FINAL PROJECT REPORT

Project Title: Economic Impact of Apple Maggot Infestation in Washington

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Total Project Funding:

Budget History:

Item	2016
Salaries	$ 18,722
Benefits	$ 5,834
Wages	
Benefits	
Equipment	
Supplies	$ 2,226
Travel	$ 4,105
Plot Fees	
Miscellaneous	
Total	$ 30,887

Recap original objectives

(1) To calculate the current direct short-term costs associated with apple maggot (*Rhagoletis pomonella*), -hereafter AM- in quarantine and non-quarantine areas for conventional and organic apple production.

(2) To estimate the indirect and induced costs of a potential AM spread in non-quarantine areas for the Washington State's economy.

Significant findings

- Direct costs of a potential AM infestation include additional chemical costs, storage cost and price effects.
- Higher losses in profits are observed for,
  - Conventional apple orchards with low CM pressure compared to moderate and high CM pressure in AM affected areas 1 and 2 (see Table 2).
  - Fuji compared to other apple varieties included in this study in all three AM affected areas.
- If there is a 100% loss of AM-free areas, the total output value of the Washington apple industry decreases by $547 million due to AM control requirements in an area of low CM pressure; $557 million due to AM control requirements in an area of moderate CM pressure; and $510 million due to AM control requirements in an area of high CM pressure. These losses are derived in comparison to their respective initial total output values (i.e., status quo).

Results & discussion

Data and assumptions

1. Representation of apple production costs and returns
   - Enterprise budget of Red Delicious – low value apples
   - Enterprise budgets of Fuji and Gala – mid-value apples
   - Enterprise budget of Honeycrisp – high value apples
2. Four areas were identified according to AM status: (1) AM threatened and quarantine, (2) threatened and non-quarantine, (3) non-threatened and quarantine, and (4) non-threatened and non-quarantine. Table 1 shows the information on the commercial apple orchards acreage located in each four areas identified, as of 2015 (WSDA Natural Resource Assessment Section, NRAS). "Threatened" means that the orchard boundary is within half a mile of an apple maggot detection that has occurred within the past 3 years (2012-2015). "Non-threatened" means that apple maggot has not been detected within a half mile of the orchard boundaries in the past 3 years (2012-2015). "Quarantine" refers to areas where the pest is established; "established" means present in an area, multiplying and expected to continue (Klaus, 2016). 0.83% of conventional and 0.24% of organic orchard acreage are located in a threatened and quarantined area. 85% of the conventional and 97% of organic apple orchard acreage are located in a non-threatened and non-quarantine area (Table 1).

Table 1. Apple orchard acreage by threat and quarantine status due to apple maggot.

Threat status of orchards (WSDA)	Quarantine status (WSDA)	Conventional apple orchards		Organic apple acreage orchards	
		Acres	% of total	Acres	% of total
AM Threatened [1]	Quarantine	1,351	0.83%	42	0.24%
AM Threatened	Non-quarantine	184	0.11%	0	0%
Non-threatened	Quarantine	23,224	14.21%	471	2.69%
Non-threatened	Non-quarantine	138,683	84.85%	17,007	97.08%
	Total	**163,442**	**100%**	**17,519**	**100%**

Source: WSDA NRAS, WSDA Pest Program (Personal communication, 2016).

For the study, we classify the areas (i.e., Area 1 through Area 4) according to the threat and quarantine status because the direct costs of AM infestation will not be the same across these four areas in terms of additional chemicals to control for AM and additional days in cold storage (see Table 2).

Table 2. Checklist of additional costs due to AM infestation by area.

Type of area	Status	Additional chemical costs	Additional storage costs[1]
Area 1	Threatened and quarantine	✓	✓
Area 2	Threatened and non-quarantine	✓	-
Area 3	Non-threatened and quarantine	-	✓
Area 4	Non-threatened and non-quarantine	-	-

[1] Includes the charge for 40 days of cold storage and the subsequent decline in the price of apples.

3. Direct costs of AM infestation in commercial Washington orchards are represented by two categories: additional chemical costs associated with AM threatened areas, and storage costs associated with AM quarantined areas.
   - WSU apple enterprise budgets were used as baseline. The baseline included control costs for CM but not AM. Therefore, we treat chemicals to control AM as additional cost to the growers. Entomologist Dr. Jay Brunner designed pest control scenarios for AM. The control window for AM overlaps with the control window for second and third generation codling moth (CM), in case second and third generation happens.

   - As the CM pressure increases, the growers spray more times to control for CM, leading to fewer sprays to control AM. The additional AM spray costs should be small when CM pressure is high, and high when CM pressure is low. Because we cannot assert with certainty the type of CM pressure an apple orchard faces, three different management scenarios to control CM were used considering a low, moderate, and high CM pressure. For each level of CM pressure, the costs of chemicals (materials and application) for additional sprays to control AM are estimated (Table 3). Also, the chemical control costs vary depending on the different harvest dates across varieties included in this study. We estimated the chemical costs for early season harvest varieties (Gala), mid-season harvest (Red Delicious, Honeycrisp) and late season harvest (Fuji). Under high CM pressure there are no costs associated with organic apples, regardless of the variety, because it is assumed that growers will not produce organic apples if CM pressure is high.

   - When estimating impact of AM to the WA economy, the costs depicted in Table 3 are considered for apples produced in AM threatened Area 1 and Area 2.

Table 3. Additional chemical (materials and application) cost for controlling AM under different degrees of CM pressure, $/acre

CM Pressure	Red Delicious	Gala	Fuji	Honeycrisp	Organic Red*	Organic Gala*	Organic Honeycrisp*
Low	$370.46	$257.50	$396.53	$370.46	$111.19	$111.19	$111.19
Moderate	$199.91	$86.92	$225.97	$199.91	$111.19	$111.19	$111.19
High	$0.00	$0.00	$26.07	$0.00	-	-	-

*All organic apples (both low and moderate CM pressure) have two applications of Entrust to control for potential AM infestation. Both applications are applied on or before the first week of August. Entrust is the product applied and has a 4 hour re-entry interval.

Source: Authors' estimates from AM pest control strategies provided by J. Brunner (Personal communication, 2016).

4. Besides the chemical costs, AM quarantine implies additional storage costs for apples shipped to Alberta (AB)/British Columbia (BC) in Canada, and China. These export destinations require apples coming from AM free zone, or having additional 40 days in storage at 1C, if they are grown in an AM quarantined area. Note that Alberta is included in the analysis to account for additional transportation costs as apples being shipped from Washington to Alberta are assumed to go through British Columbia.

   The storage cost for extra 40 days at 1C is $11 per bin. Exports to AB/BC and China represent 1.74% of total WA apple exports (based on 5-year average from 2012/13-2015/16 marketing seasons) (WSTFA, 2016). We take these percentages into account when estimating the total revenues and storage costs for apples produced in AM quarantined areas (Area 1 and Area 3).

5. The additional days in storage also cause a delay in exporting apples to AB/BC and China markets. It is assumed that if apples are not exported, importers will find other sources of apples (e.g., California) or other products that might replace apples to maintain their customer base in those destinations. As a result, WA apples will lose shelf space in these locations and exporters of apples will lower their price in order to entice the importers to purchase the WA apples when they come out of storage (F. Scarlett, personal communication, 2016). This study assumes a decrease in price of apples due to delay in shipment, and the estimation of the price decrease is further discussed below.

   WA apples that come out of storage will likely add to those quantities that are to be shipped in a given schedule (see shipment schedule in Table 4). For instance Gala quantities coming out of storage will be added to the Gala quantities actually scheduled for shipment in October, which means that the total export supply of Gala for that month will be in excess.

Table 4. Timing of harvest and export shipment of apples after 40 days in storage.

Apple varieties	Harvest schedule	End of 40-day storage	Shipment schedule
Gala	August 15	September 24	October
Red Delicious	September 15	October 15	November
Fuji	October 15	November 24	December

We estimated the elasticity of apple supply by month for Gala, Red Delicious, and Fuji to see how sensitive prices would be if there is excess supply. The supply elasticity estimates are -1.04% in October for Gala, -1.02% in November for Red Delicious, and -1.81% in December for Fuji. The supply elasticity estimate is interpreted as follows: every 1% change in the quantity of fresh shipments of Gala, leads to a -1.04% change in the price of Gala in October. The supply elasticity estimates for Red Delicious and Fuji are interpreted in the same manner.
The price discounts are applied on the month that the apples are shipped to AB/BC and China. The supply elasticity estimate is multiplied by the percentage of exports to AB/BC and China to derive the price discounts; for instance, the price discount for Gala apples shipped in October is -1.81% (i.e., -1.04% times 1.74%). The estimated price discounts after 40 days of storage for other apple varieties are shown in Table 5.

Table 5. Percentage of price reduction (5-year average from 2011/12-2015/16 marketing seasons) 40-days after harvest for each apple variety.

Red Delicious	Gala	Fuji	Organic Red Delicious*	Organic Gala*
1.78%	1.81%	3.16%	1.78%	1.81%

*Assumed to be the same as the conventional apple variety.

6. Growers who export, pay for a phytosanitary certificate regardless of where their operation is located (e.g., AM threatened or quarantined area). The cost of the phytosanitary certificate is included in the baseline costs.

7. In an alternative scenario where the entire apple production region is AM threatened and quarantined, the same additional costs will be incurred on AM chemicals, and/or storage cost, and price discounts as described above. However, there will be an additional cost for the Apple Pest Certification, which is $0.01875 per cwt net yield (M. Klaus, personal communication, 2017).

Partial budget results

AM control cost for individual WA apple operations

We compared the profits of apple operations growing in the three AM affected areas described in Table 1 with the best-case scenario, that is, when apples are produced in an area that is neither threatened nor quarantined (Area 4). Higher losses in profits due to a potential AM infestation are observed for apple orchards with low CM pressure, compared to moderate and high CM pressure, for both conventional and organic apples, in AM affected areas 1 and 2. This is mainly due to the higher costs incurred in controlling AM given a low CM pressure, compared to the moderate and high levels of pest pressure (see Table 3).

Higher losses in profits are observed for Fuji compared to the other apple varieties included in this study — when quarantined costs (storage cost and price decline) are considered (Area 1 and 3) due to Fuji's higher net yields relative to Red Delicious and Gala; and when AM threatening costs (additional chemical sprays for AM) are included (Area 1 and Area 2) since Fuji gets more chemical sprays for AM compared to other apple varieties.

Losses in profit for organic apples is the same in low and moderate CM pressure because in both degrees of pest pressure, there are two applications of Entrust to control for potential AM infestation. The detailed partial budgets are presented in Appendix A. The summary of partial budgets is presented in Table 6.

Table 6. Profit loss per year of full production ($/acre) for a representative block of different apple varieties due to AM infestation that involves additional chemical costs, storage costs and price decline for three areas.

	AM threatened, quarantined (Area 1)			*AM threatened, non-quarantined (Area 2)*			*AM quarantined, non-threatened (Area 3)*
	Low CM	Moderate CM	High CM	Low CM	Moderate CM	High CM	
Red Delicious	-$497	-$269	-$2	-$495	-$267	$0	-$2
Gala	-$370	-$127	-$3	-$367	-$124	$0	-$3
Fuji	-$568	-$326	-$41	-$565	-$322	-$37	-$4
Honeycrisp*				-$404	-$218	$0	
Org. Red Del.	-$150	-$150		-$149	-$149		-$2
Org. Gala	-$161	-$161		-$158	-$158		-$3
Org. Honeycrisp*				-$171	-$171		

*Not included in the analysis for Area 1 and Area 3 because Honeycrisp is not among apple varieties exported to AB/BC Canada and China; hence it does not require storage.

IMPLAN analysis results – AM spread cost for WA economy

Economic contributions of the Washington apple industry

To estimate the economic impact of an increased risk of an expansion of AM threatened and quarantined areas, we calculate the economic contribution of the apple industry to the WA economy. We used data from the WSU enterprise budgets. To estimate the aggregate effects of losses in profit depicted in Table 6, we considered the acreage of the 4 areas affected by AM as depicted in Table 1. For each AM area, we assume a variety mix acreage distribution similar to the WA acreage distribution. We also used the data from Globalwise, Inc. and Belrose, Inc. (2014) study as basis for the economic contributions of the fresh apple packing and processing industries, and the 2015 IMPLAN input-output (I/O) data. Second, we estimate the contributions of the apple industry to the WA economy under each degree of CM pressure: low, moderate and high. To estimate the economic contribution for 2017, we used the built-in GDP deflator in IMPLAN for 2017.

The estimated contributions of the apple industry to the WA economy go beyond the $2 billion value of fresh apple sales figure. Because we take into consideration the 3 sectors of the apple industry: apple production at the field level, fresh apple packing, and apple processing. Moreover, the contributions include direct effects, indirect effects, and induced effects. The direct effects are the immediate effects related to production, packing, and processing of apples. Indirect effects include changes arising from inter-industry transactions as supplying industries respond to the demand from the directly affected industry. Induced effects include the effects due to the household consumption expenditures by employees in the directly and indirectly affected industry sectors. IMPLAN reports the on employment, labor income, value added, and total output. Table 7 shows the Washington apple industry's estimated economic contributions. IMPLAN employment is the number of jobs, including full time, part time and temporary jobs, created after the apple industry.

Table 7. Estimated contributions of the apple industry* to the Washington State economy, 2017.

Variables	Impact type			
	Direct effects	Indirect effects	Induced effects	Total effects
Low CM Pressure				
Employment (number of jobs)[1]	37,357	25,487	13,588	76,431
Labor income ($ billion)[2]	$1.29	$1.30	$0.67	$3.27
Total Value Added ($ billion)[3]	$1.51	$1.84	$1.23	$4.58
Total Output ($ billion)[4]	$3.95	$3.42	$2.10	$9.47
Moderate CM Pressure				
Employment (number of jobs)[1]	38,273	25,609	13,536	77,418
Labor income ($ billion)[2]	$1.28	$1.31	$0.67	$3.26
Total Value Added ($ billion)[3]	$1.49	$1.86	$1.23	$4.57
Total Output ($ billion)[4]	$3.95	$3.44	$2.09	$9.48
High CM Pressure				
Employment (number of jobs)[1]	35,957	24,821	12,922	73,700
Labor income ($ billion)[2]	$1.19	$1.27	$0.64	$3.11
Total Value Added ($ billion)[3]	$1.41	$1.81	$1.17	$4.39
Total Output ($ billion)[4]	$3.81	$3.38	$2.00	$9.19

*Sum of economic contributions by the apple farming, fresh apple packing, and processed apple production sectors.
Definition (Source: IMPLAN):
[1] Employment = number of jobs.
[2] Labor income = employee compensation + proprietor income.
[3] Value added = labor income + proprietor income + other property income + indirect business taxes.
[4] Output = intermediate expenditures + value added.

Labor income is comprised of employee compensation (wages, salaries and benefits) and proprietor income (i.e., payments received by self-employed individuals and unincorporated business owners; includes capital consumption allowance and is recorded on Federal Tax form 1040C). Labor income totaled $3.27 billion of personal income to the WA economy at a low CM pressure in the commercial apple orchards; $3.26 billion at moderate CM pressure; and $3.11 billion at a high CM pressure (Table 6). The total value added is the sum of employee compensation, proprietor income, other property-type income and taxes. There are $4.58 billion in value added contribution to the WA economy at a low CM pressure; $4.57 billion at moderate CM pressure; and $4.39 billion at high CM pressure.

The direct output values of the WA apple industry are estimated in the range of $3.81 billion to $3.95 billion depending on the degree of pest pressure in the apple orchards. Due to inter-industry linkages, the total economic contribution of the apple industry, for example given moderate CM pressure, is $9.48 billion — comprised of 42% direct output, and 58% of output from other sectors within the State (the sum of indirect and induced effects). The total output multiplier for the apple industry is about 2.40 (i.e., total effects ÷ direct effects). This estimate implies that for every dollar of fresh apple packing and apple processing, about $2.40 is generated in the local economy; that is for every apple industry dollar, an additional $0.67 is generated in sectors providing inputs to the apple industry (indirect effects), and an additional $0.73 is earned by businesses providing goods and services to employees of the apple industry and indirectly affected sectors (induced effects). Note that the values reported in Table 7 are aligned with Globalwise, Inc. and Belrose, Inc. (2014) reports at $3.35 billion in direct effects, $3.67 billion in indirect and induced effects, and $7.03 billion in total effects.

Impacts of a further AM infestation on the WA economy

We examine the economic impacts considering a 100% loss of the AM free areas — that is all apples are grown in AM threatened and quarantined area, and compare to the status quo situation (distribution of apple acreage according to Table 1). This means that instead of only 0.8% of the conventional and 0.2% of the organic apple acreage incurring additional chemical costs for AM, storage costs, and price discounts, 100% of all apple acreage will incur all these additional costs. Furthermore, there is an additional apple pest certification fee per hundredweight of net yield.

Results indicate that if a complete loss of the AM free areas happens, the losses in total output value (direct, indirect, and induced) due to AM are approximately $547 million when there is low CM pressure; $557 million when there is moderate CM pressure; and $510 million when CM pressure is high, relative to their respective initial apple industry values (Table 8).

Table 8. Reduced output value[1] of the WA apple industry, considering 100% of the WA apple-producing areas are AM threatened and quarantined (100% loss of AM free area).

Degrees of pest pressure	Output value ($ billion)				Losses in total output value if 100% loss of AM free area ($ million)*	Percent reduction compared to initial apple industry value*
	Direct	Indirect	Induced	Total		
Low CM pressure	$3.69	$3.34	$1.90	$8.92	-$546.93	-5.78%
Moderate CM pressure	$3.69	$3.34	$1.90	$8.92	-$557.23	-5.88%
High CM pressure	$3.58	$3.27	$1.83	$8.68	-$509.78	-5.55%

*Change with respect to the total output value in Table 7 given different degrees of pest pressure.

Assuming a progressive loss of AM free areas, for example if 20%, 40%, 60% and 80% (instead of 100%) of the apple production region are both AM threatened and quarantined, the losses faced are listed in Table 9 and illustrated in Figure 1.

Table 9. Progressive loss of AM free areas — 20%, 40%, 60% and 80% of the apple production region are both AM threatened and quarantined.

Scenario	Low CM pressure			Moderate CM pressure			High CM pressure		
	Output value ($ billion)	Output value reduction relative to baseline ($/billion)	Percent reduction relative to baseline	Output value ($ billion)	Output value reduction relative to baseline ($/billion)	Percent reduction relative to baseline	Output value ($ billion)	Output value reduction relative to baseline ($/billion)	Percent reduction relative to baseline
Baseline	$9.47			$9.48			$9.19		
20% TQ	$9.36	-$0.11	-1.12%	$9.37	-$0.11	-1.14%	$9.09	-$0.10	-1.07%
40% TQ	$9.25	-$0.22	-2.28%	$9.26	-$0.22	-2.33%	$8.99	-$0.20	-2.19%
60% TQ	$9.14	-$0.33	-3.45%	$9.15	-$0.33	-3.51%	$8.88	-$0.30	-3.31%
80% TQ	$9.03	-$0.44	-4.61%	$9.03	-$0.45	-4.70%	$8.78	-$0.41	-4.43%
100% TQ	$8.92	-$0.55	-5.78%	$8.92	-$0.56	-5.88%	$8.68	-$0.51	-5.55%

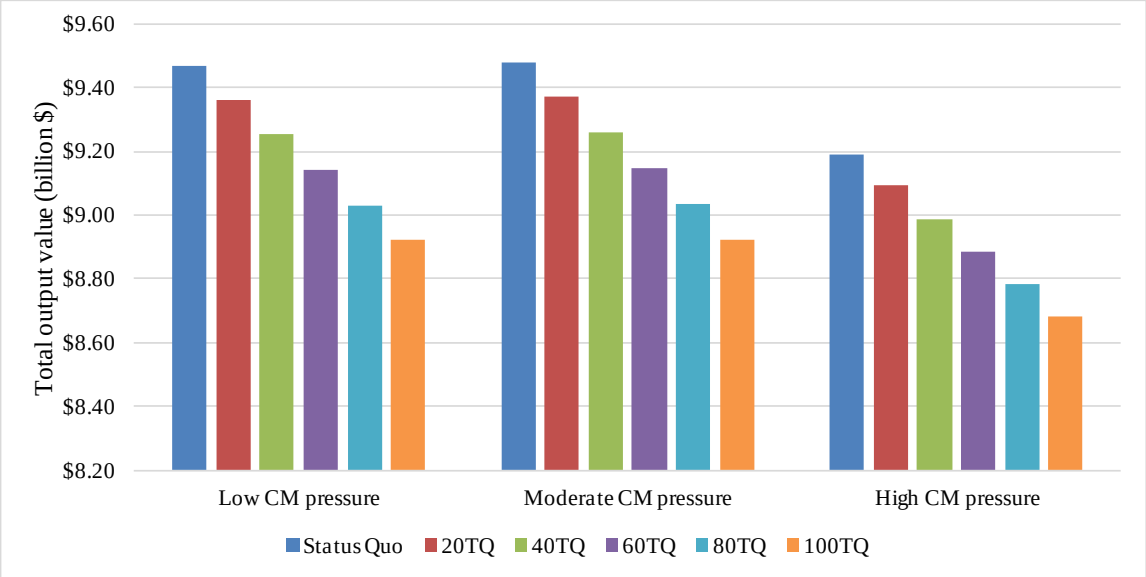

Figure 1. Changes in total output value of the apple industry given different percentages of apple production region that are threatened and quarantined due to AM and under different degrees of CM pressures. (Note: Status quo refers to current production areas affected by AM. TQ refers to threatened and quarantined areas.)

These analyses lead us to conclude the importance of an efficient control of codling moth and apple maggot due to the differences to the WA state economy for increases in CM pressure. Also findings revealed how revenues for the apple industry and thus its contribution to the overall WA economy are negatively impacted when apples are produced in quarantine areas. Given the increasing importance of export markets in special destinations such as China and Canada (BC/AB) this study illustrates the potential economic impact when quarantine areas are in risk of increasing.

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Executive summary

The conclusions of the Pest Risk Analysis* for AM moving on municipal green waste into the WA pest free area confirmed the high risk of spreading AM on the commercial fruit production areas as a result of this moving. In this report we estimated the potential costs to the WA economy of a potential spread of AM to the apple commercial production areas. We estimated three major drivers for the additional costs and consequent economic impacts: additional chemical sprays, additional time in storage, and reduction on output prices due to extended storage period required for AB/BC Canada and China.

We identified four areas according to AM status: (1) AM threatened and quarantine, (2) threatened and non-quarantine, (3) non-threatened and quarantine, and (4) non-threatened and non-quarantine. Less than 1% of conventional and organic orchard acreage is located in a threatened and quarantined area. Eighty five percent of the conventional and 97% of organic apple orchard acreage are located in a non-threatened and non-quarantine area. To estimate the additional chemical costs due to a potential AM infestation, we assume that the control window for AM overlaps with the control window for second and third generation codling moth (CM). As the CM pressure increases, already the growers are spraying more and the need for additional spray for AM declines. Thus, the additional cost of AM should be small when CM pressure is high, and relatively higher when CM pressure is low.

Because we cannot assert with certainty the type of CM pressure an apple orchard would face, three different management scenarios to control CM were used: low, moderate, and high CM pressure. Therefore, for each scenario, the costs of chemicals (materials and application) to manage CM are estimated, plus appropriate AM costs. Costs vary depending on the apple variety because of the harvest dates and the different timing of the chemical applications. We estimated the chemical costs for early season harvest varieties (Gala), mid-season harvest (Red Delicious, Honeycrisp), and late season harvest (Fuji). Additional storage costs for apples produced in AM quarantine areas and to be exported to AB/BC Canada and China are considered: (1) cost of additional 40 days in cold storage at $11/bin; and (2) decline in average price received by WA apple growers due to the required extra days in storage. This study assumes that exporters of apples will lower their price in order to entice the importers to purchase the WA apples when they come out of storage.

When comparing the profits of apple operations growing in the three AM affected areas with the best case scenario, Area 4 that is neither threatened nor quarantined, we found that: (1) Higher losses in profits are observed for conventional apple orchards with low CM pressure relative to moderate and high CM pressure in AM affected areas 1 and 2; (2) Losses are the same for organic apple orchards regardless of the degree of pest pressure because the additional chemicals costs for AM and storage costs are the same under low and moderate CM pest pressure; and (3) Higher losses in profits are observed for Fuji compared to other varieties included in the study in all affected areas.

The losses in the WA apple industry's output value due to a further spread of AM infestation to the entire apple production region are estimated at $547 million when there is low CM pressure, $557 million given moderate CM pressure, and $510 million given high CM pressure when compared to their respective initial total output values (i.e., status quo). The magnitude of the impacts of AM infestation on the WA economy depends on the proportion of the apple production area affected. The changes in the WA apple industry's total output value considering 20%, 40%, 60% and 80% of the production region that are both AM threatened and quarantined at different degrees of pest pressure are significantly lower than the changes in the output value if 100% of all apple production region is threatened and quarantined. The main reason is that instead of only some portions of conventional and organic apple acreages incurring additional chemical costs for AM, storage costs, apple pest certification fee, and price discounts, 100% of all apple acreage will incur all these additional costs in order to meet the requirements of exporting to AB/BC Canada and China.

*Sansford, C.E., Mastro, V. Reynolds, J.R., 2016. Pest Risk Analysis (PRA) for Apple Maggot (Rhagoletis pomonella) Moving on Municipal Green Waste into the Pest-free Area (PFA) of the State of Washington USA.