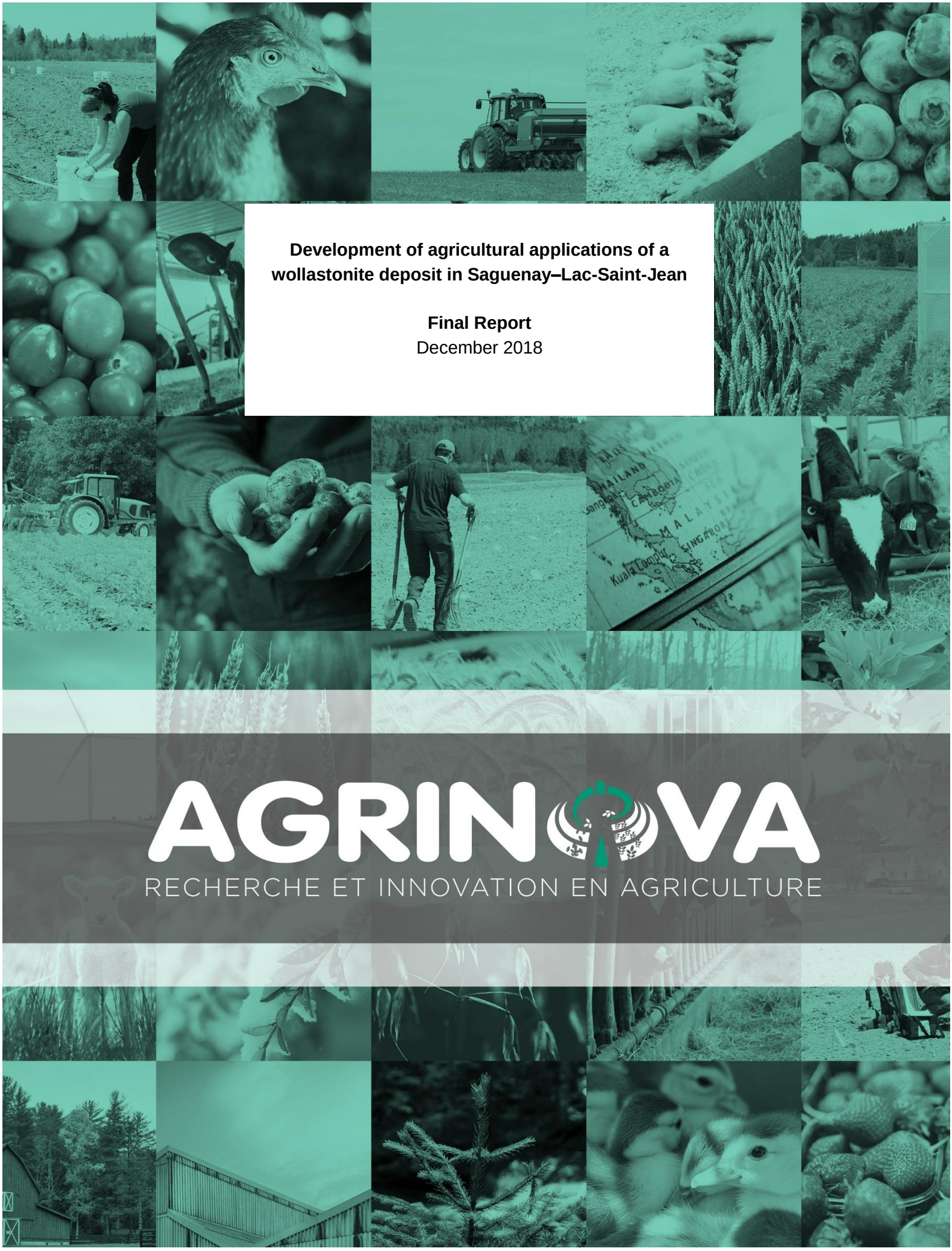

Development of agricultural applications of a wollastonite deposit in Saguenay–Lac-Saint-Jean

Final Report

December 2018

AGRINOVA

RECHERCHE ET INNOVATION EN AGRICULTURE

Development of agricultural applications of a wollastonite deposit in Saguenay–Lac-Saint-Jean

Final Report

Realized by
Agrinova

Presented by
Vertical Exploration inc.

December 2018

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1. MANDATE

In June 2018, Vertical Exploration Inc. used the expertise of Agrinova and its research staff to carry out a project to **develop agricultural applications for their wollastonite deposit located in Saguenay-Lac-Saint-Jean**.

2. BACKGROUND

Wollastonite is a mineral species from the group of silicates whose use became popular in the 1970s and 1980s as a replacement for Asbestos fiber. It then also begins to be used for the manufacture of plastics and rubbers (car interiors, fenders, trim), ceramics, paints (corrosion inhibitor and reinforcement), metallurgical materials (protective slag, welding electrodes) and abrasive products.

The physico-chemical properties of wollastonite are also very interesting for agriculture and forestry. Biological control of pests, increased crop yield achieved by enhancing plant immunity and litter use for odor management and improved animal hygiene are among the potential interests in agriculture. It is to validate these needs and the potential of the product to satisfy them that Vertical Exploration Inc. commissioned Agrinova to carry out this study. The product to be developed for agriculture comes from a natural deposit located in St-Ludger-de-Milot at Lac Saint-Jean, possibly the largest deposit in the world. It would be obtained by simple grinding and sieving. The rock would consist of 55% SiO_2, 29% CaO, 6.7% MgO, 3.0% Al_2O_3, 1.4% K_2O, 1.4% Fe_2O_3, 0.65% Na_2O, 0.21% TiO_2 and 0.06% MnO.

3. OBJECTIVES

The project involved conducting various research and innovation activities to develop agricultural uses of a wollastonite deposit. More specifically, it aimed to characterize the product according to the regulatory requirements of this field of application, to probe potentially interesting markets and to develop a research program to bring the product up to these requirements (regulation and market).

4. METHODOLOGY

To achieve the objectives targeted by the project, it was proposed to divide the project into specific steps that were in this order:

1) Agronomic characterization of the product;
2) Realization of a market study;
3) Development of a research program.

These stages were carried out in close collaboration with Frédéric Bergeron from Magnor Exploration and Bernard Lapointe, geologist.

4.1. Caracterization of the product

The first step consisted in characterizing the product according to the requirements for valorization in agriculture. The procedure from *Guide sur le recyclage des matières résiduelles fertilisantes* (Hébert, 2015) was used because it meets the criteria established by the Bureau de normalisation du Québec (BNQ) and the Canadian Food Inspection Agency (CFIA), especially. BNQ 0419-090 *Amendements calciques ou magnésiens provenant de procédés industriels* (BNQ, 2015) and the *Guide pour la présentation de demandes d'enregistrement en vertu de la Loi sur les engrais* Act (CFIA, 2018) were used as references. A resource person from AGAT Laboratories was contacted to validate the characterization parameters and associated methods. The characterization made it possible to clearly identify the values of the product for its differentiation as a soil amendment. The characterization of a comparable product, that of Canadian Wollastonite, was done in parallel. Then, additional characterizations were made in order to better know the safety of the product (barley germination test) and its potential for the environmental fixation of phosphorus (adsorption test) and the prevention of phytosanitary disorders (solubility of silica).

4.2. Market study

The completion of this step has been subdivided into three sub-steps. The first was to look for comparable products in North America and Europe and see for which applications they were marketed. Special attention was paid to a competing product from Ontario. An overall picture of the market was then produced for target crops based on the agronomic value of the product and the distance from the markets. The initial target markets being, in order: regional, Quebec and Maritimes. An online survey of regional agricultural stakeholders was finally conducted to estimate the receptivity of such a product among the existing product range as agricultural inputs.

4.3. Phone inquiry

The agronomic characterization of the product and the market study have made it possible to target interesting marketing routes for the product. The last step was to develop a research program to test and demonstrate the product performance among these valorization avenues. In this regard, Agrinova assisted Vertical Exploration Inc. in writing a grant application for its innovation project. The accompaniment consisted of exchanges with the customer on the definition of his idea or innovative project, the identification of the results expected by the innovation approach, the development of the project (scientific journal, development of the research protocol and the required expertise, budget and implementation schedule), as well as the writing of the grant application.

5. INTERPRETATION OF RESULTS

5.1. Product characteristics for agricultural valorization

Two 20-liter buckets of each product were supplied by Mr. Bernard Lapointe: a product from the St-Onge deposit (hereinafter referred to as *Product*) and another ordered from Canadian Wollastonite in Ontario (if after named *Control*). The contents of these buckets were homogenized before taking the required quantities for characterization and testing.

5.1.1. Caracterization according to the MRF Guide

Samples of approximately 1 kg were sent to AGAT Laboratories for analysis. The results of analyzes obtained are presented in Tables 1 and 2 and the certificates of analysis are reproduced in Appendix 1.

Tableau 1. Teneurs en métaux du produit wollastonite et d'un produit témoin

Paramètre	Unité	Produit	Témoin	Guide MRF	BNQ		Loi sur les engrais	
				Catégorie C1	Seuil minimal	Seuil maximal	4 400 kg/ha/an	2 000 kg/ha/an
Arsenic	mg/kg	<0,7	<0,7	13		75	75	166
Cadmium	mg/kg	<0,9	<0,9			30	20	44
Chrome	mg/kg	<2	<2	210			1 060	2 333
Cobalt	mg/kg	3	7	34			151	333
Cuivre	mg/kg	<30	<30	400		1 500	757	1 666
Mercure	mg/kg	<0,04	<0,04				5	11
Molybdène	mg/kg	3	<2	10			20	44
Nickel	mg/kg	5	11	62		420	181	400
Plomb	mg/kg	37	<5			500	505	1 111
Sélénium	mg/kg	<0,5	<0,5	2,0			14	31
Thallium	mg/kg	<15	<15				5	11
Vanadium	mg/kg	<15	<15				656	1 444
Zinc	mg/kg	<50	<50	700		2 800	1 868	4 111
Arsenic	PN/As	73,857	49,429		0,667			
Cadmium	PN/Cd	57,444	38,444		2,500			
Chrome	PN/Cr	25,850	17,300		0,047			
Cobalt	PN/Co	17,233	4,943		0,333			
Cuivre	PN/Cu	1,723	1,153		0,066			
Mercure	PN/Hg	1292,500	865,000		10,000			
Molybdène	PN/Mo	10,340	3,145		0,278			
Nickel	PN/Ni	1,397	6,920		0,100			
Plomb	PN/Pb	103,400	69,200		3,570			
Sélénium	PN/Se	0,517	0,346		0,002			
Zinc	PN/Zn	1,034	0,692		0,027			
Dioxines/furannes	mg/kg	-	-	17				

Tableau 2. Valeurs fertilisantes du produit wollastonite et d'un produit témoin

Paramètre	Unité	Produit	Témoin	Norme	Référence
Solides totaux	mg/kg	999 000	960 000	400 000	Seuil minimal BNQ 0419-090/2015
Humidité	%	<0,2	4,0		
pH	-	9,86	9,20		
Bicarbonates	mg $CaCO_3$/kg	48,7	***110***		
Carbonates	mg $CaCO_3$/kg	**33,0**	16,3		
Rapport C/N	-	1 390	1 750	70	Seuil minimal BNQ 0419-090/2015
Phosphore (P) total	mg P/kg	<40	<40		
P soluble	mg P_2O_5/kg	<50	<50		
P assimilable	mg P_2O_5/kg	<50	<50		
K_2O total	mg K_2O/kg	<70	***181***		
K soluble	mg K_2O/kg	<100	<100		
K assimilable	mg K_2O/kg	<100	<100		
Bore	mg/kg	43	***287***		
Magnésium	mg/kg	264	***691***		
Mg soluble à l'eau	mg/kg b.h.	<0,2	<0,2	10 000	Seuil minimal BNQ 0419-090/2015 si le fabricant déclare une teneur minimale garantie
Manganèse	mg/kg	***130***	94		
Soufre total	mg/kg	2 170	***5 560***		
PN	% ÉCC	***51,7***	34,6	25	Seuil minimal BNQ 0419-090/2015
Efficacité	%	***67***	46		
IVA	%	***35***	15	5	Seuil minimal BNQ 0419-090/2015
IVM	-	***2,065932***	1,337328	1	Seuil minimal Guide MRF

Logically, not being a residual material, the product can not be recognized as an MRF. However, it does meet all the safety requirements (metals and dioxins / furans content below the maximum level of category C1 of the MRF Guide) and the multiple index of agricultural value (IMV > 1). Nevertheless, the product could be valorized in agriculture in two ways:

1) In Quebec, through standard BNQ 0419-090 Calcium or Magnesium Amendments from Industrial Processes. The product meets the minimum thresholds of required fertilizer values, with a neutralizing capacity (PN) of 51.7% CC, an efficiency of 67% and an agricultural value index (IVA) of 35%. Contacted about this, a resource person at the BNQ confirmed that wollastonite did not match one of the products already included in the object and scope of the standard. This same resource, however, indicated that if the customer wanted it, it would be possible to go ahead with the addition of such a product.

2) In Canada, through the Fertilizers Act. Although it contains very little nitrogen, phosphorus or potassium, the product could be considered a fertilizer if silica was recognized as a nutrient for plants. Contacted about this, the CFIA's Fertilizer Safety Section is open to registration of any fertilizer (essential plant nutrients) and / or any supplement (products intended to be used to improve soil structure or to support plant growth or crop yield). The product would have a total SiO_2 content of 29% and the water-soluble fraction would be 360 mg/kg b.s. The product also contains significant levels of calcium, magnesium, sulfur and boron, which are other essential nutrients for plants.

The product contains no chemical contaminants, is free of pathogens, does not constitute an odor concern and is free of any foreign matter. According to the MRF Guide, it would fall into the category C1-P1-O1-E. All agricultural and silvicultural uses would be possible without restriction. However, the recommendations of use in agriculture for the amendments and the fertilizers aim at not exceeding the contributions-withdrawals balance by the soil-plant system in order to minimize the environmental losses.

Thus, for the use of the product in terms of the neutralizing power of soil acidity, the recommendations should follow Table 3.4 of the Fertilizer Reference Guide (CRAAQ, 2010). To value the product in relation to its silica content, the guide offers nothing in this sense. However, there are some indications provided for crops on the Canadian Wollastonite web page[1]. These recommendations are converted to metric units in Table 3.

[1] http://www.canadianwollastonite.com/applications/soil-amendment-2/

Tableau 3. Recommandations pour l'amendement en wollastonite (Canadian Wollastonite)

Application	Taux
Culture en serre	3,5 à 6 kg/m^3
Jardin	250 ml/m linéaire au semis et 75 ml/transplant
Culture maraîchère	4 à 10 t/ha en plein champ ou 165 à 675 kg/ha en rang
Grande culture	1,2 à 5 t/ha
Gazonnière	2,5 à 4 t/ha
Gazon et verger	20 à 35 kg/100 m^2

In addition to the neutralizing power and fertilization from silica, the product can contribute to minor elements and trace elements. A contribution of 4 t/ha of this product would bring 0.2 kg of boron, 1 kg of magnesium and 10 kg of sulfur to crops.

5.1.2. Barley growth tests

The barley germination and growth inhibition test method of the Quebec Center of Expertise in Environmental Analysis was followed for the safety test (CEAEQ, 2003). A Conviron growth chamber Model E15 was used (Figure 1). This type of chamber allowed to maintain a temperature of 24°C (± 2°C), a lighting of 4,300 lux (± 10%), a photoperiod of 16 hours of light and eight hours of dark, as specified in the method of analysis.

Figure 1. Growth Chamber Conviron model E15

Plastic vials of 50 ml capacity and 3 cm in diameter were used for the growth of barley seeds. Each initially contained 20 g of substrate and wollastonite mixture, a barley seed and 5 ml of water. Sand served as a neutral substrate for controls and mixtures. Seven wollastonite concentrations of 0, 1, 5, 10, 25, 50 and 100% were tested at five replicates per concentration. The incubation period was 20 days. At the end of the incubation period, germination and plant elongation were measured in each vial (Figure 1) and biomass was obtained from a sample consisting of five replicates per treatment. Graphical analyzes were performed to compare and calculate response rates as a function of concentration.

Figure 2. Test de croissance de l'orge

Figures 2 and 3 illustrate the response rates of barley elongation and dry biomass versus wollastonite concentration in the growth substrate. First, the response curves do not indicate any toxicity effect of the product, even at 100% incorporation. Then, the two graphs show an optimal response rate at 14% incorporation that ranges from 1.2 to 1.5 depending on elongation and dry biomass production. Such a percentage concentration would be equivalent to a field input of 310 t/ha if scaling was applied. A contribution of 4 t/ha to the field would be more realistic to apply these results in real conditions. Under these conditions, a gain in yield of at least 5% could be expected. Finally, the response curves of the investigated product are similar to the control product already marketed in Ontario, indicating that it could aspire to the same uses and similar markets if it were produced for commercialization.

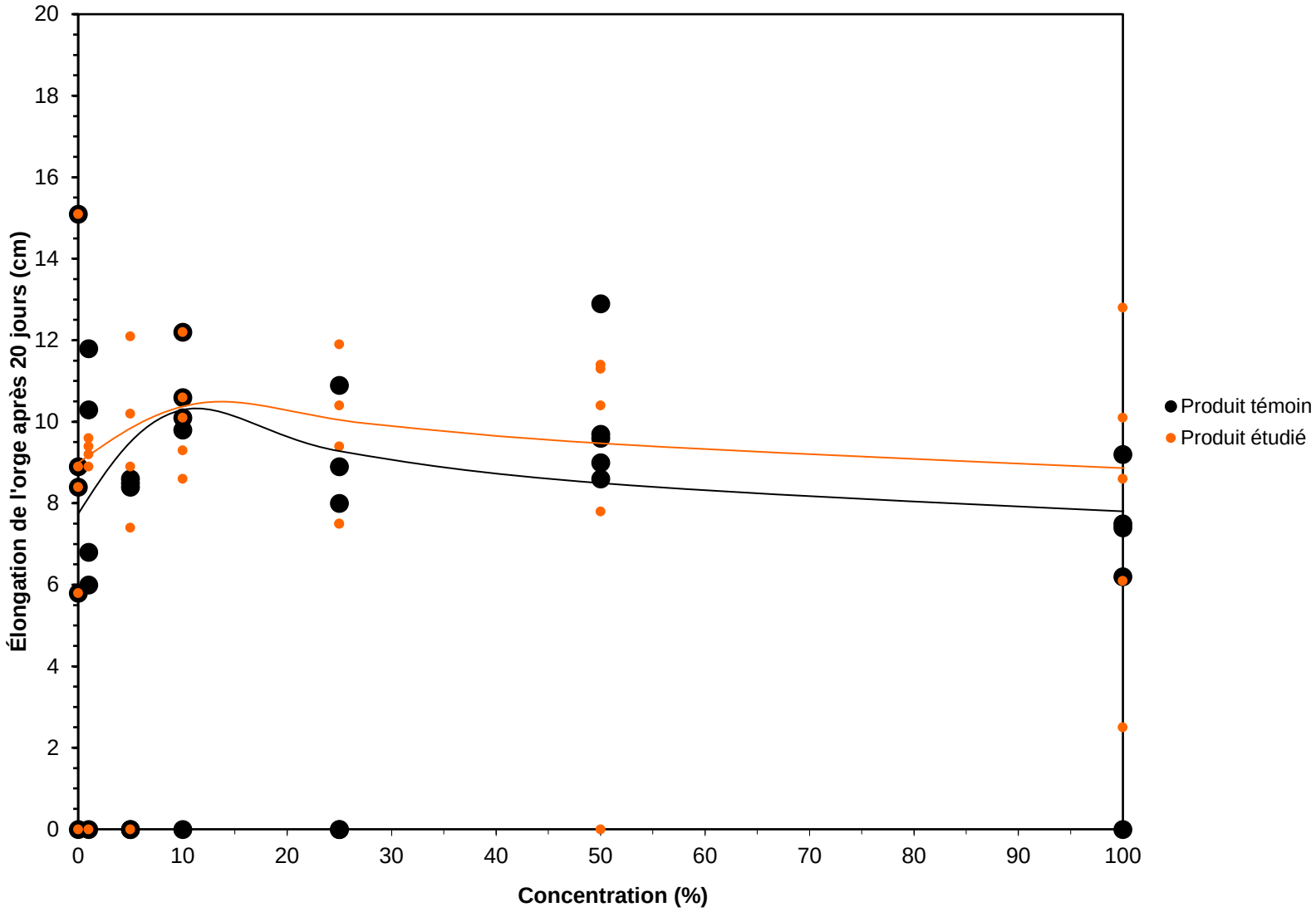

Figure 3. Élongation de l'orge en fonction de doses croissantes de wollastonite dans le substrat sableux

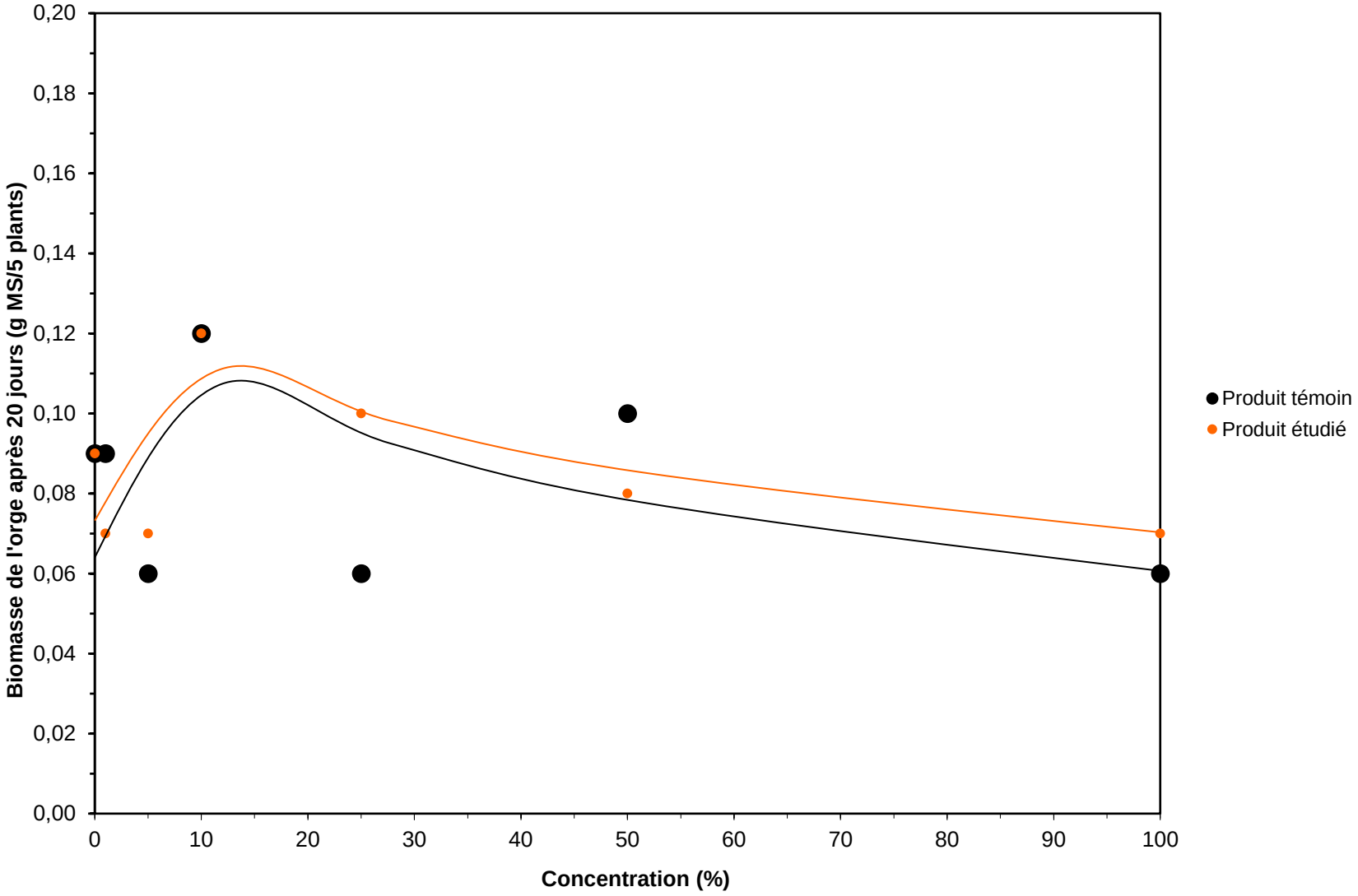

Figure 4. Biomasse d'orge produite en fonction de doses croissantes de wollastonite dans le substrat sableux

5.1.3. Phosphorus fixation test

An experimental device was developed by Agrinova to measure the ability of wollastonite to fix soluble phosphorus, which could be an additional technique to control agricultural diffuse pollution. The developed device allows the circulation of an aqueous solution in a percolation column filled with soil with different rates of incorporation of wollastonite. The amount of bound phosphorus was obtained by difference of the soluble phosphorus content measured in the water percolated through the column. The protocol is described in more detail in Appendix 2. The results of the analysis of the soluble phosphorus content of the percolation water samples collected during the test are presented in full in Appendix 3. The test compared the phosphorus fixation potential by the product of the customer to that of the control product.

After 15 hours of soaking with a saturated solution of phosphorus (119 g/L KH_2PO_4), the test carried out shows an increase in the capacity of the soil to fix the phosphorus with increasing doses of incorporation of wollastonite (Figure 5). However, this increase is only statistically significant up to 50% incorporation. These results suggest that wollastonite would need more than 15 hours to adsorb phosphorus from a saturated solution. According to Brooks et al. (1999) a fixation greater than 80% (up to 96%) was observed when the residence time was 40 hours.

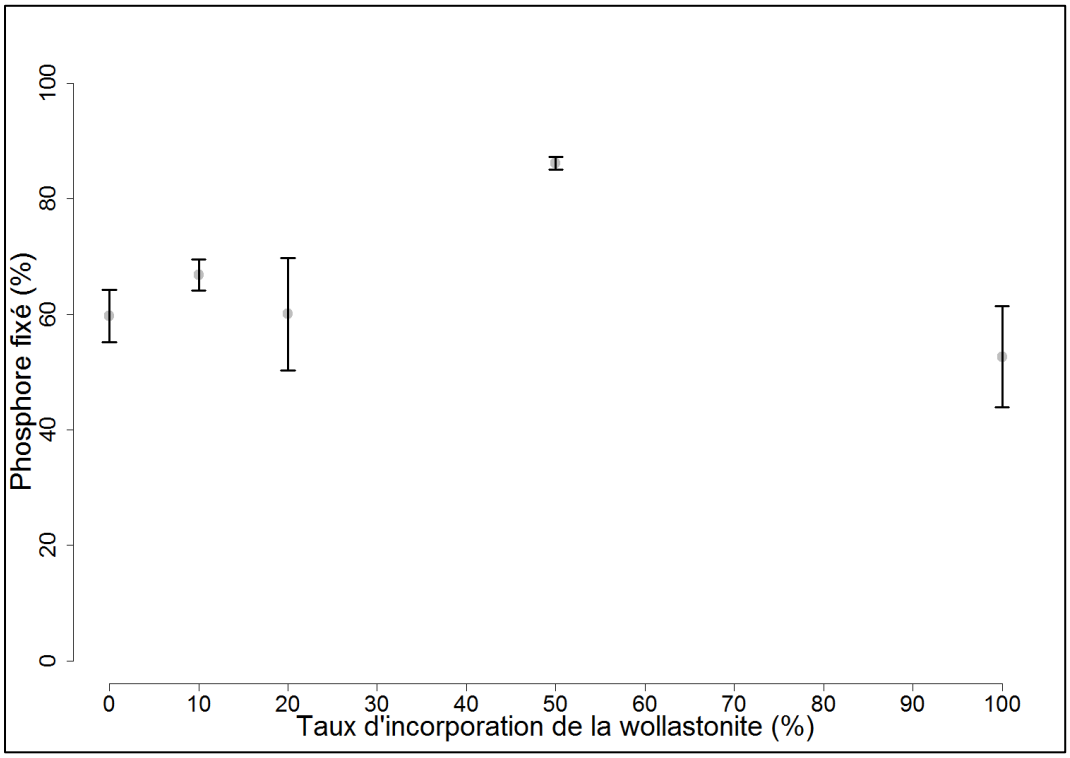

Figure 5. Courbe de fixation du phosphore d'un sol à différents taux d'incorporation du produit

The results obtained also indicate that the product and the control would have a similar phosphorus binding capacity (figure 6). Overall, the product fixed nearly 60% of the phosphorus that passed through the percolation column, compared to about 50% for the control product (P = 0.1365). These percentages represent in practice approximate fixation rates of 2,280 and 1,825 mg P/kg of product, respectively. For information, Hedström (2006) obtained a value of 850 mg P/kg for the use of wollastonite as a filter media.

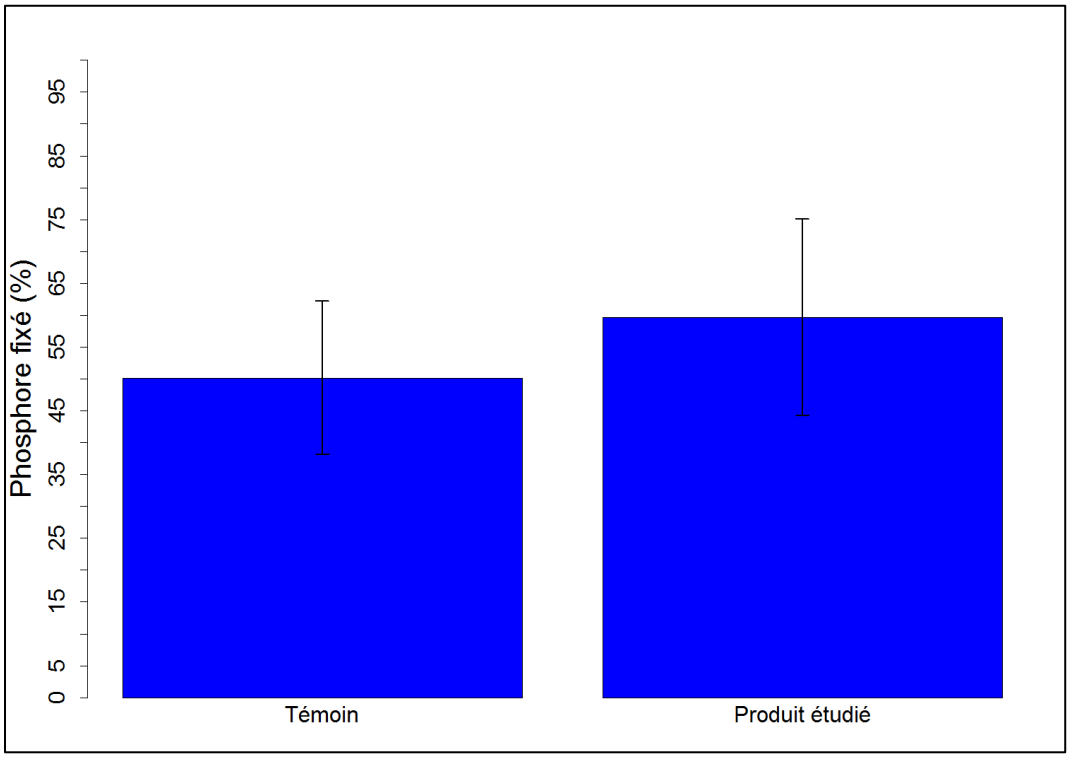

Figure 6. Comparaison de la capacité de fixation du phosphore entre le produit étudié et le produit témoin

5.1.4. Silica solubility

Table 4 summarizes the results of analyzes related to the silica content of the product compared to that of the control product and what has been found in the literature. The total silica value (SiO_2) comes from the analysis provided by the customer. The other analysis results come from AGAT Laboratories. Total extractable silicon was extracted on 0.5 g of dried sample by heating in the presence of aqua regia (2.0 mL HNO3 and 6.0 mL HCl) in a final volume of 50 mL. It has been analyzed by ICP-OES. The soluble silicon was extracted on 1 g of sample by stirring for 2 h in 50 mL of demineralized water. The conversion of the results into silica (SiO_2) comes from a calculation of conversion of the molecular masses by a multiplication factor of 2.14. The sample was filtered and analyzed by ICP-OES. The results in parentheses are expressed as a percentage of the total silica.

Tableau 4. Analyses de la silice du produit wollastonite et d'un produit témoin

Paramètre	Unité	Produit	Témoin	Littérature	Source
Silice totale (SiO_2)	%	29	-	21,4	Buck et coll. (2011)
Silicium extractible total	mg Si/kg	245	236	-	-
Silice extractible totale	mg SiO_2/kg	524 (0,2)	505 (0,2)	-	-
Silicium soluble à l'eau	mg Si/kg	360	***472***	-	-
Silice soluble à l'eau	mg SiO_2/kg	770 (0,3)	***1 010 (0,4)***	-	-

The results suggest a relatively higher total silica content of the product than was found in the literature for another deposit. However, the extractable silica (HCl) and water-soluble silica contents appear rather weak. Converted as a percentage of the total silica, they would indicate that only a very small proportion of the total silica would be soluble: 0.3% in the presence of demineralized water and 0.2% in the presence of aqua regia. Apparently, these results do not agree with the literature, but the extraction methods were different. In an evaluation of different methods of silica extraction, Buck et al. (2011) demonstrated that the silica content soluble in total silica content ranged from a minimum of 5% (citric acid extraction 5%) to a maximum of 28% (HCl 12.1 N + HF 48% extraction).) for wollastonite. To further investigate this issue, the product should eventually be analyzed with extraction methods comparable to those in the literature.

5.2. Results of the market study

In response to growing market demand, global production of wollastonite increased dramatically between 1960 and 2015 where global annual production exceeded 700,000 metric tons (mt) (Figure 7).

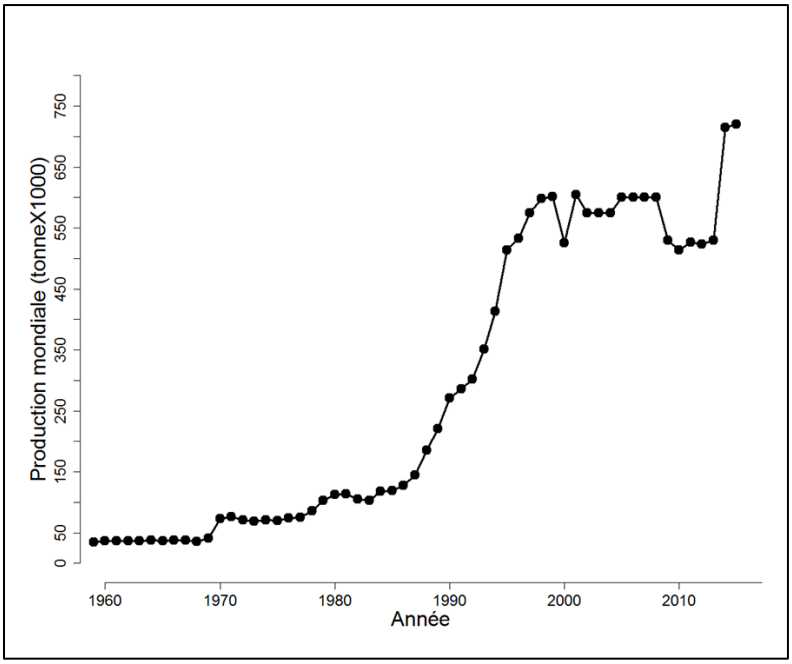

Figure 7. Évolution de la production mondiale de wollastonite (données : US Geological Survey)

In 2016, the two main producing countries were China with 500 000 mt/year and India with 150 000 mt/year (Figure 8). Recent data on the United States not being available, their production is estimated at 85 000 mt/year. Canada began wollastonite mining in Ontario in 2013 and is currently only a small player on the world stage.

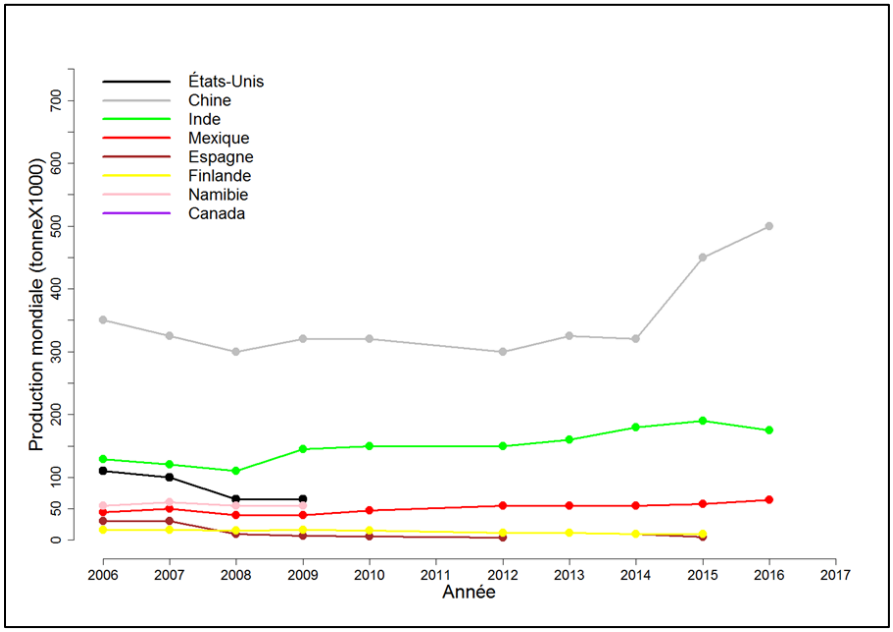

Figure 8. Évolution de l'extraction de wollastonite par pays (données : US Geological Survey)

With increasing market demand, the price of wollastonite fiber[2] has also increased, exceeding CAD 300 $/mt since 2012 (Figure 9).

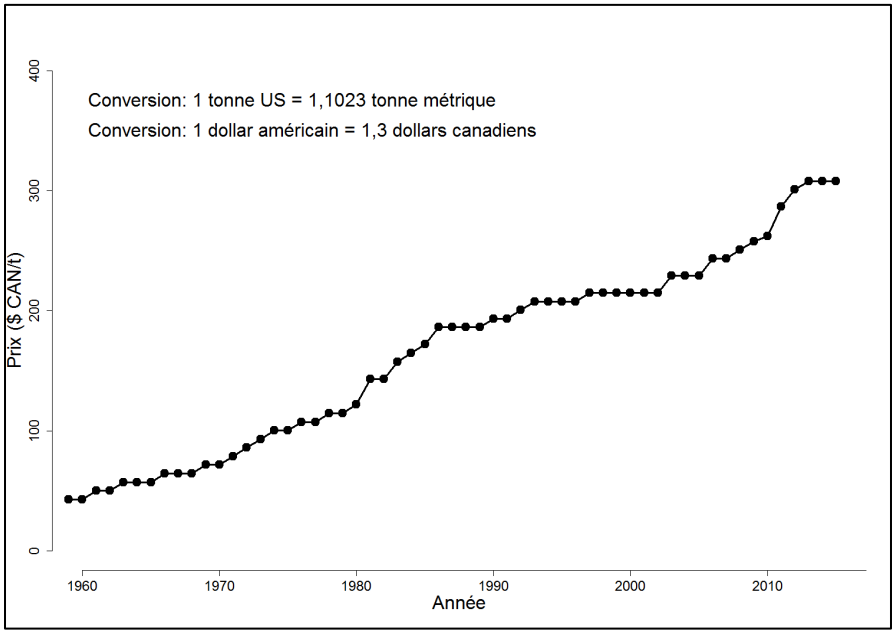

Figure 9. Évolution du prix de la fibre de wollastonite (données : US Geological Survey)

[2] Wollastonite fiber is a purified product of mineral impurities (mainly quartz, garnet or calcite) and should not be confused with wollastonite naturally occurring mineral species.

5.2.1. Revue des applications agricoles et environnementales

In an agricultural context, wollastonite has very promising applications for agriculture. The silica it contains may improve the yield of common plant crops such as corn and soybeans and improve the resistance of crops to biotic and abiotic stresses (Frew et al., 2018, Cooke and Leishman 2016). In addition, the calcium content of wollastonite makes it a very attractive product for agricultural and environmental applications. For comparison, Table 5 presents the CaO and SiO_2 contents of various commercial products based on wollastonite fiber[3] (source: INRS, 2016).

Tableau 5. Composition chimique de produits de fibre de wollastonite commercialisés

Produit	Composition (%)							
	CaO	**SiO_2**	**Al_2O_3**	**MgO**	**Fe_2O_3**	**Na_2O et K_2O**	**TiO_2**	**MnO**
Wollastonite pure (composition théorique)	48,3	51,7	0	0	0	0	0	0
NYADG (États-Unis)	46,15	51,6	0,34	0,38	0,77	0,05	0,05	0,16
Partek (Finlande)	45	52	0,4	0,6	0,2	0,11	<0,05	<0,01
Vansil (États-Unis)	44	50	1,8	1,5	0,3	0,2	-	<0,01
Kemolit (Inde)	47	49,5	0,6	-	0,43	0,13	Traces	0,29
HG Acicular (Chine)	>45	>50	<0,8	<0,1	<0,3	-	-	-
Mengshan NFW-XA (Chine)	>46	>49	<0,8	<0,8	<0,25	-	-	-

a) <u>Highlights regarding the use of wollastonite to fix phosphorus</u>

An untapped application with a lot of future is wastewater treatment. The phosphorus load in such waters can lead to eutrophication of the receiving surface water. Wollastonite is known to be able to fix phosphorus and could be used as a material for the construction of artificial wetlands for the removal of soluble phosphorus from wastewater (Brooks et al. 2000). Lagooning is a natural technique of wastewater treatment based on the principle of creating artificial environments in which wastewater will transit. Once loaded with phosphorus, wollastonite could be valorized in agriculture. For instance, according to a study by Cucarella et al. (2007), phosphorus-laden wollastonite improves barley yield.

[3] Second warning: Wollastonite fiber is a purified product of mineral impurities (mainly quartz, garnet or calcite) and should not be confused with wollastonite naturally occurring mineral species.

b) Highlights of the use of wollastonite in the slow-release fertilizer composition

The principle of a slow-release fertilizer is to increase its efficiency on the crop and to minimize the impact of its application on the environment. Despite this principle, the phosphorus utilization rate of mineral fertilizers is around 10 to 25% (Trenkel, 2010). So, a considerable part of the phosphorus applied with the mineral fertilizers is lost through leaching. The fixing property of wollastonite may help increase the efficiency of use of this nutrient in crops by intercepting excess phosphorus available after application of fertilizer.

c) Highlights of Silicon Samples from Different Cultures

The cultures differ from one another according to their needs in silicon. Canola, corn, flax, wheat, barley, soybeans, and alfalfa are considered to be crops with high silicon requirements. Major crops in the United States (corn, wheat, soybeans, barley) are thought to take up to 9.55 million metric tons of silicon per year (Tubana et al., 2016). The annual requirement for all cropland in this country is estimated at 21.1 million metric tons. Rice could even accumulate silicon at a rate of 500 kg Si/ha/year. Table 6 illustrates the silicon concentrations in different North American cultures adapted from the Hodson et al. study (2005).

Tableau 6. Teneur en silicium dans la biomasse de différentes productions végétales

Culture	Silicium (%)
Avoine	2,30 ± 2,25
Canola	0,32 ± 0,22
Soya	0,52 ± 0,65
Orge	1,86 ± 0,36
Blé	2,53 ± 3,14
Maïs	0,79 ± 0,15
Érable (acériculture)	1,04 ± 0,26
Bleuet	0,16 ± 0,29
Sapin baumier (sylviculture)	0,085
Épinette noire (sylviculture)	0,079
Tomate (maraîchage)	0,0071
Poivron (maraîchage)	0,05
Pâturin des prés (gazonnière)	1,68 ± 0,97
Fétuque rouge (gazonnière)	1,51 ± 1,05
Fétuque faux-roseau (gazonnière)	1,31 ± 0,89
Ray-grass anglais (gazonnière)	3,30 ± 4,05
Agrostide blanche (gazonnière)	3,15

To repeat the previous exercise in the Saguenay-Lac-Saint-Jean region, sampling data from Hodson et al. (2005) and data on average yields and areas cultivated between 2013 and 2017 from the Quebec Institute of Statistics were combined. The results obtained show the annual silicon removal of the main crops in the region (Figure 10). Thus, these crops alone would take annually nearly 2,000 mt of silicon from the region's soils.

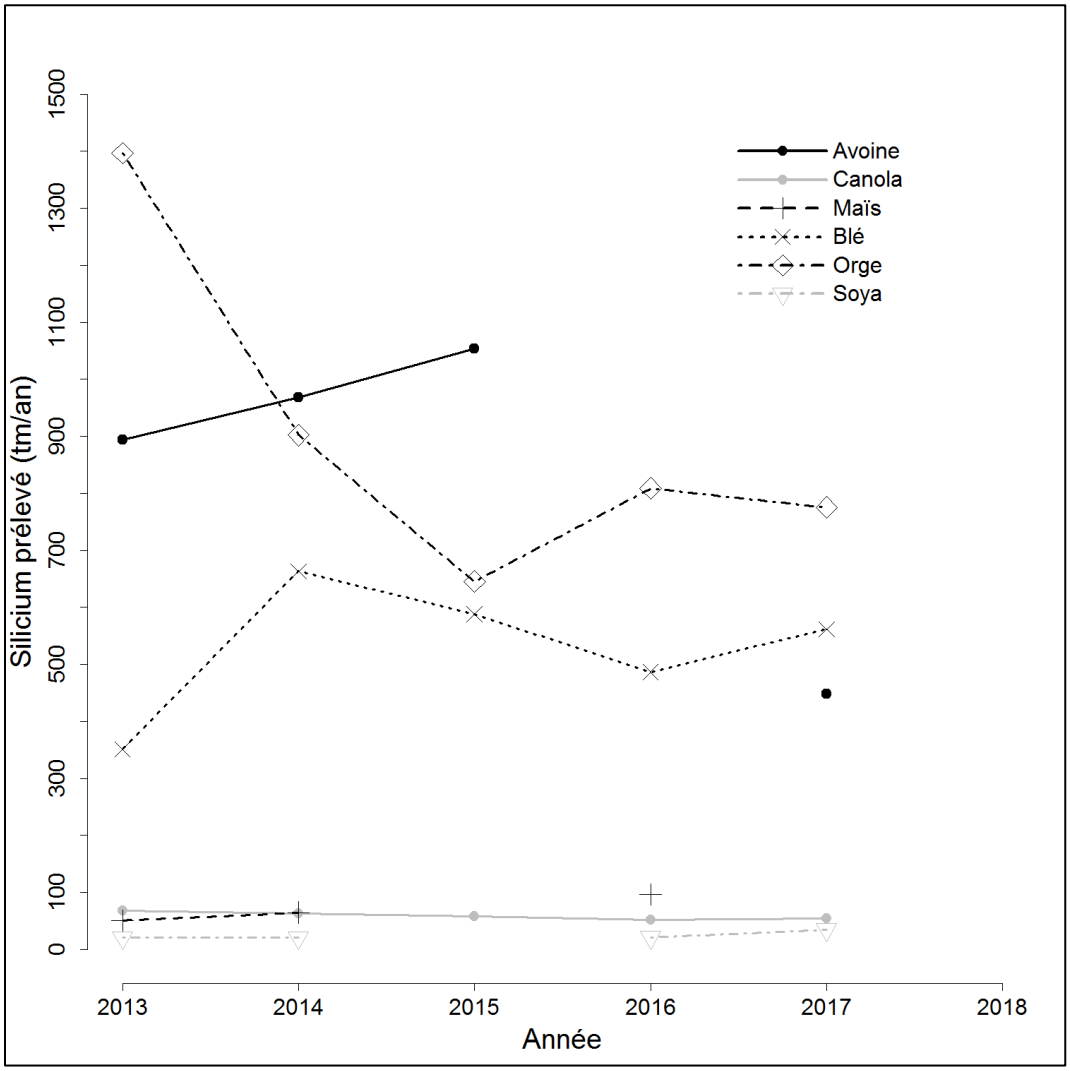

Figure 10. Prélèvement en silicium de cultures végétales du Saguenay–Lac-Saint-Jean

d) Silicon highlights and plant resistance to abiotic and biotic stress

Due to the increasing incidence of biotic (insect pests, diseases) and abiotic stresses (heat waves, droughts, soil salinization, heavy metal pollution, increased UV-B radiation) in the world, crop production is increasingly threatened. This is reflected in increased production costs associated with the prevention and control of abiotic and biotic stresses to minimize their impact on yields. Silicon has beneficial effects on plant physiology and can help reduce the effects of these types of stress (Frew et al., 2018, Cooke and Leishman, 2016). It promotes chlorophyll production and photosynthesis rate and stimulates root growth, thereby increasing biomass production. The plants therefore have better growth and thus have better resistance to the different stresses. One study found that the application of silicon as fertilizer would increase sugarcane production by 15-41% depending on the locality and that of rice by 17-30% (Haynes, 2014). In addition, silicon in the plant would reduce oxidative damage (formation of hydrogen peroxide, catalase, etc.) associated with abiotic stress. Finally, by improving the texture of the soil and its structure, wollastonite could reduce water losses and increase water stress resistance (Ma and Yamaji, 2008).

In powder form, wollastonite is formed of very fine crystals which may have insecticidal properties. These crystals act by obstructing the respiratory tract of the target insects, possibly causing their death. Thus, in animal breeding the product can be used for the control of maggots and flies. In some countries, wollastonite is used as an inert material for the manufacture of pesticides. By deduction, the granulometry and fineness of the product would be a parameter to be investigated to maximize the insecticidal performance on insect pests. In addition, wollastonite may also have an indirect effect on crop pests. By strengthening the cell walls of plants with silicon, the product would have the ability to discourage the activity of sucking and biting insects. However, these potentials are to be scientifically demonstrated.

5.2.2. Comparable Products

The application of wollastonite in agriculture is not widely practiced at present. This is due in part to the distribution of deposits worldwide, but also to the recent recognition of the benefits of silicon fertilization for plants. However, the current interest lies in the use of wollastonite as a liming product enriched in silicon. For example, Seven Springs Farm[4] offers wollastonite as a new product classified as a fertilizer and soil amendment with an organic certification. The company that distributes this product is Vanderbilt Minerals, located in Norwalk, Connecticut. The trade name of the product is VANSIL W-10 and the price of a skid of forty 50-pound (22.7 kg) bags is CAN $ 515 or CAN $ 0.57/kg.

[4] http://www.7springsfarm.com

Fedco Seeds Warehouse, based in Clinton, Maine, offers a product with unknown origins called 8207 Wollastonite. It is composed of 48% CaO and 52% SiO_2. Its retail price for a skid of forty 50-pound (22.7 kg) bags is CAN $ 850, or CAN $ 0.94/kg.

Canadian Wollastonite is an Ontario company operating and marketing a wollastonite deposit for environmental and agricultural applications. To date, the company's marketing efforts have helped develop the use of their products in soil remediation, agriculture, horticulture and forestry. One of their products is certified for use as fertilizer or soil amendment by the Organic Materials Review Institute (OMRI, 2015). The product is recommended to correct soil pH, as a source of silicon for plants and to reduce the incidence of diseases. It is also promoted for its hygroscopic and odor absorption properties and in farm litters. This product is sold at retail locations across Canada. Fairgreen Sod Farms[5] offers it at CAN $ 20 for a 10-kg bag (CAN 2.00/kg) or CAN $ 40 for a 25-kg bag (CAN $ 1.60/kg). The Spread-X company[6] offers wollastonite to agricultural producers at CAD $ 75 per tonne in bulk and also in bags of 25 kg to individuals at CAN $ 12,99 (CAN $ 0.52/kg). Finally, Rock Powder Solutions[7] offers a blend of wollastonite, mushroom compost and manure for use in vineyards. This company also aims to use wollastonite to improve the yield and potassium-calcium proportion of alfalfa.

5.2.3. Size of potential markets

The literature review demonstrated the potential of combining wollastonite with slow-mineralization fertilizers to increase the efficiency of these fertilizers in providing phosphorus to crops while minimizing leaching and erosion losses. It has also demonstrated that silicon can help improve soil properties (pH, structure), promote biomass production by meeting plant silicon requirements, and increase crop yield by reducing the impact of abiotic and biotics stresses.

a) Size of markets according to production

Maple syrup*:* In 2017, according to the Federation of Quebec Maple Syrup Producers, Quebec had more than 13,500 maple syrup producers grouped in 7,202 companies. The province of Quebec is recognized as the main maple syrup producing region of Canada and the world. In fact, Quebec production accounts for 91% of Canadian production and 71% of world production (FPAQ, 2017). During this period, the regions of the National Capital and Saguenay-Lac-Saint-Jean together produced 2 million kilograms of maple syrup with an average yield of 1.58 kg per taphole. The price of syrup is rising and the number of tapholes continues to grow, signs of a strong economy. The use of wollastonite in maple farms could contribute to improved syrup yield per taphole and optimize production as confirmed by the study of Juice et al. (2006).

5 https://www.fairgreensod.com/products/wollastonite
6 http://spreadx.ca/organic-growers/soil-amendment/
7 http://www.rockpowder.ca/field-results.html

Organic agriculture: According to data from the Federation of Organic Agriculture of Quebec (FABQ), organic farming in Quebec is expanding. Between 2011 and 2013, the areas cultivated under organic management increased significantly, from 41,629 ha in 2006 to 52,697 ha in 2013, an increase of 26%. One of the major challenges facing organic farming in Quebec today is to increase the volume of production to meet market demand. Silicon increases crop yield (Cooke and Leishman, 2016). The application of wollastonite, a natural product, could be a very interesting practice in this sector to improve the response of many crops to abiotic and biotic stresses, but also to improve their yields.

Lawn turf farms: Lawn turf is a mat of lawn taken intact with a thin layer of soil. The area of lawn turf grown for sale in Quebec was 10,802 ha in 2016 (Statistics Canada, 2018). The incorporation of wollastonite into lawn soil could improve the yield of grasses used in lawn turf production by its beneficial effect on soil texture, pH, phosphorus retention, and silicon and calcium input. In addition, this practice could make grasses more disease-resistant and more competitive with unwanted grasses, thereby reducing the use of herbicides and fertilizers.

Large-scale crops: Field crops are a very attractive market option for wollastonite. The maximum potential area where wollastonite could be applied to improve soil properties and crop yield is approximately 36,000 hectares. Figure 11 presents data on the scale of these productions from the Quebec Institute of Statistics (2018).

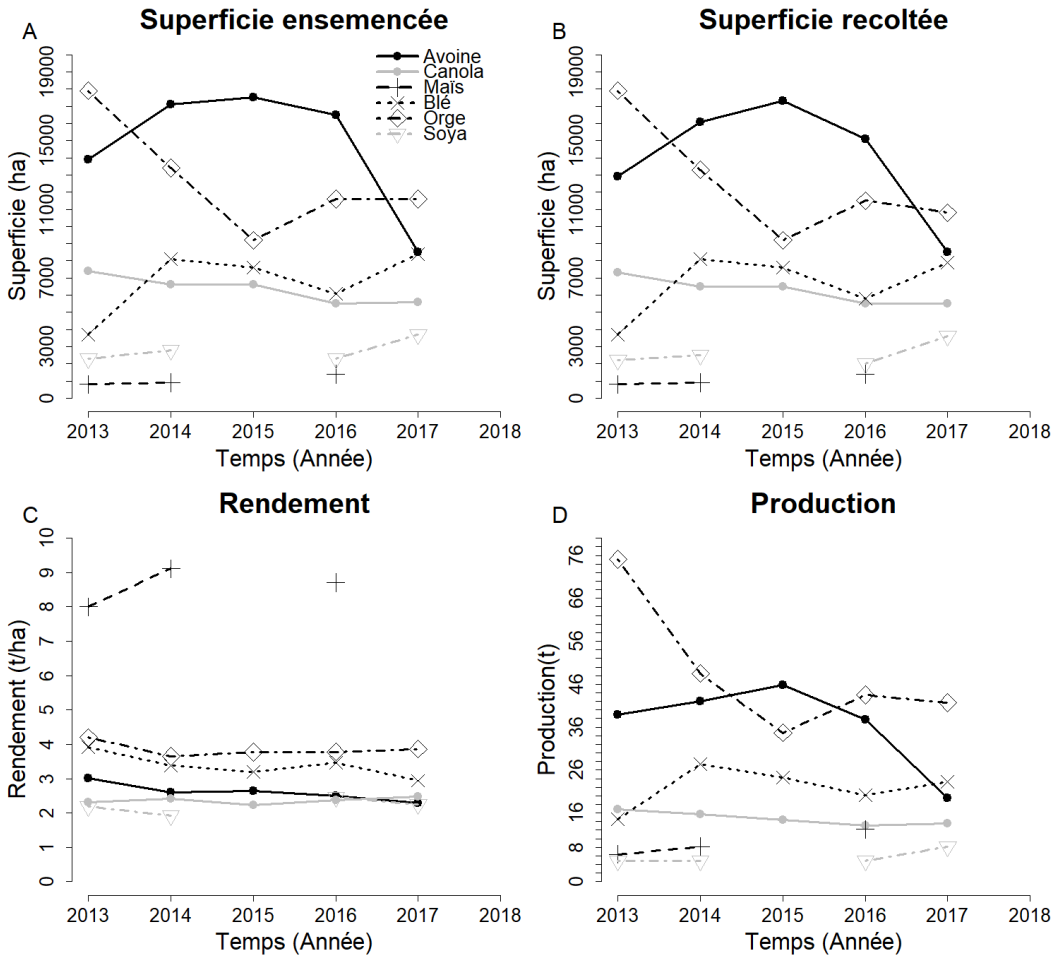

Figure 11. Données relatives aux grandes cultures au Québec

Forestry: Wollastonite can have very interesting applications in forestry. For example, it can increase biomass production, improve the regeneration of forests in operation or following a fire and prevent outbreaks of spruce budworm (TBE). Since wollastonite contains silica and calcium, two minerals that help increase biomass production, it could be applied to increase silvicultural yields. This becomes very interesting considering that the private forest production in Quebec occupies an area of 6,796,000 hectares with a gross market volume of 719.7 Mm^3, which represents about 2.6% of the gross domestic product of the province (MFFP, 2017). Wollastonite may also improve the survival and growth of young plants that are more likely to be affected by environmental stresses such as lack of nutrients or water after transplantation. The forest industry needs to invest in the regeneration of logged forests and wollastonite could make this intervention more efficient. Between 2006 and 2016, more than 700 000 ha were reforested in Quebec (MFFP, 2017).

On the other hand, insect pests cause huge economic losses for the forest industry. During epidemic periods, they destroy trees and, as a result, significantly reduce the productivity of the forest (Figure 12). These outbreaks can last for several years and affect several thousands of hectares with catastrophic consequences for local economies. For example, spruce budworm (TBE) is a very specialized insect that feeds mainly on balsam fir buds of the year. This level of specialization suggests that small variations in the physical characteristics of the foliage are very important for its food choice. In fact, TBE does not feed much on older needles that have a much higher level of mineralization and cellulose content. Leaf mineralization occurs as calcium oxalate (CaC_2O_4) crystals, calcium carbonate ($CaCO_3$) crystals, and amorphous silicon crystals embedded in the cell wall. The incorporation of these crystals increases the proportion of space occupied by the cell wall and studies show that the proportion of space occupied by the cell wall is directly proportional to the mechanical strength of the cell tissues (He et al., 2014). Thus, wollastonite, a mineral rich in calcium and silicon, could be applied aerially in the spruce forests to increase the level of needle mineralization and, as a result, reduce the susceptibility of trees to TBE herbivory-related damage.

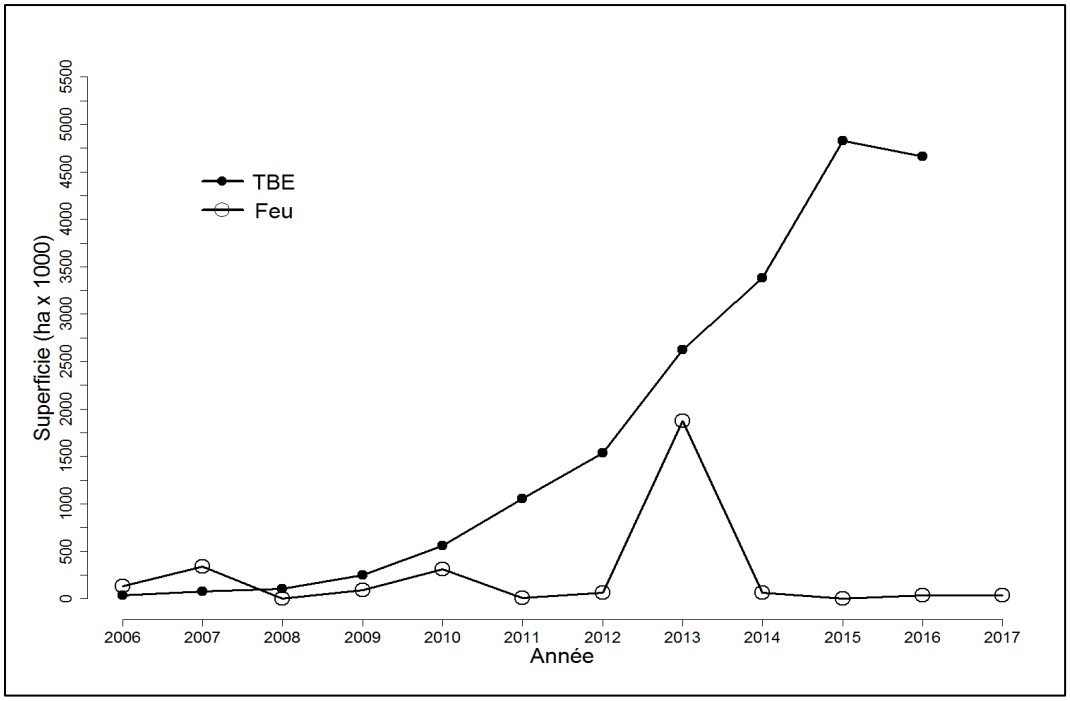

Figure 12. Superficie de forêt québécoise affectée par la dernière épidémie de TBE et par les incendies (source : base de données nationale sur les forêts)

b) Market size

Regional market: At the Saguenay–Lac-Saint-Jean scale, wollastonite could be applied to several crops. However, those with higher market potential are blueberries, alfalfa and cereals such as oats, barley and wheat (in green in Table 7). If wollastonite was applied to all crop areas at the maximum recommended doses, the demand would be 640 000 tons of product. Thus, to reach a percentage point of this demand, the supply should be 6 400 tons.

Tableau 7. Taille potentielle du marché au Saguenay-Lac-Saint-Jean

Secteur	Culture	Superficie* (ha)	Recommandations** min et max (t/ha)		Besoins selon recommandations (t)		Potentiel (%)
Fruits et petits fruits	Bleuet	36 480	2	3,5	72 960	127 680	19,9
	Canneberge	212			424	742	0,1
	Fraise	82			164	287	0,0
	Framboise	82			164	287	0,0
	Pomme	61			122	214	0,0
	Total	***36 917***			***73 834***	***129 210***	
Grandes cultures	Avoine	19 301	1,2	5	23 161	96 505	15,1
	Canola	7 576			9 091	37 880	5,9
	Luzerne	26 564			31 877	132 820	20,7
	Orge	16 321			19 585	81 605	12,7
	Soya	6 238			7 486	31 190	4,9
	Blé	12 254			14 705	61 270	9,6
	Maïs	6 485			7 782	32 425	5,1
	Seigle	323			388	1 615	0,3
	Total	***95 062***			***114 074***	***475 310***	
Légumes	Betterave	4	4	10	16	40	0,0
	Carotte	84			336	840	0,1
	Chou	77			308	770	0,1
	Citrouille	47			188	470	0,1
	Maïs sucré	79			316	790	0,1
	Tomate	21			84	210	0,0
	Total	***312***			***1 248***	***3 120***	
Pomme de terre		3 053	4	10	12 212	30 530	4,8
Pépinières		10	2	3,5	20	35	0,0
Gazonnières		484	2,5	4	1 210	1 936	0,3
Total		***135 838***			***202 598***	***640 141***	***100***

* Source : Statistique Canada

** Source : tableau 3

Extra-regional Market: Outside the region, wollastonite would have potential markets in Quebec and the Maritimes in Canada. These regions are geographically close to the production site and contain large areas dedicated to agriculture (Tables 8 and 9). It appears that Quebec alone presents an interesting potential market because of the agricultural plains of the St. Lawrence Valley with more than 5 million hectares in accessible crops. The Maritimes market is smaller with only 1 million hectares.

Tableau 8. Taille potentielle du marché au Québec

Secteur	Culture	Superficie* (ha)	Recommandations** min et max (t/ha)		Besoins selon recommandations (t)		Potentiel (%)
Fruits et petits fruits	Bleuet	93 728	2	3,5	187 456	328 048	1,2
	Canneberge	11 214			22 428	39 249	0,1
	Fraise	6 069			12 138	21 242	0,1
	Framboise	1 581			3 162	5 534	0,0
	Pomme	19 250			38 500	67 375	0,2
	Total	***131 842***			***263 684***	***461 447***	
Grandes cultures	Avoine	326 880	1,2	5	392 256	1 634 400	6,0
	Canola	46 906			56 287	234 530	0,9
	Luzerne	929 616			1 115 539	4 648 080	17,0
	Orge	198 750			238 500	993 750	3,6
	Soya	1 393 474			1 672 169	6 967 370	25,4
	Blé	349 747			419 696	1 748 735	6,4
	Maïs	1 843 864			2 212 637	9 219 320	33,7
	Seigle	27 985			33 582	139 925	0,5
	Total	***5 117 222***			***6 140 666***	***25 586 110***	
Légumes	Asperge	851	4	10	3 404	8 510	0,0
	Betterave	3 021			12 084	30 210	0,1
	Brocoli	4 891			19 564	48 910	0,2
	Carotte	10 801			43 204	108 010	0,4
	Céleri	1 625			6 500	16 250	0,1
	Chou	5 918			23 672	59 180	0,2
	Chou-fleur	2 452			9 808	24 520	0,1
	Citrouille	2 379			9 516	23 790	0,1
	Maïs sucré	26 113			104 452	261 130	1,0
	Pois vert	13 544			54 176	135 440	0,5
	Tomate	1 706			6 824	17 060	0,1
	Total	***73 301***			***293 204***	***733 010***	
Pomme de terre		54 716	4	10	218 864	547 160	2,0
Pépinières		7 224	2	3,5	14 448	25 284	0,1
Gazonnières		10 802	2,5	4	27 005	43 208	0,2
Total		***5 395 107***			***6 957 871***	***27 396 219***	***100***

* Source : Statistique Canada

** Source : tableau 3

Tableau 9. Taille potentielle du marché dans les Maritimes

Secteur	Culture	Superficie* (ha)	Recommandations** min et max (t/ha)		Besoins selon recommandations (t)		Potentiel (%)
Fruits et petits fruits	Bleuet	144 481	2	3,5	288 962	505 684	8,6
	Canneberge	1 151			2 302	4 029	0,1
	Fraise	1 647			3 294	5 765	0,1
	Framboise	206			412	721	0,0
	Pomme	7 471			14 942	26 149	0,4
	Total	***154 956***			***309 912***	***542 346***	
Grandes cultures	Avoine	61 964	1,2	5	74 357	309 820	5,3
	Canola	2 127			2 552	10 635	0,2
	Luzerne	160 861			193 033	804 305	13,7
	Orge	129 092			154 910	645 460	11,0
	Soya	102 613			123 136	513 065	8,7
	Blé	79 647			95 576	398 235	6,8
	Maïs	101 812			122 174	509 060	8,7
	Seigle	4 258			5 110	21 290	0,4
	Total	***642 374***			***770 849***	***3 211 870***	
Légumes	Asperge	103	4	10	412	1 030	0,0
	Betterave	186			744	1 860	0,0
	Brocoli	142			568	1 420	0,0
	Carotte	1 041			4 164	10 410	0,2
	Céleri	42			168	420	0,0
	Chou	602			2 408	6 020	0,1
	Chou-fleur	39			156	390	0,0
	Citrouille	699			2 796	6 990	0,1
	Maïs sucré	1 028			4 112	10 280	0,2
	Pois vert	180			720	1 800	0,0
	Tomate	198			792	1 980	0,0
	Total	***4 260***			***17 040***	***42 600***	
Pomme de terre		205 705	4	10	822 820	2 057 050	35,1
Pépinières		739	2	3,5	1 478	2 587	0,0
Gazonnières		2 559	2,5	4	6 398	10 236	0,2
Total		***1 010 593***			***1 928 496***	***5 866 689***	***100***

* Source : Statistique Canada

** Source : tableau 3

Pour la province du Québec, le produit aurait une niche plus appréciable auprès des cultures de la luzerne, du maïs et du soya, alors que dans les Maritimes, le bleuet, l'orge et la pomme de terre s'ajoutent à cette liste (en vert dans les tableaux). Au Québec, pour rejoindre un point de pourcentage de la demande maximale, l'offre devrait être de 274 000 tonnes, tandis qu'elle serait de 59 000 tonnes dans les Maritimes.

5.2.4. Product receptivity in the market

A survey was developed and submitted to agricultural stakeholders in the Saguenay-Lac-Saint-Jean region to find out how receptive they are to a new product in agriculture. Out of a total of 22 stakeholders surveyed, 9 responded to the SurveyMonkey questionnaire. The analysis of the survey results is given in Appendix 4.

In sumary, 7 out of 9 respondents were involved in the sale of agricultural inputs and all were very supportive of using a new product for soil amendment, especially if the product offered more than nutrients than lime traditionally applied in the region. In this respect, the appreciable levels of silicon, sulfur, boron, magnesium and manganese of wollastonite were of great interest to the respondents, beyond the simple neutralizing power of the product. For field applications, the particulate form was preferred to the granular form in the survey results. In addition, respondents indicated a product interest for all crops in the region, but also more specifically for cereals, grasslands and lucerne, row crops (corn and soybeans) and vegetable production. Finally, many of these respondents were interested in receiving product for testing in plots side by side at agricultural producers. In the comments made by the respondents, the question of the price of the product was recurrent. According to their experience, the price of the product should be competitive with that of lime (currently $ 45 per ton in the region, depending on the delivery distance) to break into the market. In addition, agricultural producers can receive financial support for liming their land under a MAPAQ program[8]. They must demonstrate that the pH of their land is less than 6 units of pH and must bear the costs of a minimum volume.

[8] https://www.mapaq.gouv.qc.ca/en/Productions/md/programmesliste/developpementregional/Pages/Soutiendrainagechaulageterres.aspx

6. CONCLUSION

As mentioned in Section 3 at the beginning of the report, the project aimed specifically at characterizing the wollastonite product according to regulatory requirements for agricultural applications, probing potentially interesting markets for it and developing research programming in order to allow it to be upgraded according to regulatory requirements and markets.

The characterization results of the customer supplied wollastonite samples clearly indicate that the product could be BNQ certified or registered under the Fertilizers Act. The safety of the product was demonstrated by a germination and elongation test with barley. The product has a neutralizing power and efficiency comparing it advantageously with current lime products. It also has appreciable levels of major and minor elements (Ca, S, B, Mg and Mn) essential for plant nutrition. In addition, the scientific literature indicates that wollastonite has the ability to retain and fix soluble phosphorus. It also indicates that the material could be used in the manufacture of slow-mineralizating fertilizer. Another obvious benefit of wollastonite would be its availability of silicon for crops as studies show significant needs in this element for plants that are not filled with commercial fertilizers. Finally, a deeper interest in the product could come from the knowledge that silicon contributes to the strengthening of plant resistance to abiotic and biotic stress.

From a market perspective, depending on the types of agricultural and forestry production, wollastonite has a greater potential for maple production (maple syrup production), organic agriculture, sod production, large-scale crops (cereals, corn and soybeans) and boreal forestry (spruce budworm control and post-fire regeneration). The market size per agricultural production area (supply to reach a percentage point of the maximum demand) would be of the order of 6 400 tonnes for the Saguenay-Lac-Saint-Jean region, 274 000 tons for the province Quebec and 59,000 tons for the Maritime Provinces of Canada. More specifically, blueberry would have increased potential for regional marketing and potatoes would be an attractive market for the Maritimes.

Regarding the definition of a research program, this will be the subject of another document produced for the client. This programming will take into account the context developed in this report. It will also consider the scientific content of other funding applications to NSERC (see Appendix 5). The main axes of the program will be environmental (development of phosphorus fixation potential), agricultural (optimization of potato production, cereals, organic and sod farms) and silvicultural (maximization of maple and blueberry production and biological control of the spruce budworm). In the shorter term, the effects of particle size and chemical extraction method on the solubility of silicon will be studied in the laboratory to solve some uncertainties raised by the characterization of the product.

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ANNEXE 1.
CERTIFICATS D'ANALYSES POUR LA WOLLASTONITE

AGAT Laboratoires

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TEL (418)266-5511
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À L'ATTENTION DE: **Régis Pilote**

N° DE PROJET: **MI-2098**

N° BON DE TRAVAIL: **18A394791**

ANALYSE DES SOLS VÉRIFIÉ PAR: **Frédéric Drouin, chimiste**

DATE DU RAPPORT: **2018-10-30**

VERSION*: **1**

NOMBRE DE PAGES: **7**

Si vous désirez de l'information concernant cette analyse, S.V.P. contacter votre chargé de projets au (418) 266-5511.

NOTES

Nous disposerons des échantillons dans les 30 jours suivants les analyses. S.V.P. Contactez le laboratoire si vous désirez avoir un délai d'entreposage.

AGAT Laboratoires

350, rue Franquet
Québec, Québec
CANADA G1P 4P3
TEL (418)266-5511
FAX (418)653-2335
http://www.agatlabs.com

Certificat d'analyse

N° BON DE TRAVAIL: 18A394791

N° DE PROJET: MI-2098

NOM DU CLIENT: AGRINOVA

À L'ATTENTION DE: Régis Pilote

PRÉLEVÉ PAR:

LIEU DE PRÉLÈVEMENT:

Analyses inorganiques - Efficacité / Indice de valeur agricole

DATE DE RÉCEPTION: 2018-10-09

DATE DU RAPPORT: 2018-10-30

	IDENTIFICATION DE L'ÉCHANTILLON:			Produit W	Produit témoin
	MATRICE:			Solide	Solide
	DATE D'ÉCHANTILLONNAGE:				
Paramètre	Unités	C / N	LDR	9609522	9609570
Efficacité	%		NA	67	46
Indice de valeur agricole (Base humide)	%		NA	35	15
Pourcentage passant 0,150 mm	%		NA	17.6	14.7
Pourcentage passant 2 mm	%		NA	100	67.0
Pouvoir neutralisant	% - ECC		2.0	51.7	34.6
Solides totaux	mg/kg		2000	999000	960000

Commentaires: LDR - Limite de détection rapportée; C / N - Critères Normes

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Certificat d'analyse

N° BON DE TRAVAIL: 18A394791

N° DE PROJET: MI-2098

NOM DU CLIENT: AGRINOVA

À L'ATTENTION DE: Régis Pilote

PRÉLEVÉ PAR:

LIEU DE PRÉLÈVEMENT:

Analyses inorganiques - Matières résiduelles fertilisantes

DATE DE RÉCEPTION: 2018-10-09

DATE DU RAPPORT: 2018-10-30

IDENTIFICATION DE L'ÉCHANTILLON:				Produit W		Produit témoin
MATRICE:				Solide		Solide
DATE D'ÉCHANTILLONNAGE:						
Paramètre	Unités	C / N	LDR	9609522	LDR	9609570
Arsenic	mg/kg		0.7	<0.7	0.7	<0.7
Bore	mg/kg		20	43	200	287
Cadmium	mg/kg		0.9	<0.9	0.9	<0.9
Chrome	mg/kg		2	<2	2	<2
Cobalt	mg/kg		2	3	2	7
Cuivre	mg/kg		30	<30	30	<30
Magnésium	mg/kg		20	264	20	691
Mercure	mg/kg		0.04	<0.04	0.04	<0.04
Molybdène	mg/kg		2	3	2	<2
Nickel	mg/kg		2	5	2	11
Plomb	mg/kg		5	37	5	<5
Sélénium	mg/kg		0.5	<0.5	0.5	<0.5
Sodium	mg/kg		100	<100	100	<100
Zinc	mg/kg		50	<50	50	<50
Bicarbonates	mg/kg - CaCO3		5.0	48.7	5.0	110
Phosphore total	mg/kg - P		40	<40	40	<40
Carbonates	mg/kg - CaCO3		5.0	33.0	5.0	16.3
pH	pH		NA	9.86	NA	9.20
Soufre total	mg/kg		200	2170	200	5560
Pouvoir neutralisant	% - ECC		2.0	51.7	2.0	34.6
Rapport Carbone / Azote	NA		0.1	1390	0.1	1750
Magnésium soluble à l'eau	mg/kg (BH)		0.02	<0.02	0.02	<0.02
K2O total	mg/kg		70	<70	70	181
Humidité	%		0.2	<0.2	0.2	4.0
Silice	mg/kg		320	524	320	505
Silicium	mg/kg		150	245	150	236
Silicium soluble à l'eau	mg/kg		150	360	150	472
Vérif. Chimiste / Report reviewer Montreal	10/18/2018			Y. Chouinard		Y. Chouinard

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Certificat d'analyse

N° BON DE TRAVAIL: 18A394791

N° DE PROJET: MI-2098

NOM DU CLIENT: AGRINOVA

À L'ATTENTION DE: Régis Pilote

PRÉLEVÉ PAR:

LIEU DE PRÉLÈVEMENT:

Analyses inorganiques - Matières résiduelles fertilisantes

DATE DE RÉCEPTION: 2018-10-09

DATE DU RAPPORT: 2018-10-30

	IDENTIFICATION DE L'ÉCHANTILLON:			Produit W		Produit témoin
	MATRICE:			Solide		Solide
	DATE D'ÉCHANTILLONNAGE:					
Paramètre	Unités	C / N	LDR	9609522	LDR	9609570
Phosphore assimilable (P) (AOAC 993.31)	mg/Kg		50	<50	50	<50
K soluble (AOAC 983.02)	mg/Kg		50	<50	50	<50
Phosphore assimilable (P2O5) (AOAC 993.31)	mg/kg		100	<100	100	<100
Potassium soluble (K2O) AOAC 983.02 (mg/kg)	mg/kg		100	<100	100	<100

Commentaires: LDR - Limite de détection rapportée; C / N - Critères Normes

9609522-9609570 Les analyses du soufre, pouvoir neutralisant, phosphore total, P2O5, K2O soluble, silice totale et silice soluble sont réalisées au laboratoire AGAT de Montréal.
Le résultat de du silicium total devrait être supérieur ou égal à celui du silicium soluble à l'eau. Les résultats sont acceptables car ils se situent à l'intérieur de l'écart analytique pour ces deux paramètres.

Une LDR plus élevée indique qu'une dilution a été effectuée afin de réduire la concentration des analytes ou de réduire l'interférence de la matrice.
Les résultats d'analyses ci-haut sont, à moins d'indication contraire à même le nom du paramètre, exprimés sur base sèche.

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Contrôle de qualité

NOM DU CLIENT: AGRINOVA | **N° BON DE TRAVAIL: 18A394791**

N° DE PROJET: MI-2098 | **À L'ATTENTION DE: Régis Pilote**

PRÉLEVÉ PAR: | **LIEU DE PRÉLÈVEMENT:**

Analyse des Sols

Date du rapport:			DUPLICATA			MATÉRIAU DE RÉFÉRENCE				BLANC FORTIFIÉ			ÉCH. FORTIFIÉ		
PARAMÈTRE	Lot	N° éch.	Dup #1	Dup #2	% d'écart	Blanc de méthode	% Récup.	Limites		% Récup.	Limites		% Récup.	Limites	
								Inf.	Sup.		Inf.	Sup.		Inf.	Sup.
Analyses inorganiques - Matières résiduelles fertilisantes															
Arsenic	9609570	9609570	<0.7	<0.7	NA	< 0.7	82%	80%	120%	97%	80%	120%	97%	70%	130%
Bore	9609570		NA	NA	NA	< 20	93%	80%	120%	89%	80%	120%	NA	70%	130%
Cadmium	9609570	9609570	<0.9	<0.9	NA	< 0.9	96%	80%	120%	98%	80%	120%	102%	70%	130%
Chrome	9609570	9609570	<2	<2	NA	< 2	95%	80%	120%	107%	80%	120%	117%	70%	130%
Cobalt	9609570	9609570	7	5	NA	< 2	96%	80%	120%	109%	80%	120%	114%	70%	130%
Cuivre	9609570	9609570	<30	<30	NA	< 30	91%	80%	120%	98%	80%	120%	92%	70%	130%
Magnésium	9609570	9609570	691	625	10.0	< 20	96%	80%	120%	88%	80%	120%	109%	70%	130%
Mercure	9609522	9609522	<0.04	<0.04	NA	< 0.04	106%	80%	120%	92%	80%	120%	NA	70%	130%
Molybdène	9609570	9609570	<2	<2	NA	< 2	99%	80%	120%	94%	80%	120%	97%	70%	130%
Nickel	9609570	9609570	11	9	13.8	< 2	84%	80%	120%	98%	80%	120%	98%	70%	130%
Plomb	9609570	9609570	<5	<5	NA	< 5	92%	80%	120%	105%	80%	120%	105%	70%	130%
Sélénium	9609570	9609570	<0.5	<0.5	NA	< 0.5	103%	80%	120%	102%	80%	120%	101%	70%	130%
Sodium	9609570	9609570	<100	106	NA	< 100	83%	80%	120%	91%	80%	120%	109%	70%	130%
Zinc	9609570	9609570	<50	<50	NA	< 50	97%	80%	120%	103%	80%	120%	102%	70%	130%
Bicarbonates	1		243	245	0.8	< 5.0									
Carbonates	1		0.60	0.70	NA	< 5.0									
pH	9598202		7.45	7.52	0.9		101%	95%	105%	NA			NA		
Soufre total			NA	NA	0.0	< 200	92%	80%	120%	88%	80%	120%	98%	80%	120%
Pouvoir neutralisant			NA	NA	0.0	< 2.0	99%	80%	120%	NA	80%	120%	NA	80%	120%
Humidité	9603556		75.5	75.7	0.3	< 0.2	101%	80%	120%	NA			NA		
Silicium	1					< 150	NA	80%	120%	105%	80%	120%	NA	80%	120%
Silicium soluble à l'eau	1					< 150	NA	80%	120%	105%	80%	120%	NA	80%	120%
Phosphore assimilable (P) (AOAC 993.31)	9609570	9609570	<50	<50	NA	< 50	NA	80%	120%	98%	80%	120%	89%	80%	120%
K soluble (AOAC 983.02)	9609570	9609570	<50	<50	NA	< 50	NA	80%	120%	88%	80%	120%	96%	80%	120%

Commentaires: NA : Non applicable
NA dans l'écart du duplicata indique que l'écart n'a pu être calculé car l'un ou les deux résultats sont < 5x LDR.
NA dans le pourcentage de récupération de l'échantillon fortifié indique que le résultat n'est pas fourni en raison de l'hétérogénéité de l'échantillon ou de la concentration trop élevée par rapport à l'ajout.
NA dans le blanc fortifié ou le MRC indique qu'il n'est pas requis par la procédure.
Le pourcentage de récupération du MRC peut être en dehors du critère d'acceptabilité de 80-120%, s'il est conforme à l'écart du certificat du matériau de référence

Certifié par:

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Sommaire de méthode

NOM DU CLIENT: AGRINOVA **N° BON DE TRAVAIL: 18A394791**

N° DE PROJET: MI-2098 **À L'ATTENTION DE: Régis Pilote**

PRÉLEVÉ PAR: **LIEU DE PRÉLÈVEMENT:**

PARAMÈTRE	PRÉPARÉ LE	ANALYSÉ LE	AGAT P.O.N.	RÉFÉRENCE DE LITTÉRATURE	TECHNIQUE ANALYTIQUE
Analyse des Sols					
Efficacité	2018-10-16	2018-10-16	INOR-161-6031F, non accrédité MDDELCC	BNQ 0419-090/2005	TAMISAGE
Indice de valeur agricole (Base humide)	2018-10-17	2018-10-17	NA	BNQ 0419-090/2005	CALCUL
Pourcentage passant 0,150 mm	2018-10-16	2018-10-16	INOR-161-6031F, non accrédité MDDELCC	MA. 100 - Gran. 2.0	TAMISAGE
Pourcentage passant 2 mm	2018-10-16	2018-10-16	INOR-161-6031F, non accrédité MDDELCC	MA. 100 - Gran. 2.0	TAMISAGE
Pouvoir neutralisant	2018-10-16	2018-10-17	INOR-101-6060F	MA. 110 - ACISOL 1.0	TITRAGE
Solides totaux	2018-10-12	2018-10-13	INOR-161-6006F	MA. 100 - S.T. 1.1	GRAVIMÉTRIE
Arsenic	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Bore	2018-10-11	2018-10-12	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Cadmium	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Chrome	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Cobalt	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Cuivre	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Magnésium	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Mercure	2018-10-11	2018-10-11	MET-161-6107F	EPA 245.5	VAPEUR FROIDE/AA
Molybdène	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Nickel	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Plomb	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Sélénium	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Sodium	2018-10-11	2018-10-11	MET-161-6106F, 6108F, non accréditable MDDELCC	MA. 200 - Mét 1.2	ICP/MS
Zinc	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	ICP/MS
Bicarbonates	2018-10-10	2018-10-10	INOR-161-6027F, non accrédité MDDELCC	SM 4500-CO2 D	CALCUL
Phosphore total	2018-10-23	2018-10-25	INOR-101-6048F	MA.300-NTPT 2.0	COLORIMÉTRIE
Carbonates	2018-10-10	2018-10-10	INOR-161-6027F, non accrédité MDDELCC	SM 4500-CO2 D	CALCUL
pH	2018-10-10	2018-10-10	INOR-161-6009F	MA. 100 - pH 1.1	ÉLECTROMÉTRIE
Soufre total	2018-10-16	2018-10-16	INOR-101-6056F	MA.310-CS 1.0	COMBUSTION
Pouvoir neutralisant	2018-10-16	2018-10-17	INOR-101-6060F	MA. 110 - ACISOL 1.0	TITRAGE
Rapport Carbone / Azote	2018-10-16	2018-10-16	INOR-161-6006F, 6071F	MA. 100 - S.T. 1.1, MA. 300 - NTPT 2.0	CALCUL
Magnésium soluble à l'eau	2018-10-15	2018-10-15	AOAC 937.02	AOAC 937.02	ICP-MS
K2O total	2018-10-11	2018-10-11	MET-161-6106F, 6108F	MA. 200 - Mét 1.2	CALCUL
Humidité	2018-10-12	2018-10-13	INOR-161-6006F	MA. 100 - S.T. 1.1	GRAVIMÉTRIE
Silice	2018-10-16	2018-10-16	MET-101-6107F, non accrédité par le MDDELCC	MA. 200 - Mét 1.2 ; MA. 203 - Mét 3.2	ICP/OES
Silicium	2018-10-16	2018-10-16	MET-101-6107F, non accrédité par le MDDELCC	MA. 200 - Mét 1.2 ; MA. 203 - Mét 3.2	ICP/OES
Silicium soluble à l'eau	2018-10-16	2018-10-16	MET-101-6107F; Non accrédité par le MDDELCC		ICP/OES
Vérif. Chimiste / Report reviewer Montreal			NA	NA	
Phosphore assimilable (P) (AOAC 993.31)	2018-10-17	2018-10-17	MET-101-6107F, non accrédité par MDDELCC	AOAC 993.31 modifié	ICP/OES
K soluble (AOAC 983.02)	2018-10-17	2018-10-17	MET-101-6107F	AOAC 983.02 modifié	ICP/OES

AGAT Laboratoires

350 rue Franquet
Québec, QC
G1P 4P3
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Tél.: 418.266.5511 · Téléc.: 418.653.2335

Chaîne de traçabilité ▪ Environnement

À l'usage exclusif du laboratoire
Température à l'arrivée: 20°C
Bon de travail AGAT: 18A394791
Notes:

Information du client
Compagnie : Agrinova
Adresse : 640, rue Côté Ouest, Alma, QC, G8B 7S8.
Téléphone : 418-480-3300 Téléc. :
Projet : MI-2098
Lieu de prélèvement :
Prélevé par :

Rapport envoyé à
1. Nom: Régis Pilote
Courriel: regis.pilote@agrinova.qc.ca
2. Nom:
Courriel:

Format de rapport
☐ **Portrait** *un échantillon par page*
☐ **Paysage** *plusieurs échantillons/page*
☐ Un échantillon par bon de travail

Délais d'analyse requis (jours ouvrables)
Environnemental: ✓
Régulier: ☑ 5 à 7 jours
Urgent: ☐ < 12 heures ☐ 24 heures ☐ 48 heures ☐ 72 heures
Haute Résolution:
Régulier: ☐ 10 à 15 jours
Urgent: ☐ < 10 jours
Date Requise:

Facturé à Même adresse : ☑ Oui ☐ Non
Compagnie :
Contact :
Courriel :
Adresse :
Bon de commande : Soumission :

Critères à respecter
☐ PRTC ☐ Eau consom. ☐ RQEP ☐ RESC
☐ CCME ☐ Eau résurg. ☐ Autre :

LES ÉCHANTILLONS REÇUS APRÈS 16 H SERONT ENREGISTRÉS COMME ÉTANT REÇUS LE JOUR OUVRABLE SUIVANT.

Commentaires:

Matrice (légende)
S Sol — B Boue — ES Eau de surface
SL Solide — EU Eau usée — EF Effluent
SE Sédiment — ST Eau souterraine — AF Affluent
EP Eau potable (Note pour réseau : Veuillez fournir votre formulaire MDDELCC) — A Air

IDENTIFICATION DE L'ÉCHANTILLON	DATE DE PRÉLÈVEMENT	MATRICE	NOMBRE DE CONTENANTS
Produit N		solide	2
Produit témoin		solide	2

BTEX ☐ HAM ☐ COV: HAC-HAM ☐ THM ☐
HAP
Hydrocarbures pétroliers C10-C50
AGR ☐ Chlorobenzènes ☐ Phtalates ☐
BPC : Congénères ☐ Arocolor ☐
Éthylène glycol ☐ Glycols (balayage) ☐
Formaldéhyde
Huiles et graisses : Minérales ☐ Totales ☐
Pesticides (spécifier) :
Phénols (GC-MS) ☐ Indice phénolique (4AAP) ☐
6 métaux (Cd, Cr, Cu, Ni, Pb, Zn)
13 Métaux TC - Sol ☐ 16 Métaux TC - Eau ☐
Métaux (spécifier): As, Cd, Cr, Cu, Mo, Ni, Zn, Sol, BO, Mg
Mercure ☐ Sélénium - Sol ☐ Dureté totale ☐
Alcalinité ☐ Bicarbonates ☐ Conductivité ☐
Chlorures ☐ Fluorures ☐ Sulfates ☐ Bromures ☐
Cyanures : Totaux ☐ Disponibles ☐ Oxydables ☐
DCO ☐ P total ☐ COT ☐
NH_3 ☐ NTK ☐ $NO_2 + NO_3$ ☐
Solides : Totaux ☐ Dissous ☐ MES ☐ MESV ☐
Sulfures - Eau ☐ Soufre total - Sol ☐

COURT DÉLAI DE CONSERVATION

Métaux dissous filtrés au laboratoire :
Chrome hexavalent ☐ pH ☐
Absorbance UV ☐ Couleur ☐ Turbidité ☐
DBO_5 ☐ DBO_5 Carbonée ☐
NO_2 ☐ NO_3 ☐ o-PO4 ☐
Coliformes : Totaux ☐ Fécaux ☐ *E.coli* ☐
Microbiologie (autre) :
HR/MS : PCDD/PCDF ☐ HAP ☐ BPC ☐
CMM 2008-47 : Sanitaire ☐ Pluvial ☐
RMD ☐ REIMR art. ☐
Pouvoir nutritionnel: P2O5, K2O total, Silice total, Silice soluble (acide), Matière organique, Humidité (TEF), Rapport C/N, Capacité de rétention en eau

Échantillon remis par (nom en lettres moulées et signature)	Date/heure	Échantillon reçu par (nom en lettres moulées et signature)	Date/heure
			2016/10/19
Échantillon remis par (nom en lettres moulées et signature)	Date/heure	Échantillon reçu par (nom en lettres moulées et signature)	Date/heure
			10h30

Copies : Rose – Client, Jaune – AGAT, Blanche – AGAT

Page ____ de ____

N°: 056394

No. de document: 2IV-107-1542F.003
Date de révision: 4 juin, 2014

ANNEXE 2.
PROTOCOLE DE FIXATION DU PHOSPHORE

ANNEXE 3.
CERTIFICATS D'ANALYSES POUR LE PHOSPHORE SOLUBLE LESSIVÉ DANS LES COLONNES DE PERCOLATION

Maxxam
Une société du Groupe Bureau Veritas

Le succès par la science®

Votre # du projet: MI-2098
Votre # Bordereau: N-A

Attention: Régis Pilote
Agrinova
640, rue Côté Ouest
Alma , QC
CANADA G8B 7S8

Date du rapport: 2018/11/13
Rapport: R2411061
Version: 1 - Finale

CERTIFICAT D'ANALYSES

 # DE DOSSIER MAXXAM: B850274
Reçu: 2018/11/06, 08:45

Matrice: EAU
Nombre d'échantillons reçus: 33

Analyses	Quantité	Date de l' extraction	Date Analysé	Méthode de laboratoire	Référence Primaire
Métaux dissous par ICP-MS	33	N/A	2018/11/10	STL SOP-00006	MA.200–Mét. 1.2 R5 m

Remarques:

Les laboratoires Maxxam sont certifiés ISO/IEC 17025:2005 pour certains paramètres précis des portées d'accréditation. Sauf indication contraire, les méthodes d'analyses utilisées par Maxxam s'inspirent des méthodes de référence d'organismes provinciaux, fédéraux et américains, tels que le CCME, le MDDELCC, l'EPA et l'APHA.

Toutes les analyses présentées ont été réalisées conformément aux procédures et aux pratiques relatives à la méthodologie, à l'assurance qualité et au contrôle de la qualité généralement appliqués par les employés de Maxxam (sauf s'il en a été convenu autrement par écrit entre le client et Maxxam). Toutes les données de laboratoire rencontrent les contrôles statistiques et respectent tous les critères de CQ et les critères de performance des méthodes, sauf s'il en a été signalé autrement. Tous les blancs de méthode sont rapportés, toutefois, les données des échantillons correspondants ne sont pas corrigées pour la valeur du blanc, sauf indication contraire. Le cas échéant, sauf indication contraire, l'incertitude de mesure n'a pas été prise en considération lors de la déclaration de la conformité à la norme de référence.

Les responsabilités de Maxxam sont restreintes au coût réel de l'analyse, sauf s'il en a été convenu autrement par écrit. Il n'existe aucune autre garantie, explicite ou implicite. Le client a fait appel à Maxxam pour l'analyse de ses échantillons conformément aux méthodes de référence mentionnées dans ce rapport. L'interprétation et l'utilisation des résultats sont sous l'entière responsabilité du client et ne font pas partie des services offerts par Maxxam, sauf si convenu autrement par écrit. Maxxam ne peut pas garantir l'exactitude des résultats qui dépendent des renseignements fournis par le client ou son représentant.

Les résultats des échantillons solides, sauf les biotes, sont rapportés en fonction de la masse sèche, sauf indication contraire. Les analyses organiques ne sont pas corrigées en fonction de la récupération, sauf pour les méthodes de dilution isotopique.
Les résultats s'appliquent seulement aux échantillons analysés. Si l'échantillonnage n'est pas effectué par Maxxam, les résultats se rapportent aux échantillons fournis pour analyse.
Le présent rapport ne doit pas être reproduit, sinon dans son intégralité, sans le consentement écrit du laboratoire.
Lorsque la méthode de référence comprend un suffixe « m », cela signifie que la méthode d'analyse du laboratoire contient des modifications validées et appliquées afin d'améliorer la performance de la méthode de référence.
Notez: Les données brutes sont utilisées pour le calcul du RPD (% d'écart relatif). L'arrondissement des résultats finaux peut expliquer la variation apparente.

Note : Les paramètres inclus dans le présent certificat sont accrédités par le MDDELCC, à moins d'indication contraire.

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Maxxam
Une société du Groupe Bureau Veritas

Le succès par la science®

Votre # du projet: MI-2098
Votre # Bordereau: N-A

Attention: Régis Pilote

Agrinova
640, rue Côté Ouest
Alma , QC
CANADA G8B 7S8

Date du rapport: 2018/11/13
Rapport: R2411061
Version: 1 - Finale

CERTIFICAT D'ANALYSES

 # DE DOSSIER MAXXAM: B850274
Reçu: 2018/11/06, 08:45

clé de cryptage

Veuillez adresser toute question concernant ce certificat d'analyse à votre chargé(e) de projets
Stephane Gagnon, Chargé de Projets
Courriel: SGagnon@maxxam.ca
Téléphone (418)543-3788 Ext:7066202

==========

Ce rapport a été produit et distribué en utilisant une procédure automatisée sécuritaire.
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Maxxam
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Le succès par la science®

Dossier Maxxam: B850274
Date du rapport: 2018/11/13

Agrinova
Votre # du projet: MI-2098
Initiales du préleveur: JM

MÉTAUX DISSOUS (EAU)

ID Maxxam		FY8635	FY8636		FY8637	FY8638		
Date d'échantillonnage		2018/11/01	2018/11/01		2018/11/01	2018/11/01		
# Bordereau		N-A	N-A		N-A	N-A		
	Unités	550VW50,4 (2)	590CV,2(2)	Lot CQ	590VW10,2 (2)	5MW2 (1)	LDR	Lot CQ
MÉTAUX								
Phosphore	ug/L	3100000	8900000	1951491	12000000	21000000	1000	1951494

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité

ID Maxxam		FY8639	FY8640		FY8641		FY8642		
Date d'échantillonnage		2018/11/01	2018/11/01		2018/11/01		2018/11/01		
# Bordereau		N-A	N-A		N-A		N-A		
	Unités	590CW10,4 (2)	5100,4 (2)	Lot CQ	VW100,4 (2)	Lot CQ	580VW20,2 (2)	LDR	Lot CQ
MÉTAUX									
Phosphore	ug/L	9700000	10000000	1951491	12000000	1951494	10000000	1000	1951491

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité

ID Maxxam		FY8643		FY8644		FY8645		
Date d'échantillonnage		2018/11/01		2018/11/01		2018/11/01		
# Bordereau		N-A		N-A		N-A		
	Unités	550CW50,4 (2)	Lot CQ	5M,4, (1)	Lot CQ	580VW20,4 (2)	LDR	Lot CQ
MÉTAUX								
Phosphore	ug/L	11000000	1951491	22000000	1951494	7500000	1000	1951491

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité

ID Maxxam		FY8646		FY8647	FY8648		FY8649		
Date d'échantillonnage		2018/11/01		2018/11/01	2018/11/01		2018/11/01		
# Bordereau		N-A		N-A	N-A		N-A		
	Unités	CW100,4 (2)	Lot CQ	550CW50,2 (2)	580CW20,4 (2)	Lot CQ	5MW2 (2)	LDR	Lot CQ
MÉTAUX									
Phosphore	ug/L	15000000	1951494	12000000	9800000	1951491	21000000	1000	1951494

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité

2018/11/13 08:25

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Dossier Maxxam: B850274
Date du rapport: 2018/11/13

Agrinova
Votre # du projet: MI-2098
Initiales du préleveur: JM

MÉTAUX DISSOUS (EAU)

ID Maxxam		FY8650		FY8651		FY8652	FY8653		
Date d'échantillonnage		2018/11/01		2018/11/01		2018/11/01	2018/11/01		
# Bordereau		N-A		N-A		N-A	N-A		
	Unités	**5100,3 (2)**	**Lot CQ**	**5M4 (2)**	**Lot CQ**	**580CW20,2 (2)**	**580VW20,3 (2)**	**LDR**	**Lot CQ**
MÉTAUX									
Phosphore	ug/L	8400000	1951491	21000000	1951494	12000000	11000000	1000	1951491

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité

ID Maxxam		FY8654		FY8655		FY8656		FY8657		
Date d'échantillonnage		2018/11/01		2018/11/01		2018/11/01		2018/11/01		
# Bordereau		N-A		N-A		N-A		N-A		
	Unités	**590VW10,4 (2)**	**Lot CQ**	**VW100,2 (2)**	**Lot CQ**	**5100,2 (2)**	**Lot CQ**	**550VW50,3 (2)**	**LDR**	**Lot CQ**
MÉTAUX										
Phosphore	ug/L	7100000	1951491	13000000	1951494	8800000	1951491	3600000	1000	1951494

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité

ID Maxxam		FY8658		FY8659		FY8660		FY8661		
Date d'échantillonnage		2018/11/01		2018/11/01		2018/11/01		2018/11/01		
# Bordereau		N-A		N-A		N-A		N-A		
	Unités	**550VW50,2 (2)**	**Lot CQ**	**5M,3 (1)**	**Lot CQ**	**CW100,2 (2)**	**Lot CQ**	**VW100,3 (2)**	**LDR**	**Lot CQ**
MÉTAUX										
Phosphore	ug/L	11000000	1951491	23000000	1951494	16000000	1951491	9700000	1000	1951494

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité

ID Maxxam		FY8662	FY8663		FY8664	FY8665	FY8666		
Date d'échantillonnage		2018/11/01	2018/11/01		2018/11/01	2018/11/01	2018/11/01		
# Bordereau		N-A	N-A		N-A	N-A	N-A		
	Unités	**5M,3 (2)**	**CW100,3 (2)**	**Lot CQ**	**590CW,3 (2)**	**550CW50,3 (2)**	**590VW10,3 (2)**	**LDR**	**Lot CQ**
MÉTAUX									
Phosphore	ug/L	20000000	12000000	1951494	8800000	8600000	8300000	1000	1951491

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité

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Dossier Maxxam: B850274
Date du rapport: 2018/11/13

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Votre # du projet: MI-2098
Initiales du préleveur: JM

MÉTAUX DISSOUS (EAU)

ID Maxxam		FY8667	FY8667		
Date d'échantillonnage		2018/11/01	2018/11/01		
# Bordereau		N-A	N-A		
	Unités	580CW20,3 (2)	580CW20,3 (2) Dup. de Lab.	LDR	Lot CQ
MÉTAUX					
Phosphore	ug/L	9800000	9900000	1000	1951491

LDR = Limite de détection rapportée
Lot CQ = Lot contrôle qualité
Duplicata de laboratoire

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Dossier Maxxam: B850274
Date du rapport: 2018/11/13

Agrinova
Votre # du projet: MI-2098
Initiales du préleveur: JM

REMARQUES GÉNÉRALES

Métaux dissous par ICP-MS: Échantillon reçu plus de 24hres après échantillonnage, filtré et préservé au labo.: FY8635, FY8636, FY8637, FY8638, FY8639, FY8640, FY8641, FY8642, FY8643, FY8644, FY8645, FY8646, FY8647, FY8648, FY8649, FY8650, FY8651, FY8652, FY8653, FY8654, FY8655, FY8656, FY8657, FY8658, FY8659, FY8660, FY8661, FY8662, FY8663, FY8664, FY8665, FY8666, FY8667

MÉTAUX DISSOUS (EAU)

Les limites de détections indiquées sont multipliées par les facteurs de dilution utilisés pour l'analyse des échantillons.
Les échantillons FY8635, FY8636, FY8637, FY8638, FY8639, FY8640, FY8641, FY8642, FY8643, FY8644, FY8645, FY8646, FY8647, FY8648, FY8649, FY8650, FY8651, FY8652, FY8653, FY8654, FY8655, FY8656, FY8657, FY8658, FY8659, FY8660, FY8661, FY8662, FY8663, FY8664, FY8665, FY8666, FY8667 ont été filtrés en laboratoire avant l'analyse des métaux.

Les résultats ne se rapportent qu'aux échantillons soumis pour analyse

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Dossier Maxxam: B850274
Date du rapport: 2018/11/13

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Votre # du projet: MI-2098
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RAPPORT ASSURANCE QUALITÉ

Lot AQ/CQ	Init	Type CQ	Groupe	Date Analysé	Valeur	Réc	Unités
1951491	RNP	Blanc fortifié	Phosphore	2018/11/10		91	%
1951491	RNP	Blanc de méthode	Phosphore	2018/11/10	77, LDR=10		ug/L
1951494	RNP	Blanc fortifié	Phosphore	2018/11/10		95	%
1951494	RNP	Blanc de méthode	Phosphore	2018/11/10	<10		ug/L

LDR = Limite de détection rapportée

Blanc fortifié: Un blanc, d'une matrice exempte de contaminants, auquel a été ajouté une quantité connue d'analyte provenant généralement d'une deuxième source. Utilisé pour évaluer la précision de la méthode.

Blanc de méthode: Une partie aliquote de matrice pure soumise au même processus analytique que les échantillons, du prétraitement au dosage. Sert à évaluer toutes contaminations du laboratoire.

Réc = Récupération

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Dossier Maxxam: B850274
Date du rapport: 2018/11/13

Agrinova
Votre # du projet: MI-2098
Initiales du préleveur: JM

PAGE DES SIGNATURES DE VALIDATION

Les résultats analytiques ainsi que les données de contrôle-qualité contenus dans ce rapport furent vérifiés et validés par les personnes suivantes:

Miryam Assayag, B.Sc. Chimiste

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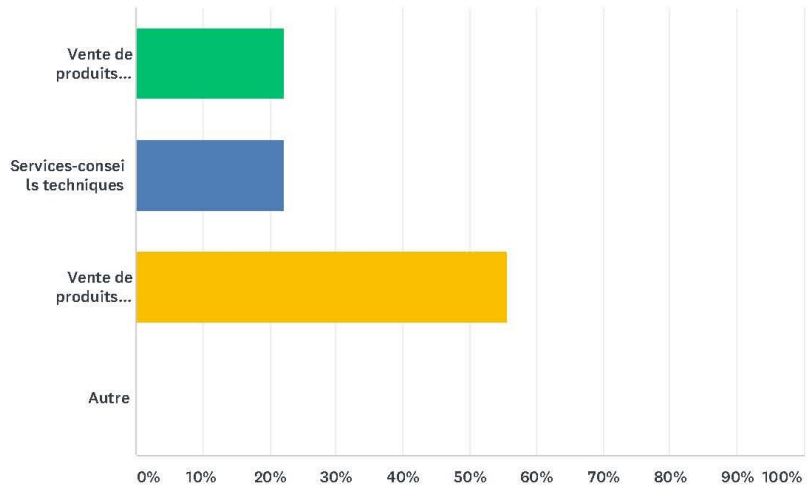
ANNEXE 4.
SONDAGE SUR LA RÉCEPTIVITÉ D'UN NOUVEAU PRODUIT DANS LA RÉGION DU SAGUENAY–LAC-SAINT-JEAN

Q1 Pour quel type de service en agriculture travaillez-vous?

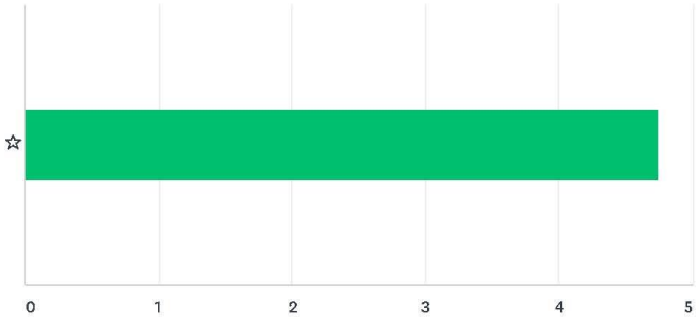
Answered: 9 Skipped: 0



CHOIX DE RÉPONSES	RÉPONSES	
Vente de produits agricoles	22,22%	2
Services-conseils techniques	22,22%	2
Vente de produits agricoles et services-conseils techniques	55,56%	5
Autre	0,00%	0
TOTAL		9

Q2 Sur une échelle de 0 à 5, 0 étant pas du tout favorable et 5 étant très favorable, êtes-vous favorables à l'utilisation d'un nouveau produit pour l'amendement des sols en agriculture?

Answered: 8 Skipped: 1

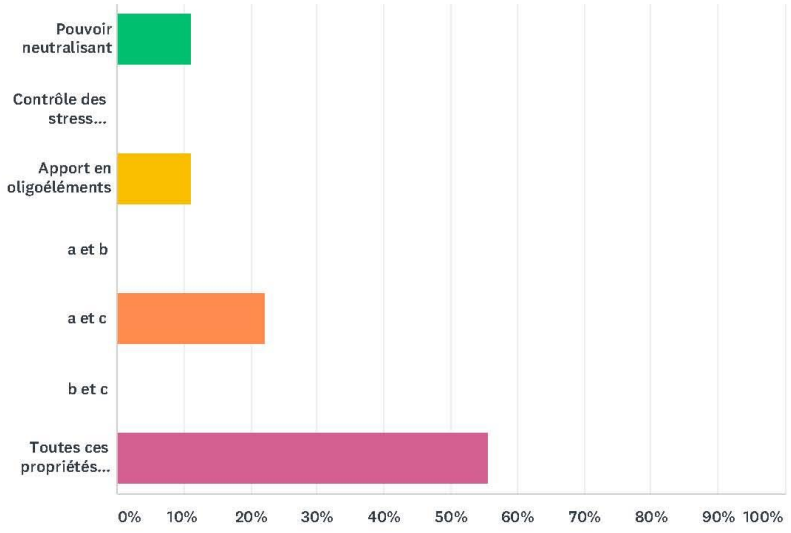


	1	2	3	4	5	TOTAL	MOYENNE PONDÉRÉE
☆	0,00% 0	0,00% 0	0,00% 0	25,00% 2	75,00% 6	8	4,75

#	JUSTIFIEZ :	DATE
1	5, en autant qu'il respecte les reglements en place et qu'il est à valeur ajoutée pour les producteurs	27/11/2018 10:38
2	en autant que le produit offre plus d'élement que la chaux traditionnel	26/11/2018 15:09
3	Le produit doit combler un besoin réel de l'agriculteur	22/11/2018 14:47

Q3 Le nouveau produit proviendrait de l'exploitation d'un gisement minéral de la région et aurait des propriétés uniques pour l'amendement des sols : pouvoir neutralisant de 50 % ÉCC, efficacité de 65 % et IVA de 35 %. Il contiendrait aussi des teneurs appréciables en silice soluble, un élément bénéfique lié à différentes formes de protection contre les stress biotiques et abiotiques rencontrés par les plantes. Enfin, un apport de 4 t/ha de ce produit apporterait 0,2 kg de bore, 1 kg de magnésium, 0,5 kg de manganèse et 10 kg de soufre. Parmi ces propriétés, laquelle vous intéresse le plus?

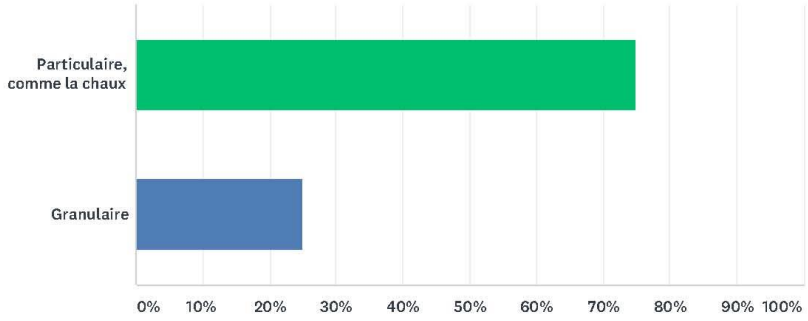
Answered: 9 Skipped: 0



CHOIX DE RÉPONSES	RÉPONSES	
Pouvoir neutralisant	11,11%	1
Contrôle des stress biotiques et abiotiques par la silice	0,00%	0
Apport en oligoéléments	11,11%	1
a et b	0,00%	0
a et c	22,22%	2
b et c	0,00%	0
Toutes ces propriétés m'intéressent	55,56%	5
TOTAL		9

Q4 Sous quelle forme préconiseriez-vous l'application en plein champs de ce produit?

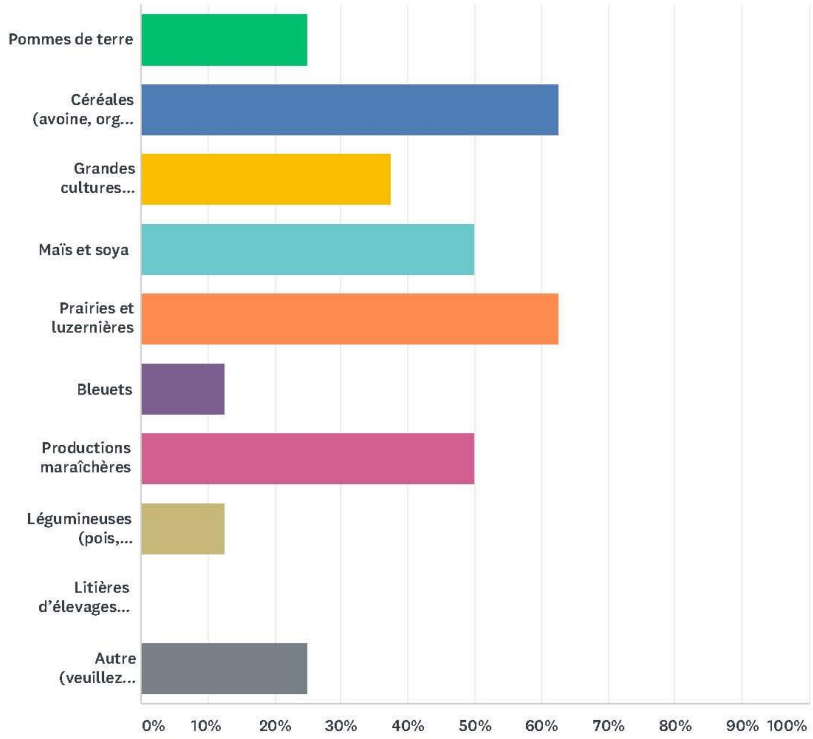
Answered: 8 Skipped: 1



CHOIX DE RÉPONSES	RÉPONSES	
Particulaire, comme la chaux	75,00%	6
Granulaire	25,00%	2
TOTAL		8

Q5 Selon vous, dans quelle(s) culture(s) ce produit serait-il plus intéressant à appliquer? Vous pouvez sélectionner plus d'une réponse.

Answered: 8 Skipped: 1



CHOIX DE RÉPONSES	RÉPONSES	
Pommes de terre	25,00%	2
Céréales (avoine, orge et blé)	62,50%	5
Grandes cultures biologiques (chanvre, lin et sarrasin)	37,50%	3
Maïs et soya	50,00%	4
Prairies et luzernières	62,50%	5
Bleuets	12,50%	1
Productions maraîchères	50,00%	4
Légumineuses (pois, haricots, fèverole et gourgane)	12,50%	1
Litières d'élevages animaux (ex, volailles)	0,00%	0
Autre (veuillez préciser)	25,00%	2

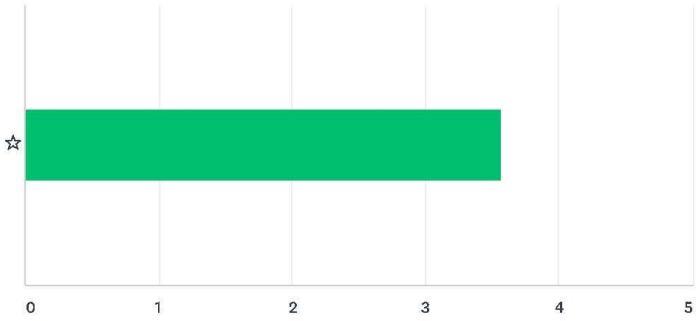
Sondage projet MI-2098

Nombre total de participants : 8	

#	AUTRE (VEUILLEZ PRÉCISER)	DATE
1	Canola et blé automne	27/11/2018 10:38
2	Canola	26/11/2018 10:35

Q6 Sur une échelle de 0 à 5, 0 étant pas du tout intéressé et 5 étant très intéressé, seriez-vous intéressé à recevoir gratuitement de ce produit pour en faire l'essai en parcelles côte-à-côte chez vos clients producteurs agricoles?

Answered: 7 Skipped: 2



	1	2	3	4	5	TOTAL	MOYENNE PONDÉRÉE
☆	14,29% 1	0,00% 0	28,57% 2	28,57% 2	28,57% 2	7	3,57

#	QUANTITÉ DEMANDÉE :	DATE
1	5, oui avec une enveloppe budgétaire pour le suivi au champ	27/11/2018 10:38
2	pour le moment pas d'idée	26/11/2018 15:09
3	à déterminer. un essai en grandes cultures bio et un essai en maraîchage bio.	26/11/2018 10:09

Q7 Si vous avez un ou des commentaires à formuler, merci de nous en faire part.

Answered: 3 Skipped: 6

#	RÉPONSES	DATE
1	Est ce que le produit est approuvé par le CARTV ?	26/11/2018 10:09
2	Quelle forme de Silice? Quelle forme de Mn? À quel coût? la forme de l' "amendement" dépend des équipement du producteur!	22/11/2018 14:47
3	Tout est une question de prix. À mon expérience, si le produit est donné ou presque au client, beaucoup seront intéressé et il pourra remplacer d'autres sous-produits déjà utilisés en agriculture. Par contre, si le prix est pour être de quelques centaines de dollars/tonne; je ne serai pas du tout intéressé à le développer avec vous puisqu'il n`y aura aucun avantage économique vs d'autres produits déjà existants.	22/11/2018 13:48

ANNEXE 5.
SOMMAIRE DES PROJETS SUBVENTIONNÉS PAR LE CRSNG EN LIEN AVEC LA WOLLASTONITE POUR LA PÉRIODE 2010-2011 À 2017-2018

Titre*	Année financière	Financement ($)	Sujet de recherche	Chercheur	Université	Département	Programme	Partenaires
The role of silicon in temperate and boreal forest ecosystems in a changing environment	2017-2018	25 000	Écologie végétale	Côté, Benoît	McGill University	Natural Resource Sciences	Programme de subventions à la découverte - individuelles	Aucun
Novel wollastonite-modified pervious concrete flooring system for nutrient removal from water runoff	2013-2014	24 400	Génie civil	Nehdi, Moncef	University of Western Ontario	Civil and Environmental Engineering	Programme de subventions d'engagement partenarial	Canadian Wollastonite
Optimization of the composition of glass powder based geopolymer concrete	2013-2014	25 000	Genie civil	TagnitHamou, Arezki	Université de Sherbrooke	Génie civil	Programme de subventions d'engagement partenariat	Antex Western
A fundamental investigation into wollastonite beneficiation: physicochemical properties and process mineralogy	2017-2018	22 300	Traitement des minéraux	Waters, Kristian	McGill University	Mining & Materials Engineering	Subventions de recherche et développement coopérative	Canadian Wollastonite et SGS CANADA INC.
Wollastonite flotation	2017-2018	25 000	Traitement des minéraux	Waters, Kristian	McGill University	Mining & Materials Engineering	Programme de subventions d'engagement partenarial	Canadian Wollastonite
Breeding soybean cultivars for improved silicon absorption/disease resistance	2014-2018	149 000	Phytopathologie	Bélanger, Richard	Université Laval	Phytologie	Subventions de recherche et développement coopérative	Syngenta Crop Protection (Canada) Inc.
Nonconsumptive analysis of silicon and other elements in plants	2014-2015	40 905	Phytopathologie	Bélanger, Richard	Université Laval	Phytologie	Outils et instruments de recherche - Catégorie 1 (<150 000 $)	Aucun

* Source : CRSNG

THE ROLE OF SILICON IN TEMPERATE AND BOREAL FOREST ECOSYSTEMS IN A CHANGING ENVIRONMENT

Climate change with its predicted higher incidence of droughts and longer growing seasons is likely to change the nutrient supply and requirements of forests. Silicon (Si), one of the most abundant element in soils, is now considered a nutrient for some species. It has attracted lots of interests lately for its role in mitigating the effects of increasing CO2 concentrations. My recent research indicates that sugar maple and beech, two dominant hardwoods in northeastern America, may be active accumulators of Si. If confirmed, this would suggest that it is required to grow at optimum levels and that researchers have been underestimating its role in these species.

My research will therefore focus on the role of Si in the physiology/nutrition of sugar maple and beech with the primary objective of getting a more comprehensive understanding of their nutrition and physiology, and of the way they drive soil fertility in forests. The first step will consist in revising the nutritional norms for both species. To get a complete measure of the nutritional balance, we will include Si in the nutrient indices/ratios. A set of at least 200 trees per species growing on contrasting soil conditions will be sampled. Optimal nutrient concentrations and ratios will be determined based on boundary-line regressions. The second step will consist in assessing the physiological role of Si. I hypothesize that the energy saved by producing a "cheap" silicate structure will increase the production of defensive chemicals e.g. phenolics, tannins. For this study, seedlings will be grown in hydroponics with and without Si. A series of morphological variables of the roots and stems/leaves, and leaf chemistry will be monitored and compared.

As active Si accumulators, one would expect sugar maple and beech to have developed specialized mechanisms to access Si and associated nutrients from minerals/rocks. I therefore propose to test their capacity to extract nutrients from three rocks used in ecological agriculture: wollastonite (Ca), apatite (P), and greensand (K). Testing would be done in controlled conditions (hydroponics) and in the field. With a greater capacity to absorb soil Si, I also expect a faster cycling and a greater accumulation of plant-derived silicates and silicate occluded C under sugar maple and beech. To test for these effects, we will make use of a plantation designed to maximize species interactions. With 19 species of trees grown in pure and mixed plots, we will be able to test the full spectrum of Si absorption potential of tree species commonly grown in eastern Canada.

These studies will provide some new insights on how sugar maple and beech can become dominant in old forests of eastern Canada while likely playing a significant role in mitigating the negative effects of the increase in atmospheric CO2. Two novel and simple approaches will also be developed to assess soil Al toxicity and estimate the rate of transpiration in trees.

NOVEL WOLLASTONITE-MODIFIED PERVIOUS CONCRETE FLOORING SYSTEM FOR NUTRIENT REMOVAL FROM WATER RUNOFF

Agricultural activities, and in particular those associated with animal production facilities, can adversely affect water quality. Pollution in water runoff from these facilities includes sediments, pathogens, and nutrients. Such nutrients in surface waters can be detrimental to most forms of aquatic life, and cause serious health and water quality concerns for neighboring communities. One problem with current operational practices for animal confinement facilities is the use of impervious flooring surfaces such as normal concrete, which increase runoff from these facilities, leading to higher pollutant levels in the surrounding environment. It is believed that pervious concrete incorporating wollastonite additives can be an optimum flooring system for such animal production facilities. Pervious concrete is a highly permeable concrete with a high flow rate for water through its body. On the other hand, wollastonite is a naturally occurring acicular mineral (calcium meta-silicate) that is known to act as an effective medium for nutrients removal. Combining these two features of wollastonite and pervious concrete can lead to a novel flooring system with high efficiency in reducing nutrients concentrates and water runoff, leading to innovation in environmental and waste management practice in animal confinement facilities.

OPTIMIZATION OF THE COMPOSITION OF GLASS POWDER BASED GEOPOLYMER CONCRETE

In the construction industry, cement is essential for the design of concrete. However, the production of cement contributes to 5 to 8% of CO2 emisions and is more energy intensive process related to the calcination of limestone. Consideration of sustainable development in the design of concrete is needed to minimize its carbon footprint. Many efforts have been made by researchers to replace part of the cement in concrete by industrial residues such as slag, fly ash, silica fume. To meet this environmental challenge, the laboratory of research on alternative cementitious materials of the Université de Sherbrooke (UdeS), has conducted over the past twenty years, studies allowing the development of efficient and environmentally friendly concrete by the use of supplementary cementitious materials (SCM) that are industrial wastes (silica fume, slags, fly ash) to replace part of the cement. Recently, it has been shown that glass powder, obtained from grinding mix waste glass, is an excellent alternative cementitious material. In addition, a new research area focused on the development of less expensive and more environmentally friendly binders (lower CO2 emissions, use of industrial by-products) as alternative cements in the construction industry, has been initiated. These binders provide the same or even better performance in comparison with ordinary Portland cements, when using the alkali activation method. This new field of research also intends to develop new characterization techniques suited to alkaline-activated materials.

The company Antex Western specializes in commercial construction industry has been providing building and interior finishing solutions since 1928. From access floors, to finish flooring and mechanical insulation and sprayed fireproofing, Antex Western always applies commitment and craftsmanship to building finishes. To make their products more sustainable, Antex Western companies innovate by developing geopolymer-based materials. In collaboration with this company, the Research Laboratory on Alternative Cementitious Materials of UdeS will develop and optimize glass powder, bauxite, and wollastonite-based geopolymer products.

A FUNDAMENTAL INVESTIGATION INTO WOLLASTONITE BENEFICIATION: PHYSICOCHEMICAL PROPERTIES AND PROCESS MINERALOGY

Wollastonite is a calcium silicate industrial mineral, which is commonly used as a filler in paints and plastics. It is also used in the construction industry as a substitute for asbestos; ceramic applications including ceramic glazes and bodies; in metallurgical applications wollastonite is commonly added to formulated powders for steel casting and welding. Wollastonite is mined across the globe, with major deposits found in China (China being the main producer) as well as in India and the United States of America. To date, little work has been conducted on the extraction of wollastonite from its ores, or on the physico-chemical properties of this mineral. As such, this project is centred on determining the physico-chemical properties of wollastonite and other minerals within the Seeley's Bay deposit in Ontario, and using this knowledge to improve the understanding of wollastonite processing. This will have implications for both the Seeley's Bay deposit, and other wollastonite deposits globally. This project will investigate the properties of wollastonite and how these can be utilised in separation systems to produce a sustainable high grade concentrate to be used in various industries. Canada is one of the most important mining nations in the world, producing more than 60 minerals and metals. Mining and mineral processing has long been one of the country's key wealth generators. In 2014 the sector employed approximately 375,000 people and contributed $57 billion to Canada's Gross Domestic Product (GDP), accounting for 18.2% of the value of Canadian goods exports. Improved knowledge of the processing of valuable minerals is of vital importance to Canada, and the sustainable processing of these deposits, both in recovering the valuable minerals and in reducing the negative impact of the mining industry is required.

WOLLASTONITE FLOTATION

Wollastonite is a calcium silicate ($CaSiO_3$) industrial mineral, which is commonly used as a filler in paints and plastics. It is also used in the construction industry as a substitute for asbestos; ceramic applications including ceramic glazes and bodies; in metallurgical applications wollastonite is commonly added to formulated powders for steel casting and welding. The properties that are most commonly utilised include the low loss on ignition, low thermal conductivity and the shape, which allows for smooth coatings and enhanced durability informulations. Canadian Wollastonite is also providing wollastonite to mitigate calcium losses and acidification in temperate soils and forests; in wastewater treatment applications; and for carbon sequestration. As such, ithas great potential in environmental applications. To date, little work has been conducted on the beneficiation of wollastonite from its ores, or on the physico-chemical properties of this mineral. As such, this project is centred on determining the physico-chemical properties of wollastonite and other minerals within the Seeley's Bay deposit in Ontario, and using this knowledge to improve the understanding of wollastonite beneficiation. This will have implications for both the Seeley's Bay deposit, and other wollastonite deposits globally. Canada is one of the most important mining nations in the world, producing more than 60 minerals and metals. Mining and mineral processing has long been one of the country's key wealth generators. In 2014 the sector employed approximately 375,000 people and contributed $57 billion to Canada's Gross Domestic Product (GDP). The industry accounted for 18.2% of the value of Canadian goods exports in 2014. Industrial minerals are an important sector of the mining industry, being used in a wide variety of products. A more effective method of producing industrial minerals such as wollastonite in a sustainable manner will be of benefit to the Canadian mining industry, and the economy.

BREEDING SOYBEAN CULTIVARS FOR IMPROVED SILICON ABSORPTION/DISEASE RESISTANCE

Silicon is known to alleviate both biotic and abiotic stresses when fed to plants. However, very little is known about the spectrum of efficacy of Si, how plants react to different sources of Si, and if there is inter and intra species variation in plants' receptivity to the element. In this project, we will test different sources of silicon (potassium silicate, sodium silicate, calcium silicate) on different cultivars of selected plant species against a number of biotic stresses (fungal diseases) and abiotic stresses (e.g. water stress). For each combination of parameters, a large number of variables will be measured (e.g. disease incidence, disease progression, fresh and dry weight and yield) in order to determine which combination offers the best results. These experiments will be repeated three times under greenhouse conditions. Based on those results, the best source of silicon, together with the best cultivars of the tested species will be retained for field evaluations. Field trials will be carried out over two growing seasons and plant's productivity under Si treatment will be compared to that of control plants. The ultimate objective is to select the best source of silicon and the best cultivars to determine if this approach could be part of an integrated management program.

NONCONSUMPTIVE ANALYSIS OF SILICON AND OTHER ELEMENTS IN PLANTS

The use of silicon (Si) in agriculture is gaining worldwide attention because of the benefits plants gain from its absorption while its application fits in well with the concept of sustainable agriculture. One of the difficulties inherent to Si research is the measure of biogenic Si in biologically heterogeneous material. The few techniques available are digestion-based techniques that are hazardous and time-consuming, fastidious, expensive and particularly in the case of Si, suffer from low accuracy due to incomplete solubilization and potential volatilization. In recent reports, portable X-ray fluorescence spectrometers (P-XRF) have been shown to offer precise nonconsumptive analysis of multiple elements, including those known to be difficult to measure such as Si, in large numbers of samples. This equipment overcomes many of the problems related to Si measurements, including sample digestion, and offers many advantages such as versatility, ease of use, cost and time reduction that will render any research lab interested in elemental analysis in plant and soil samples more efficient and productive.