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ECOLOGICAL GOODS AND SERVICES AND AGROFORESTRY: THE BENEFITS FOR FARMERS AND THE INTERESTS FOR SOCIETY

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Abstract: The main objective of this project is to estimate the social value of environmental goods and services (EG&S) generated by agroforestry practices and to evaluate the profitability of these practices for agricultural producers and for society. Two agroforestry practices are considered: riparian buffer zones and windbreaks. Moreover, the situations in two representative agricultural watersheds serve our analysis (Chateauguay and Fouquette watersheds). Among the numerous EG&S that are provided through agroforestry practices, nine have been chosen for this study: agriculture-related odors, aestheticism of the landscape, terrestrial biodiversity, surface water quality, carbon sequestration, road accidents, clearing snow from roads, treatment of drinking water and wild pollinating insects. Several economic valuation methods have been used, such as hedonic pricing value, benefit transfer, productivity method or experimental economics.

Key Words: benefit-cost analysis, extrapolation, windbreaks, riparian buffers, watershed, hedonic prices, benefit transfer, experimental economics, productivity method, Quebec.

INTRODUCTION

Québec's agricultural sector is facing diverse environmental problems: water quality degradation, appearance of blue algae, soil erosion from wind and water, and the presence of odors associated with certain types of animal manure management. The voluntary and deliberated introduction of trees and bushes in the agricultural environment, of agroforestry techniques such as windbreaks and of agroforestry riparian systems can contribute to mitigating these problems.

In fact, agroforestry generates a number of ecological goods and services (EG&S) of value to society, such as the protection of watercourses, biological diversity, embellishment of the landscape and carbon sequestration. The generation of EG&S by farmers is likely to ease their relations with other residents of rural areas and to improve their image vis-à-vis society. However, it remains highly questionable that the benefits of the agroforestry systems that produce EG&S outweigh the costs for the farmers.

METHODOLOGY

As we could not measure the costs and benefits of all agroforestry practices implemented throughout the entire province of Québec, we selected the two practices most likely to be implemented in the province: windbreaks[1] and riparian agroforestry systems[2] (De Baets et al. 2007). Our research approach also concentrated on the ecological goods and services that seemed most important. In order to estimate the private costs and public benefits of these EG&Ss, we chose two watersheds that represent two different realities - one in the proximity of urban agglomerations (Châteauguay watershed) and the second one in a remote area (Fouquette watershed). The ensuing results were then extrapolated unto the total area of Québec.
For the two watersheds studied, we conceived and developed three scenarios of agroforestry installations: a regulatory-level scenario that reflects Québec regulations on riparian buffers[3]; a priority-level scenario developed with members of watershed committees who, as a matter of priority, seek to implement installations to protect watercourses and problematic road segments, and to reduce odors from livestock barns[4]; and lastly, a high-level scenario[5], which seeks to generate a maximum of EG&S. The selection and arrangement of plant species in the riparian agroforestry systems and in the windbreaks were made in function of protection objectives, climate zones and watershed soils (for more details see De Baets and Vézina 2008).

ECONOMIC RESULTS

The economic analysis began with a study of the private costs and benefits of agroforestry implementations (see Simard et al. 2009). The net costs for famers were then compared with the social benefits evaluated for the EG&S. We carried out a cost-benefit analysis according to factor costs (thereby excluding government transfers) on a 40-year planning horizon with a real discount rate of 6%.

Private cost-benefit analysis

Comparison of agroforestry systems

The following table presents the economic results of the high-level implementation scenario for the two watersheds studied and allows us to compare to what extent the different agroforestry systems are of interest to farmers.

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[1] In Québec, we distinguish between two principal types of windbreaks: windbreak structures that protect crops and soils and windbreak structures around agricultural infrastructure (buildings, roads, farms, manure pits, etc).

[2] De Baets et al. (2007) propose applying the term "riparian agroforestry system" to riparian buffers that were intentionally created by planting arborescented or shrubby ligneous species

[3] The regulatory scenario in the two watersheds encompassed trees and shrubs every 3 meters with a width of 3 meters on all banks qualified as "weak", "very weak" and "average".

[4] The priority scenario in the Fouquette river watershed encompassed trees and shrubs along 10 meters in width on very weak banks and along both banks of the fish spawning area. The priority scenario of the Esturgeon river watershed encompassed trees and shrubs along 10 meters in width on very weak banks of the Esturgeon and Noire rivers and on the main Saint-Rémi watercourse (Cinq branch).

[5] The high-level scenario in the two watersheds encompassed riparian installations of 25 meters in width for all riparian zones in agricultural environments qualified as "very weak", "weak" and "average".

Table 1: Economic results from the high-level scenario in the two watersheds (in thousands of dollars)

	RB		WBb		WBc		WBr	
	Fouquette	**Esturgeon**	**Fouquette**	**Esturgeon**	**Fouquette**	**Esturgeon**	**Fouquette**	**Esturgeon**
Length (km)	134	296	9.43	24.81	140	219	8.15	48.48
Total costs (C)	3,293	8,007	83.12	239.72	663.92	1,093	24.92	158.86
Total benefits (B)	754.92	1,664	387.25	1,074	412.27	1,210	2.69	16.01
B-C	**-2,538**	**-6,343**	**304.13**	**834.81**	**-251.65**	**117**	**-22.22**	**-142.85**
Ratio (B/C)	**0.23**	**0.21**	**4,66**	**4.48**	**0.62**	**1.11**	**0.11**	**0.10**

Source: CEPAF Calculator (www.wbvecan.ca)

Legend: RB = Riparian buffers
WBb = Windbreaks adjacent to buildings
WBc = Windbreaks protecting crops
WBr = Windbreaks adjacent to roads
m: meter
B: benefits; C: costs
B/C: benefits/costs ratio

A comparison of the agroforestry systems in the two studied watersheds demonstrates that windbreaks along roads are less interesting for farmers because their benefit-cost ratio is below 0.12. Next come riparian buffers with a ratio of 0.2. Windbreaks that protect crops, which increase crop output, have a ratio approaching 1 while the ratio of windbreaks next to buildings is above 4. Windbreaks installed along livestock barns are therefore highly profitable and offer important benefits (avoided snow clearing and heating costs).

If installed riparian buffers also have a windbreak function that protects crops or livestock barns, one would have to calculate the additional benefits and the findings would improve. According to our hypothesis, a riparian buffer is likely to only become profitable if it also offers wind protection for buildings and roads closed to farms.

Comparison of three scenarios on two watersheds

Of the regulatory, priority and high-level scenarios in the two watersheds studied, no implementation scenario is economically profitable for farmers. In fact, all benefit-cost ratios are below 1. The following table outlines the economic results of the three implementation scenarios studied for the two watersheds that were analyzed.

TABLE 2: PRIVATE OVERVIEW OF THE THREE SCENARIOS IN THE TWO WATERSHEDS (IN THOUSANDS OF DOLLARS)

	Regulatory-level		Priority-level		High-level	
	Fouquette	**Esturgeon**	**Fouquette**	**Esturgeon**	**Fouquette**	**Esturgeon**
Total costs (C)	554.18	1,401	1,627	1,039	4,065	9,499
Total benefits (B)	79.40	199.07	346.10	175.86	1,557	3,965
B-C	**-474.77**	**-1,202**	**-1,281**	**-863.59**	**-2,508**	**-5,534**
Ratio (B/C)	**0.14**	**0.14**	**0.21**	**0.17**	**0.38**	**0.42**

Source: CEPAF Calculator (www.wbvecan.ca)
It is important to note that, in the Esturgeon river watershed, the length of installations in the priority-level scenario (79 km) is smaller than in the regulatory-level scenario (296 km).

The high-level scenario is most in deficit (-$2.5 million margin for the Fouqette river watershed and -$5.5 million for that of the Esturgeon river).

The benefit-cost (B/C) ratios of the scenarios go from 0.14 for the regulatory-level scenario of the two watersheds to 0.42 (high-level, Esturgeon river). Even though the high-level scenarios are more in deficit in absolute terms than the others, they demonstrate a more favorable B/C ratio (however, the costs remain more than two times higher than the benefits). This is due to the composition of the other two scenarios (regulatory and priority-level), which include less beneficial agroforestry systems made up of riparian buffers (for the regulatory-level scenario) and windbreaks adjacent to roads (for the priority-level scenario). For these two scenarios, the total costs are four to seven times higher than the total benefits.

Farmers' lack of enthusiasm for agroforestry practices can be explained in part by the fact that discounted private benefits rarely outweigh the costs farmers incur. Except for windbreaks that protect livestock barns and windbreaks that protect crops, the aggregate private costs of the studied agroforestry systems are 4 to 20 times higher than the private benefits they generate. On average, for all the simulations carried out in the framework of this stage, the costs are three times higher than the benefits. This conclusion holds even truer for farmers if we include the support of *Assurance stabilisation des revenus agricoles* (ASRA), which increases costs related to the loss of farmland. What remains to be determined is whether the ecological goods and services that agroforestry practices provide to society, justify a State intervention.

Social benefits

To estimate the value of the EG&S generated by the implementation of agroforestry practices in the two watersheds, four economic evaluation methods were used (see Olar et al. 2009a). The hedonic method helped to evaluate the reductions in agriculture-related odors and the aestheticism of the landscape. Experimental economics were used in the evaluation of the enrichment in terrestrial and aquatic biodiversity, as well as in the aestheticism of the landscape. The benefit transfer method was used for the monetary evaluation of the improvement of water quality, carbon sequestration and enrichment in terrestrial and aquatic biodiversity. The

productivity method was used to calculate reductions in costs for clearing snow from roads and treating potable water, and to estimate the economic value of an increase in the number of wild pollinating insects.

The results relating to the monetary value of EG&S, evaluated over a 40-year period and discounted accordingly, are presented in the following table. The EG&S are organized according to monetary order of importance.

TABLE 3: CLASSIFICATION OF EG&S AND CURRENT MONETARY VALUE (IN MILLION $)

Order	EG&S	Scenario	Monetary value	
			Fouquette	Châteauguay
1	Carbon sequestration	Regulatory-level	0.224	7.317
		Priority-level	0.689	4.080
		High-level	2.057	56.081
2	Terrestrial biodiversity	Regulatory-level	0.540	2.422
		Priority-level	0.358	1.830
		High-level	1.351	50.308
3	Reduction in costs for clearing snow from roads	Regulatory-level	Not applicable in the case of RB	
		Priority-level	0.088	4.229
		High-level	0.142	12.147
4	Improvement in the quality of surface water	Regulatory-level	0.068	3.618
		Priority-level	0.068	2.763
		High-level	0.070	3.618
5	Improvement of the landscape	Regulatory-level	0	1.770
		Priority-level		1.145
		High-level		3.437
6	Increase in the number of wild pollinating insects	Regulatory-level	0.0001	0.533
		Priority-level	0.0005	0.590
		High-level	0.002	3.442
7	Decrease in treatment costs of potable water	Regulatory-level	Not applicable: subterranean source of potable water in this watershed	0.393
		Priority-level		0.085
		High-level		0.393
8	Reduction in agriculture-related odors	Regulatory-level	Not applicable because there are no WBb in these scenarios	
		Priority-level		
		High-level	0	0
Total		Regulatory-level	**0.347**	**16.056**
		Priority-level	**1.205**	**14.725**
		High-level	**3.623**	**129.430**

Legend: RB = Riparian buffers, WBb = Windbreaks adjacent to buildings

It is highly interesting and surprising to note that carbon sequestration is the EG&S that falls into first place in the two watersheds. That value represents between 27% and 64% of the total benefits according to the implementation scenario. As a result, carbon sequestration provides a considerable benefit. The absolute value is even more important in the Châteauguay river watershed because of the implementation surface. As this watershed is less wooded than that of the Fouquette river, more agroforestry installations are possible and, as a result, there are more possibilities to sequester carbon.

Biodiversity was attributed a high value but it remains comparable to those found in other literature reviews. We note that the aggregate value is higher in the Châteauguay river watershed than in that of the Fouquette river. This is due to the fact that the implementation surface in the Châteauguay river watershed is larger than that of its counterpart. We also note that the priority-level scenario offers fewer benefits than the two other scenarios in the case of the Châteauguay river. This is due to the decreased surface of agroforestry installations implemented in this scenario.

The impact on the reduction of snow clearing costs for public roads is significant in both watersheds in the priority and high-level scenarios. According to the results of the measurement protocol that was used, the presence of hedges along roads diminishes the number of snow clearing rounds by 29%, which affects the absolute value of avoided costs.

The most surprising result was that improvements in the quality of surface water came in fourth in terms of the value of benefits provided by agroforestry implementations. It is important to underline that the estimated value of the improvement of water quality is a low estimation as the impact of agroforestry installations on phosphorous were not measured and the impact on the established parameters (turbidity and fecal coliform bacteria) were estimated at the river mouth. This in part explains the low result. On the other hand, we note that the value is much higher in the Châteauguay river watershed than in that of the Fouquette river, primarily due to the larger number of households found there.

As for the value of landscapes, our results indicate that the implementation of agroforestry systems has no impact on the improvement of the landscape in the Fouquette river watershed, which has large forest coverage, contrary to that of the Châteauguay river. These results are interesting because they support the idea that adding trees to places where many exist already, adds no value, whereas adding them to places where there are not many trees, adds value to the landscape.

The priority-level scenario in the Châteauguay river watershed offers the least benefits because the number of properties to have improved landscapes depends directly on the length of agroforestry installations, which are the shortest in the priority-level scenario.

However, it is important to mention that the value of the landscape is only captured in part because the methodology used only targets the residents of the two watersheds. Non-residents' appreciation of the landscape is ignored by this methodology.

An increase in the number of wild pollinating insects comes in sixth position on the basis of their monetary value for both watersheds. The difference in value between the two watersheds is essentially due to the larger crop variety found in the Châteauguay river watershed as well as its larger surface area. The most important value is traced back to the high-level scenario, followed by the priority-level scenario and the regulatory-level scenario, both for the Châteauguay and Fouquette river watersheds. This classification is due to the fact that the high-level scenario encompasses the most expansive area of agroforestry implementations and that wild pollinators increase with the habitat areas available to them.

The impact of agroforestry implementation on the reduction of treatment costs of potable water is fairly weak because the latter only takes water turbidity into consideration. Savings on the annual treatment costs of potable water in the watershed can be considered negligible.

It also seems that the implementation of agroforestry systems has no impact on the reduction of agriculture-related odors in either of the watersheds. There are few pig farms in the area of the watersheds studied, which is probably why the value of a reduction in odors is not significant. However, all the values found are comparable to those in other literature reviews.

For the Châteauguay river watershed, the value of all EG&S is in the same ballpark for the regulatory and priority-level scenarios ($16 and $14.7 million, respectively). This is essentially due to the fact that the agroforestry implementation area, in the case of the Châteauguay river watershed, is higher in the regulatory scenario that in the priority-level scenario. The social benefits in the regulatory-level scenario are therefore higher in absolute value, and even more so as the value of carbon sequestration is significant. For the Fouquette river watershed, the value of all EG&S is, in contrast, three times higher in the priority-level scenario than in the regulatory-level scenario.

For the high-level scenario, which encompasses agroforestry implementation seeking a maximization of EG&S, the social value of EG&S is $129.43 million for the Châteauguay river watershed and $3.6 million for the Fouquette river watershed. This difference in scale between both watersheds for the same scenario can be explained by the larger surface area of the Châteauguay river watershed. The fact that average revenues are higher there also increases the value. In addition, the improvement of the landscape and reduction in the treatment costs of potable water were, respectively, zero and unquantifiable in the Fouquette river watershed.

The scenario that received the highest value is by far the high-level scenario, characterized by the most expansive area of agroforestry implementations. The regulatory-level scenario comes in last in the case of the Fouquette river watershed and second in the case of the Châteauguay river watershed. It is important to note that the value of the priority-level scenario, characterized by the placing of installations in the most critical locations, is probably underestimated due to the evaluation methods used. These did not allow us to capture the value-added of resolving the worst environmental problems.

Global analysis at the watershed level

The total social benefits and private net costs for both watersheds were compared in order to confirm or disprove the starting hypothesis that an intervention by the government favoring the establishment of agroforestry practices would be justified (see Olar et al. 2009b for further details).

The two following tables show the net present values (NPV) and benefit-cost ratios at the private level (table 4) as well as the benefit-cost ratios at the level of society (table 5) in the Fouquette and Châteauguay river watersheds.

TABLE 4: PRIVATE NET COSTS AND PUBLIC BENEFITS FOR THE TWO WATERSHEDS

		Private net costs		Public benefits	
Scenario		**Fouquette**	**Châteauguay**	**Fouquette**	**Châteauguay**
Regulatory-level	NPV (M$)	-0.474	-15.658	0.347	16.056
	B/C	0.14	0.14	*N/A*	*N/A*
Priority-level	NPV (M$)	-1.293	-1.441	1.205	14.725
	B/C	0.21	0.17	*N/A*	*N/A*
High-level	NPV (M$)	-2.508	-73.310	3.623	129.430
	B/C	0.38	0.42	*N/A*	*N/A*

Source: CEPAF and ÉcoRessources Consultants
Legend: NPV = Net Present Value, B/C: Benefit/Cost Ratio, N/A: Not Applicable

TABLE 5: OVERVIEW OF THE COST-BENEFIT ANALYSIS FOR THE TWO WATERSHEDS

		Public benefits – Private net costs		Ratio of public benefits / private net costs	
Scenario		**Fouquette**	**Châteauguay**	**Fouquette**	**Châteauguay**
Regulatory-level	NPV (M$)	-0.1	0.4	*N/A*	*N/A*
	B/C	*N/A*	*N/A*	0.73	1.03
Priority-level	NPV (M$)	-0.09	3	*N/A*	*N/A*
	B/C	*N/A*	*N/A*	0.93	1.29
High-level	NPV (M$)	1.1	56	*N/A*	*N/A*
	B/C	*N/A*	*N/A*	1.44	1.77

Legend: NPV = Net Present Value, B/C: Benefit/Cost Ratio, N/A: Not Applicable

In reading the table we note that in all the scenarios in the Châteauguay river watershed, the public benefits outweigh the costs incurred by farmers to establish and maintain agroforestry practices. However, this is not the case for the Fouquette river watershed, in which only the high-level scenario results in sufficient public benefits to more than compensate the costs incurred by farmers for establishing and maintaining agroforestry practices. In this manner, installations in Fouquette-type watersheds (extensive) are less profitable than those in Châteauguay-type watersheds (intensive).

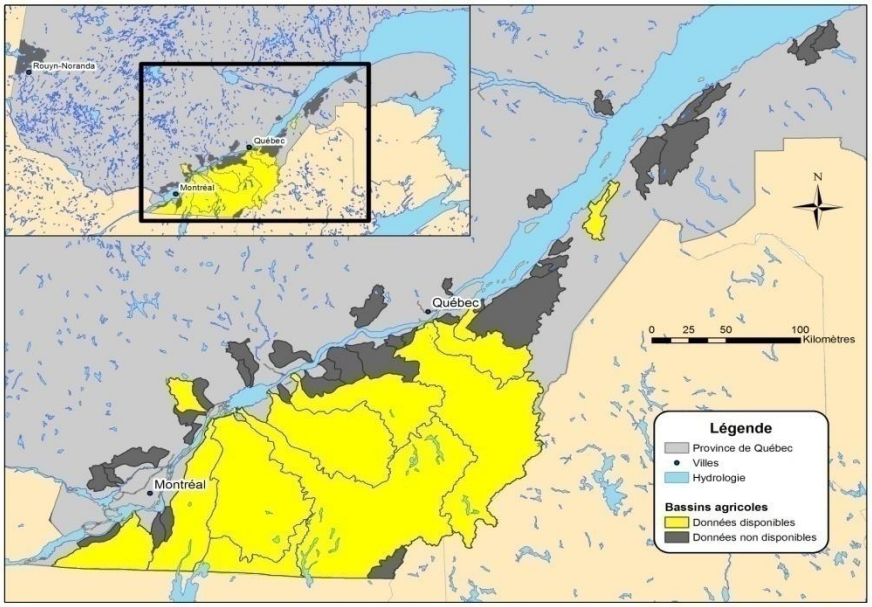
If we take into consideration the number of EG&S that were not considered in the current analysis, as well as the practical difficulties of defining some of the EG&S we analyzed, we realize that this evaluation constitutes a low estimation of the total value of EG&S. We thereby find that the value of EG&S that emanate from the establishment of agroforestry practices is significantly higher for the public than the costs they engender for farmers.

Global analysis at a Québec level

Following our analysis of two watersheds that are representative of two different realities affecting the territory of Québec, an extrapolation was carried out for the totality of Québec's agricultural land (see Olar et al. 2009b for further details). The global overview sought to integrate all the results from the two watersheds and to extrapolate them to a Québec scale by basing itself on 13 watersheds. The selection of the 13 watersheds[6] was made according to different criteria: (1) the agricultural watersheds (of level 1) have to have a cultivated area higher than 20% of their total area, (2) the watersheds have to be amongst the 33 priority watersheds outlined by the National Water Policy and (3) the data of the River Network of the Ministry of Sustainable Development, Environment and Parks in Québec (MDDEP) must be available.

The following figure illustrates the location of the 13 watersheds on which we based our extrapolation. We note that almost all of Québec's agricultural land was covered.

FIGURE 1: LOCATION OF THE 13 EXTRAPOLATED WATERSHEDS



Source: Compilation made by Activa Environnement based on data from the Ministry of Natural Resources and Fauna (MRNF), the *Commission de protection du territoire agricole du Québec* (CPTAQ) and the *Centre d'expertise hydrique du Québec* (CEHQ).

The extrapolation was conducted per EG&S, agroforestry system and implementation scenario. The following table shows the net present values (NPV) and the private and public benefit-cost ratios of the three implementation scenarios at a Québec level.

[6] The thirteen watersheds studied are Baie Missisquois, Bayonne, Bécancour, Boyer, Châteauguay, Chaudière, Etchemin, Fouquette, Kamouraska, Nicolet, Richelieu, Saint-François and Yamaska.

TABLE 6: RESULTS FROM THE COST-BENEFIT ANALYSIS AT A QUÉBEC LEVEL

Scenario		Private Net Costs	Public Benefits	Public benefits – Private net costs	Ratio of public benefits / private net costs
Regulatory-level	NPV (M$)	-209.39	244.15	35 M$	*N/A*
	B/C	0.14	*N/A*	*N/A*	1.11
Priority-level	NPV (M$)	-211.05	288.8	78 M$	*N/A*
	B/C	0.16	*N/A*	*N/A*	1.37
High-level	NPV (M$)	-1,038.54	1,902	864 M$	*N/A*
	B/C	0.43	*N/A*	*N/A*	1.83

Legend: NPV = Net Present Value, B/C: Benefit/Cost Ratio, N/A: Not Applicable

At the level of the 13 watersheds, the regulatory, priority and high-level scenarios show private net deficits of, respectively, $209, $211 and $1,038 million and B/C ratios of 0.14, 0.16 and 0.43. Although the high-level scenario was in greater deficit than the others, it offers a more favorable B/C ratio (0.43). This is explained by the fact that this scenario contains profitable agroforestry installations such as windbreaks that reduce heating and snow clearing costs and that enable higher crop turnout.

The public benefits of the scenarios for the entire Québec area go up to $244, $288 and $1,901 million for the regulatory, priority and high-level scenarios, respectively. These social benefits are more significant than the private net costs and result in public net benefits of an order of $35 million in the case of the regulatory-level scenarios, of $78 million in the case of the priority-level scenario and of $864 million in the case of the high-level scenario. In the case of the high-level scenario, EG&S-related benefits are twice as great as the private costs incurred by farmers.

At first glance, it is a bit surprising to note that the priority-level scenario leads to lower results than the high-level scenario. Indeed, one of the starting assumptions was that the public benefit/cost ratio of the priority-level scenario would be higher because it targeted what seemed to be priority installations. However, our results simply reflect the fact that, contrary to previous beliefs, the most important benefits relate to carbon sequestration and not water quality. The area of the implementation, which determines the carbon sequestration capacity, is the element that most affects the public value of agroforestry installations. The high-level scenario generates a higher ratio of public benefits / private net costs than the priority-level scenario, which wrongly assumed that the most important benefits would be derived from improvements in water quality.

As public benefits outweigh private net costs, society gains from the implementation of agroforestry systems. Although the extrapolation is based on weaker information than that used for the representative watersheds, the obtained ratios both for the regulatory scenario (low estimation) and for the high-level scenario (high estimation) should comfort us. The implementation scenarios seem to result in enough public benefits to justify a government intervention in the establishment of agroforestry practices.

DISCUSSION

The results of this study lead us to the conclusion that identified agroforestry practices do not generate sufficient and immediate revenues to prompt farmers to implement such practices. On average, for all the simulations carried out in the framework of this project, the private costs were three times higher than the private benefits. This conclusion would hold even truer from the perspective of the Québec farmer if we considered the support of ASRA, which would increase the costs related to lost farmland.

Nonetheless, the ratio of public benefits / private net costs obtained for the different implementation scenarios can comfort us. Although our extrapolation is based on weaker information than that used for the representative watersheds, the ratios seem to result in sufficient public benefits to justify providing assistance to farmers in order to help them implement and maintain agroforestry practices.

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