Scandinavian Forest Economics

No. 42, 2008

Proceedings

of the Biennial Meeting of the

Scandinavian Society of Forest Economics

Lom, Norway, 6th-9th April 2008

Even Bergseng, Grethe Delbeck,

Hans Fredrik Hoen (eds.)

Ås

The social costs of sequestering carbon on private forest lands; the case of the south-western French forest

Dr Guillaume Pajot, The Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen AB15 8QH, Scotland, UK, T +44 1224 498200, g.pajot@macaulay.ac.uk

Abstract :

This paper considers forestry as an approach to climate change mitigation in the forests of southwest of France. In this region, little agricultural area is available to afforest, as forest already covers the major part of the land (more than 50%). However, shifts in forest management, especially longer rotation lengths, can help to enhance carbon uptake. Many studies show that appropriate tax systems implemented on carbon uptakes by trees are an incentive to longer rotation length (see Capparos *et al.*, 2003; Enzinger and Jeffs, 2000; or Hoen and Solberg, 1994), but only a few of them attempt to assess the cost effectiveness of tax systems. The aim of the present study is to provide a measure of the cost effectiveness of a tax system, implemented on forest management in south western French forests.

For a range of carbon prices between 0 and 100 euros/tC, rotations lengths vary between 51 (Faustmann rotation) and 68 years, which increases substantially carbon stocks.

The marginal costs of sequestering one ton of carbon vary between 90 and 140 euros. A sensitivity analysis shows that these costs vary positively with wood prices (higher opportunity costs to extend rotation lengths) and negatively with the discount rate.

Keywords: carbon sequestration, tax system, cost effectiveness, carbon sinks

1- Introduction

Climate change is now recognised as the major environmental threat that human kind will have to face in the next decades. The fourth assessment report published by IPCC (2007) concludes that global warming is now indisputable and that it is likely that it is due to emissions of greenhouse gas (GHG) emissions from human activities. Atmospheric concentrations of GHG are higher than any time over the last 650,000 years.

Fossil fuel use (energy generation, transport, industrial/domestic uses) remains the dominant concern, representing two thirds of global greenhouse gas emissions. Land use, including agriculture and forestry represent 31% of GHG emissions, while removing 16% through sequestration in soils and biomass (IPCC, 2007).

International action has been undertaken, the Earth summit being a starting point in 1992. Then, the Kyoto Protocol has been agreed in 1997 and has come into force since 2005. It obliges participating developed countries to reduce their emissions by 5.2% below 1990 levels, averaged over the period 2008-2012. A cap and trade system has been created. It has to be emphasised that forestry is recognised as a part of the problem and as a part of the solution as the Kyoto Protocol considers both emissions from fossil fuels use and from land use.

Under article 3-3, Annex I countries can claim carbon credits with regards to the afforested areas (induced by human activities, since 1990) (and can be debited for deforestation activities).

Article 3-4 mentions various activities potentially eligible to claim carbon credits. Grazing, pasture and forest management are some of these activities. However, the amount of carbon credits potentially eligible is limited.

But the framework of this paper goes beyond the Kyoto perspective and examines the total potential (not only the eligible potential). It has been shown that in order to stabilise GHG atmospheric concentrations at an acceptable level (which would imply an increase in the global average temperature of 2 Celsius degrees), global emissions should be divided by 2. In this context, France has set a target of reducing by 75% its emissions by 2050 (DGEMP, 2006). In this respect, none strategy must be neglected.

This paper considers forestry as an approach to climate change mitigation in the forests of southwest of France. In this region, little agricultural area is available to afforest, as forest already covers the major part of the land (more than 50% (Teruti, 2003)). However, shifts in forest management, especially longer rotation lengths, can help to enhance carbon uptake. Many studies show that appropriate tax systems implemented on carbon uptakes by trees are an incentive to longer rotation length (see Capparos *et al*., 2003; Enzinger and Jeffs, 2000; or Hoen and Solberg, 1994), but only a few of them attempt to assess the cost effectiveness of tax systems. The aim of the present study is to provide a measure of the cost effectiveness of long rotation lengths in the south west of France.

The paper is organised as follows. The first section deals with the assessment of the tax system, and the methods and data that are needed. Then, a marginal cost curve is provided, as well as a sensitivity analysis. In the third section, the assumptions made and the policy issues are discussed.

2- Assessing the tax system

The methodology used in this paper has been used by Sohngen and Brown (2006), then by Im *et al.* (2007). The purpose of the methodology is to measure the cost effectiveness of a tax system, based on carbon fluxes. For this purpose, we need to compare both costs and benefits of the tax system. These steps are summarised in the following paragraphs.

2-1: Theoretical model

Let us assume a forest owner whose objective consists in maximising the net present value of his income. His temporal horizon is infinite, as it allows to take into account the opportunity cost of land. To maximise his income, he has to choose the optimum rotation length. This model is just an adaptation of Hartmann model (1976), who considers a double forestry output; wood and environmental benefits. He shows that a forest owner paid for environmental services would extend the rotation length, beyond the economic optimum rotation length (Faustmann criteria). Many studies show that a tax system based on carbon fluxes is a factor leading forest owners to extend postpone clear-cutting (Capparos *et al.*, 2003; Enzinger and Jeffs, 2000; or Hoen and Solberg, 1994). The carbon price is assumed to be constant. Associated with discounting, this assumption has an important impact on the following results. This will be discussed further.

The maximisation problem can be written as follows

$$f(T) = \frac{-c + pv(T)e^{-rT} + \int_0^T p_c s'(t)e^{-rt}dt - p_c S(t)e^{-rT}}{1 - e^{-rT}}$$

Where

c is the plantation cost; , p is the timber price, T is the clear-cutting age, r is the discount rate, s' is the marginal carbon stock change, p_c is the carbon price; $S(T)$ is the total carbon stock, $f(T)$ is the function that the forest owner seeks to maximise

The first order condition states, from an economic point of view, that the rotation length is optimal when the marginal cost of waiting an additional period equals the marginal benefit of waiting an additional period. It can be written as

$$pv'(T^*) + rp_c S(T^*) = rpv(T^*) + rf(T)$$

The rotation length is longer than the optimal economic one because the marginal benefit of waiting includes a delay in the tax payment. (Capparos *et al.*, 2003; Enzinger and Jeffs, 2000; or Hoen and Solberg, 1994)

2-2: Data

The empirical study focuses on the mono specific maritime pine forest, which represents the major part of the total forest area. For the purpose of previous studies relative to optimise forest management in south-western French forest, the software Optimfor using dynamic programming has been elaborated[31]. The economic parameters have been provided by CRPF (CRPF, personal communication). Parameters are summarised in the following table.

Table 1: Economic parameters (CRPF, 2006)

Plantation costs (€/ha)	1200
Clear cut cost (€/ha)	90
Thinnings costs (€/ha)	60
Annual management costs (€/ha)	50
Discount rate	3%

Wood prices are an asymptotic function of unit volumes. The basic data has been provided by CRPF (regional timber standing sales, 2005, see http://www.crpfaquitaine.fr/). The equation describing the relation between timber prices and wood volumes per unit is

$$p(v) = -9.17774v^2 + 34.6889v + 3.395182$$

where p are timber prices and v timber volumes per tree.

2-3: Results:

2-3-1: The reference situation:

To estimate the costs and the benefits of the tax system, it is necessary to define a reference situation. This reference situation corresponds to forest management without consideration for carbon sequestration. The focus of the forest owner is to get some incomes from wood production. This reference management is defined by the Faustmann criteria

[31] The software has been developed by C.Belle and Lysianne Guenneguez (IAE, Bordeaux). I thank them for giving me the permission to use the software.

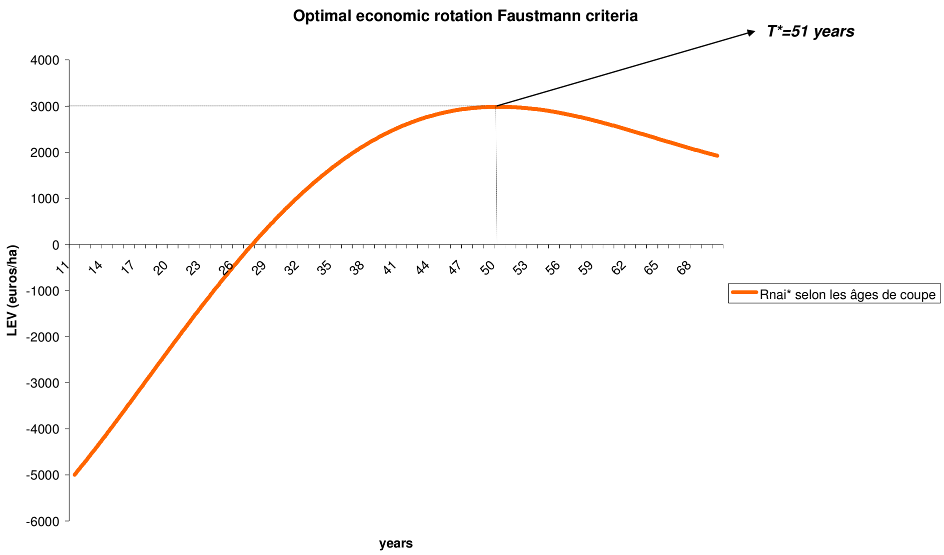

Figure 1: The rotation length determines the net present value of an infinite series of identical rotations. The optimal rotation length is the one that maximises the net present value of an infinite series of rotations.

The optimal cutting age is 51 years for a maritime pine stand. The land expected value is 2,957 euros per hectare. The carbon stocks are at a level of 171 tons per hectare.

Let us now consider the impacts of a tax system on rotation lengths and carbon stocks, for various carbon prices assumptions.

2-3-2: Estimating the benefits of the tax system

Several approaches have been suggested in the literature (see Richards and Stokes (2004) for a detailed review).

Flow summation involves summing annual carbon flows over a given number of years, but the choice of ending dates can be quite arbitrary and has a substantial impact on the results.

The average storage approach involves averaging carbon stocks over a given number of years.

The problem with the average storage approach is that it does not consider intertemporal issues associated with carbon sequestration and forestry. We can consider for instance that early sequestration has a greater value than late sequestration; this could be related to the idea of biological sequestration as a mean to buy time, while waiting for new technologies, "climate friendly". To take it into account, some have used discounting techniques to estimate the carbon benefits of forestry. The main advantage of this methodology lies in the possibility to compare "fairly" mitigation projects through forestry and other mitigation projects, within the energy or industrial sectors. Another interest is that benefits (for the forest owner) of getting new sources of income are compared to the benefits (in terms of carbon storage) on an identical basis (Sonhgen and Brown, 2006).

The framework of this study is the one of an existing forest. For this reason, quantities sequestered under the assumption of a traditional rotation (until the forest stand reaches 51 years) should not be considered as a benefit of the tax system. Those quantities would have been sequestered without the tax system for the purposes of wood production. These quantities are not taken into account in this study.

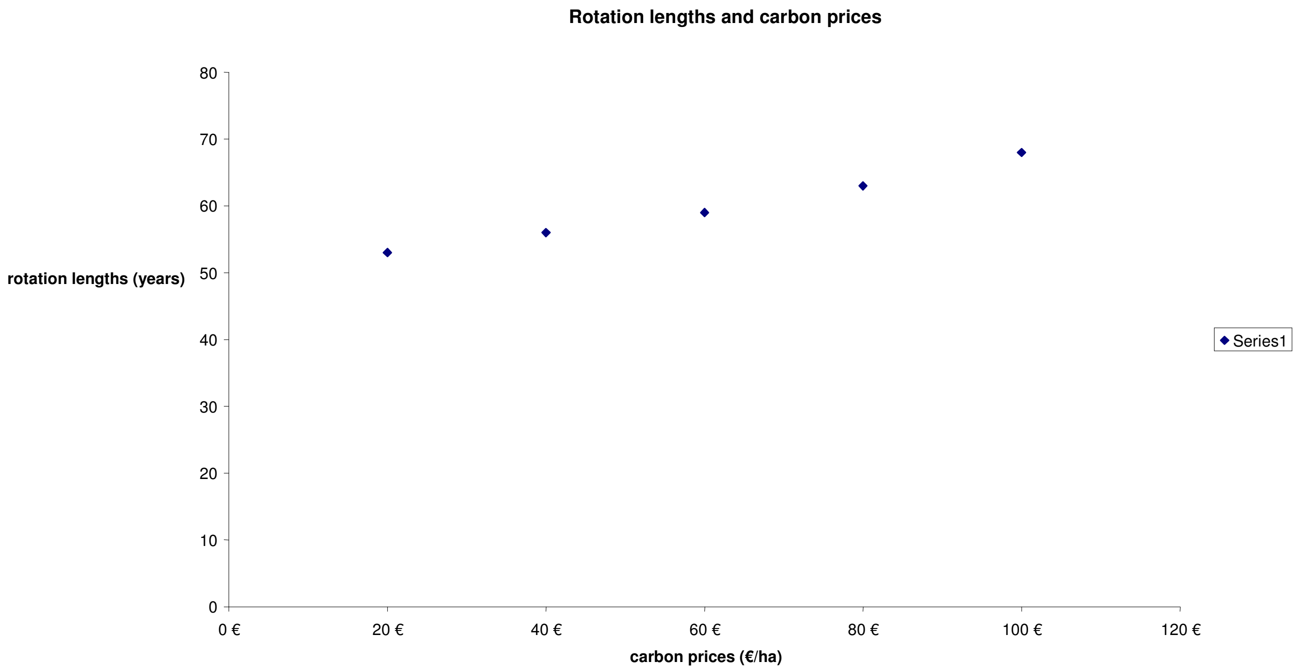

Figure 2: Carbon prices and the impact of a tax system:

2-3-3: Estimating the costs

Tax system costs are simply constituted by the present value of the amount of money provided by the society to the forest owner.

Table 2: Carbon prices, rotation lengths and tax system costs:

Carbon price (€/Ton)	Rotation length (years)	Cost (present value/ha)
20 €	53	981 €
40 €	56	2,079 €
60 €	59	3,343 €
80 €	63	4,868 €
100 €	68	6,443 €

3- The marginal costs estimates:

3-1: The marginal cost curve

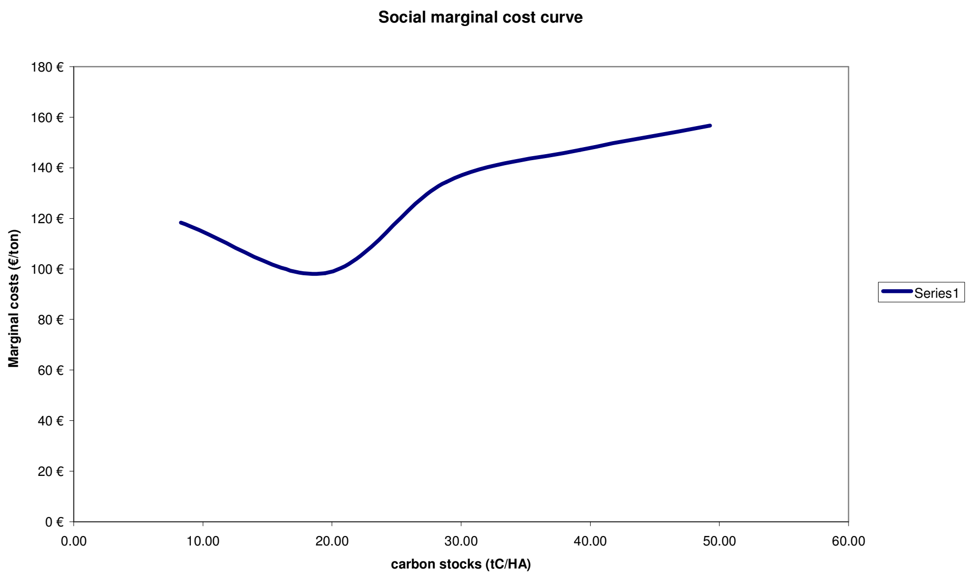

Figure 3: The marginal cost curve is relatively flat. The decreasing shape of the curve could be explained as follows. Intuitively, we would expect a rising cost. As long as the trees get older, less and less quantities are sequestered (due to a slower growth, and the impact of discounting), diminishing by the way, the benefits of the tax system.

However, we assume that wood prices increase as a function of trees volumes. As a consequence, for a carbon price of 30 euros/ton (additional carbon stocks = 20 tons), another effect, under the form of an increase in timber prices, provides an incentive to the forest owner to extend the rotation length.

Then as timber prices are an asymptotic function of wood volumes, that trees growth slows, the benefits of the project tend to increase at a lower rate than the costs, which explains the increasing shape of the curve.

The marginal costs of sequestering one ton of carbon vary between 90 and 140 euros. The costs seem relatively high (between 24.5€ and 38€ per ton of Co2), compared to the general assertion considering forestry as a least cost mitigation option. It is due to the fact that the benefits of the system, in terms of carbon storage, exclude the quantities sequestered until the stand reaches its optimal age according to Faustmann criteria. These quantities are not considered as additional. However, the values are comparable to values for other regions of the world, Oregon, California, see Sohngen and Brown, 2006).

3-2: Sensitivity to timber prices.

When the forest owner tries to maximise his income with regard to the value of wood production, an increase in wood prices conducts him to decrease rotation length (he can get the same income on a shorter time scale). Payments for carbon sequestration provide him an incentive to postpone clear-cutting. As a consequence, as timber prices increase, the competition between wood production and carbon sequestration becomes more important and the opportunity cost of sequestration increases. Low value forest areas (public forests managed for other purposes, as coastal protection) could be used, instead of private forests, for the purposes of carbon sequestration.

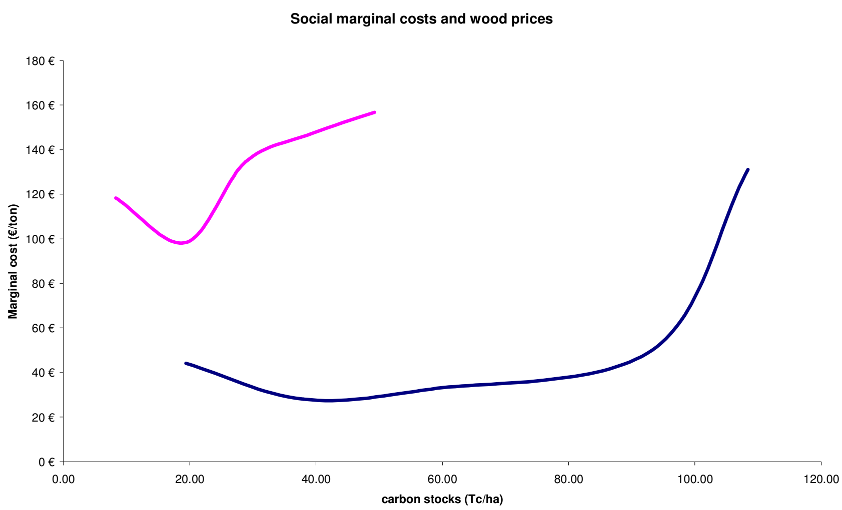

Figure 3: The social costs of carbon sequestration and timber prices

3-3: Sensitivity to the discount rate:

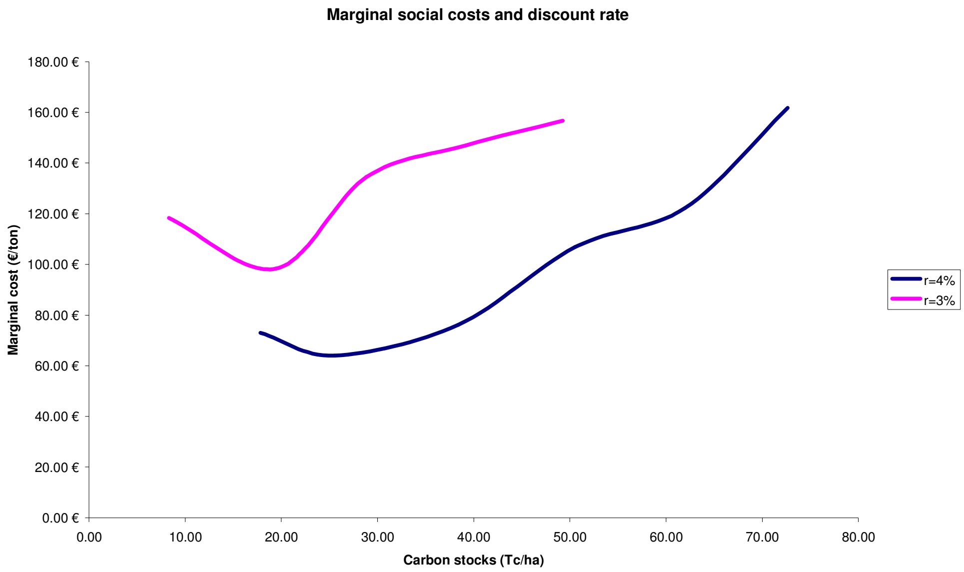

Figure 4: Social costs of carbon sequestration and discount rate. As the discount rate increase, the share of carbon sequestration incomes in the total income of the forest owner and this one seems to be more reactive to the implementation of the tax system. Therefore, sequestering carbon by extending rotation lengths seems to be less costly as the discount rate increase.

3-4: A comparison between the private opportunity cost and the social opportunity cost:

An interesting measurement of the cost effectiveness of the tax system is to compare the social opportunity cost to the private opportunity cost that would face the forest owner.

The costs have been estimated according to a comparison between the land expected value when the rotation length is optimal and the land expected value when the rotation length is longer. Benefits are estimated by the same methodology as described in section 1.

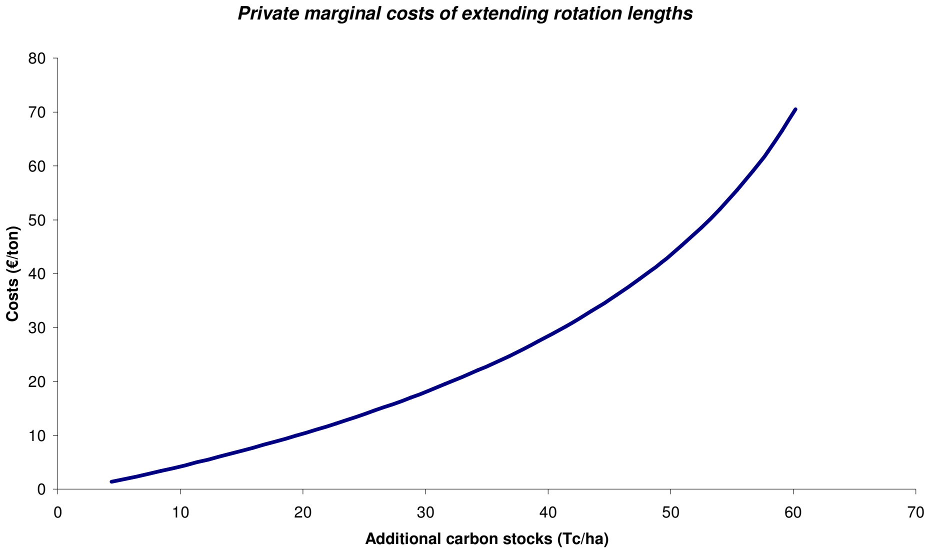

Figure 5: The private marginal costs of carbon sequestration by extending rotation lengths. We can see there is an important difference between the private and social marginal costs, as the private costs range from 2 to 70 euros per ton of carbon.

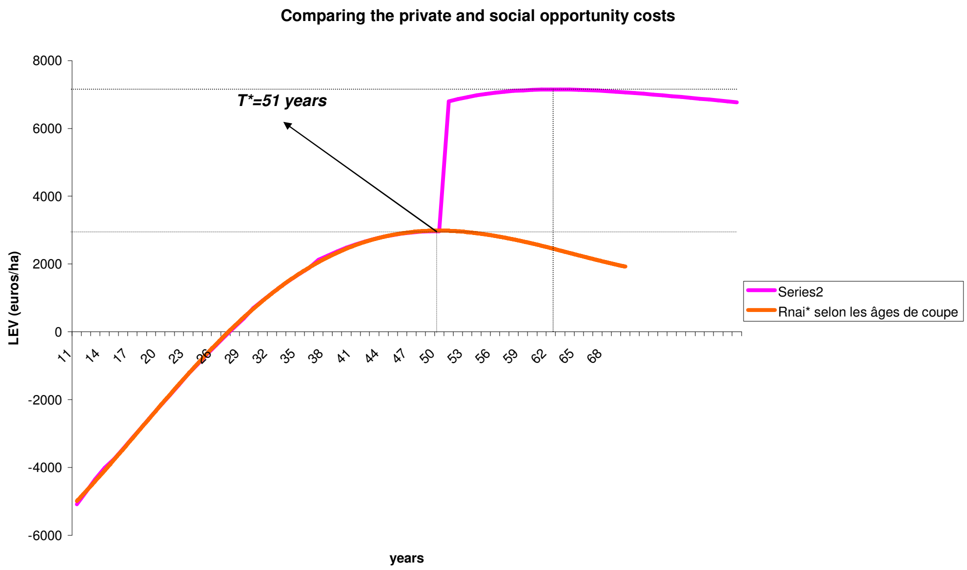

Figure 6: A comparison between the incomes (related to rotation lengths) received by the forest owner in the two situations. The red curve is the NPV of wood production over an infinite series of rotation. The pink curve is the additional income received for carbon sequestration. The area between the two curves is the social cost.

4- Discussion

The study provides some estimates of the costs of sequestering additional carbon in existing and actively managed forests (during the period 1988-1998, 94% of the annual increment has been harvested).

The cost effectiveness of a tax system has been assessed by a comparison between its social costs and its social benefits. The results show that sequestering carbon in these forests is relatively costly, while comparable to the costs in other parts of the world.

Timber prices increases have an impact on carbon sequestration costs through the opportunity costs of extending the rotation beyond the optimal economic one. An increase in timber prices means an increase in the opportunity costs of carbon sequestration.

An increasing discount rate reduces the land expected value; and its opportunity cost. By the way, the social costs of carbon sequestration are lower than with a low discount rate.

A comparison between the social and the private marginal cost of extending rotation length has been done. It shows that the cost of the tax system is far beyond the private opportunity costs faced by the forest owner. It means that with regard to the costs involved, the benefits do not appear so important.

Several limitations can be mentioned:

- The first is relative to the carbon price, which has been assumed constant. Assuming a falling carbon price is the same as assuming that in the next decades, climate change problem will be solved. However, many factors can affect carbon prices. Conjectural factors (energy demand linked to weather conditions for instance) explain monthly or seasonal variations. A structural factor is technology (geological sequestration, hydrogen, hybrid vehicles). The other main factor is the political will to tackle climate change; which should be expressed as a restricting limit on Co2 emissions. If technology is not improving enough in the next decades and/or the constraint on Co2 emissions is at a high level, demand for carbon credits will be at a high level and the carbon price will rise. In the case of a rising carbon price, the social costs of carbon sequestration would be higher, as well as the private costs. We can show that a rising carbon price generates negative incomes for the forest owner. Therefore, rotations lengths are reduced, by the way, creating a counter productive tax system (as in this case, it could be anticipated that less areas should be forested).
- The second is based on the underlying assumption regarding the discount rate. A constant discount rate implies the early benefits to be worth more than the late benefits (and the late costs). However, the physical cost of a ton of Co2 emitted now or in a few years will remain the same. Actually, it could even be worse, as it is expected there are, with the increase in Co2

atmospheric concentration, some cumulative and irreversible effects. Therefore, the assumption of a constant discount rate is equivalent to the one of a decreasing carbon price. It assumes that the climate change problem will be solved (at the scale of a rotation, i.e. 50/60 years) and that early sequestration is definitely better than late releases. But it could be the case that late releases could also be costly, and it is not reflected by the use of a discount rate.

- Third, the tax system would presumably generate high transaction and monitoring costs. For simplification purposes, these costs have been excluded.
- The 1999 storm damaged in the south west of France more than hectares, in variable proportions, felling down around 16% of wood volumes and carbon stocks. In a broader sense, the storm raised the issues of risk and vulnerable stands (to diseases, storms or fires) because longer rotation lengths are potentially a more risky situation. This should be considered as a factor increasing the costs of carbon sequestration.
- Finally, relatively to wood products, two issues affect the robustness of the model. between 1988 and 1998, 94% of the mean annual increment of the maritime pine forest has been harvested. This has allowed the storage of significant quantities of carbon in wood products (3% of the biomass carbon stocks, according to Malfait *et al.*, 2003). Longer rotations lengths should reduce the harvesting rate and the carbon stocks in wood products. The second issue (that could help solving the first) about wood products is that, in this study, they are not considered as a benefit of the tax system. However, there are two ways to think about the benefits of the wood products. First, it is an additional storage capacity (compared to storage in trees). Then, wood products substitute to CO_2 intensive materials (as concrete or steel in the building sector), and this represents a benefit to the society.

References:

CAPAROS A., CAMPOS P., MARTIN D. (2003), *Influence of carbon dioxyde abatement and recreational services on optimal forest rotations,* International Journal of Sustainable Development, Volume 6, No3, pp 345-359.

CREEDY J., WURZBACHER A.D. (2001), *The economic value of a forested catchment with timber, water and carbon sequestration benefits,* Ecological Economics, Volume 38, No1 pp 71-83.

DGEMP (2006), *Groupe Facteur 4*, Plan, Ministère de l'Ecologie et du Développement Durable, Ministère délégué à l'industrie.

DIAZ-BALTEIRO Luis, ROMERO Carlos (2003), *Carbon captured as a new instrument in forest management: some implications,* Scientia Forestalis No 63, pp 103-114

ENZINGER Sharn, JEFFS Carol (2000), *Economics of forests as carbon sinks: an Australian Perspective,* Journal of Forest Economics, Volume 6, Issue 3 pp 227-249.

FAUSTMANN Martin (1995), *Calculation of the value which forest land and immature stands possess for forestry,* new edition (original paper, 1849), Journal of Forest Economics, Volume 1, Issue 1 pp 7-44.

HIM Ho Eun, ADAMS Darius M, LATTA Gregory S. (2006), *Potential impacts of carbon taxes on carbon flux in western Oregon private forests*, Forest Policy and Economics 9 pp 1006-1017.

HOEN Hans Fredrik, SOLBERG Birger (1997), *Co^2 taxing, timber rotations and market implications*, Critical Reviews in Environmental Science and Technology 27 pp 151-162 'Economics of Carbon Sequestration in Forestry'.

IPCC, 2007: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IntergovernmentalPanel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA., XXX pp.

MALFAIT Jean-Jacques, PAJOT Guillaume, POINT Patrick (2003), *Le puits de carbone Landais*, Actes du VII Colloque Arbora, Pessac, décembre 2003.

SONGHEN Brent, BROWN Sandra (2006), *The cost and the quantity of carbon sequestration by extending the forest rotation age*

RICHARDS Kenneth, STOKES Carrie (2004), *A review of forest carbon sequestration cost studies: a dozen years of research,* Climatic Change, 63 pp 1-48.