Agriculture and Agri-Food Canada | Agriculture et Agroalimentaire Canada

Ecological Goods and Services (EG&S) and Agroforestry: the Benefits for Farmers and the Interests for Society

Synthesis and Recommendations

ÉCO RESSOURCES CONSULTANTS

ACTIVA ENVIRONNEMENT INC.

CEPAF Centre d'expertise sur les produits agroforestiers

Canada

Funding for this pilot project is provided through Agriculture and Agri-Food Canada's Adaptation Programming.

Disclaimer

It is with pleasure that Agriculture and Agri-Food Canada is participating in the production of this publication. With our sectoral partners, we work to sensitize Canadians to the importance of the agriculture and agri-foods industry in this country. The opinions expressed in this document are those of ÉcoRessources, CÉPAF, and Activa Environnement, and do not necessarily represent the opinions of the Ministry.

March 2009

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Cat. No.A22-531/2011E-PDF
ISBN 978-1-100-18442-5
AAFC No. 11370E
Aussi offert en français sous le titre : *Biens et services écologiques et agroforesterie : l'intérêt du producteur agricole et de la société*

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EXECUTIVE SUMMARY

The project "Ecological Goods and Services (EG&S) and Agroforestry: The Benefits for Farmers and the Interests for Society" seeks to estimate the social value of Ecological Goods and Services that emanate from agroforestry practices and to evaluate their costs and benefits for agricultural businesses. This report is the synthesis of the whole project (step 14).

In order to verify whether the public benefits of agroforestry practices outweigh the costs for farmers in Québec, we developed a methodology that allowed us, on one hand, to determine the costs incurred by farmers who establish agroforestry systems and, on the other hand, to get a sense of the value of the ensuing benefits for society. Our work concentrated on the two agroforestry practices that are most likely to be established in Québec (windbreaks and riparian agroforestry systems). Our research approach also concentrated on the nine Ecological Goods and Services that seemed most important. As the value of ecological benefits and services is a function of the surrounding population and of the ecosystems that are primarily associated with agricultural production, we selected two watersheds that represent two very different realities for our analytical basis: one in a periurban agricultural area with intensive agricultural production (Esturgeon River watershed); the other in a remote area with extensive agricultural production (Fouquette River watershed). For the two watersheds, we conceived and developed three scenarios of agroforestry installations: a regulatory-level scenario that reflects Québec regulations on riparian buffers; 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 odours from livestock barns; and lastly, a high-level scenario, which seeks to generate a maximum of EG&S.

Four other stages were carried out in parallel to this general process. Based on the technical-economic analysis (step 6), a financial analysis model was developed in order to produce a decision-making tool. The latter intended to help farmers make choices regarding the species, types of agroforestry practices and implementation areas on the basis of the estimated costs and benefits of the diverse choices available to them. Subsequently, the obstacles and incentives for agroforestry development were identified through a literature review and expert consultations. The last step aims at structuring an exchange network at Québec and Canadian levels.

A comparison of the agroforestry systems in the two studied watersheds demonstrates that windbreaks along roads are less interesting for farmers (benefit-cost ratio is below 0.12). Next come riparian buffers (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). 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. In both watersheds, the only returns that can offset or earn back the total implementation costs are savings on heating and snow clearing as well as increased yields due to the protection of crops against the wind.

A comparison of expenditures both for the Fouquette River watershed as well as for the Esturgeon River watershed demonstrates that the first expenditure is the cost of setting up tree screens, followed by maintenance costs, and lastly, the opportunity costs related to the loss of farmland.

In a second step, to estimate the value of the nine EG&S generated by the implementation of agroforestry installations in the two watersheds, four economic evaluation methods were used. The results relating to the monetary value of EG&S, evaluated over a 40-year period and discounted accordingly, show 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.

The impact on the reduction of snow clearing costs for public roads is significant in both watersheds in the priority and high-level scenarios, while the biodiversity was attributed a high value.

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 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).

The results about the value of landscapes 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, does add value.

An increase in the number of wild pollinating insects comes in sixth position on the basis of their monetary value for both watersheds, while 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. It also seems that the implementation of agroforestry systems has no impact on the reduction of agriculture-related odors in either of the watersheds. Finally, the impact on the gravity of road accidents is statistically undeterminable in both watersheds.

The implementation scenario that generates the most public benefits 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 added value of resolving the worst environmental problems.

The overview of the two watersheds shows 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.

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.

At the Quebec level, the regulatory, priority, and high-level scenarios show private net deficits of $209, $211, and $1,038 million, respectively, and B/C ratios of 0.14, 0.16, and 0.43, respectively,. 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 $864 million in the case of the high-level scenario.

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. But the benefits to society that agroforestry practices can offer will not be realized if certain vigorous measures are not carried out.

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1. 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[2]) 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.

2. OBJECTIVES

The project "Ecological Goods and Services (EG&S) and Agroforestry: The Benefits for Farmers and the Interests for Society" seeks to estimate the social value of Ecological Goods and Services that emanate from agroforestry practices and to evaluate their costs and benefits for agricultural businesses.

The sub-objectives of this process include:

- Biophysically quantifying and economically evaluating the Ecological Goods and Services associated with agroforestry;
- Verifying whether the commercial products derived from agroforestry generate sufficient and immediate revenues to prompt farmers to establish agroforestry practices in their operations; and
- Verifying whether the social value of EG&S that emanate from agroforestry justifies the creation of economic incentives to favour such implementations.

[2] According to Agriculture Canada (AAC 2006a), "EG&S are the advantages human populations gain, directly or indirectly, from the healthy functioning of evolving ecosystems including air, water, soil, and biodiversity."

The parallel objectives of this project include:

- Identifying obstacles to agroforestry development;
- Identifying the conditions and incentives that are necessary for agroforestry development; and
- Framing the dialogue between farmers, public administrators, and experts in the field by creating a formal information exchange network in Québec and Canada.

3. METHODOLOGY

In order to verify whether the public benefits of agroforestry practices outweigh the costs for farmers in Québec, we developed a methodology that allowed us, on one hand, to determine the costs incurred by farmers who establish agroforestry systems and, on the other hand, to get a sense of the value of the ensuing benefits for society.

As we could not measure the costs and benefits of all agroforestry practices implemented throughout the entire province of Québec, our work concentrated on the agroforestry practices that are most likely to be established in Québec. 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 an agricultural area and the other in a periurban area – in which to simulate the implementation of agroforestry practices. The ensuing results were then extrapolated to the total area of Québec.

The following chart describes the principal stages of the project.

FIGURE 1: PRINCIPAL STAGES OF THE PROJECT

1: Definition and inventory of agroforestry practices

⇩

2: Definition of potential Ecological Goods and Services (EG&S) and selection of priority EG&S

⇩

3: Selection of representative territories to be studied and from which to acquire data

⇩

4: Characterization of representative watersheds

⇩

5: Development of implementation scenarios for each selected watershed

⇩

6: Analysis of technical-economic feasibility for farmers

⇩

8: Biophysical quantification of EG&S for each scenario tested

⇩

9: Evaluation of the value of EG&S for society per watershed and according to different implementation scenarios

⇩

10: Extrapolation, economic overview and global analysis

3.1. Review of the primary methodology used

After having compiled an overview of agroforestry practices, we selected the two practices[3] most likely to be implemented in the province: windbreaks[4] and riparian agroforestry systems[5].

As the value of ecological benefits and services is a function of the surrounding population and of the ecosystems that are primarily associated with agricultural production, we selected two watersheds that

[3] In the agroforestry portrait of Québec, De Baets and co. (2007) short-list the following practices: windbreaks, riparian buffer systems, silvopastoral systems, silviculture, production under forest cover, intercropping and aqua-forestry.

[4] 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).

[5] De Baets and co. (2007) propose applying the term “riparian agroforestry system” to riparian buffers that were intentionally created by planting arborescented or shrubby ligneous species

represent two very different realities for our analytical basis[6] : one in a periurban agricultural area with intensive agricultural production; the other in a remote area with extensive agricultural production. The watersheds were selected according to specific criteria: type of agricultural use of the watershed, proximity and distance from an urban center, availability of data, diversity of agricultural practices, population density, presence of environmental problems related to agricultural activities, existence of agroforestry installations, potential for recreation and tourism, as well as the presence of local actors. We selected two watersheds from the 33 priority watersheds that were short-listed in the framework of the National Water Policy of Québec: the Fouquette River watershed and the Esturgeon[7] River watershed.

Similarly, from all the EG&S identified in our literature review, we selected those that seemed likely to have the most value for Québec society. In this manner, nine priority EG&S were selected by process of gradual elimination in function of four criteria, which are listed below in order of importance:

- Biophysical changes had to be quantifiable (existence of evaluation methods or sufficient information for acceptable quantification);
- Biophysical changes induced by the agroforestry practices in question could not be marginal;
- The impacts from these installations had to be perceptible to the public (attribution of use); and
- The EG&S had to be considered as priorities by the two watershed committees consulted.

The nine EG&S that were retained are: improvement in surface water quality, reduction in treatment of potable water, enrichment of terrestrial and aquatic biodiversity, reduction of odours in the proximity of agricultural areas, carbon sequestration, reduction in snow clearing of roads, reduction of road accidents, enrichment of terrestrial biodiversity, and aestheticism of the landscape.

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[8]; 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 odours from livestock

[6] See stage 3 report : Selection of representative territories for the application of this research and the acquisition of data.

[7] The surface of the Châteauguay River watershed was too large for data collection and for a biophysical quantification of EG&S. Based on consultations with the Watershed Committee, the sub-watershed of the Esturgeon River was selected.

[8] 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”.

barns[9]; and lastly, a high-level scenario[10], 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[11].

Modifications to the nine chosen EG&S, following the establishment of agroforestry implementation scenarios, were measured by developing quantification protocols based on a literature review for the two types of agroforestry practices and three implementation scenarios[12]. This quantification served as a premise for the economic evaluation.

Some of the challenges encountered in the course of the project

- A lack of basic information and scientific knowledge (biophysical) in Québec.
- The zoning of watersheds and their lack of administrative status. This resulted in minimal socio-economic data being available. Example: a special compilation was necessary to establish the population of the watersheds studied.
- The fact that scientists tend to work on small territorial areas (small watersheds), which they master well, and economists need to work on much larger scales (large watersheds) in order to support public administrators in their decision- and policy-making process. As a result, we encountered problems reconciling the existing knowledge and scientific expertise with the socio-economic needs at the heart of this decision-making exercise.
- The almost complete lack of original economic studies on the values of Ecological Goods and Services in Québec made it difficult to use existing studies to support our estimates. As a result, the use of the benefit transfer method is rooted in a weaker premise.
- The extrapolation to the entire territory of Québec is based on weaker information than that which we have for the representative watersheds. In fact, one of the factors that led to the selection of those watersheds, which later provided the basis for extrapolation, was the fact that information was available.

[9] 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).

[10] 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”.

[11] See stage 5 report: Elaboration of implementation scenarios.

[12] See stage 8 report: Quantification of EG&S.

3.2. Parallel Stages

Four other stages were carried out in parallel to this general process. The following figure illustrates these stages.

FIGURE 2: PARALLEL STAGES TO THE GENERAL PROCESS

7: Development of a decision-making tool for farmers
11: Identification of institutional obstacles to the development of agroforestry
12: Identification and evaluation of different forms of incentives to favour the development of agroforestry
13: Structuring an exchange network at Québec and Canadian levels

A technical-economic analysis enabled us to evaluate the implementation and maintenance costs of the retained agroforestry practices. Based on this, a financial analysis model was developed in order to produce a decision-making tool. The latter intended to help farmers make choices regarding the species, types of agroforestry practices, and implementation areas on the basis of the estimated costs and benefits of the diverse choices available to them.

Subsequently, the obstacles and incentives for agroforestry development were identified through a literature review and expert consultations[13].

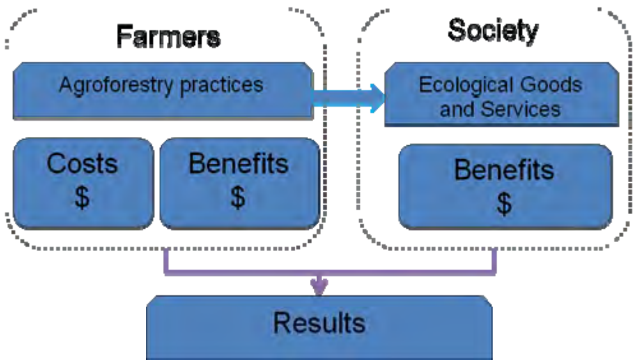
4. ECONOMIC RESULTS

The economic analysis began with a study of the private costs and benefits of agroforestry implementation[14]. The net costs for famers were then compared with the social benefits evaluated for the nine EG&S, which were first selected at the level of the reference watersheds and then at a Québec level. These findings sought to answer the following question: If the implementation of agroforestry systems by farmers does not provide sufficient financial benefits to offset their implementation costs, will the social benefits be significant enough to justify an intervention from the government to remunerate farmers for the production of these public benefits and to favor the implementation of these systems in Québec?

[13] See stage 11 and 12 reports: "Identification of institutional obstacles to the development of agroforestry" and "Identification and evaluation of different forms of incentives to favor the development of agroforestry".
[14] See stage 6 report: "Technical-economic feasibility analysis for farmers".

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%.

The following figure outlines the economic analysis carried out.



4.1. Private cost-benefit analysis

The CEPAF calculator (www.wbvecan.ca) was used in order to estimate the private costs and benefits associated with the three implementation scenarios in each of the two watersheds studied.

4.1.1. 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.

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

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 increases 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 become profitable only if it also offers wind protection for buildings and roads close to farms.

4.1.2. 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. 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).

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
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 benefit-cost (B/C) ratios of the scenarios go from 0.14 for the regulatory-level scenario of the two watersheds to 0.42 for the high-level in the Esturgeon River. Even though the high-level scenarios are more in deficit in absolute terms than the others, they demonstrate a more favourable 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.

4.1.3. Comparison of private benefits associated with different implementations in the two watersheds

In both watersheds, the only returns that can offset or earn back the total implementation costs are savings on heating and snow clearing as well as increased yields due to the protection of crops against the wind. The only situations in which the benefits are equal to or greater than the costs (in other words in which the B/C ratio is greater than or equal to 1) are those in which windbreaks (WB) protect either crops or buildings.

TABLE 3: PRIVATE BENEFITS OF THE HIGH-LEVEL SCENARIO IN THE TWO WATERSHEDS ($)

	RB		WBb		WBc		WBr	
	Fouquette	**Esturgeon**	**Fouquette**	**Esturgeon**	**Fouquette**	**Esturgeon**	**Fouquette**	**Esturgeon**
Length (m)	134,409	296,297	9,430	24,815	140,466	219,311	8,152	48,480
Heating ($)	*N/A*	*N/A*	70,961	399,689	*N/A*	*N/A*	*N/A*	*N/A*
Snow clearing ($)	*N/A*	*N/A*	297,211	624,647	*N/A*	*N/A*	*N/A*	*N/A*
Berries ($)	266,392	587,244	6,230	16,395	46,400	72,444	2,693	16,014
Wood ($)	488,534	1,076,950	12,846	33,798	47,975	74,903	*N/A*	*N/A*
Yields ($)	*N/A*	*N/A*	*N/A*	*N/A*	317,897	1,063,432	*N/A*	*N/A*
Total benefits ($)	**754,926**	**1,664,194**	**387,249**	**1,074,529**	**412,271**	**1,210,779**	**2,693**	**16,014**

Source: CEPAF calculator

Legend: RB = Riparian buffers
WBb = Windbreaks adjacent to buildings
WBc = Windbreaks protecting crops
WBr = Windbreaks adjacent to roads
N/A: Not Applicable

The production of wood and berries is not enough to create a net benefit for farmers. In the case of wood harvesting, which is carried out over a period of 20 years for poplar trees and 40 years for other tree species, the discount rate used (6%) explains why the present value of wood harvesting is so low.

4.1.4. Comparison of expenditures

A comparison of expenditures both for the Fouquette River watershed as well as for the Esturgeon River watershed demonstrates that the first expenditure is the cost of setting up tree screens, followed by maintenance costs, and lastly, by the opportunity costs related to the loss of farmland[15].

[15] As specified in the stage 6 report, the support from ASRA was excluded from this calculation.

TABLE 4: COMPARISON OF EXPENDITURES ASSOCIATED WITH THE TOTAL IMPLEMENTATION OF THE HIGH-LEVEL SCENARIO IN THE TWO WATERSHEDS

	Fouquette	**Esturgeon**
Length (m)	292,457	588,903
Implementation costs ($)	2,577,267	5,520,829
Maintenance costs ($)	1,071,344	2,631,299
Opportunity costs ($)	416,729	1,347,495
Total costs ($)	4,065,340	9,499,624

Source: CEPAF calculator

Even though the *Prime-Vert* program is not aimed exclusively at agroforestry policies, it pays 90% of implementation costs at the beginning of the project (i.e. at the moment when expenditures are highest). If we included this program, the importance of implementation costs would fall into second or third place behind maintenance costs, which would go up into first.

Thus, it is understandable that farmers are reluctant to implement agroforestry systems, particularly riparian agroforestry systems. The real costs they face are most often higher than the expected benefits, particularly because the latter are less tangible (avoided costs and not additional revenues, or benefits that are difficult to measure) or because they are related to unusual activities or markets (berries, wood).

Farmers' lack of enthusiasm for agroforestry practices can be explained in part by the fact that the 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 Government intervention.

Obstacles

Several elements create obstacles for the adoption of agroforestry practices in Québec. In first place come the implementation costs, followed by the loss of farmland discussed above, and anticipated nuisances (roots that block drains and branches that extend into fields, obstructing farming operations). Then come transaction costs, the costs of transitioning into a new and little known crop, uncertainty about the possible trade outlets for some agroforestry products, and lastly, sociological factors such as cultural reluctance, risk aversion, lack of succession, etc. These elements provide rationale that can obstruct the development of agroforestry in Québec.

In addition, several internal factors in provincial and federal institutions slow the establishment of agroforestry programs and thereby the adoption of identified agroforestry practices. These factors include: a lack of recognition for agroforestry and particularly for some agroforestry practices, weak transfers of technology and know-how relating to the implementation of certain agroforestry installations, a lack of long-term technical and financial support, high public transaction costs, as well as occasional lack of coherence between different government policies.

4.2. Social benefits

To estimate the value of the nine EG&S generated by the implementation of agroforestry installations in the two watersheds, four economic evaluation methods were used. The hedonic method helped to evaluate the reductions in agriculture-related odours 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, enrichment in terrestrial and aquatic biodiversity, and reduction in road accidents. 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.

TABLEAU 5: CLASSIFICATION OF EG&S AND CURRENT MONETARY VALUE (IN MILLION $ 2008)

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
9	Reduction in the gravity of road accidents	Regulatory-level	Not applicable in the case of RB	
		Priority-level	Indeterminable	Indeterminable
		High-level	Indeterminable	Indeterminable
Total		Regulatory-level	**0.347**	**16.056**
		Priority-level	**1.205**	**14.725**
		High-level	**3.623**	**129.430**

Source: Model developed by ÉcoRessources Consultants

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. In fact, 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 River and the 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 odours 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 odours is not significant. However, all the values found are comparable to those in other literature reviews.

Finally, the impact on the gravity of road accidents is statistically undeterminable in both watersheds. This surprising result can possibly be explained by the fact that drivers tend to be twice as careful in wintertime when weather conditions are bad. The impact of agroforestry systems is, in fact, impossible to isolate from other factors that affect the gravity of accidents.

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 implementation 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 added value of resolving the worst environmental problems.

Experimental economics

Experimental economics allow us to test economic theories, market models, and the preferences of market actors in a controlled environment. It is an interesting alternative approach to measuring the non-market value of public goods.

The application of this experimental approach in the current project allowed us to evaluate the value that individuals place on the agroforestry practices studied. It aimed to measure: the value of the landscape or of ecological biodiversity following the installation of riparian buffers and/or windbreaks in a watershed, as well as the impact on these values of an increase in the width and length of the riparian buffers and/or windbreaks in a watershed.

According to the results of this experimental approach, there is a willingness to pay between $65 and $135 per hectare of agroforestry installations in order to benefit from improvements in landscape and biodiversity. According to the model used in the calculation of biodiversity, for both the Fouquette and Esturgeon River watersheds, the value of biodiversity is situated between $101 and $301 per hectare of agroforestry installations per year. As a result, we note that the willingness to pay is slightly lower when calculated using an experimental approach. The latter may only reflect the willingness to pay for the implementation of these installations and not the annual value of the biodiversity they generate.

4.3. Overview of the two watersheds

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 favouring the establishment of agroforestry practices would be justified.

The two following tables show the net present values (NPV) and benefit-cost ratios (B/C) at the private level (table 6), as well as the benefit-cost ratios at the level of society (table 7) in the Fouquette and Châteauguay River watersheds.

TABLE 6: PRIVATE NET COSTS AND PUBLIC BENEFITS FOR THE TWO WATERSHEDS (MILLIONS OF DOLLARS)

		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 7: OVERVIEW OF THE COST-BENEFIT ANALYSIS FOR THE TWO WATERSHEDS (MILLIONS OF DOLLARS)

		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

Source: CEPAF and ÉcoRessources Consultants

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.

4.4. Global analysis at a Québec level

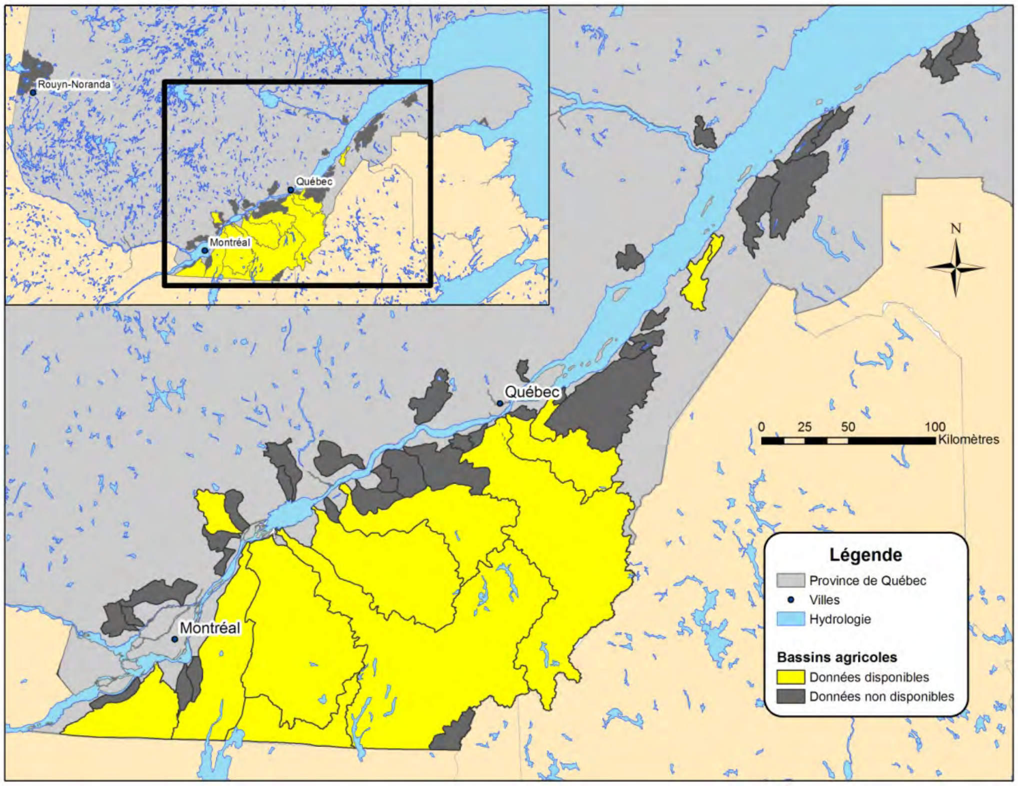
Following our analysis of two watersheds that are representative of two different realities affecting the territory of Québec, an extrapolation was carried out for the totality of Québec's agricultural land. The global overview (stage 10) sought to integrate all the results from the two watersheds and to extrapolate them to a Québec scale by basing itself on 13 watersheds. The selection of the 13 watersheds[16] was made according to different criteria:

- The agricultural watersheds (of level 1) have to have a cultivated area higher than 20% of their total area;
- The watersheds have to be amongst the 33 priority watersheds outlined by the National Water Policy;
- 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.

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

FIGURE 3: 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 (B/C) of the three implementation scenarios at a Québec level.

TABLE 8: 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

Source: CEPAF and ÉcoRessources Consultants

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 favourable 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 on 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.

5. THE RATIONALE BEHIND GOVERNMENT INTERVENTION

The results of this study lead us to the conclusion that identified agroforestry practices do not generate sufficient and immediate private revenues to prompt farmers to implement such practices. In light of the results of the report on technical-economic interests of different agroforestry scenarios for farmers (stage 6), we note that no proposed agroforestry installation offers private benefits that are higher than the private costs for farmers in the two watersheds studied.

Furthermore, the results show that the public value of EG&S (stage 9) provided by agroforestry installations justifies transfers from society to farmers in order to, on the one hand, prompt them to implement agroforestry installations and, on the other, to compensate or remunerate them for maintaining such installations.

Incentive programs that encourage farmers to adopt these practices should cover private costs, in whole or in part, which would amount to an annual total of between $14 million and up to $69 million in an ideal scenario such as the high-level scenario. On another note, a portion of the public surplus should be transferred to farmers in order to compensate them for the obstacles identified in the stage 11 report. More concretely, the net benefits derived from the high-level scenario across 40 years indicate that it would be justified for the Québec government to invest up to $57 million annually, on average, in agroforestry practices in Québec in the course of the next 40 years. The net benefits derived from the priority-level scenario across 40 years indicate, for their part, that it would be justified for the Québec Government to invest $5 million annually, on average, over the course of the next 40 years.

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.

Although agroforestry can offer important benefits to society, these will not be realized if certain vigorous measures are not carried out. Concretely, such measures should include, amongst others:

- Defining the status of agroforestry and recognizing it within agriculture and forest policies;
- Applying the principle of ecoconditionality to all Québec and Canadian agricultural programs;
- Setting up a dialogue between agricultural and forestry finance organizations in order to make funding effective and efficient;
- Establishing an effective incentive program that remunerates Ecological Goods and Services and covers at least the implementation and maintenance costs of agroforestry practices;
- Adapting the modalities of support program to the characteristics and needs of the watersheds;
- Linking agroforestry support programs with existing support programs in Québec (ASRA, amongst others);
- Opening traditional insurance programs to agroforestry practices;
- Facilitating the development of markets for agroforestry products;

- Adopting an integrated and multi-sectoral intervention approach in the watersheds;
- Emphasizing research and development in order to learn about and optimize the productivity of different agroforestry practices in Québec;
- Supporting the dissemination of knowledge and transfer of technology, particularly regarding the results obtained in this study, to stakeholders in both agricultural and municipal fields;
- Providing reliable information on the market entry potential of products resulting from agroforestry practices; and
- Encouraging concrete local actions in concert with the interventions of the agriculture and forestry sectors.

Incentives

The investment subsidies (*Prime-Vert, Programme de mise en valeur de la biodiversité des cours d'eau en milieu agricole*, Greencover Canada program) currently in place in Québec can be used to effectively prompt farmers to establish targeted agroforestry practices but are not enough to support their maintenance. As a result, they fail to secure real engagement from farmers.

In the Québec context, environmental conditionality is one of the most interesting financial incentives for the establishment of agroforestry practices. However, this tool is not rigorously applied (except in the framework of the *Politique de protection des bandes riveraines et des zones inondables)*. It is necessary to first ensure that the current agricultural programs conform to this principle.

The establishment of subsidies is administratively easier and lighter because these are managed by the appropriate ministry. One could therefore envisage subsidizing organizations that are currently working on establishing and maintaining riparian agroforestry buffers and windbreaks in Québec's regions. Despite the complexity of compensation programs and the important public transaction costs this would entail, if the subsidies were high enough to compensate opportunity, installation, and maintenance costs, they may be the most appropriate way to lift most of the obstacles identified for farmers and within government institutions.

On the other hand, one would have to propose measures to address the internal factors in provincial and federal institutions that obstruct the establishment of agroforestry programs and, thereby, the adoption of identified agroforestry practices. These factors include the lack of recognition for agroforestry and agroforestry programs, weak transfers of technology and know-how relating to the implementation of agroforestry installations, technical support, insufficient long-term technical and financial support, and occasional lack of coherence between different government policies.

At the scientific level, it would help to:

- Target the acquisition of scientific knowledge on EG&S emanating from agroforestry;
- Encourage work by multi-disciplinary teams of specialists from both the biophysical and the social sciences in order to develop knowledge that is useful to decision-making;
- Carry out applied monetary evaluation studies of EG&S in order to enlarge the knowledge base and thereby gain more data with which to support decision-making; and
- Develop a knowledge base with the help of new information technologies on the conditions to establish and to respect in order to extrapolate the results of local-level studies to scales that are useful for resources management.

A research avenue

Most of the work being done on the impact of agricultural practices or best management practices on water quality is conducted at the level of a sub-basin of small size. This is particularly due to constraints imposed by scientific experimentation protocols, which have to deal with the complexity of the ecosystems and the diversity of anthropogenic interventions.

Due to the nature of the information obtained in this manner, it is difficult to generalize and transpose scientific results into language that could feed into the public decision-making process. The difficulty resides in the challenge of generating scientific results that will be useful on the scale of the territories where decisions are to be taken.

We should therefore ask ourselves, considering our policy-making needs and the state of information, what are the most effective extrapolation strategies and at which scale would they be appropriate? The answer to this question could differ across Canada’s regions in function of ecosystem differences and availability of knowledge. An underlying question is, what do we need to know in order to improve the quality of such extrapolations?

A basic component of any project that seeks to explore this question will be the use of new information technologies (satellite imaging, etc) and geomatics.

Final stage the project:
« Ecological Goods and Services and Agroforestry: The Benefits for Farmers and the Interest for Society»

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Agriculture et Agroalimentaire Canada
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