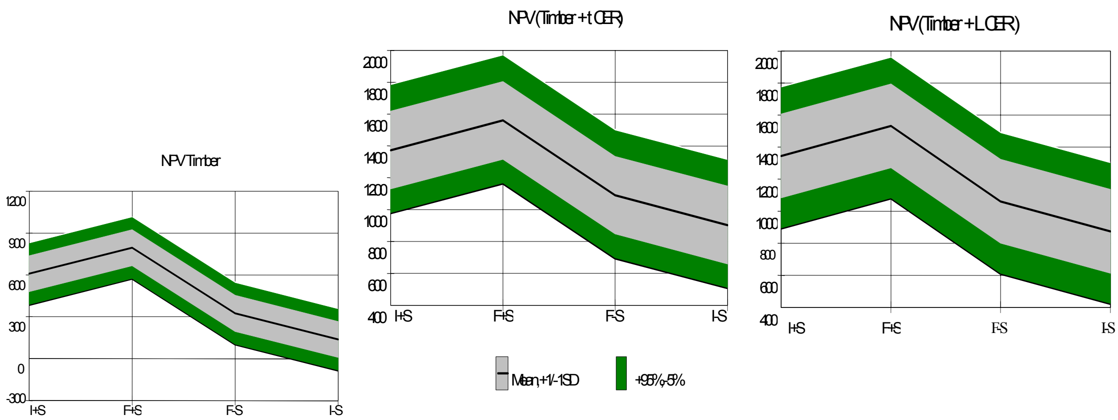
Economic Indicator	Scenario: decision-maker	Timber		Timber + TCER		Timber + LCER	
		Mean	SD	Mean	SD	Mean	SD
NPV (8%)	Farmer (+ subsidies)	796	130	1561	245	1532	262
	Investor (+ subsidies)	609	130	1373	245	1345	262
	Farmer (- subsidies)	326	130	1090	245	1061	262
	Investor (- subsidies)	139	130	903	245	874	262
EAI (8%)	Farmer (+ subsidies)	68	11	134	21	131	23
	Investor (+ subsidies)	52	11	118	21	115	23
	Farmer (- subsidies)	28	11	94	21	91	23
	Investor (- subsidies)	12	11	77	21	75	23

The NPV of timber plus TCER sales was about 765 \$/ha larger than the NPV of timber production, and almost 29 \$/ha larger than the NPV of timber plus LCER sales. The same results were achieved from the farmer perspective or from the investor standpoint.

The outcome of the Latin Hypercube simulations (@RISK software) with 8% discount rate, 600 ha project size and 8,2 €/t CO_2 is illustrated in Figure 17.

The standard deviation (SD) was smaller for the NPV of timber sales than for other options. This could be related with the number of uncertainty variables and the type of distribution set on @RISK programme. Only one variable (volume of forest products) was set as normal distribution variable in the estimation of NPV for timber sales. Whereas, two variables (transaction costs and biomass) were assumed as normal distribution variables in the estimation of NPV for timber plus carbon credits sales.

Figure 17. Comparison between three sources of income scenarios and four decision maker points of view for 600 ha pine plantation project (i = 8% and 8,2 €/t CO_2).



Secondly, the impact of the different accounting approaches on the project **cash flow** was determined. The first verification was set when the income generated by CERs sales was larger than the transaction costs.

The temporary accounting approach reached a positive and increasing cash flow from year 10 and every five years until the end of the project (see Figure 18). Nonetheless, the long term method produced a positive and increasing cash flow from year 5 up to year 20. Thereafter, even though the cash flow remained positive, it decreased sharply (see Figure 19). Both accounting methods started with a negative cash flow the 3rd year. This is due to the pre-implementation costs (search costs, project design, baseline determination, monitoring plan, approval costs and registration fee) faced by the project.

Figure 18. Cash Flow of 'TCER' approach on 35 years afforestation project. Only transaction costs and revenues from carbon credit sales were taken into account (600 ha project).

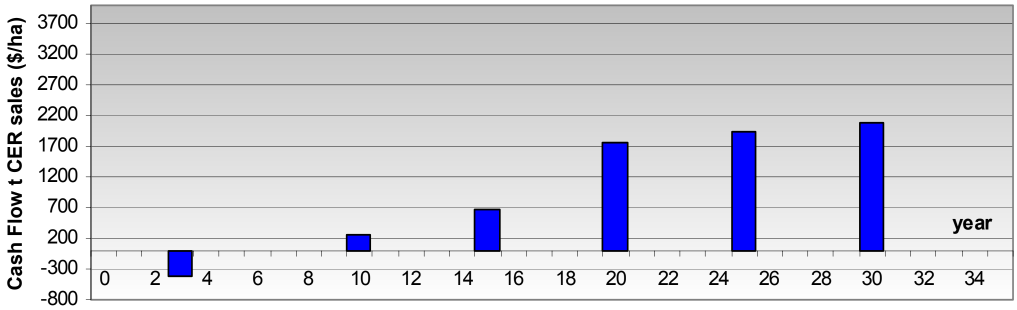
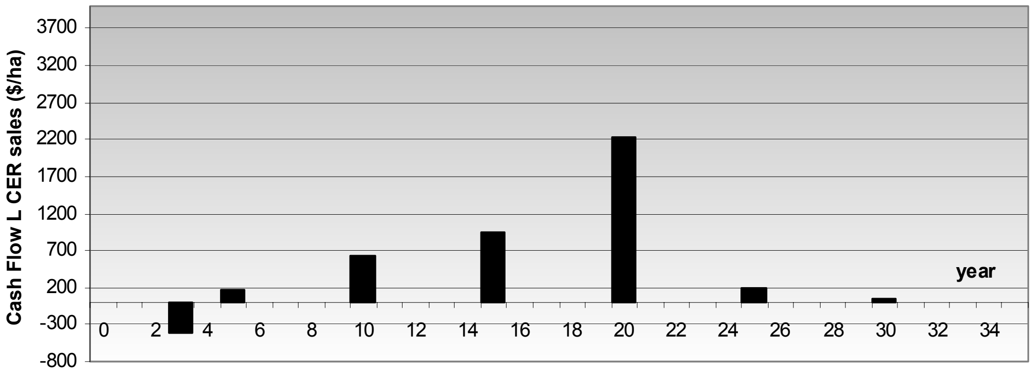


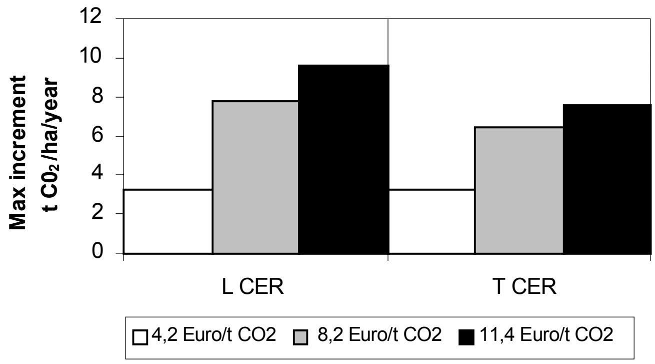
Figure 19. Cash Flow of an afforestation project applying the 'LCER' approach. Only transaction costs and revenues from carbon credit sales were considered (600 ha project).



Thirdly, the **maximum baseline level admissible** in order to make a project profitable was calculated. The baseline was defined as the sum of changes in the carbon pools that would have occurred in the absence of the CDM project activity (see equation VI).

Therefore, the maximum annual increment in carbon stocks was computed as the value at which the present value of transaction costs equals the present value of the revenues from CER's sales. In Figure 20 a comparison between the accounting approaches at different CERs prices is depicted.

Figure 20. Maximum annual increment in carbon stocks in absence of the afforestation project according to 'TCER' and 'LCER' method at three CER prices.



In both accounting methods, the rule was the higher the price of CERs, the higher the annual increment in carbon pools admissible. Moreover, the maximum level allowed by the 'LCERs' approach was larger than the value obtained by the 'TCERs' approach. For instance, with 8% discount rate, 600 ha of project size and a CERs price of 8,2 €/ t CO_2, the maximum annual increment admissible reached for LCER was 21% larger compared to the TCER. These differences became even larger when the price of CERs increased.

Comparing the maximum annual increment estimated with the annual increment in the stock assumed in this study, the latter was between 10 to 30 times lower than the maximum admissible.

Finally, the outcome on the **minimum carbon price admissible** in order to make a plantation project profitable was estimated. It was calculated as the CER price where the NPV became zero. The results pointed out that the minimum CER's price required to make profitable an afforestation project was smaller in the TCER approach (2,77 €/CER) than in the LCER method (3,02 €/CER). Nonetheless, the difference in the prices was smaller than 10%. Utilising the equation (III), the equivalent TCER price and LCER price was determined for a CER price of 3 €/t CO_2 and 8% discount rate.

Table 10. Equivalencies between CER, TCER, and LCER prices with 8% discount rate.

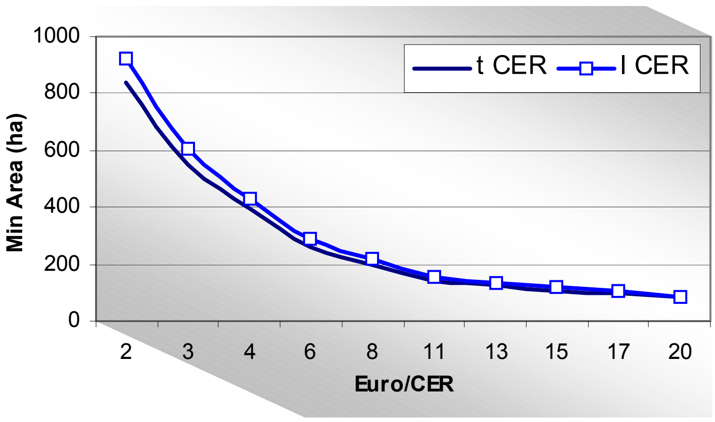
Project life (year)	€/ CERs	Lifetime (years)	€/ TCERs	Credit lifetime (years)	€/ LCERs	Credit lifetime (years)
5	3.00	permanent	0.96	5	2.70	30
10			0.96	5	2.56	25
15			0.96	5	2.36	20
20			0.96	5	2.05	15
25			0.96	5	1.61	10
30			0.96	5	0.96	5

Consequently, when compared with the information available, the minimum CER price admissible calculated for the current study was lower than the prices paid until now, and than the prices forecasted as well.

4.5 Minimum profitable project area

The minimum profitable area for an afforestation project in Patagonia was assumed as the area where the NPV became zero (see equation XI). Hence, the NPV considered only expenses and incomes generated by carbon credit sales. The minimum profitable area was associated to the accounting methods selected, the discount rate, the price of CERs, the transaction cost level, and the baseline of the project. Thus, different variables had to be supposed in order to analyse its behaviour. The result in an average scenario for different CER prices is illustrated in Figure 21.

Figure 21. Minimum project area using TCER and LCER approach for different CER prices (8% discount rate).



The minimum project area varied according to the CERs price assumed. Given a discount rate, no matter which accounting approach was used, the lower the price of carbon credits the higher the minimum profitable area. The reason for this was that the lower the price of CER the lower the income generated. Thus, a larger area was required to produce a higher amount of credits in order to exceed the transaction costs.

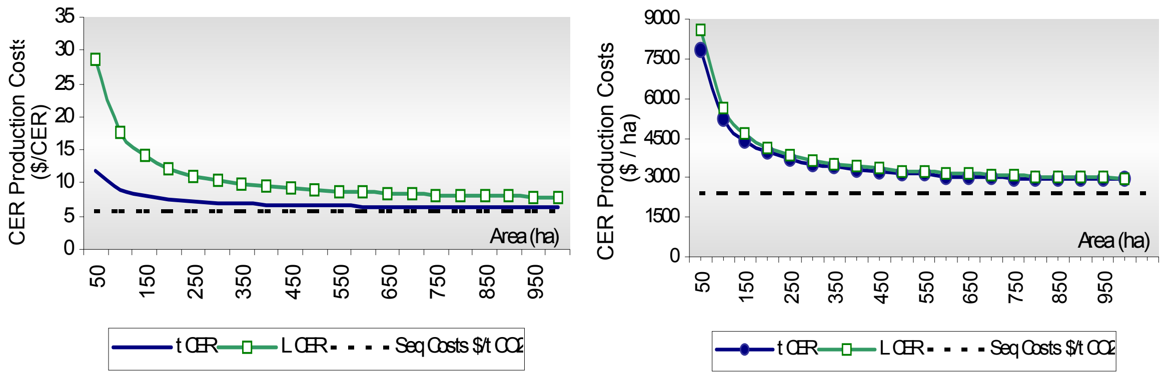
The output was that the 'TCERs' approach admitted project sizes slightly smaller than the 'LCERs' approach. Assuming an average scenario (8,2 €/CER, i=8%) the size of profitable projects had to be either bigger than 200 ha using the 'TCERs' approach, or bigger than 220 ha using the 'LCERs' method. When the CER price felt under 8 €/CER the minimum profitable area rose sharply. On the contrary, when the CER price went over 8 €/CER the minimum profitable area went down slightly.

4.6 Carbon sequestration costs

The cost of carbon sequestration was determined through the present value of the forest management per hectare divided by the total carbon dioxide stored per hectare. The outcome indicated that to sequester 455 t CO_2 for a ponderosa pine afforestation a present value of 2425 $/ha or 5,3 $/t CO_2 stored was required (see figure 22). If the present value of the transaction costs was added to the cost of carbon sequestration, then the result was the cost of sequestering and issuing a certified emission reduction. It was called CER Production Costs. The first verification was set when the income generated by CERs sales was larger than the transaction costs. Hence, the first verification for the TCER approach was at year 10 and for the LCER method at year 5.

Figure 22. Present value of carbon sequestration per CER (a) and per hectare (b). And, present value of sequestering and emitting TCERs and LCER per hectare and per CER at different project sizes. (It includes land price, 8% discount rate, and 8,2 €/CER)

a) b)



As it is illustrated in Figure 22b, comparing the values per hectare, the TCER and the LCER approaches present roughly the same figures. For a project size of 300 ha, the 'CER Production Costs' were close to 3590 $/ha. If the size increased to 600 ha, the present value decreased by 13% (3120 $/ha).

On the other hand, the same analysis was carried out in order to know the present value of carbon sequestration per ton and the present value of CER production (sequester + issue) per carbon credit. The results are depicted in Figure 22a. The unitary CER production costs were larger when the credits were issued through the 'LCER', than through the 'TCER' approach. These differences were due to the amount of credits obtained by each approach; however, these became smaller when the project size increased. For instance, in a project of 300 ha the present value of sequestering and issuing a unit of CER was about 7 $ for TCER and 10,4 $ for LCER emitted. These values decrease by 7% and 17% respectively if the project size increases to 600 ha.

4.7 Sensitivity analysis

The sensitivity analysis was carried out on the profitability of afforestation projects under changes in the following variables: a) discount rate; b) prices of inputs and outputs; c) scale of the project.

4.7.1 Changes in the project discount rate

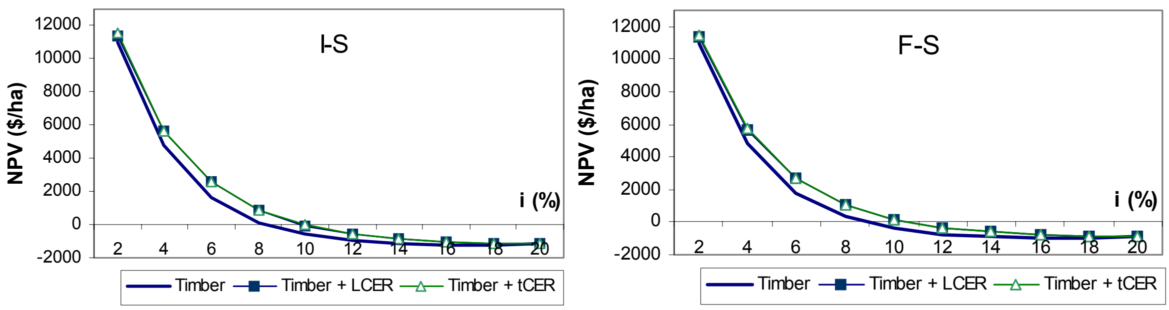
As expected, in all cases analysed the higher the discount rate the lower the NPV. Profitability figures could be ordered, whatever discount rate was applied, from the highest to the lowest value as: (F+S) > (I+S) > (F-S) > (I-S). Hence, the scenarios with subsidies and without land expenses have been the most profitable alternatives. The effects of distinct discount rates on different alternatives of financing sources, for farmers and investors without subsidies were considered. The values derived for these two decision maker scenarios had the same results and are shown in Figure 23.

Despite the discount rate applied, timber production plus carbon credits sales achieved a higher NPV compared to timber production. Furthermore, the difference between the NPV of timber plus TCER and the NPV of timber plus LCER was smaller than 10%.

For instance for the farmer without subsidies (F-S) scenario, with 4% discount rate (assuming as self-financing situation) the NPV ranged from 4080 $/ha for timber production to 5763 $/ha for timber plus TCER sales. On the other hand, in the situation assumed as external-financed (i = 12%), the NPV ranged from -742 $/ha for timber production to –318 $/ha for timber plus TCER sales. And then, under this condition the project was unprofitable. The reason of these negative figures was that the higher the discount rates and the later the receipts the lower their present values. Thus, the expenses in the first years are relative more important than the revenues at the end of the project.

Figure 23. NPV ($/ha) for the scenarios 'Investor without subsidies' (a) and 'Farmer without subsidies' (b) under different discount rates and source of income (size 600 ha and 8,2 €/CER).

a) b)



4.7.2 Changes in input and output prices

The impact of changes in forest management costs, timber prices, land prices, and CER prices was evaluated. Table 11 shows the results of a sensitivity analysis for an afforestation project in Patagonia to changes in input and output prices.

As expected, the NPV declined with rising forest management costs and land prices. Moreover, the NPV goes down with decreasing timber and CER prices. For example, the NPV of timber production in the scenarios without subsidies become negative when an increment in forest management costs of 20% or a reduction in timber prices of 20% was simulated.

Changes in the land price affected mainly the investors' situation. In the scenario timber production without subsidies a land price higher than 500 $/ha made the project unfeasible. Equally, a land price lower than 1000 $/ha was required to make a project profitable in the situation with subsidies. However, if carbon credit sales were considered even at land prices of 1000 $/ha the NPV was positive.

According to the interviews with real estate experts, land prices have risen steadily last years and it was expected the same trend for the next years. One reason for this could be that the environmental, recreational and potentially tourist value of the region has become interesting to foreign investors. Therefore, the land price at the end of the project would be probably larger. If so, the profitability of afforestation for an investor, who would buy the land at the beginning of the project and would sell it at the end, would be slightly increase.

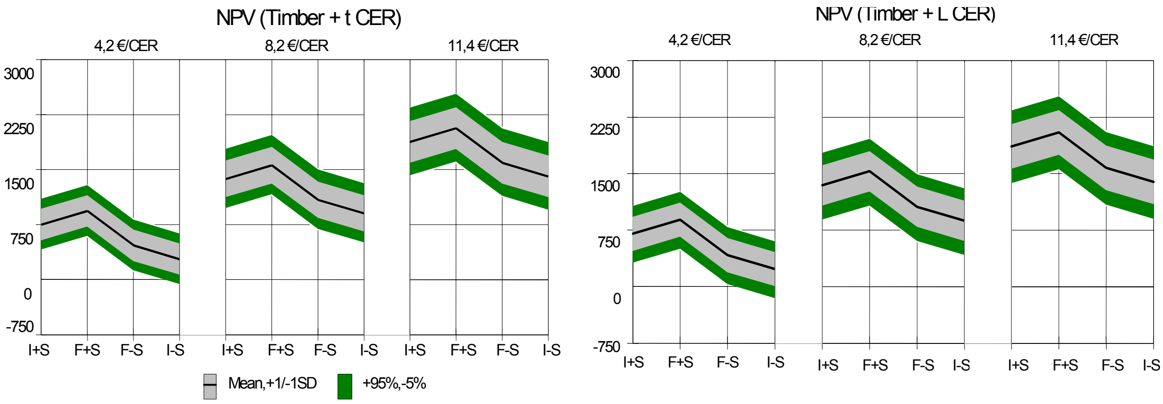
The report of IETA (2003) determined that the possible carbon price in 2010 is going to be 8,2 €/tCO_2, ranging from 4,2 €/tCO_2 (25th percentile) to 11,4 €/tCO_2 (75th percentile). The NPV of timber plus TCER sales was 142 $/ha higher than the NPV of timber production considering the lower CER price scenario and 1263 $/ha higher taken into account the 75th percentile price. Otherwise, for timber plus LCER sales these values were 90 $/ha and 1252 $/ha respectively.

Table 11. Sensitivity analysis for afforestation in Patagonia to changes in input and output prices.

	Scenario	I+S		F+S		F-S		I-S		Obs.
		NPV	EAI	NPV	EAI	NPV	EAI	NPV	EAI	
Reference scenario	i = 8%	609	52	796	68	326	28	139	12	Timber production
Increment in forest management costs	10%	357	31	574	49	104	9	-113	-10	
	20%	105	9	352	30	-118	-10	-365	-31	
Reduction in timber prices	10%	353	30	540	46	69	6	-118	-10	
	20%	96	8	283	24	-187	-16	-374	-32	
Increment in land price (baseline 300 $/ha)	400 $/ha	516	44					45	4	
	500 $/ha	423	36					-48	-4	
	1000 $/ha	-44	-4					-514	-44	
Increment in land price at the project end (baseline 300 $/ha)	450 $/ha	619	53					149	13	
	600 $/ha	629	53					159	14	
	900 $/ha	650	56					179	15	
Reference scenario	8,2 €/CER	1373	118	1561	134	1090	93	903	77	Timber + TCER
Increm. in land price	1000 $/ha	719	62					249	21	
Changes in CER price	4,2 €/CER	751	64	938	80	468	40	281	24	
	11,4 €/CER	1872	161	2059	177	1589	136	1402	120	
Reference scenario	8,2 €/CER	1345	117	1532	131	1061	91	874	77	Timber + LCER
Increm. in land price	1000 $/ha	692	59					221	19	
Changes in CER price	4,2 €/CER	699	60	886	76	416	36	229	20	
	11,4 €/CER	1861	160	2048	176	1578	135	1391	119	

Lastly, in Figure 4 is possible to appreciate how the NPV move upwards when the price of CERs was increased. Making a comparison with all the possible scenarios, the NPV generated by timber plus temporary credits sales was slightly higher than the NPV produced by timber plus long-term credits sales.

Figure 24. Comparison of NPV using long term and temporary CER at different CER prices and decision maker scenarios (8% discount rate and project area 600 ha)

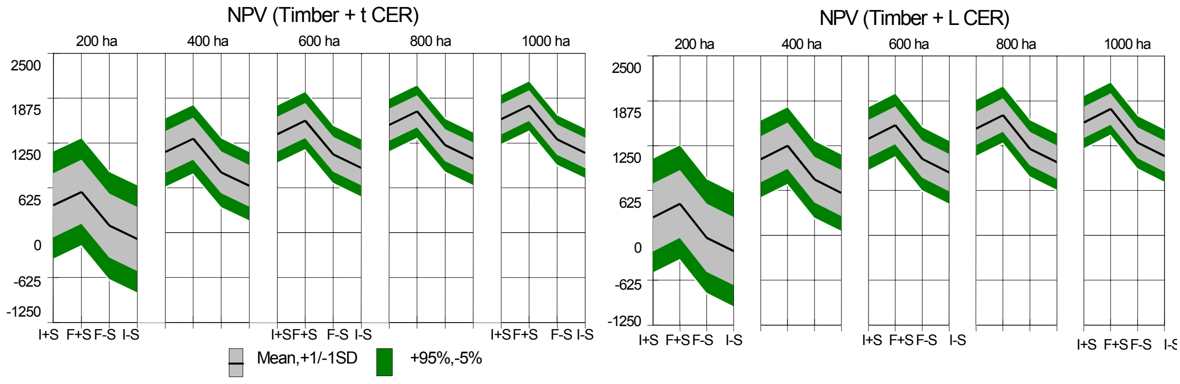


4.7.3 Changes in the project scale

Firstly, the effects of changes on the spatial scale of the project were tested. The result was that given a CER price, the larger the size of the project the higher the NPV. The relative weight of the fixed cost was smaller when the area of the afforestation project increases and this could be the supporting idea behind the findings.

The scale effect on the NPV considering temporary and long-term carbon credits is depicted respectively in Figure 25. The discounted rate assumed was 8 % and the CER price was 8,2 €/t CO_2. The outcome was that, using either 'TCERs' or 'LCERs' methods, scales over 600 ha showed slightly increments in their NPV. Just as an example, the NPV of timber plus TCER sales for the I+S scenario was 360 $/ha for a project size of 200 ha. However, it went up 3,8 times when the scale was tripled and 4,4 times when the scale was multiplied by five. Nonetheless, if LCER were considered these values would have been 5,4 and 6,3 times respectively. This meant that the effect of the project size was more important effect when the LCER approach was used.

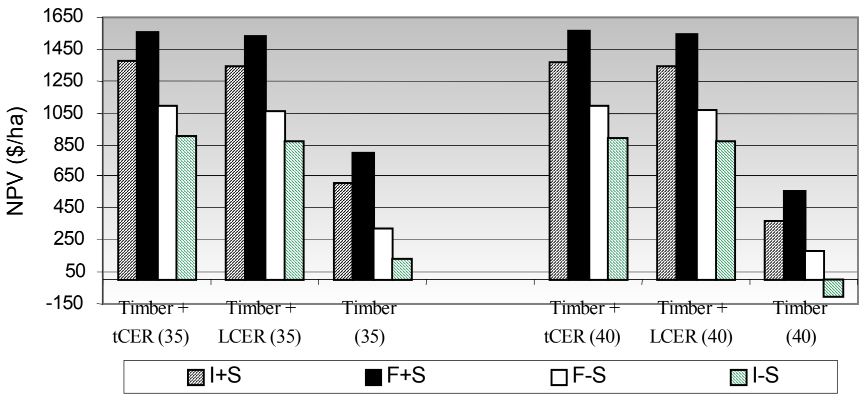
Figure 25. Temporary credits (left) and Long-term credits (right) at 8,2 €/CER, and 8% discount rate, with 200, 400, 600, 800 and 1000 ha afforestation project area.



Secondly, the effects of changes on the temporal scale were analysed and projects of 35 years and 40 years were compared. This latter, allowed an additional verification period at the year 35. Moreover, the production of the better classes of timber rose. The volume of clear wood estimated went up 15% and first class round wood increased 78%. The results are shown in Figure 26.

Comparing the NPV of timber production, a delay of 5 years in the final felling increased the volume produced and thus the revenues achieved. Nonetheless, the profitability decreased because the NPV is strongly affected by the length of the period to be discounted. Otherwise, comparing timber production plus carbon credits sales, the difference in the NPV between both projects was smaller than 1%. Even though, the contribution of CER sales to the NPV was 55% for a 35 years project, and 73% for a 40 years project.

Figure 26. Comparison between the profitability of 35 years and 40 years afforestation project in Patagonia (8,2 €/CER, 8% discount rate, and 600 ha).



5. DISCUSSION AND CONCLUSIONS

The main limitations of the current research are described at the beginning of the discussion. Afterwards, the leading conclusions about the economic analysis of afforestation projects for carbon sequestration in Patagonia are summarised. Last, but not least, the results achieved in the present research are associated with the international context and one alternative to develop CDM projects in Patagonia is briefly described.

5.1 Limitations of the present research

The availability of data gives the bases to developing a research. Nevertheless, when no sufficient data is found a number of assumptions and generalisations have to be made. In the area of research, more information is required about forest management costs for different project scales and stages, especially, for the elder stages of growth (pruning, thinning, final cut). However, the lack of information is basically because, most of the plantations are still in their early ages, fragmented on large areas, and also because the forestry sector is on its first steps of development. Hence, the suppositions and generalisations taken for the costs calculations of forestry activities may differ from particular situations.

It is worth to mention that according to the Law N° 25.080 "Inversiones para Bosques Cultivados, Resolución 22/01", when projects receive benefits from CER sales, the state subsidies reached become credits, and then, the farmer shall to return it. However, up to now the interest rate and the devolution period length have not been agreed on. Therefore, this fact was not included in the analysis.

The economic analysis was based only on timber and certificate emissions reduction sales. Therefore, other environmental services of the forest like biodiversity, bio-restoration, wildlife protection, and so forth were not considered in the current study.

The Kyoto Protocol Mechanisms are topics of continuous development and thus, new information, procedures and methodologies appear frequently. The conclusions achieved are related with the available information when this research was carried out.

5.2 Economic analysis of afforestation projects for carbon sequestration

5.2.1 Impact of CER accounting methods

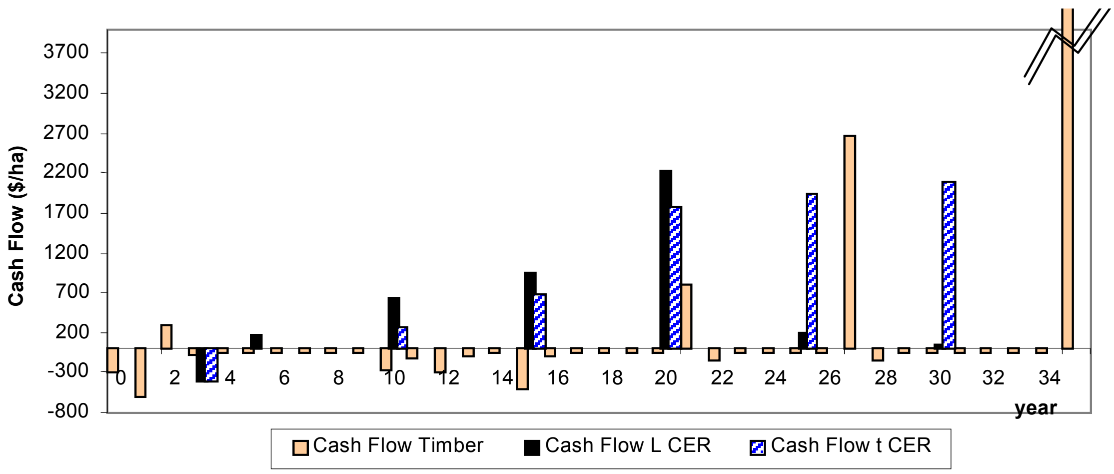
The effect of the temporary and long-term CER has been assessed from different angles. The impact on economic indicators -NPV & EAI (before taxes)-, on the cash flow, on the maximum baseline level admissible and on the minimum carbon price admissible were estimated.

Firstly, the profitability under the scenarios considered could be ordered from the highest to the lowest value as follow: (F+S) > (I+S) > (F-S) > (I-S). With no surprise, the scenarios with subsidies (+S) and without land expenses have been the most profitable alternatives. When comparing different source of incomes -timber production, timber plus TCER sales and timber plus LCER sales-, the results were similar either taking NPV or EAI. They clearly pointes out that the most profitable alternative was income from ‘timber plus TCER sales’. Nonetheless, the difference in the results between both accounting methods was smaller than 2,5 %.

Secondly, the distribution of the cash flow along the lifetime of the project was different between both accounting approaches. On the one hand, the surplus generated by the LCER method was concentrated in the first 20 years of the project, and thereafter the surplus fell sharply. Moreover, in every verification period before the 20th year the cash flow was higher than the achieved by the TCER approach. On the other hand, the surplus reached by the TCER method was increased almost steadily. The surplus was lower at the beginning of the project but it went up after the 20th year. In addition, both accounting methods started with an additional expense at the 3rd year caused by fixed costs in the pre-implementation stage and baseline determination costs.

The incorporation of carbon credits sales would improve the feasibility of afforestation projects in Patagonia. First, by selling CERs the periodicity of payments during the project’s life span would increase. Moreover, the first surplus of the project (excluding the subsidy to plant) would be generated earlier. Second, the income reached by TCER or LCER may be used to cover the costs of non-commercial thinning at the year 10 as well as the pruning costs required to produce high quality timber. However, an additional expense generated at the year 3 would have to be considered, and thus this may implies an economic barrier. A comparison between the cash flow of timber production and the cash flow of CER sales is depicted in Figure 27.

Figure 27. Comparison between the cash flow considering timber sales, TCER sales and LCER sales (I+S scenario, scale = 300 ha, i = 8% and 8,2 €/t CO_2)



Thirdly, the maximum baseline level admissible in order to make a project profitable was calculated. The value reached by the LCER approach was 21% larger compared to TCER method and these differences became even greater as the CERs price increased. Also, the maximum annual increment estimated was between 10 to 30 times higher than the value assumed in this study (see Figure 20). This might suggest that the range of areas suitable for CDM forestry projects are larger than expected.

Finally, the minimum carbon price required to make profitable an afforestation project was 10 $/CER (2,77 €/CER) and 10,9 $/CER (3,02 €/CER) in an average scenario for the TCER and LCER approach respectively. The values achieved were lower compared to the prices paid until now and the prices forecasted for the period 2010 according to IETA (2003). Therefore, afforestation for carbon sequestration in Patagonia seems to be profitable even in less favourable price scenarios.

Carbon credit sales improve the profitability of forestry projects in an average scenario. And even though the farmer perspective appears to be more favourable than the investor’s, when subsidies were considered both became better off. The NPV of timber production increased more than 700 $/ha when CER sales were taken into account and their contribution in the final NPV figure was of 55%. Both accounting approaches have had almost the same performance, even though the major difference could be found on the cash flow payment distribution.

5.2.2 Scale of CDM forestry projects

The minimum profitable area is related with the accounting methods selected, discount rates, prices of CERs, transaction cost levels, and the baseline of the project. No matter which discount rate was used the 'TCERs' approach allows smaller project sizes than the 'LCERs' method. In order to generate additional revenues, assuming an average situation (8,2 €/ t CO_2 and i = 8%), the project size has to be either bigger than 200 ha using the 'TCERs' approach, or bigger than 220 ha using the 'LCERs' method.

As previously mentioned, UNFCCC (2003b) defined 'small-scale afforestation project activities' as those that are expected to result in net anthropogenic GHG by sinks of less than 8 kilotons of CO_2/year. Therefore, supposing a baseline of 11 t CO_2/ha and a stock of carbon of 455 t CO_2/ha, the maximum area for small-scale projects is about 630 ha. Although, up to now there has been no agreement on small scale forestry project advantages – economic, bureaucratic, methodological, etc. -, it is possible to affirm that the larger the area the more profitable and less risky the project. Consequently, from the economic perspective plantation projects of 600 ha are preferable to smaller project areas.

Effects of changes in the temporal scale of the project were also analysed and a comparison of projects lasting 35 years with ones lasting 40 years was performed. The difference in the NPV between both lengths was smaller than 1% even when the contribution of CER sales to the NPV was 55% for the thirty five year project, and 73% for a forty year project. From the economic standpoint any alternative had additional advantages. However, to make a decision other factors like risk perception or the forecast of timber and CER prices should be taken into account.

5.2.3 Carbon sequestration costs

Comparative advantages were found on some transaction cost components when data from international literature was contrasted with own estimations based on local expertise. The baseline determination and monitoring report costs would be reduced by one-third when developed locally. Therefore, transaction costs would decrease because salaries, displacement costs, insurance, etc. in developing countries are lower for local than for international experts. Moreover, they already have been trained and acquired knowledge on the project area.

As expected, the larger the project the smaller the transaction costs per hectare. For instance, the baseline determination costs estimated in Patagonia was around 45 $/ha and the monitoring cost was close to 19 $/ha for a project of 600 ha, but these values went up to 88 $/ha and 32 $/ha respectively when the size decreased to 300 ha.

The cost of sequestering carbon dioxide for a ponderosa pine afforestation in Patagonia (455 t CO_2/ha) was about of 5,3 $/t CO_2 stored (in terms of present value). This value was assumed constant for the range of project sizes evaluated.

When the present value of the transaction costs is added to the cost of carbon sequestration, the result is the cost of sequestering and issuing a certificate emission reduction. For the cases under study this was called CER Production Costs –always in terms of present value-. The CER Production Costs calculated per hectare with either 'TCERs' or 'LCERs' have presented roughly the same figures. They were close to 3120 $/ha for projects of 600 ha. When they were estimated per ton of carbon credits, the values were 6,2 $/ TCER and 8,3 $/ LCER.

To conclude, sequestering CO_2 and issuing CER in Patagonia have comparative advantages. The costs are sharply smaller than the costs found by Huang et al. (2003) in USA and Castro Salazar (1999) in Costa Rica.

5.2.4 Sensitivity analysis

Firstly, both the length of time between payments and receipts, and the discount rate charged play a determinant role on the feasibility of projects. Hence, expenses at early stages have higher impact on it than revenues perceived at the end of the project. For instance, with 4% discount rate (assuming a self-financing situation) the NPV was positive for every alternative considered. Whereas, in the situation assumed as external-financed (i = 12%) the NPV always was negative.

Secondly, changes in input and output prices also play a determinant role on the feasibility of projects. When analysed, the main factors that harm the profitability of afforestation projects were the increments in forest management costs and the reduction of timber prices. Instead, the NPV of timber plus CER sales was positive and larger than the NPV of timber production alone even for the lowest CER price scenario forecasted by IETA (2003).

For instance, the NPV of timber production for those scenarios without subsidies became negative when an increment in forest management costs of 20% or a reduction in timber prices of 20% was simulated. It suggests that subsidies might be necessary to decrease investment risk in afforestation projects in Patagonia and to improve its attractiveness. In addition, if the profitability of timber production is compared to the profitability of timber plus CER sales, the outcome reveals that the conjoint production NPV is equivalent to an increment of 30% in timber prices or a reduction of 30% in forest management costs. Consequently, the addition of carbon credits sales may be seen as a margin of profitability under unfavourable condition in input and output prices.

5.3 Final conclusions

The objective of this research was to evaluate the following hypothesis: "given the current uncertainty about carbon prices for carbon credits and the high level of transaction costs, CDM forestry projects of small scale will be unfeasible in Patagonia".

To the contrary, the results supported the idea that small scale CDM afforestation projects in Patagonia would be feasible and advantageous under the scenarios assumed. Also, the conjoint production –timber plus CER sales- would increase the profitability of timber production alone. Furthermore, Ponderosa pine plantations located in the area of study showed comparative advantages in CO_2 sequestration costs.

Yet, two key questions rise from the current discussion. The first one is how the international context may affect the viability of afforestation projects? The second one, how to develop a system economically attractive and efficient for CDM forestry activities in Patagonia?

Primary, comparative advantages are not sufficient to participate in the global market. The international context has a strong impact on the viability of projects and it determinates who might be able to benefit from the CDM. For this reason, the decision makers should take into consideration both, internal and external factors that influence the feasibility of CDM projects. An approach of the main factors is shown in Table 12.

Table 12. Strengths and weakness of Patagonia forestry sector, and opportunities and threats of CDM market.

Strengths	Weakness
- Scientific and technical institutions developed - Large availability of suitable forest land - Relative faster growth of pine plantations - State promotion policies - Low carbon sequestration costs	- Forestry sector still in development - Delay in the payments of state subsidies - Traditional activities of farmers do not include forestry production - Few agreements and projects with international organisation related to CDM
Opportunities	**Threats**
- Emission growth in Annex B countries - Low implementation rate of CDM projects in other countries, basically China and India - Increasing prices of CER	- Delay in Kyoto Protocol ratification - Diminishing attractiveness of Argentina due to economic and political crisis - High competence between suppliers - High negotiation power of buyers - High negotiation power of intermediate organisations likes operational entities, etc. - Supply of CERs from others climate-related activities

As described in Table 12, Patagonia presents favourable conditions and comparative advantages for CDM projects. Also, there are opportunities in the global market to develop this kind of projects. However, world markets are dynamic and any advantage is only temporal. At the same time, external facts denote a very competitive market with small margins of negotiation. In addition, the ratification delay of the Kyoto Protocol and the increasing supply of CERs from others climate-related activities appear to be the biggest threats for carbon sequestration projects.

Hence, some strategies could be highlighted as they seemed of fundamental importance to translate the existing comparative advantages into competitive ones. To name but a few, encouraging economies of scale to reduce costs; improving the quality of projects to differentiate the product in the market; developing new agreements with international traders, buyers associations, NGOs, etc.

The second key question was related to promoting the development of CDM forestry activities in Patagonia. Clearly, the challenge is how to generate a system economically attractive and efficient in the use of factor endowment?

The project area has had a great weight when determining the viability of the CDM afforestation projects. The larger the scale the higher the profitability. The reason for this is a reduction on unitary fixed cost whilst the afforestation project area enlarges. The results reached in this study have shown that the scale of the forestry projects should be at least 200 ha, although, from the economic perspective plantations of 600 ha are preferable to smaller ones.

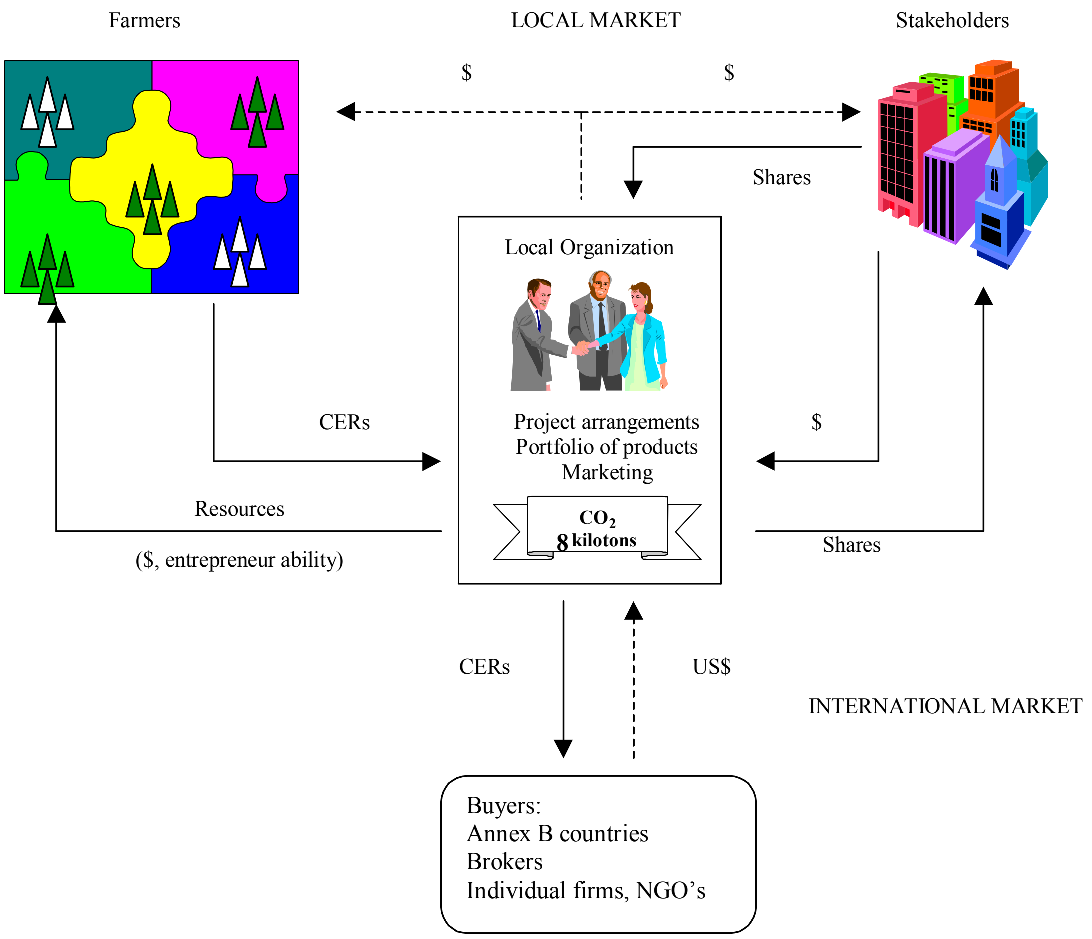
A project area of 600 ha does not seem to be a big challenge for large farmers or large investors in Patagonia. However, another question arises here. Would this type of projects be considered as 'small-scale afforestation project activities' by the UNFCCC? Because of small-scale projects should be developed or implemented by low-income communities and individuals (UNFCCC, 2003). Therefore, two other possible scenarios emerge from this potential restriction.

The project could be carried out by small farmers or even small investors associations. Each part could plant areas up to 300 ha in order to maximise the state subsidy (500 $/ha) perceived. At the same time, they should bear in mind environmental and location factors that will would affect the transaction costs and the profitability of the project. Nevertheless, the project should to be implemented in a single year resulting in a concentration of higher expenses at the beginning and higher benefits at the end of the project lifetime. On the contrary, forestry business usually attempts to build up a production cycle. Where after the first rotation, every year the firm not only will plant but also will harvest. Therefore, payments and receipts would be equilibrated.

The other possible alternative could be to design project portfolios where the product offered is a net anthropogenic GHG removal by sinks of 8 kilotons of CO_2 per year. No matter how many hectares, or how is the ownership distribution, continual cash flow would be produced.

But, in order to make this alternative feasible, a local financial scheme would need to be developed. It could be based on a local organisation (association, co-operative, NGO, etc.) and it should be the nexus between farmers, local stakeholders and international buyers. The farmers would receive economic resources as well as training from the local organisation and their goal would be to produce timber and CERs. The stakeholders could be small savers or investors from urban or even rural areas who would receive shares for future CER sales and even for the timber production in return of their capital investment. The local organisation would have to make project portfolios and offer them in the global market. Thereafter, the local organisation would receive the CER funds from the international buyers and the income would be shared among producers and stakeholders. An approach for a local financial scheme to develop CDM project portfolios is illustrated in Figure 28.

Figure 28. Example of the proposed financial scheme for project portfolios.



The local financial scheme would have to develop its own incentives, rules and mechanisms to assure its functionality. These should be done without excessively increasing transaction costs and taking into account environmental and location factors.

It is worth to mention that the financial scheme should follow the UNFCCC rules and procedures in order to make it attractive for foreign investors.

To conclude, using a local financial scheme both the risk and the benefits of projects would be shared among the participants. And at the same time that scarce production factors - land, capital, labour and entrepreneur ability – would be pooled, the attractiveness of the project would increase.

As Locatelli & Pedroni (2003) have suggested, other climate-related activities could be added to the forestry projects. Energy generation from wood, water and specially wind could be very interesting alternatives in the Patagonia Region. This combination of small forestry and energy projects may allow issuing permanent credits and contributing not only to mitigate the global warming but also to improve the life standard of rural communities in Patagonia.

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Appendix I. CDM projects in Latin America with host country approval.

Country	Program	Type (Description)	GHG Reduction [tCO_2]
Bolivia*	CERUPT	Energy efficiency (Efficient gas plant)	319.392
Brazil	PCF	Sinks & fuel switch	12.041.356
Brazil*	CERUPT	Biomass (Retrofit CHP bagasse sugar mill; 15 M/)	259.506
Brazil*	CERUPT	Gas capture (Landfill gas recovery)	700.000
Brazil	NCDF, Japan	Fuel switch (Charcoal based steel production)	21.000.000
Brazil	NCDF	Gas capture (Combustion and flaring credits)	11.800.000
Brazil	VEGA	Gas capture (8MW power from landfill gas)	5.208.344
Chile	PCF	Hydro (26 MW run-of-river)	2.812.000
Columbia	PCF	Wind energy (19.5 MW new capacity)	1.168.000
Costa Rica	PCF	Wind energy (9.6 MW new capacity)	327.000
Costa Rica	PCF	Wind energy (8.4 MW new capacity)	300.000
Costa Rica	PCF	Wind energy (25 MW new capacity)	204.000
Costa Rica	CERUPT	Hydro (7.5 MW new capacity)	184.360
Costa Rica*	CERUPT	Hydro (35.4 MW new capacity)	806.800
Costa Rica*	CERUPT	Gas capture (3 MW landfill gas)	97.850
Nicaragua	CERUPT	Biomass (electricity production)	212.395
Panama*	CERUPT	Hydro (120 MW new capacity)	3.575.927
Panama*	CERUPT	Hydro (in total 100 MW new capacity)	366.923
Panama*	CERUPT	Hydro (increase capacity)	261.000
Peru	CERUPT	Hydro (90.6 MW new capacity)	2.158.917
Total			**63.803.770**

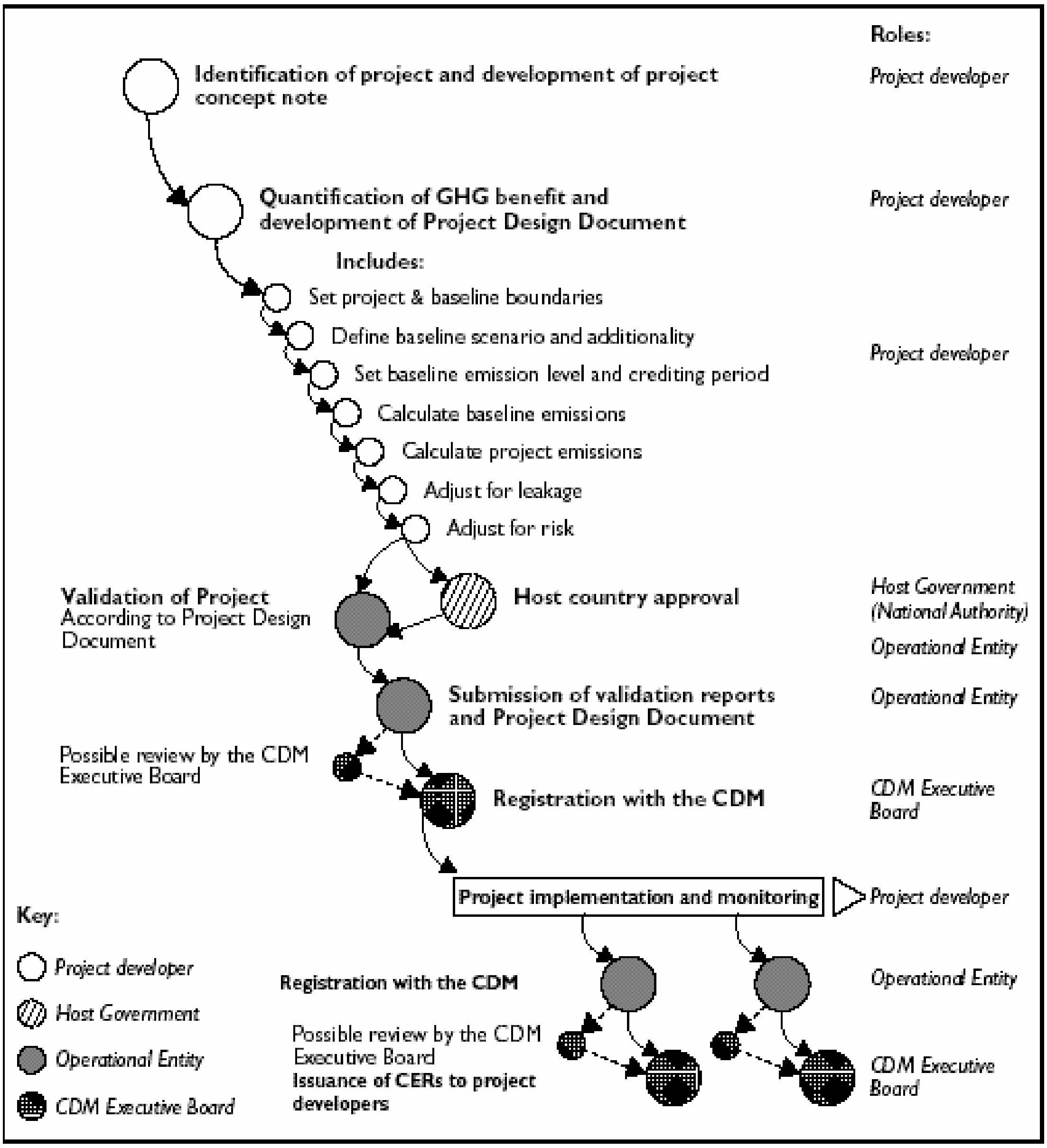
Source: IETA, 2003

Appendix II. Emission reduction prices and volume by technology type

Technology Type	**Volume (metric tons CO_2)**	**% of Total Volume**	**Approx. Price (US$/ton CO_2)**
Afforestation	1,018,000	2.35%	3.63
Cogeneration	2,460,730	5.69%	8
Energy Efficiency	2,610,319	6.03%	2.46 - 5.18
Flare Vent Reduction	100,000	0.23%	3.00 - 5.00
Fuel Switch	5,000,000	11.55%	3.50
Landfill Gas Capture	3,655,644	8.45%	0.65 - 6.79
Process Change (Chemical)	131,000	0.30%	2.00 - 4.00
Renewable Energy (total)	27,604,800	63.78%	3.02 - 7.92
Biomass	6,835,636	15.79%	3.15 - 7.92
Geothermal	464,553	1.07%	3.02 - 5.99
Hydropower	14,807,674	34.21%	3.00 - 5.99
Wind	3,746,937	8.66%	3.43 - 7.92
Unspecified	1,750,000	5.6%	3.83
TOTAL	**43,280,493**	**100.00%**	**1.03 - 8.00**

(Source: IETA, 2003)

Appendix III. A simplified CDM project flow.



Source: Aukland L, *et al.* (2001)

Appendix IV. Description of transaction cost components.

Pre-implementation Costs	**Description**
Search costs	Costs incurred by investors and hosts as they seek out partners for mutually advantageous projects.
Project design	Includes those costs incurred in the preparation of the project design document that also documents assignment and scheduling of benefits over the project time period. It also includes public consultation with key stakeholders.
Baseline determination	Development of a baseline (scenario in the absence of the project activities).
Monitoring Plan	Techniques and methods for sampling and measuring carbon pools, identification leakage, socio-economic and environmental impacts, measures to minimize the risk of non-permanence
Approval costs	Costs of authorisation from host country.
Validation costs	Review and revision of project design document by operational entity.
Registration fee	Registration by UNFCCC Executive Board / JI Supervisory Committee.
Share of proceeds	2% of CER generated by the project.
Administration costs	It has to be fixed by UNFCCC.
Implementation Costs	
Monitoring Costs	Costs of collecting data.
Verification Costs	Cost to hire an operational entity and to report to the UNFCCC Executive Board /Supervisory Committee.
Certification Costs	Issuance (emission) of Certified Emission Reductions (CERs for CDM) and Emission Reduction Units (ERUs for JI) by UNFCCC Executive Board /Supervisory Committee.
Enforcement Costs	Includes costs of administrative and legal measures incurred in the event of departure from the agreed transaction.
Risk mitigation	Percentage of CER generated by the project.
Trading	
Transfer Costs	Brokerage costs.
Registration costs	Costs to hold an account in national registry. In Argentina this costs are zero according with Climate Change Office Bs. As.

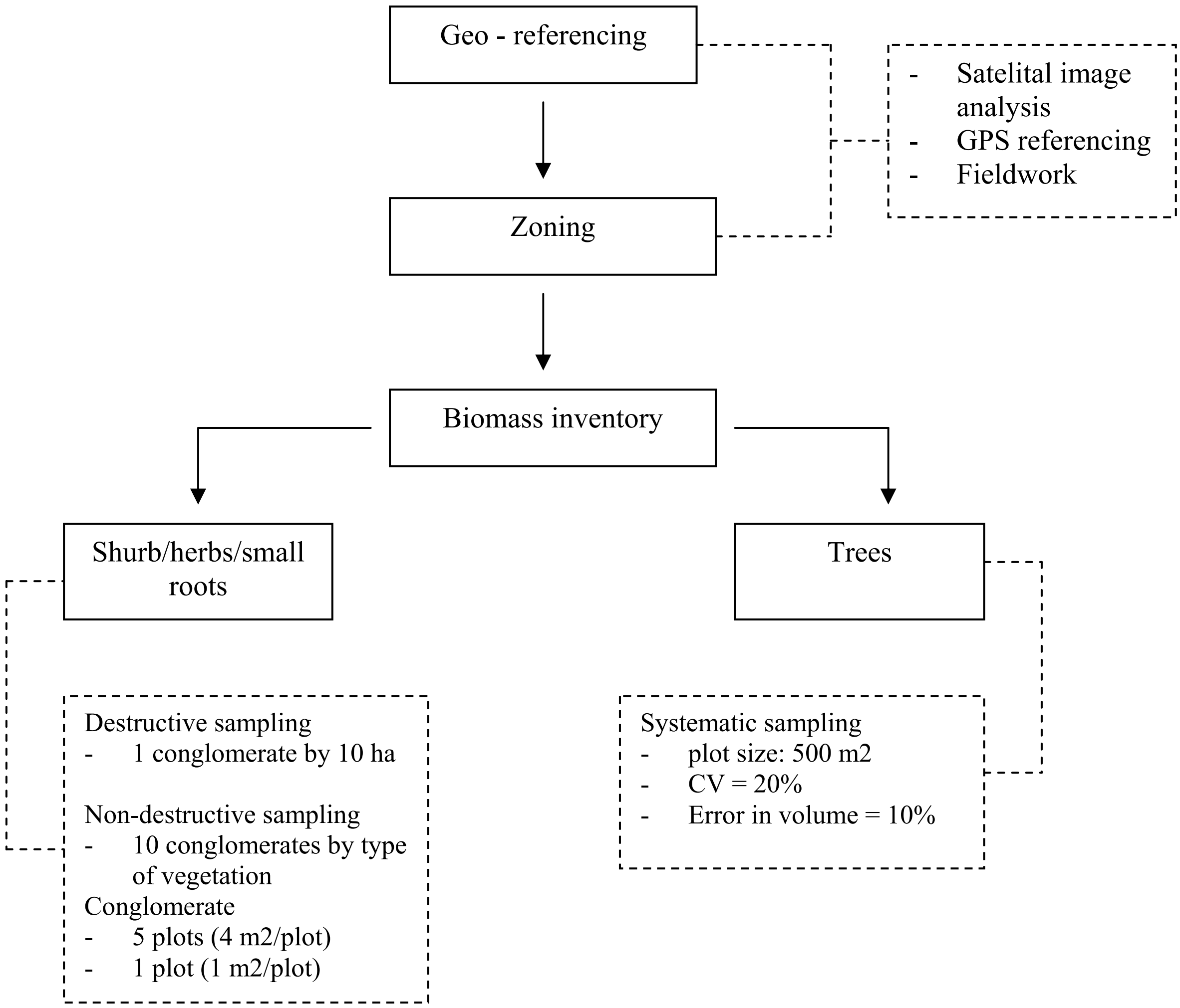
(Source: Michaelowa and Stronzik, 2002)

Appendix V. Comparison of log prices for different forest products.

Forest Products	AMAYADAP	SAGPyA	Sawmill Zona Norte	Sawmill Zona Pto. Esperanza	Average* $/m3
Post (p.f. 8 cm, L. 2,5 m)					2
Roundwood 3rd quality (p.f. 15-25 cm, L 3,60-6,0 m)	37.2	26.6	36	25.5	25.43
Roundwood 2nd quality (p.f. 25-30 cm, L 3,60-6,0 m)	44.6	35.2	45	34	33.80
Roundwood 1st quality (p.f. >30 cm, L 3,60-6,0 m)	52	46.5	56	39	42.48
Pruned wood (p.f. > 45 cm, L 4,0 m)	94	-	-	-	88.10
Pulp (p.f. 5-11cm)	21	-	-	-	15.10

(Source: Price of Pinus elliottii and Pinus taeda in the northeast of Argentina in local currency. * Transport costs excluded. Exchange rate 1US$ = 2,90 $. p.f.= smallest diameter. L= length. AMAYADAP: Asociación de Madereros y Aserraderos de . SAGPyA: Secretaría de Agricultura, Ganadería, Pesca y Alimentación.)

Appendix VI. Scheme of baseline determination and monitoring methodology



Appendix VII. Expenses estimated for a plantation project in Patagonia (600 ha project area; i=8%; 8,2 €/ CER).

Expenses		**$/ha**	**Year**
Forest management costs			
Plantation		352	1
Administ-legal reports		18	1
Maintenance		124	1
		10	1 a 3
		127	2
1rst Pruning and pre-commercial thinning		267	10
Branch porcessing		57	11
2nd pruning		203	12
3rd pruning		395	15
Branch porcessing		37	13 y 16
2nd thinning (pl. Inic.600 ext.270 pl.)		869	21
Residual processing		84	22
3rd thinning (330 pl. Inic. Ext.130 pl.)		671	27
Residual processing		84	28
Removal cut		1840	35
Fire prevention & control		19	1
		40	2 a 35
Technical management		2	1 a 35

		$/ha	**Year**
CER transaction costs	TCER	LCER	
	423	423	3
	99	123	5
	145	210	10
	219	267	15
	414	547	20
	443	134	25
	467	109	30

Administration (% of total cost)	5 %	1 to 35
Unexpected events (% of total costs)	10 %	1 to 35
Opportunity costs	8	1 to 35
Land price	300	0

Appendix VIII. Income estimated for a plantation project in Patagonia (600 ha project area; i=8%; 8,2 €/ CER).

Income	**Unit**	**Tech. Coef.**	**N pl/ha**	**Price $/m3**	**m3/ha**	**Total $/ha**	**Year**
Timber products							
2 nd thinning							
Posts	Unit/pl	1	270	2.0	270.0	540	21
Roundwood 3rd	m3/pl	0.1931	270	25.4	52.1	1325	21
3rd thinning							
Posts	Unit/pl	1	120	2.0	120.0	240	27
Roundwood 3rd	m3/pl	0.2435	120	25.4	29.2	742	27
Roundwood 1rst	m3/pl	0.4950	120	42.5	59.4	2524	27
Final felling							
Roundwood 3rd	m3/pl	0.1293	200	25.4	25.9	657	35
Roundwood 2nd	m3/pl	0.2975	200	33.8	59.5	2011	35
Roundwood 1rst	m3/pl	0.6549	200	42.5	131.0	5567	35
Pruned wood	m3/pl	0.9850	200	88.1	197.0	17355	35
Pulp	m3/pl	0.0166	200	15.1	3.3	50	35
Subsidies							
Plantation	$/ha					500	2
Pruning	$/ha					40	10
Thinning	$/ha					50	10

Long term CERs	L CER/ha	(Euro/CER)	($/ha)	Year
	9.59	7.39	255	5
	32.98	7.00	831	10
	52.41	6.44	1215	15
	137.29	5.62	2775	20
	20.71	4.40	328	25
	16.89	2.62	159	30

Temporary CERs	T CER /ha	(Euro/CER)	($/ha)	Year
	9.59	2.62	90	5
	42.57	2.62	401	10
	94.98	2.62	896	15
	232.27	2.62	2190	20
	252.98	2.62	2385	25
	269.87	2.62	2545	30

STATUTORY DECLARATION

I herewith declare that I composed my thesis submitted independently without having used any other source or means than stated therein.

Date:.....30/04/2004........... Signature:..Gustavo Salvador.........