Agricultural Performance Indicators

2019-2020 Progress Report submitted to:

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Table of content

Figures

Tables

1 Introduction

This short progress report on the development of Agricultural Performance Indicators (API) summarizes the work completed during the 2019-2020 fiscal year. For this second year of the project, the emphasis was on providing precise and useful elements to assess the monetary value of specific APIs: crop yield loss and farm building damages.

2 Objectives and tasks

During the second year of this project, we developed a simple and coherent methodology to assess the monetary values of specific APIs under historical flooding conditions and various mitigation scenarios for inter-comparison purposes.

Completed 2019-2020 tasks

Here is a brief description of the tasks completed during the April 2019 to Marsh 2020 period.

1. Retrieval of crop spatial data. Crop maps from Agriculture and Agri-food Canada (AAFC) for years 2011, 2012, 2013, 2014, 2015, 2016.

2. Processing of crop maps (AAFC) and extraction of crop types.

3. Intersection of 2011 flood scenario events and crop maps (AAFC).

4. Review of HAZUS (Multi-hazard Loss Estimation Methodology - Flood Model) and STICS (*Simulateur mulTIdisciplinaire pour les Cultures Standard*, or multidisciplinary simulator for standard crops) model documentations.

5. Extraction of crop yield loss flood curves from HAZUS model database.

6. Documentation of characteristic dates of crop development from La financière Agricole du Québec (FADQ).

7. Retrieval of crop yields from FADQ and transfer onto AAFC crop map.

8. Retrieval of crop market values from FADQ and transfer onto AAFC crop map.

9. As an example, evaluation of crop yield losses of various AAFC crop maps (2011 2012 2013 2014 2015 2016) given the 2011 flood scenario.

10. Production of a short technical note explaining data, methodology and preliminary results of the 2011 flood scenario.

11. Production of a short presentation explaining data, methodology and preliminary results of the 2011 flood scenarios.

12. To facilitate the implementation of the methodology and the integration of the required data into the ISEEE platform (*Système d'Intégration Sociale-Économique-Environnementale*), production and transfer of an Excel spreadsheet of AAFC data. All required information to perform crop yield loss calculation was regrouped into Excel spreadsheets and files and transferred to ECCC. Any new version or improved components will be updated and transferred accordingly.

13. For the U.S.A, extraction of crop yields for Maine, New Hampshire, New York and Vermont. Such data have not been used to this day, but could become relevant.

14. Retrieval of farm building stage-damage curves from HAZUS database. These curves were entered into an Excel file and transferred to ECCC

15. Other tasks (document consultation, data research).

16. Delineation of farm buildings affected by the 2011 Flood scenario and sketching of farm building footprints. Map of farm building footprints with database was transferred to AAFC to enable calculation within ISEEE platform.

17. Short comparison of crop yield loss methodologies applied to 2011 flood map with flood agricultural compensation for the actual 2011 event (excluding individual or group insurance compensations).

18. First assessment of the effect of mitigation scenarios on cropland using the ISEEE platform.

19. Drafting of the API Progress report.

3 Methodology, data and first results

The first step of the monetary valuation focused on identifying those APIs defined in Samson-Tshimbalanga and Rousseau (2018) that could be assessed based on an extensive literature review, data availability, implementation time and available resources. Table 3.1 introduces the selected and left out APIs.

Table 3.1 Prioritized APIs

API
Prioritized
Total area of flooded agricultural land
Yield loss ($)
Number of flooded farm buildings
Farm buildings damages ($)
Left out
Sedimentation
Soil erosion
Nutrient loss
Pesticide loss
Impaired surface and subsurface drainage systems
Drinking water systems for livestock
Road access to markets and processing plants (Milk collection)
Power outage
Livestock

3.1 Crop yield loss

The overall methodology to assess the monetary valuation of crop yield loss or farm building damage is mainly inspired by the HAZUS framework. “The HAZUS flood loss estimation methodology (Flood Model) provides local, state, and regional officials with state-of-the-art decision support software for estimating potential losses from flood scenarios. This loss estimation capability enables the users to anticipate the consequences of future flood and to develop plans and strategies for reducing risk. The Geographic Information System (GIS)-based software can be applied to study small or large geographic areas with a wide range of population characteristics.” “The HAZUS methodology was developed for the Federal

Emergency Management Agency (FEMA) by the National Institute of Building Sciences to provide a tool for developing earthquake loss estimates. HAZUS has been expanded to perform similar loss evaluation for hurricane wind, flood, and tsunami." https://en.wikipedia.org/wiki/HAZUS

General list of data requirements

- **2011 to 2016 annual crop maps from AAFC.** Such maps include a reduced number of crop classes in comparison with other products available through the declared crop production parcels database. Thus, AAFC crop maps are simpler to use. Table 3.2 provides the list of AAFC crop classes for the Québec portion of the Richelieu River watershed.

Table 3.2 Crop classes of AAFC maps of the Québec portion of the Lake Champlain / Richelieu River watershed.

Code	Label
120	Agriculture (undifferentiated)
122	Pasture and Forages
132	Cereals
133	Barley
134	Other Grains
136	Oats
137	Rye
138	Spelt
139	Triticale
140	Wheat
145	Winter Wheat
146	Spring Wheat
147	Corn
153	Canola and Rapeseed
154	Flaxseed
158	Soybeans
162	Peas
167	Beans
175	Vegetables
176	Tomatoes
177	Potatoes
179	Other Vegetables
181	Berries
183	Cranberry
185	Other Berry
188	Orchards
189	Other Fruits
190	Vineyards
197	Hemp

- **Annual crop yields from La Financière Agricole du Québec (2018 - reference year).** For certain crop classes, due to unavailable information, annual yields were estimated and based on our knowledge of crop production in Quebec. Table 3.3 presents crop yields for the selected AAFC crop classes.

Table 3.3 Yields for various AAFC crop classes found in the Québec portion of the Lake Champlain / Richelieu River watershed.

Code	Label	Yield	Unit	Comments
120	Agriculture (undifferentiated)	6 304	kg/ha	Moyenne des cultures (Foin, Orge, Avoine, Épeautre, Triticale, Blé, Maïs, Soya, Pois, Haricots, Pomme de terre)
122	Pasture and Forages	6688	kg/ha	Source: Moyenne Foin superficie Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
132	Cereals	3 127	kg/ha	Estimation: Moyenne (Orge, Blé, Avoine) Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
133	Barley	3326	kg/ha	Source : Orge Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
134	Other Grains	3 127	kg/ha	Estimation: Moyenne (Orge, Blé, Avoine) Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
136	Oats	2578	kg/ha	Source : Avoine Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
137	Rye	3000	kg/ha	Estimation: Seigle Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
138	Spelt	3478	kg/ha	Estimation: Blé Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
139	Triticale	3478	kg/ha	Estimation: Blé Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
140	Wheat	3478	kg/ha	Source : Blé Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
145	Winter Wheat	3478	kg/ha	Source : Blé Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
146	Spring Wheat	3478	kg/ha	Source : Blé Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
147	Corn	10707	kg/ha	Source : Maïs-Grain (collectif) Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
153	Canola and Rapeseed	1882	kg/ha	Source : Canola (valeur provinciale) Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
154	Flaxseed	2250	kg/ha	Estimation: Lin Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
158	Soybeans	3165	kg/ha	Source : Soya Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
162	Peas	1976	kg/ha	Source : Pois secs Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
167	Beans	1740	kg/ha	Source : Haricots secs Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
175	Vegetables	7 689	kg/ha	Estimation: Légumes Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
176	Tomatoes	20000	kg/ha	Estimation: Agri-Réseau
177	Potatoes	31561	kg/ha	Source : Pomme de terre Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
179	Other Vegetables	7689	kg/ha	Estimation: Légumes Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
181	Berries	5041	kg/ha	Estimation: Petits fruits (fraise, framboise) Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
183	Cranberry	24110	kg/ha	Source : Canneberge Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)

185	Other Berry	5041	kg/ha	Estimation: Petits fruits (fraise, framboise) Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
188	Orchards	290	kg/unité arbre (500 unité arbre/ha)	Source : Pomme Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
189	Other Fruits	5041	kg/ha	Estimation: Petits fruits (fraise, framboise) Financière Agricole du Québec (Rendements de référence 2018 en assurance récolte)
190	Vineyards	8000	kg/ha	Estimation: MAPAQ, Agri-Réseau
197	Hemp	1500	kg/ha	Estimation: MAPAQ

- **Crop unit prices from La Financière Agricole du Québec insurance program (2018 - reference year).** For certain crop classes, due to unavailable information, unit prices were estimated based on our knowledge of crop production in Quebec. Table 3.4 introduces the unit prices for various AAFC crop classes.

Table 3.4 Crop unit prices for various AAFC crop classes found in the Québec portion of the Lake Champlain / Richelieu River watershed.

Code	Label	Price	Unit	Comments
120	Agriculture (undifferentiated)	287.42 $	$/tonne	Moyenne des cultures (Foin, Orge, Avoine, Épeautre, Triticale, Blé, Maïs, Soya, Pois, Haricots, Pomme de terre)
122	Pasture and Forages	142.00 $	$/tonne	Source: Foin conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
132	Cereals	224.67 $	$/tonne	Estimation: Moyenne (Orge, Blé, Avoine) Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
133	Barley	210.00 $	$/tonne	Source : Orge conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
134	Other Grains	224.67 $	$/tonne	Estimation: Moyenne (Orge, Blé, Avoine) Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
136	Oats	230.00 $	$/tonne	Source : Avoine conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
137	Rye	890.00 $	$/ha	Source: Seigle conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
138	Spelt	292.00 $	$/tonne	Source: Épeautre conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
139	Triticale	234.00 $	$/tonne	Source: Triticale conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
140	Wheat	234.00 $	$/tonne	Source: Blé d'alimentation animale conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
145	Winter Wheat	279.00 $	$/tonne	Source: Blé d'alimentation animale de semence conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
146	Spring Wheat	234.00 $	$/tonne	Source: Blé d'alimentation animale conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
147	Corn	194.00 $	$/tonne	Source: Maïs-grain conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
153	Canola and Rapeseed	518.00 $	$/tonne	Source: Canola conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
154	Flaxseed	930.00 $	$/ha	Source: Lin conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
158	Soybeans	454.00 $	$/tonne	Source: Soya conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)

162	Peas	256.00 $	$/tonne	Source: Pois secs conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
167	Beans	723.00 $	$/tonne	Source: Haricots secs conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
175	Vegetables	8 500.00 $	$/ha	Estimation: Moyenne légumes Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
176	Tomatoes	9 800.00 $	$/ha	Source: Tomates à l'état frais Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
177	Potatoes	201.00 $	$/tonne	Source: Pomme de terre de table Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
179	Other Vegetables	8 500.00 $	$/ha	Estimation: Moyenne légumes Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
181	Berries	0.75 $	$/kg	Estimation: Moyenne Fruits Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
183	Cranberry	0.50 $	$/kg	Source: Canneberges Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
185	Other Berry	0.75 $	$/kg	Estimation: Moyenne Fruits Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
188	Orchards	0.45 $	$/kg	Source: Pommes option qualité multirisque Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
189	Other Fruits	0.75 $	$/kg	Estimation: Moyenne Fruits Financière Agricole du Québec (Assurance récolte prix unitaire 2018)
190	Vineyards	1.80 $	$/kg	Estimation: MAPAQ, Agri-Réseau
197	Hemp	1 170 $	$/ha	Source: Chanvre conventionnel Financière Agricole du Québec (Assurance récolte prix unitaire 2018)

- **HAZUS crop yield loss curves.** For certain crop classes and based on our knowledge of crop production in Quebec, yield loss curves due to flooding were estimated when the information was not available from HAZUS or anywhere else. HAZUS proposes crop yield loss due to flooding for specific crop classes (Alfalfa Hay, Almonds, Barley, Corn, Corn Silage, Cotton, Flax, Fruits & Nuts, Grapes, Oats, Other Hay, Rice, Safflower, Soybeans, Sugarbeets, Tomato, Truck Crops, Walnuts, Wheat, and Winter Wheat). Table 3.5 gives an example of such crop yield losses.

Table 3.5 Corn yield loss due to flooding as reported in the HAZUS Flood model database.

Crop	Function Source	Calendar Date	Julian Day	PctCropLoss	PctLossDuration 0_days	PctLossDuration 3_days	PctLossDuration 7_days	PctLossDuration 14_days
Corn	USACE	1-Jan	1	0	0	0.75	1	1
Corn	USACE	2-Jan	2	0	0	0.75	1	1
Corn	USACE	3-Jan	3	0	0	0.75	1	1
Corn	USACE	4-Jan	4	0	0	0.75	1	1
Corn	USACE	5-Jan	5	0	0	0.75	1	1
…	…	…	…	…	…	…	…	…
Corn	USACE	15-Jun	166	0.88	0	0.75	1	1
Corn	USACE	16-Jun	167	0.888	0	0.75	1	1
Corn	USACE	17-Jun	168	0.896	0	0.75	1	1
Corn	USACE	18-Jun	169	0.904	0	0.75	1	1
Corn	USACE	19-Jun	170	0.912	0	0.75	1	1
…	…	…	…	…	…	…	…	…
Corn	USACE	27-Dec	361	0.009	0	0.75	1	1
Corn	USACE	28-Dec	362	0.007	0	0.75	1	1
Corn	USACE	29-Dec	363	0.005	0	0.75	1	1

Corn	USACE	30-Dec	364	0.002	0	0.75	1	1
Corn	USACE	31-Dec	365	0	0	0.75	1	1

PctCropLoss : crop loss at day t of the year (% of maximum revenue)
PctLossDuration: the crop loss factor for flood duration (percent of maximum potential loss)

- **Last dates for sowing and harvesting according to La Financière Agricole du Québec.** For certain crop classes and based on our knowledge of crop production in Quebec, last dates for sowing and harvesting were estimated due to unavailable information. Tables 3.6 and 3.7 present these dates for various AAFC crop classes.

Table 3.6 Last date for crop sowing for various AAFC crop classes found in the Québec portion of the Lake Champlain / Richelieu River watershed.

Code	Label	Date	Julian day	Comments
120	Agriculture (undifferentiated)	01-juin	152	Plus faible valeur des cultures (Maïs, Lin)
122	Pasture and Forages			
132	Cereals	10-juin	161	Estimation: Moyenne (Orge, Blé, Avoine) Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
133	Barley	15-juin	166	Source : Orge Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
134	Other Grains	10-juin	161	Estimation: Moyenne (Orge, Blé, Avoine) Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
136	Oats	15-juin	166	Source : Avoine Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
137	Rye	15-juin	166	Source : Seigle Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
138	Spelt	01-juin	152	Estimation: Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
139	Triticale	01-juin	152	Estimation: Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
140	Wheat	01-juin	152	Source : Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
145	Winter Wheat			
146	Spring Wheat	01-juin	152	Source : Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
147	Corn	01-juin	152	Source : Maïs-Grain Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
153	Canola and Rapeseed	10-juin	161	Source : Canola 2600 UTM et moins Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
154	Flaxseed	01-juin	152	Source : Lin Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
158	Soybeans	10-juin	161	Source : Soya Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
162	Peas	15-juin	166	Source : Pois sec Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
167	Beans	15-juin	166	Source : Haricots sec Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
175	Vegetables	10-juin	161	Estimation: Autres légumes Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
176	Tomatoes			

177	Potatoes	10-juin	161	Source : Pomme de terre Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
179	Other Vegetables	10-juin	161	Estimation: Autres légumes Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
181	Berries			
183	Cranberry			
185	Other Berry			
188	Orchards			
189	Other Fruits			
190	Vineyards			
197	Hemp	15-juin	166	Source : Chanvre Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)

Table 3.7 Last date for crop harvesting for various AAFC crop classes found in the Québec portion of the Lake Champlain / Richelieu River watershed.

Code	Label	Date	Julian day	Comments
120	Agriculture (undifferentiated)	25-nov	329	Plus forte valeur des cultures (Maïs)
122	Pasture and Forages	01-nov	305	Source : Foin (dernière fauche) Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
132	Cereals	10-oct	283	Estimation: Moyenne (Orge, Blé, Avoine) Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
133	Barley	10-oct	283	Source : Orge Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
134	Other Grains	10-oct	283	Estimation: Moyenne (Orge, Blé, Avoine) Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
136	Oats	10-oct	283	Source : Avoine Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
137	Rye	10-oct	283	Source : Seigle Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
138	Spelt	10-oct	283	Estimation: Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
139	Triticale	10-oct	283	Estimation: Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
140	Wheat	10-oct	283	Source : Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
145	Winter Wheat	10-oct	283	Source : Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
146	Spring Wheat	10-oct	283	Source : Blé Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
147	Corn	25-nov	329	Source : Maïs-Grain Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
153	Canola and Rapeseed	15-oct	288	Source : Canola Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
154	Flaxseed	25-oct	298	Source : Lin Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
158	Soybeans	10-nov	314	Source : Soya (Zone de 2350 UTM à 2550 UTM) Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
162	Peas	15-nov	319	Source : Pois sec Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
167	Beans	01-nov	305	Source : Haricots sec Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)

175	Vegetables	15-oct	288	Estimation: Autres légumes Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
176	Tomatoes	31-oct	304	Estimation: Légumes vivaces Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
177	Potatoes	15-oct	288	Source : Pomme de terre Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
179	Other Vegetables	15-oct	288	Estimation: Autres légumes Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
181	Berries	15-oct	288	Estimation: Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
183	Cranberry	15-oct	288	Estimation: Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
185	Other Berry	15-oct	288	Estimation: Autres légumes Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
188	Orchards	20-oct	293	Source : Pomme Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
189	Other Fruits	15-oct	288	Estimation: Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
190	Vineyards	15-oct	288	Estimation: Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)
197	Hemp	25-oct	298	Source : Chanvre Financière Agricole du Québec (Répertoire des dates pour l'application du programme d'assurance récolte, Année-Récolte 2018)

In order to evaluate crop yield loss, a simple methodology was developed based on the following steps. In this context, the 2011 flood scenario was used as a reference. This methodology was derived from the information conveyed in the HAZUS Flood model documentation.

1. Determination of the flooded area (A) for available AAFC crop maps (2011 to 2018) based on the 2011 flood scenario.

   Figure 3.1 illustrates the delineation of the flooded crop area based on the 2011 AAFC crop map and 2011 flood scenario.

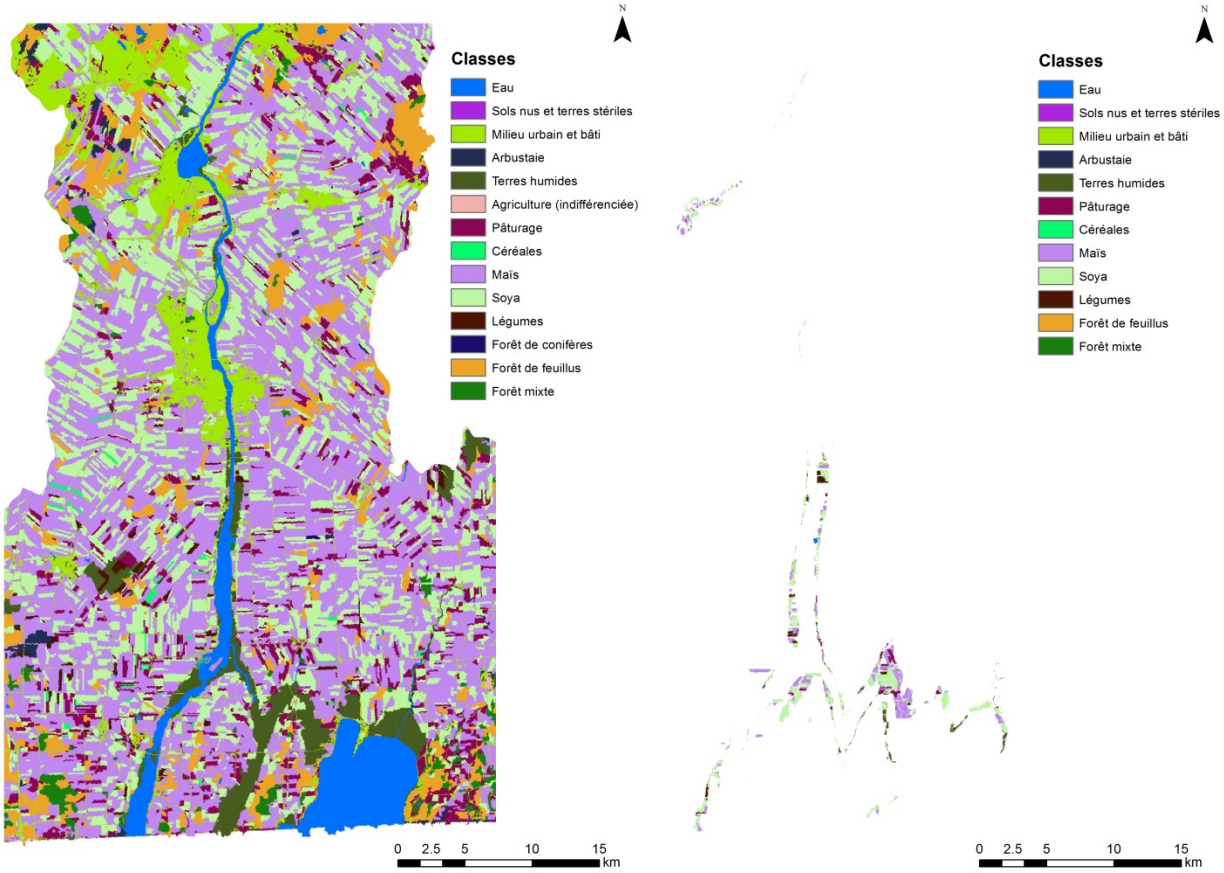

Figure 3.1 Delineation of the flooded area based on the 2011 AAFC map and 2011 flood scenario.

2. Identification of the flooding date (June 15th). This date will then be compared to last dates for sowing and harvesting.

3. Determination of the crop yield loss based on different approaches: (1) 100% yield loss regardless of the flooding, sowing or harvesting dates; and (2) yield loss considering the flooding date (June 15th) and the original HAZUS flood crop yield loss curves; (3) yield loss considering the flooding date (June 15th), while adapting the sowing and harvesting dates according to the shape of the HAZUS flood crop yield loss curves. It is noteworthy HAZUS curves are generic and, thus, can be adapted to any sowing and harvesting dates.

   Figure 3.2 shows the original and adjusted annual corn yield loss curve.

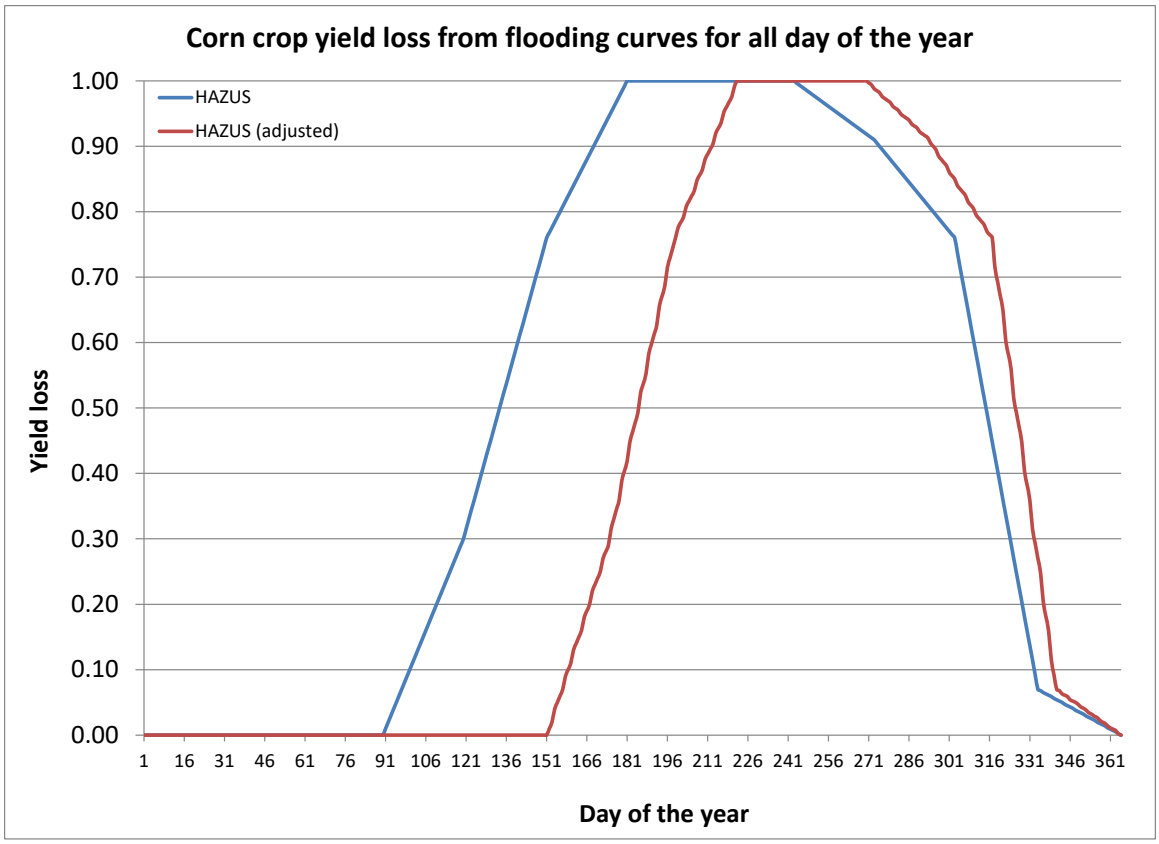

Figure 3.2 Original HAZUS corn flood yield loss curve or adjusted with respect to different sowing and harvesting dates.

Methodology application

The simplest approach to estimate crop revenue loss can be written as follows:

$$L = A_{wet} * P * Y * D(t) * R(t) \quad (3.1)$$

where:

L: crop yield loss ($) from flooding for a specific flooding day or period;

A_{wet}: Flooded crop area (ha) for a specific day or period;

P: Crop unit price ($/T or $/ha) based on 2018 market price from La Financière Agricole du Québec crop insurance program (e.g., for oat 210 $/T);

Y: Crop yield (kg/ha or T/ha) based on 2018 annual crop yields from La Financière Agricole du Québec (e.g. for oats 2578 kg/ha);

$D(t)$: crop loss on day t of the year (% of maximum net revenue). Value can be fixed to one (1), but can also be based on crop yield loss from the original HAZUS curve, adjusted or not to sowing and harvesting dates.

$R(t)$: Crop loss factor accounting for flood duration (percent of the maximum potential loss). HAZUS model suggests values for 3, 7, and 14 days of flooding. For this study, it was suggested to use at least 7 days of flooding duration. Given the ISEE model will be run using a quarter month time step and that this factor is likely to have a very minor effect (i.e. almost all crops have a factor of 1 after a few days), we did not consider this factor.

Table 3.8 shows the monetary values of crop yield losses for the following scenario: a combination of the 2011 flooding conditions in Quebec and the 2011 to 2016 AAFC crop maps. The three types of crop yield loss calculation were applied: (i) Maximum loss, (ii) Original HAZUS model based on day of the year loss curves; and (iii) HAZUS model curves adjusted to sowing and harvesting dates). The crop loss factor (R(t)) was set to one which corresponded to null attenuation and long flood duration.

Table 3.8 Example of results for crop flood revenue losses based on the 2011 Richelieu River flood event on June 15th.

Code	Label	2011	2012	2013	2014	2015	2016
		119 156 $	176 682 $	194 119 $	174 288 $	189 247 $	279 511 $
122	Pasture and Forages	84 600 $	125 444 $	137 825 $	123 745 $	134 365 $	198 453 $
		84 600 $	125 444 $	137 825 $	123 745 $	134 365 $	198 453 $
		1 834 $					
132	Cereals	1 614 $					
		128 $					
			4 085 $	21 370 $		9 742 $	6 348 $
133	Barley		3 595 $	18 805 $		8 573 $	5 586 $
			41 $	214 $		97 $	63 $
				948 $	7 903 $	14 226 $	
134	Other Grains			835 $	6 955 $	12 519 $	
				66 $	553 $	996 $	
				2 081 $		3 842 $	534 $
136	Oats			1 831 $		3 381 $	470 $
				21 $		38 $	5 $
							1 842 $
137	Rye						1 621 $
							18 $

			25 706 $	27 757 $	13 109 $	67 963 $	
140	Wheat		22 621 $	24 426 $	11 536 $	59 808 $	
			4 884 $	5 274 $	2 491 $	12 913 $	
							8 732 $
145	Winter Wheat						8 391 $
							8 391 $
							92 863 $
146	Spring Wheat						81 720 $
							17 644 $
		1 791 113 $	3 427 996 $	3 134 494 $	1 615 759 $	3 158 983 $	2 721 534 $
147	Corn	1 576 179 $	3 016 637 $	2 758 354 $	1 421 868 $	2 779 905 $	2 394 950 $
		340 311 $	651 319 $	595 554 $	306 994 $	600 207 $	517 091 $
		1 604 885 $	485 474 $	565 395 $	1 788 651 $	615 572 $	1 028 756 $
158	Soya	1 163 541 $	351 969 $	409 912 $	1 296 772 $	446 290 $	745 848 $
		187 772 $	56 801 $	66 151 $	209 272 $	72 022 $	120 364 $
		999 855 $	187 425 $	393 210 $	71 145 $	8 415 $	1 821 $
175	Vegetables	724 895 $	135 883 $	285 077 $	51 580 $	6 101 $	1 320 $
		116 983 $	21 929 $	46 006 $	8 324 $	985 $	31 $
							26 775 $
179	Other Vegetables						19 412 $
							3 133 $
		4 516 842 $	4 307 369 $	4 339 374 $	3 670 856 $	4 067 991 $	4 169 389 $
Total		3 550 829 $	3 656 149 $	3 637 065 $	2 912 456 $	3 450 942 $	3 457 771 $
		729 795 $	860 418 $	851 110 $	651 379 $	821 623 $	865 195 $

It is noteworthy that the losses of revenue introduced in the above table do not necessarily correspond to the amount of money that would have been awarded by La Financière Agricole through their crop insurance program.

Nonetheless, the results that are based on the adjusted HAZUS curves are larger than the cumulative amount of compensation money awarded by the Governments of Québec and Canada (474,000$) following the 2011 Richelieu River flood. It is worth mentioning that the cumulative amount did not reflect precisely crop unit prices.

Integration in the ISEEE platform

Figure 3.3 proposes a first version of a crop yield loss decision-making flowchart for any specific crop.

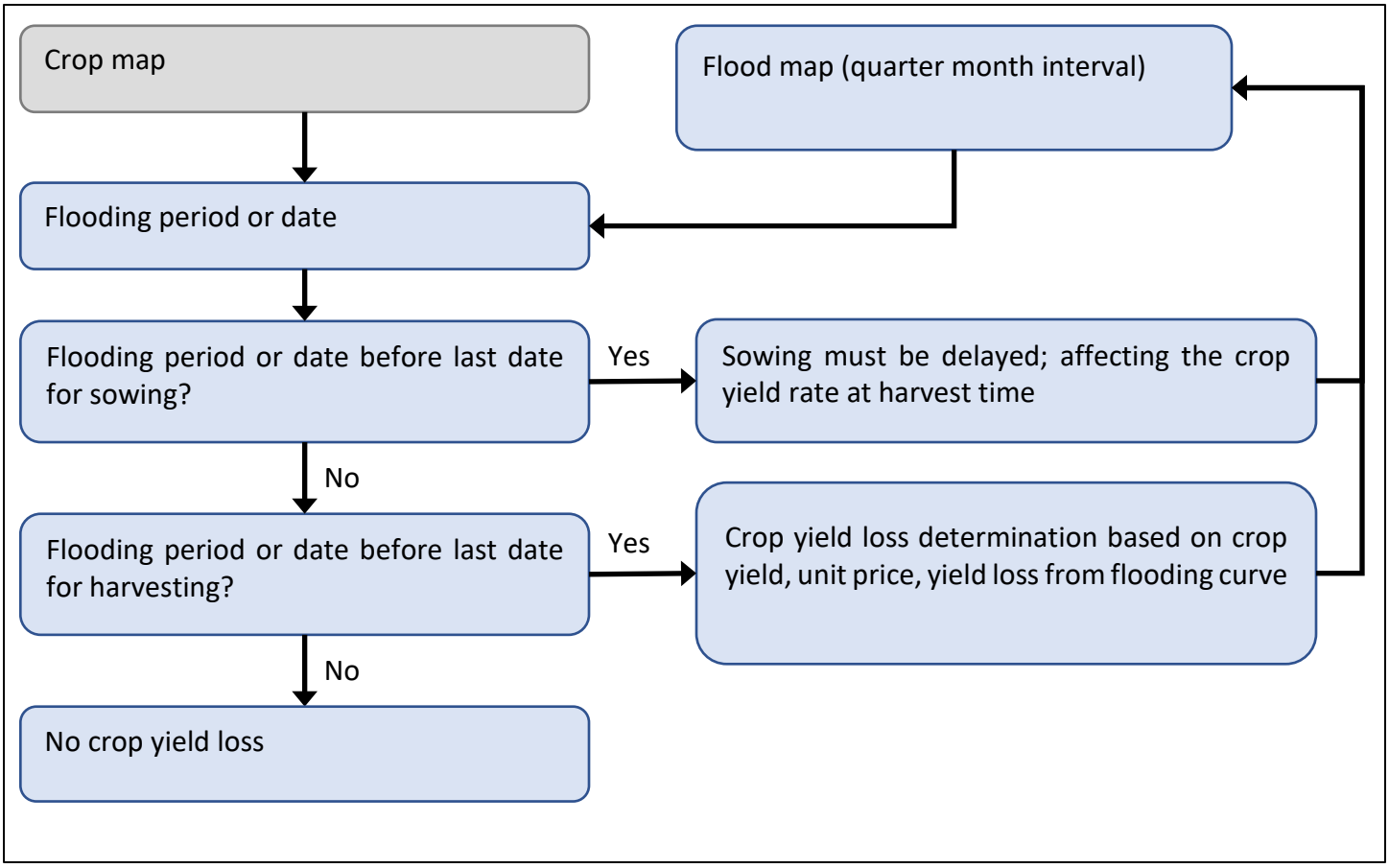

Figure 3.3 Example of a crop yield loss decision-making flowchart.

3.2 Farm building damages

Farm building damages are generally based on water stage reached by flood at the building level and stage-damage curves given the building type and role value. Also, over a long flooding period, only the maximum stage-damage assessed should be considered in the determination of the cost.

Two types of maps must be considered for the evaluation of farm building damages: (1) the flooded area (e.g. 2011 Richelieu River flood map) and (2) the farm building footprints. Since the second map was not readily available, we manually drew the footprints (i.e., perimeters) of farm buildings at risk of being flooded and identify whether or not it was indeed possible, and the types of farm buildings. To perform this task, diverse maps were combined. We superimposed a Bing ArcMap reference layer onto a polygon map of flooded areas of the Quebec Ministry of Public Safety. The map of flooded polygons does not necessarily match the flood boundary. Validation was performed as much as possible using the Google

Street View tool. Farm buildings within 30 m of a flooded polygons were retained and their footprints were drawn. The resulting layer could then contribute to the estimation of farm building damages. Figure 3.4 gives an example of farm building footprints on the outskirt of the 2011 flooded area (i.e., flooded polygons).

Figure 3.4 Example of farm building footprint drawing near the 2011 flooded area.

Limiting the drawing of farm building footprints within 30 m of flooded polygons depicting the 2011 Richelieu River flood may be viewed as a restrictive approach when compared to include all farm buildings within the same distance of the flood limit; which in all likelihood will not overlap the flooded polygons. Using flood limit would end up including a larger number of farm buildings that may not necessarily be flooded when compared to flooded polygons delineated using hydrodynamic modeling.

Such limiting approach could be too restrictive and other farm building footprints may need to be added to the layer to improve the assessment of the of flood scenarios.

We also faced the challenge of attempting to obtain farm building values. Without a specific roll value for each building, damage would then need to be estimated using a constant nominal surface values ($/m²).

Similarly to crop yield loss, the HAZUS Flood model proposes stage-damage curves for farm buildings, including content and inventory. Combined with building footprints and maximum water height characterizing a flood scenario, it becomes possible to estimate total farm building damages. Table 3.9 summarizes the farm building stage-damage database available in the HAZUS Flood model.

Table 3.9 Farm building stage-damages database of the HAZUS model

Description	Submersion (m)																							
	0.0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.4	3.7	4.0	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3
Average Agriculture, structure	0	6	11	15	19	25	30	35	41	46	51	57	63	70	75	79	82	84	87	89	90	92	93	95	96
Average Agriculture, Contents (Equipment /Inventory)	6	20	43	58	65	66	66	67	70	75	76	76	76	77	77	77	78	78	78	79	79	79	79	80	80
Agriculture /Dairy Processing, Inventory	0	25	50	75	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

The following equation can be used to estimate total farm building damages.

$$D = A_{wet} * B * SD_B + A_{wet} * C * SD_C + A_{wet} * I * SD_I \quad (3.2)$$

where:

D: Total farm building damages ($) (structure, content, inventory) for a flood event;

A_{wet}: Farm building flooded area (m²);

B: Farm building value ($/m²) could be based on gross reference value or proposed value;

C: Content value ($/m²) could be based on gross reference value or proposed value;

I: Inventory value ($/m²) could be based on gross reference value or proposed value;

SD_B: Stage-damage (%) for from flooding based on HAZUS stage-damages curves for a specific water height and flooding scenario;

SD_c: Stage-damage (%) for content damages from flooding based on HAZUS stage-damages curves for a specific water height and flooding scenario;

SD_i: Stage-damage (%) for inventory damages from flooding based on HAZUS stage-damages curves for a specific water height and flooding scenario;

4 Mitigation scenarios

Recently ECCC provided to INRS preliminary results for four flood mitigation scenarios. Different flood events were combined with six mitigation scenarios using the ISEEE modelling platform. Crop yield loss results were available for baseline scenarios and four different structural mitigation scenarios. The other mitigation scenarios could be modelled later upon approval of the Study Board. Table 4.1 presents the list of mitigation scenarios and identifies those transferred to INRS.

Table 4.1 List of mitigation scenarios including those transferred to INRS.

ID	Mitigation scenarios	Availability
0	Alternative 0. Baseline (no mitigation)	X
1	Alternative 1: Dredging shoal and human interventions	X
2	Alternative 2: Chambly Canal diversion	X
3	Alternative 3: Chambly Canal diversion + some dredging	X
4	Alternative 4: Fixed submerged weir upstream of Saint-Jean-sur-Richelieu	
5	Alternative 5: Inflatable weir upstream of Saint-Jean-sur-Richelieu	
6	Alternative 6: Inflatable weir at the Shoal	X

Results include temporal series of crop yield losses for historical Richelieu River hydrological conditions from 1924 to 2018 for contemporary (2011 to 2018) crop maps.

A quick assessment of the results was performed in terms of maximum annual yield loss as a pessimistic indicator and maximum gain based on an inter-comparison of mitigation scenarios. It is noteworthy that using multiple AAFC crop maps (2011 to 2018) should intuitively describe well current crop rotation practices and variability. Results were also produced for both adjusted and non-adjusted flood crop yield loss curves.

To our understanding, crop yield losses were evaluated using a quarter month interval and maximum losses were extracted accordingly.

Table 4.2 Non-adjusted average total maximum annual crop yield loss due to flooding

	Hydrologic events											
	1947		1973		1983		1984		2011		2013	
Scenario	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)
Baseline	2 286 303 $		922 693 $		1 132 631 $		725 293 $		2 522 480 $		1 282 345 $	
Alternative 1	2 128 259 $	158 043 $			1 008 845 $	123 786 $	637 254 $	88 039 $	2 366 947 $	155 532 $	1 129 479 $	152 865 $
Alternative 2	2 210 587 $	75 716 $	911 970 $	10 723 $	964 408 $	168 223 $	725 293 $	0 $	2 184 703 $	337 776 $	1 282 345 $	0 $
Alternative 3	2 099 039 $	187 264 $			922 572 $	210 059 $	637 254 $	88 039 $	2 123 005 $	399 474 $	1 129 479 $	152 865 $
Alternative 4												
Alternative 5												
Alternative 6	2 006 794 $	279 509 $	902 799 $	19 894 $	857 542 $	275 089 $	725 293 $	0 $	1 326 269 $	1 196 211 $	1 282 345 $	0 $

Table 4.3 Adjusted average total maximum annual crop yield loss due to flooding

	Hydrologic events											
	1947		1973		1983		1984		2011		2013	
Scenario	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)	Loss ($)	Sc. Gain ($)
Baseline	884 507 $		492 808 $		189 279 $		90 049 $		541 068 $		769 129 $	
Alternative 1	783 921 $	100 587 $			164 616 $	24 662 $	77 651 $	12 399 $	486 925 $	54 142 $	671 927 $	97 202 $
Alternative 2	796 375 $	88 132 $	487 006 $	5 802 $	113 995 $	75 284 $	90 049 $	0 $	421 269 $	119 799 $	769 129 $	0 $
Alternative 3	729 629 $	154 878 $			108 071 $	81 208 $	77 651 $	12 399 $	406 021 $	135 047 $	671 927 $	97 202 $
Alternative 4												
Alternative 5												
Alternative 6	501 948 $	382 559 $	482 065 $	10 743 $	99 002 $	90 277 $	90 049 $	0 $	198 924 $	342 144 $	769 129 $	0 $

4.1 Comments on the outcomes of mitigation scenarios

A series of general comments can be derived from a preliminary analysis of the outcomes of the aforementioned mitigation scenarios with respect to crop yield loss due to flooding. They are:

1. Results for the 2011 hydrological events and those introduced in Table 3.8 are of the same order of magnitude.

2. Why is not crop class #146, spring wheat, not introduced in Tables 4.2 and 4.3?

3. The 1947 and 2011 hydrological events generated the greatest average total maximum annual crop yield loss due to flooding.

4. Why was the 1973 hydrological event only used to assess mitigation scenarios 2 (Chambly canal diversion) and 6 (Inflatable weir at the shoal)?

5. For the 1984 and 2013 hydrological events, mitigation scenarios 1 (Dredging shoal and human interventions) and 3 (Chambly canal diversion + some dredging) provided identical average total maximum annual crop yield loss due to flooding and as a result identical gains when compared to the reference scenario (Baseline). Is this simply a coincidence?

6. For the 1984 and 2013 hydrological events, mitigation scenarios 2 (Chambly canal diversion) and 6 (Inflatable weir at the shoal) as well as the baseline scenario had identical average total maximum annual crop yield loss. Thus, both scenarios offer no gain; it seems a bit surprising?

7. It is interesting to observe that mitigation scenario 6 (Inflatable weir at the shoal) seems to lead to the most important gain with respect to alleviate crop yield loss due to flooding.

5 Improvements, challenges, future work

The assessment of APIs remains challenging from a methodological point of view. The proposed methodology for crop yield loss could be improved through updating unit prices if required. But small variation in crop unit prices, annual yields or sowing and harvesting dates would not have much of an impact on the inter-comparison of mitigation scenarios when compared to any baseline scenarios. Also integrating any plant growth model into ISEE would require extensive resources (i.e., time and data collection) without any guarantee in the end that the results would be more accurate.

Discussions should focus on locating and accounting for dikes, in the hydrodynamic model since these infrastructures could limit crop yield loss due to flooding. Locating dikes could be possible with visual interpretation or automatic processing of LiDAR data. Indeed, it might be possible to explore this avenue. Dike location would in all likelihood lead to a better representation of the baseline scenario.

Finally, factoring in watershed storage components (wetlands restoration, diversion of water on cropland, flood plain management) using hydrological modelling could lead to the construction of new mitigation scenarios and perhaps provide additional cropland protection and reduce farm building damages. It is important to underscore that the INRS hydrological modelling platform (PHYSITEL/HYDROTEL) is not readily adapted to explicitly simulate the impact of dikes on water levels (submersion heights) and, thus, cannot be substituted at this time for hydrodynamic modelling.

6 References

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