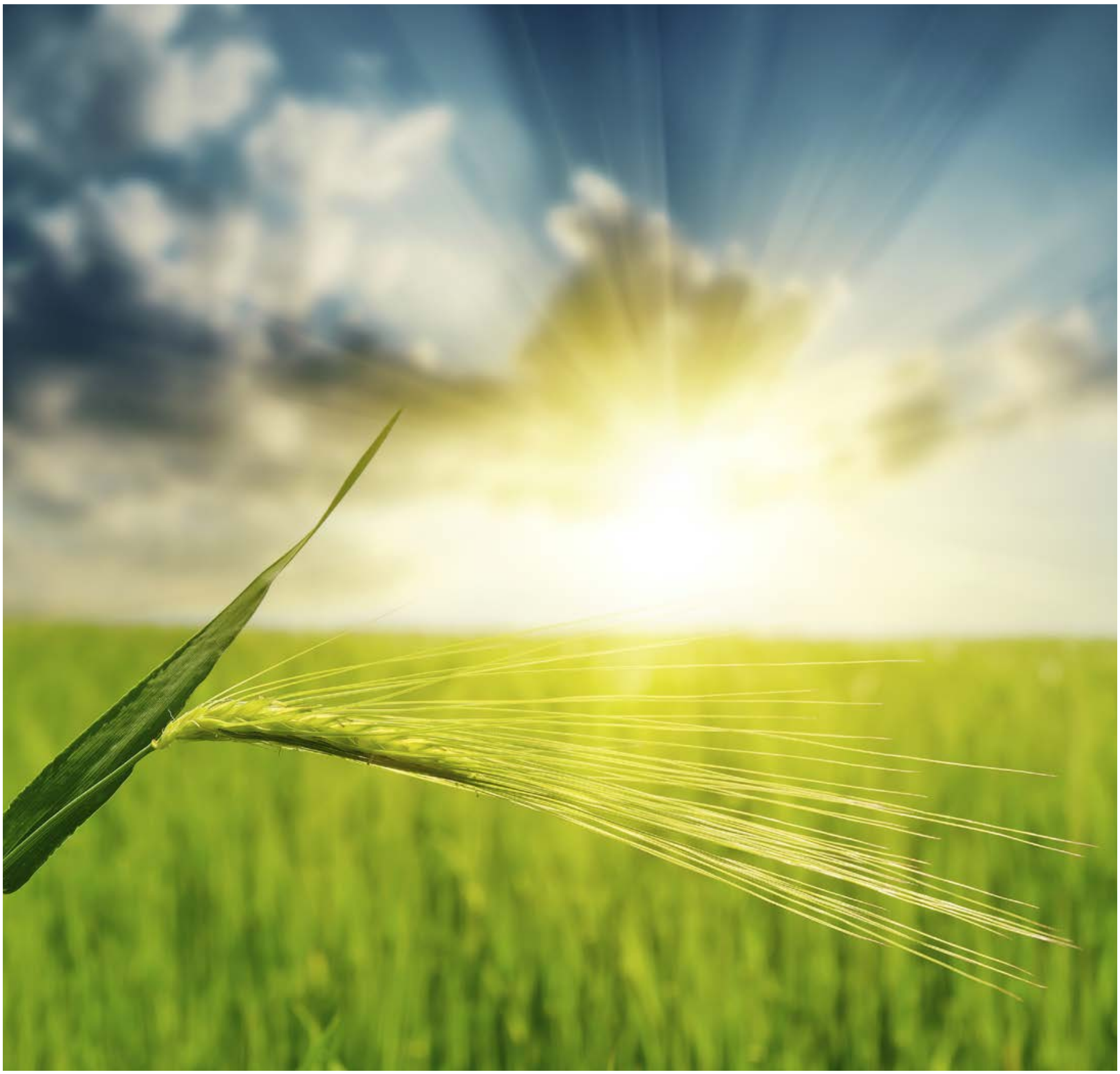
AgInfomatics

The Value of Neonicotinoids in North American Agriculture:

Executive Summary



2015

This report series, researched and produced by AgInfomatics, LLC, is a comprehensive analysis of the economic and societal benefits of nitroguanidine neonicotinoid insecticides in North America. The research was sponsored by Bayer CropScience, Syngenta and Valent in support of regulatory review processes in the United States and Canada, with Mitsui providing additional support for the turf and ornamental studies.

AgInfomatics, an agricultural consulting firm established in 1995 by professors from the University of Wisconsin-Madison and Washington State University, conducted independent analyses exploring the answer to the question: *What would happen if neonicotinoids were no longer available?* Comparing that answer to current product use revealed the value of neonicotinoids.

Robust quantitative and qualitative study methods included econometrics modeling of insecticide use, crop yield data and market impacts; surveys of growers, professional applicators and consumers; regional listening panel sessions; and in-depth case studies.

Active ingredients in the study included clothianidin, dinotefuran, imidacloprid and thiamethoxam.

The Value of Neonicotinoids in North American Agriculture

Reports include:

Estimated Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers

Methods and Assumptions for Estimating the Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers

Value of Insect Pest Management to U.S. and Canadian Corn, Soybean and Canola Farmers

A Meta-Analysis Approach to Estimating the Yield Effects of Neonicotinoids

An Economic Assessment of the Benefits of Nitroguanidine Neonicotinoid Insecticides in the United States and Canada

A Summary of Grower and Agri-Professional Perspectives From Regional Listening Sessions in the United States and Canada

A Case Study of Neonicotinoid Use in Florida Citrus

A Case Study of Neonicotinoid Use in Mid-South Cotton

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The Value of Neonicotinoids in Turf and Ornamentals

Reports include:

Estimating the Economic Value of Neonicotinoid Insecticides on Flowers, Shrubs, Home Lawns and Trees in the Homescape

The Value of Neonicotinoids to Turf and Ornamental Professionals

A Case Study of Neonicotinoid Use for Controlling Chinch Bug in Florida St. Augustinegrass

A Case Study of Neonicotinoid Use for Controlling Emerald Ash Borer—The Naperville, Illinois, Experience

A Case Study of Neonicotinoid Use for Controlling Silverleaf Whitefly in Ornamentals

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Faculty members listed above are acting solely in his or her individual capacity and are not speaking for or acting on behalf of the university. Moreover, while these faculty members are identifying their university status in rendering a service to AgInfomatics, they are not speaking, acting or making representations on behalf of the university, nor expressing or implying an institutional endorsement of these reports.

A Synopsis of the Agricultural Reports

AgInfomatics, LLC was charged with providing a comprehensive analysis on the socio-economic benefits of the nitroguanidine neonicotinoid insecticides used in North American agriculture. The eight agricultural studies summarized in this report are built upon two foundational concepts: methodological triangulation and a counterfactual scenario. The use of nitroguanidine neonicotinoid insecticides in North American agriculture is diverse, complex and dynamic. Establishing the value of these compounds requires multiple methods operating at different scales, all focused on the value question. Value becomes evident under a counterfactual scenario, *when you assume the neonicotinoids are no longer available,* and all the impacts of the adaptations and impacts emerge.

The take home messages

- The loss of neonicotinoids would force growers to rely on few older classes of insecticides. Insecticide treated acres will increase, and integrated pest management practices (IPM) will be negatively impacted. [Reports 1, 5]. Acres in the Conservation Reserve Program (CRP) and cover crops are projected to decrease. [Reports 4, 5]
- Neonicotinoids add several billion dollars to the North American economy and benefit entire communities, not just farmers. [Reports 2, 4, 5, case studies]
- The current 4 million pounds of neonicotinoids would be replaced with 19.1 million pounds of organophosphate or pyrethroid insecticides, equaling an increase in application rates per acre of ~375 percent. [Report 1]
- A loss of neonicotinoids would reduce crop yield and quality and in some cases cause catastrophic damage due to the lack of alternatives to manage invasive pests. [Reports 3, 5, citrus case study, whitefly case study in non-crop project]

Brief overview of reports

1. ***Methods to Establish Value*** – AgInfomatics analyzed pest management strategies used in over 133 million acres of neonicotinoid treated crops in the U.S., including corn, soybean, wheat, cotton and sorghum and developed data-driven, non-neonicotinoid scenarios. Grower costs increase $848 million in the non-neonicotinoid scenario, and acres treated with alternative insecticides are projected to increase 185 percent adding almost 105 million insecticide product acres annually. This analysis was recapped in two reports; one on methodology and another to summarize the complex analysis.

2. ***Value of Insect Pest Management*** – Analysis of surveys of over 1,700 corn, soybean and canola farmers in the U.S. and Canada show that neonicotinoids contributed a total value to farmers of $1.43 billion in 2013, based on the contingent valuation analytical approach. This includes value of simplicity, convenience, yield risk, and human and environmental safety to North American farmers.

3. ***Yield Meta Analysis*** – Yield data from over 1,500 efficacy studies were analyzed for corn, soybean, wheat, cotton, sorghum, canola, potato and tomato. Data show neonicotinoids increased yield versus the untreated control and versus other insecticides in all crops.

4. ***Overall Economic Value*** is based on a multi-market equilibrium analysis model (AGSIM) for commodity crops and a partial equilibrium analysis for specialty and Canadian crops. Based on cost increase data from report 1 and yield impacts based on data from report 3 (both are data driven and realistic) neonicotinoids contribute over $4.5 billion to the North American economy based on use in U.S. corn, soybeans, wheat, cotton, sorghum, potato and tomato, and Canadian canola, corn and soybeans only.

5. ***Grounding the Reports*** – Eight grower listening sessions were held across the U.S. and Canada. Growers discussed their pest management strategies, and how they and their communities would be affected under a non-neonicotinoid scenario. Insights from these sessions were used to structure the quantitative studies.

6-7. ***Two Case Studies*** of growers with crops where neonicotinoids play an especially important role in pest management are presented: Florida citrus and Mid-South cotton.

These reports are the result of in-depth analysis over a 15-month period by independent experts. Research methodology, analytics and documentation are designed to meet or exceed the standards of peer-reviewed publications.

Summary of reports

The first study, ***Methods to Establish Value***, begins with the identifying current pest management strategies used in U.S. agriculture. Understanding both the crops on which these products are used and the targeted pests represent critical baseline information needed to elucidate the counterfactual scenario (the determination of available alternatives if neonicotinoids were no longer available). The shift to these alternatives carries a cost, which ranges from approximately $7.5 million for spring wheat up to almost $677 million for corn growers. Corn accounts for the majority of the $848 million cost increase under the non-neonicotinoid scenario, while soybean accounts for $100 million. This first report concludes by identifying other consequences of the shift to the counterfactual scenario that were re-stated in other reports discussed below, thus confirming the value of the triangulation methodology. These are accelerated pest resistance, detrimental impacts on IPM programs and assorted negative environmental impacts.

The second study, ***Value of Insect Pest Management,*** is based on a survey of over 1,700 corn, soybean and canola farmers in the U.S. and Canada that establish the value of the nonpecuniary dimensions of neonicotinoids. A form of contingent valuation was employed. The easiest way to understand this is to ask, *What is the value of simplicity, convenience, yield risk and human and environmental safety to North American farmers?* Based on farmer responses and the aforementioned analytical technique, neonicotinoid seed treatments were the most valued insect management practice for North American corn, soybean and canola farmers, valued at $1.43 billion. Bt corn was second, with a total farmer value of $1.3 billion in 2013. The total farmer

value of foliar and soil insecticides were $306 million and $175 million, respectively.

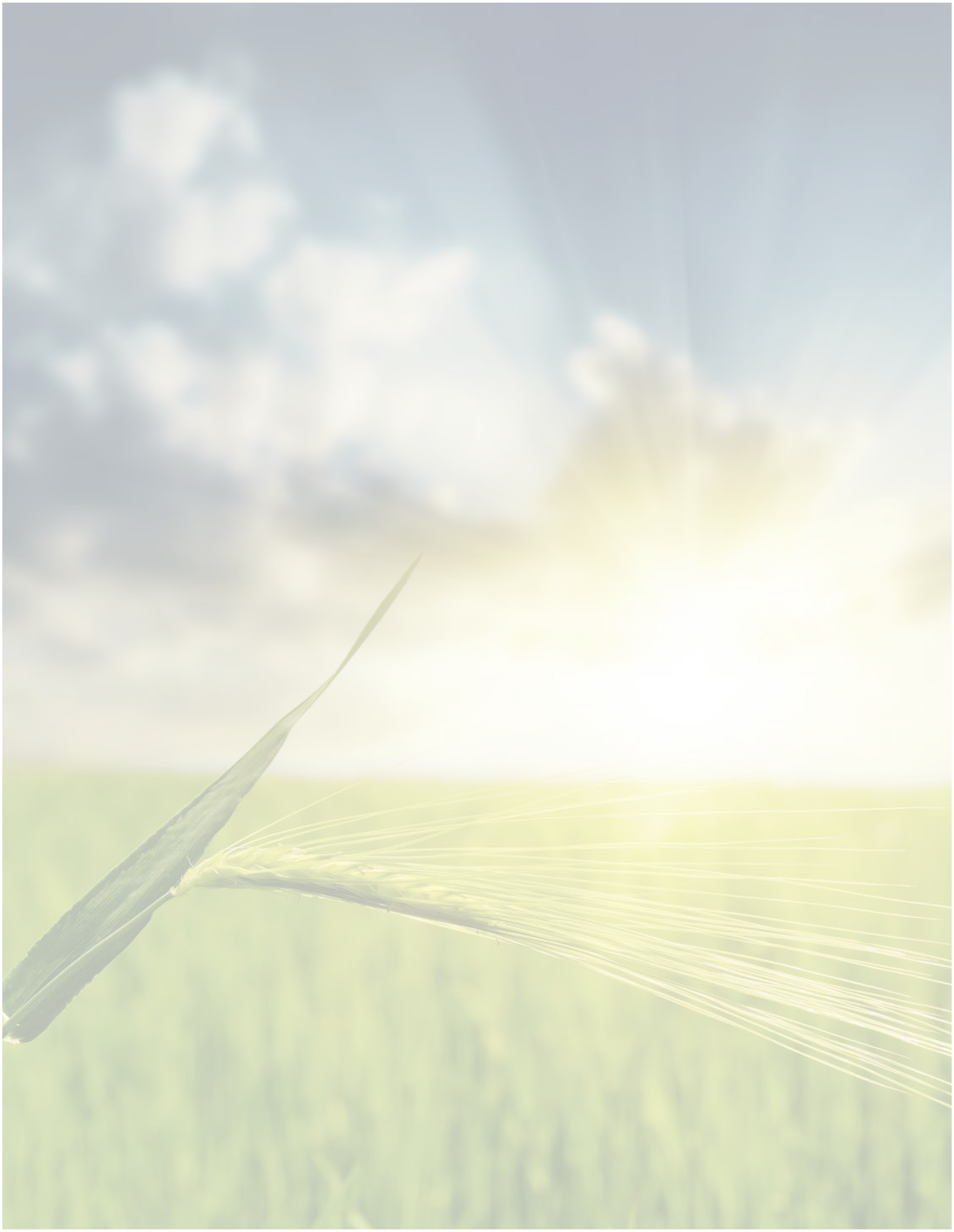
The third study in the series, ***Managing Pest and Yield Impacts***, addresses the interesting question of whether different crops experience yield impacts from the use of neonicotinoids. The report is based on a meta-analysis of all publically available documented U.S. and Canada data and reports on the yield impacts of clothianidin, dinotefuran, imidacloprid and thiamethoxam. Efficacy reports generated between 1993 and 2014 were sought for corn, soybean, wheat, cotton, sorghum, canola, potato and tomato. Data from a total of 1,550 studies were assembled, generating 3,359 observations of yield for both a neonicotinoid insecticide treatment and an untreated control. In addition, data from a total of 955 studies were assembled, generating 1,611 observations of yield for both a neonicotinoid insecticide treatment and a non-neonicotinoid insecticide treatment. Yield benefits of neonicotinoids relative to an untreated control ranged from 3.6 percent in soybeans up to 71.3 percent in potatoes. When compared to a non-neonicotinoid insecticide, yield benefits were more modest, ranging from 0.2 percent for soybeans up to 12.6 percent for potatoes.

The fourth study on ***Overall Value*** is based on a multi-market equilibrium analysis model, AGSIM, for commodity crops and a partial equilibrium analysis for specialty and Canadian crops. The AGSIM model calculates simultaneous changes in costs and crop yields for multiple crops, then shifts crop acreages and prices as farmers seek more profitable crop allocations until prices and acreages settle on a long-term equilibrium. Establishing the yield and costs shifts under a non-neonicotinoid scenario is a critical and sensitive part of the analysis. Consequently, a range of values is generated for both yield and cost that are then used in the equilibrium analysis models. The resulting value of neonicotinoids to the U.S. economy ranges from $3.05 to $4.34 billion depending on the yield and cost values employed. The value of neonicotinoids to the Canadian economy ranges from $57 to $276 million depending on the yield and cost values employed.

The fifth study on ***Grounding the Reports*** addresses a series of activities that occurred early in the overall project. Parts of the triangulation strategy required listening to growers discuss current pest management strategies and what they would do under a non-neonicotinoid scenario. A series of eight listening sessions were organized and managed by AgInfomatics in the major production regions of North American agriculture. The growers and other agricultural professionals across these diverse production areas identified common concerns with the counterfactual scenario: (1) higher costs, (2) lower yields, (3) loss of effective pest control, (4) alternatives harming pollinators and beneficial insects, (5) acceleration of pest resistance, (6) increased human health and environmental risk, (7) negative 'spin-off' impacts on local economies, and (8) frustration that emotion rather than science is driving public and media discussions.

This project is completed by two case studies of agricultural situations where neonicotinoids play an important role in pest management. The case study on Florida Citrus highlighted the devastating role that Huanglongbing disease is having on the citrus industry. The disease agent (the bacterium '*Candidatus Liberibacter, asiaticus'*) is introduced to citrus trees by the Asian citrus psyllid, an invasive insect. The Florida grower interviewed in the case study explained how neonicotinoids are the only effective method to protect young trees from this disease. A recurring theme in this case study is the potential loss of a large segment of the citrus industry, with devastating consequences to corollary businesses if this pest is not controlled. A similar conclusion but under very different conditions emerged in the second case study on Mid-South Cotton. Pest management in cotton has a long history, and the grower interviewed in this case study described how neonicotinoids play a critical role in pest management. The seeds he uses for growing cotton, corn and soybean are treated with neonicotinoids, and he uses neonicotinoids as part of early-season insect control in cotton. The neonicotinoids control wireworms, thrips and plant bugs. He rotates his use of pesticides to maximize efficacy and manage pest resistance problems. The grower pointed out that area farmers would shift to other crops if cotton pests could not be controlled, or it became too expensive to do so. A decline in cotton production would have significant, negative impacts for the local economy, as there are many business and supply chain intermediaries involved.

The reports conclude by pointing out many of the uncertainties that would emerge under a non-neonicotinoid scenario. Unintended consequences such as an accelerated loss of pollinators and other beneficial insects, loss of pollinator habitat, reduction in cover crop acreage, and negative impacts on IPM and pest resistance programs are discussed.



1.0 Introduction

AgInfomatics was charged with providing a comprehensive analysis on the socio-economic benefits of the nitroguanidine neonicotinoid insecticides used in North American agriculture. The function of these reports is to inform discussions regarding policy that may influence the use of these insecticides, specifically clothianidin, dinotefuran, imidacloprid and thiamethoxam, in North American agriculture. Public policy – a guide to future action to achieve specified objectives – should take into consideration both the costs and benefits of the action being considered. Much of the media coverage of neonicotinoids in agriculture has focused on costs (perceived or real). What has been lacking is a robust assessment of the *value* of neonicotinoids, possibly because of the challenges presented in characterizing this widely used chemical class that possesses such diverse use patterns. The purpose of a series of AgInfomatics reports is to provide an estimate of the benefits of neonicotinoids in North American agriculture.

AgInfomatics is an independent agricultural research firm located in Madison, Wisconsin. Dr. Fran Pierce, a soil scientist and past President of the American Society of Agronomy was joined by Dr. Peter Nowak, a rural sociologist who specialized in measuring the adoption of agricultural technologies, as the principals of this firm. Dr. Paul Mitchell, an agricultural economist who is acknowledged as the foremost authority on the economics of pesticides in modern agriculture, was contracted to join the AgInfomatics principals in this project. As the project was implemented, additional experts were hired as sub-contractors. In alphabetical order the AgInfomatics team on the benefits of neonicotinoids project for agriculture included:

Dr. Fenxia Dong is an associate scientist with the department of agricultural and applied economics at the University of Wisconsin-Madison.

Dr. Ken Genskow is an associate professor in the department of urban and regional planning and specializes in environmental planning and policy at University of Wisconsin-Madison and has extensive experience in survey research.

Dr. Russell Groves is an associate professor of entomology at University of Wisconsin-Madison who served as a technical advisor on the entomological dimensions of this project.

Dr. Terry Hurley is an associate professor of agricultural economics at the University of Minnesota-St Paul and specializes in valuation of non-market goods and services.

Dr. Paul Mitchell is an associate professor in the department of agriculture and applied economics at the University of Wisconsin-Madison and is a leading expert in the field of economic entomology.

Dr. Pete Nowak is an emeritus professor in the Nelson Institute for Environmental Studies at University of Wisconsin-Madison and a principal and co-founder of AgInfomatics.

Dr. Fran Pierce is an emeritus professor at Washington State University, former director of the Center for Precision Agricultural Systems, past-president of the American Society of Agronomy and co-founder of AgInfomatics.

Dr. Bret Shaw is an associate professor in the department of life sciences communication at the University of Wisconsin-Madison with both private and public sector experience with quantitative and qualitative measurement techniques.

2.0 Research Strategy

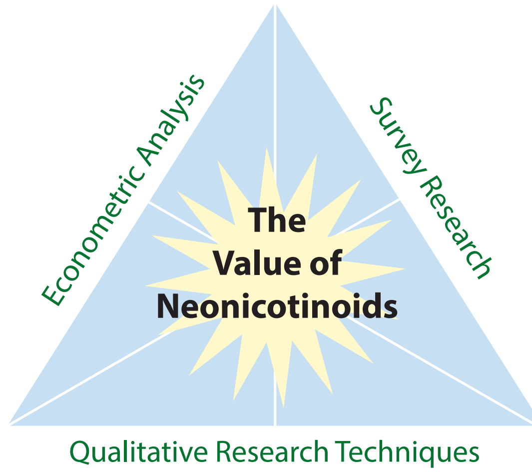
A counterfactual logic was used to guide the overall analysis on assessing value of neonicotinoids. In layman's language, the basic approach taken was to develop a non-neonicotinoid scenario of what agriculture would be like without these neonicotinoids, then using the differences between this non-neonicotinoid scenario and the current system to identify the benefits from these products. By hypothetically removing neonicotinoids, their value is revealed by measuring substitutions, adjustments, gains and losses in the metrics of commercial agriculture (e.g., yield), and other impacts related to human safety and the environment (Ferraro, 2009).

Counterfactual analyses are common in economic and political disciplines where it is necessary to assess the likely impacts of proposed policies and regulations (Courtois, 2010; Falck-Zepeda et al. 2000; Mitchell 2014; Moschini et al. 2000; Price et al. 2003). Cowan and Foray (2002) note that counterfactual condition statements are ubiquitous in any scientific endeavor and discuss the strengths and pitfalls of this approach. The counterfactual analysis in this case was based on addressing the question, *What would happen to North American agriculture if neonicotinoids were not available?*

Identifying the value of neonicotinoids in North American agriculture required a sophisticated methodology. AgInfomatics selected a strategy of data triangulation to provide the most robust answer to the counterfactual question (Campbell and Fiske,1959; Denzin and Lincoln, 2000). Data triangulation means using multiple methods to analyze the same phenomena. In this case qualitative techniques were used to define the scope of the issues and to provide in-depth perspectives that are not possible with just statistical analyses or data summaries. Multiple quantitative techniques allowed development of specific measurements that could then be integrated with other results for further analysis or provide a stand-alone understanding of the value of specific attributes of neonicotinoids. According to Denzin (2012), *"The combination of multiple methodological practices, empirical materials, perspectives, and observers in a single study is best understood as a strategy that adds rigor, breadth complexity, richness and depth to any inquiry."* There are two key advantages to data triangulation:

1. Measuring the same phenomena using different methods enhances the validity of the results through eliminating bias and potential alternative explanations of the research question.

2. Methodological triangulation also provides an opportunity to explore unanticipated findings when there is some divergence in the results of different methods. Triangulating methods does not mean all the methods generate consistent results, but differences or nuanced discrepancies may lead to further understanding of the phenomena being investigated. Working to understand why different methods may generate different outcomes increases the credibility of the analysis.



The reports used a data-driven approach to define current crop production systems and the non-neonicotinoid alternatives, relying primarily on data from GfK Kynetec, supplemented by United States Department of Agriculture (USDA) data, as well as peer-reviewed literature, extension publications, and efficacy and yield trials by public institutions.

AgInfomatics refined these alternatives based on an innovative array of sources, including the knowledge of those involved in day-to-day insecticide decisions – crop advisors, scientists and extension professional working at salient land grant universities, purveyors of plant protection products, and services and farmers. A panel of innovative growers was convened early in the project for a 'grounding' of this approach, which was followed by a series of expert panels in different production areas, to gain insights on the alternatives, the value derived from the convenience and safety of neonicotinoids, and to provide evidence relating to agronomic, socioeconomic and environmental impacts of moving toward non-neonicotinoid alternatives.

Economic analysis based on the base case and non-neonicotinoid scenarios used a range of approaches to capture the short- and long-run differences between the two scenarios. Of the economics reports conducted, the economic assessment of the benefits of neonicotinoids for U.S. commodity crops is the most comprehensive, relying on AGSIM, a simulation model of the U.S. agricultural economy. AGSIM is based on a large set of econometrically estimated dynamic demand and supply equations for major field crops and has been used by academic and government analysts to analyze a wide variety of agricultural policies, including one related to pesticides (Mitchell, 2014). Because a model comparable to AGSIM is not available for specialty crops, the economic analysis for these crops relied on evaluations that require less information, and as a result, the economic assessments do not take into effect control of invasive species or disease transmission benefit impacts in crops such as citrus or other specialty crops.

These economic analyses focus on the monetary benefits derived from yield and cost benefits of neonicotinoids. However, these neonicotinoids provide several non-monetary benefits, such as convenience, applicator safety, longevity and consistency of control, resistance management, and reduced environmental impacts. To estimate the value of these non-mone-

tary benefits, AgInfomatics used survey-based techniques for corn, soybean and canola farmers.

In these reports, data triangulation involved the following methods and techniques:

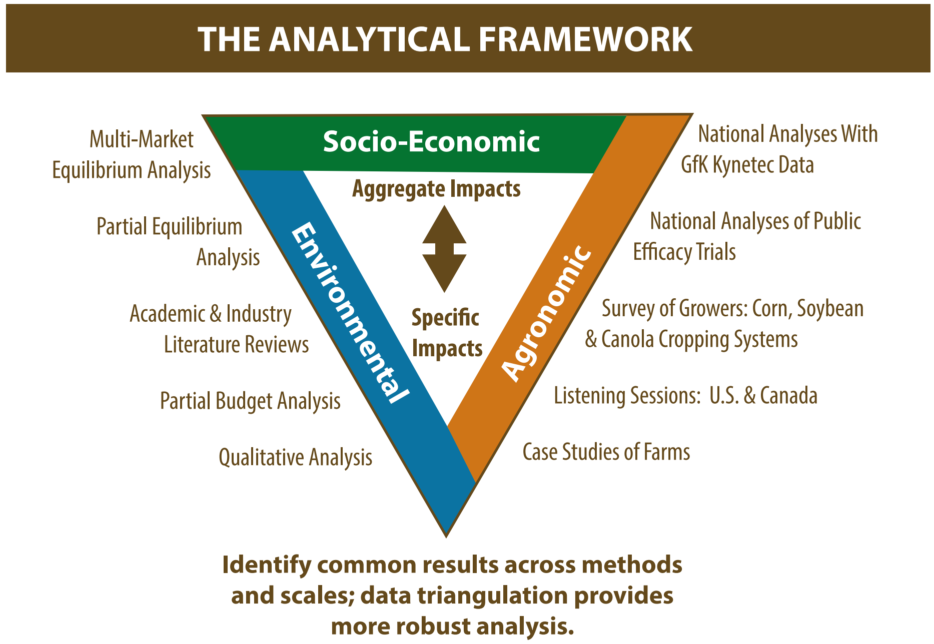
- **Partial budget analysis** — A partial budget analysis is the tabulation of expected gains and losses due to a change in overall farming method or production practice, such as a change in access to neonicotinoids.
- **Partial equilibrium analysis** — The partial equilibrium analysis looks at the production processes that impact the price for one good or commodity while holding other changes in the market constant. This assumption of holding all other factors constant is the crux of partial equilibrium analysis.
- **Multi-market equilibrium model** — These are complex and sophisticated techniques that account for all changes and reactions in the economy when a new policy or technology is introduced. Changes in production of one commodity may induce shifts in the production of other commodities or the prices associated with both inputs and outputs. Capturing this interplay between the conditions influencing supply and demand is the role of multi-market equilibrium models. In this case, AGSIM is the model employed due to its accepted standing in the academic and policy communities.
- **Case studies** — A case study is an in-depth descriptive analysis and investigation of a specific situation. The advantage is the richness and elaboration in gaining an understanding of the specific phenomena being studied, while the disadvantage is the time and costs it takes to produce this outcome. Case studies give you an in-depth understanding of a particular situation but lack the ability to generalize results.
- **Survey research** — There are many types and degrees of sophistication in survey research. Commonalities include the selection of individuals from a larger population using a specific and often a probability-based method, a set of standardized questions, statistical analysis and some level of generalization to the larger population. In this study, growers in both the U.S. and Canada were surveyed.
- **Secondary data analysis** — Taking advantage of the wealth of information that already exists is a role of secondary data analysis. In this case, prior research included all public product efficacy studies and market research (e.g., GfK Kynetec) data on current agronomic practices.

The relation of these data sources and techniques is represented in Figure 1, which illustrates using these techniques at different scales in order to generate a more robust calculation of the value of neonicotinoids in North American agriculture.

3.0 North American Agriculture

Agriculture in the U.S. and Canada is composed of an integrated chain involving input manufacturers, distributors, professional applicators and consultants, farm families, points of sale where crops and products are sold, aggregators and processors, food wholesalers, distributors and food retail-

Figure 1. The analytical framework used for these reports.



ers. According to government agencies (Agriculture and Agri-Food Canada and the USDA Economic Research Service) this agricultural system is a major provider to a global food markets. Canadian agriculture generated $103.5 billion in 2012 representing 6.7 percent of Canada's GDP. U.S. farms generated $166.9 billion representing about 1 percent of U.S. GDP. Canada produces 20 percent of the world's canola/rapeseed while the U.S. produces 46 percent of the world's soybeans, 41 percent of the world's corn, 20 percent of the world's cotton and 13 percent of the world's wheat.

3.1 Methods to establish economic value

Methods and Assumptions for Estimating the Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers

Following is a brief description of the comprehensive report ***Methods and Assumptions for Estimating the Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers***. The length and detail of this report necessitated a separate executive summary, ***Estimated Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers.***

Establishing the value of neonicotinoids begins by establishing current use patterns. AgInfomatics focused its analysis on neonicotinoid use in commodity crops (corn, soybeans, wheat, cotton and sorghum), by application method (seed treatment, soil or foliar), and the pests being targeted by the treatment. One also has to determine planted acres, base acres and product acres[1] for crops being protected by neonicotinoids. The next phase of

[1] For a crop, planted acres are the number of acres planted, base acres are the unique number of these planted acres treated with an insecticide once or more, and product acres are the number of acres treated with insecticides, potentially the same acre more than once.

this process of establishing value is based on the counterfactual assumption of neonicotinoids no longer being available. This means that for all the current uses just established, one now has to determine the pests being targeted by crop and then matching these to alternative insecticides registered for those situations. Costs are then assigned to these alternatives that may be associated with efficacy, application methods, and whether differences in scouting are involved. For example, changing from a seed treatment to several foliar applications involves a number of new costs. Another nuance is that some crops do not have grower-accepted registered insecticides for certain pests, as the method and/or timing of application may not fit with farmer practices or equipment inventory. Examples of this are soil pests in U.S. soybean and wheat, and wireworm control in cotton. In cases such as these, one has to calculate the cost of adaptation strategies used by growers such as changing seeding densities, bringing more land into production or shifting to other crops. Finally, when a non-neonicotinoid insecticide is registered for use on a specific pest previously controlled by neonicotinoids in a specific crop, the assumption is made that this registration would be amended when necessary to label this pest in new crops. For example, chlorpyrifos is registered for wireworm control in corn; it is registered for both foliar and soil application in cotton to control multiple pests but not wireworm. In this case, the assumption is made that chlorpyrifos would be used for wireworm control in cotton because registration would be sought and approved in a non-neonicotinoid scenario.

3.1.1 Current use

Neonicotinoid insecticides are the most widely used class of insecticides in U.S. corn, soybean, wheat, cotton and sorghum according to GfK Kynetec data. The annual average for 2010-2012 was 133 million base acres treated at least once with a neonicotinoid insecticide or almost 56 percent of the 240 million acres of corn, soybean, wheat, cotton and sorghum (see Figure 2). Seed treatments are the primary method of application of neonicotinoid insecticides for these crops, accounting for more than 98 percent of the 133 million base acres treated. This popularity suggests that U.S. commodity crop farmers find neonicotinoid insecticides and seed treatments to be a valuable class of insecticides and application method.

3.1.2 Pest management

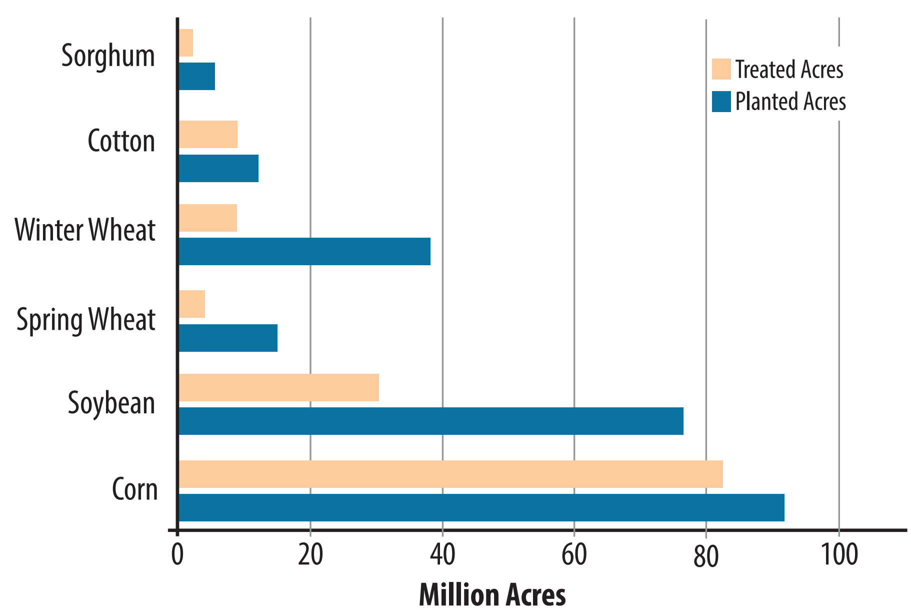
The GfK Kynetec data for these crops include product acres by application method and target pest for 98 different insecticide AIs (active ingredients), including four neonicotinoids (clothianidin, dinotefuran, imidacloprid and thiamethoxam). Cotton is the most complex crop in terms of pest management in that there is pest targeting with both foliar and soil applications. In the 2010-2012 GfK Kynetec data, cotton growers identified 72 different target pest species and four different insecticide application methods (banded, broadcast, seed treatment and spot treatment). Also recorded were situations where no answer was provided on the use of a preventive program.[2] The cotton analysis, the most complex among all commodity crops, then served as the template for analyzing the other commodity crops. A summary of the pests targeted for each commodity crop is presented in Table 1.

2 A preventive program according to the EPA "may mean rotating between different crops, selecting pest-resistant varieties or planting pest-free rootstock" (http://www.epa.gov/pesticides/controlling/agriculture.htm).

Table 1. Percent neonicotinoid product acres targeted at each insect pest by crop.

	Corn		Soybean		Cotton		Winter Wheat		Spring Wheat		Sorghum	
Pest	Foliar	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil
Aphid			29.7	24.9	13.1	12.1		21.6		2.9		38.7
Fleahopper					9.4	5.7						
Plant Bug					59.0	4.7						
Stink Bug			41.8	1.5	11.8							
Thrips					6.6	75.2						
Wireworm		32.8		13.2		2.3		59.9		97		28.2
Rootworm		23.9										
Cutworm		5.6										
Flea Beetle		1.6										
Seed/Corn Maggot		21.0		14.0								2.0
White Grubs		15.1		5.9								
Bean Leaf Beetle			7.1	36.7								
Japanese Beetle			7.0	1.0								
3-Cornered Alfalfa Hopper			14.3	2.8								
Hessian Fly								18.4		0.1		
Chinch Bug												27.6
Ant												3.5

Figure 2. Proportion of planted acres treated with neonicotinoids by crop.



3.1.3 The non-neonicotinoid scenario

The next step described in the reports is allocation of the neonicotinoid product acres to non-neonicotinoid AIs and practices for the non-neonicotinoid scenario. The allocation is derived from the average market shares during 2010-2012 seasons for each AI for each target pest. Neonicotinoid product acres are allocated to alternative non-neonicotinoid insecticides based on product acre shares for each insecticide and the frequency that insecticide targets different pest groups. The analysis under the non-neonicotinoid scenario projected that 77 percent of neonicotinoid acres would use alternative non-neonicotinoid insecticides. Switching from a neonicotinoid seed treatment to a foliar-based IPM program, the assumption is that 10 percent of neonicotinoid acres would be scouted but not treated for the original target pest. Finally, due to lack of registered or widely used soil-applied chemical alternatives for some crops, about 13 percent of neonicotinoid acres are assumed to switch to using higher initial seeding densities or replanting to help compensate for stand loss due to soil-dwelling pests.

3.1.4 Use of alternative active ingredients

As a result of these changes, acres treated with non-neonicotinoid insecticides are projected to increase 185 percent, adding almost 105 million product acres annually. The largest increases were projected for pyrethroids and organophosphates, which would add 66 million and almost 38 million acres respectively; all other insecticides classes were projected to add less than 1 million product acres in total. In terms of total pounds of insecticide active ingredients applied, the non-neonicotinoid scenario replaced 4.0 million pounds of neonicotinoids with 19.1 million pounds of non-neonicotinoids, so that the total pounds of insecticide active ingredients applied to these crops would increase from 13.0 million pounds to 28.2 million pounds, a 116 percent increase. The neonicotinoids replacement products are used at a 375 percent greater application rate. Total pounds of organophosphates applied to these crops tripled, and pyrethroids quadrupled, even though only 77 percent of neonicotinoid treated acres continued to use insecticides under the non-neonicotinoid scenario. This is a significant increase in organophosphates and pyrethroids as soil-applied and foliar insecticides. Further, because there are essentially no alternative soil insecticides used for soybean and wheat to control existing pests, according to GfK Kynetec data, an estimated 17 million acres of these crops would use higher seeding densities and/or replant reduced stands. These changes are portrayed in Figure 3.

3.1.5 Costs

The next step in this analysis is estimating the costs to the grower resulting from the switch to alternative chemicals and practices using a partial budget analysis. There are three costs associated with the shifting to non-neonicotinoid alternatives. These are the costs of the alternative insecticides, application costs (since neonicotinoid seed treatments are no longer an option) and scouting costs. The reports use GfK Kynetec data to develop estimates of the per acre costs for each AI. Both USDA-NASS and state extension publications were used to estimate application and scouting costs for each commodity crop. There is a significant amount of detail in these

Figure 3. Neonicotinoids to non-neonicotinoid alternatives.

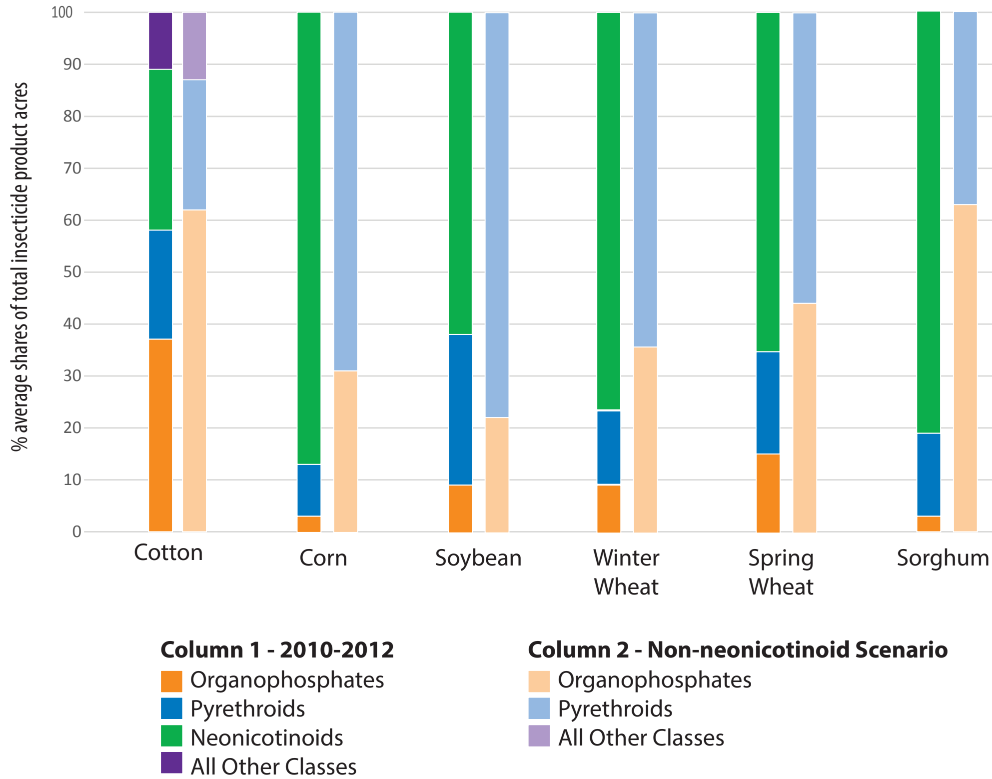
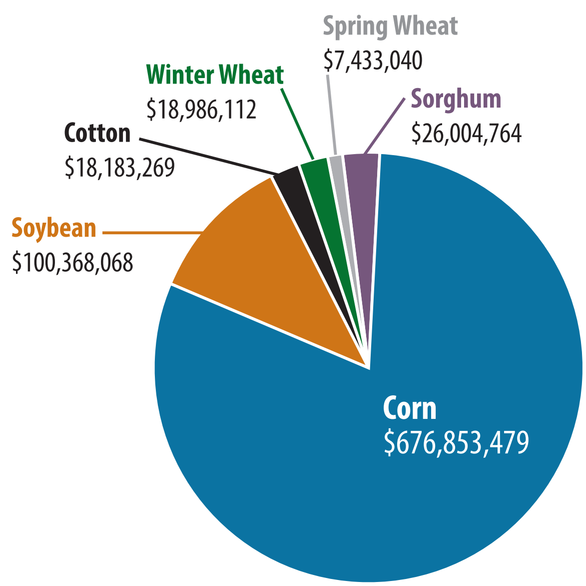


Figure 4. Net change in grower expenditures by crop.



partial budget analyses based on the pest management system (in-furrow versus foliar), machinery, number of applications required and interest rates. The budget analysis also illustrated another important dimension of neonicotinoids compared to the alternative insecticides. In many cases the cost of the alternative insecticides was cheaper per acre than the cost of neonicotinoids, and yet the widespread use of neonicotinoids highlights the fact that growers find value from these products in ways that go beyond direct costs. The estimated cost to the growers by crop is illustrated in Figure 4. These costs range from approximately $7.5 million for spring wheat up to almost $677 million for corn growers. Corn accounts for the majority of the $848 million cost increase under the non-neonicotinoid scenario, while soybean accounts for $100 million.

3.1.6 Other issues

These projected changes raise several concerns. The first is that the non-neonicotinoid scenario implies a much greater reliance on only two chemical classes (i.e., pyrethroids and organophosphates) and associated modes of action. This increases the probability that a heritable change in the sensitivity of the targeted pest will occur as the level of expected control is not achieved. This process of natural selection leads to pesticide resistance.

A second issue is that the increased use of non-selective insecticides that are broadcast applied will have negative impacts on non-target insects and organisms, including beneficial insects. These beneficial insects are often an integral part of an IPM program, and these benefits would be lost or significantly reduced under the non-neonicotinoid scenario.

There are other issues not considered in this analysis associated with increased potential for spray drift, field runoff and increased compaction as more passes are made on fields, thereby inducing yield losses.

3.2 Further exploration of value

Value of Insect Pest Management to U.S. and Canadian Corn, Soybean and Canola Farmers

The reports on ***Methods and Assumptions for Estimating the Impact of Neonicotinoid Insecticides on Pest Management Practices and Costs for U.S. Corn, Soybean, Wheat, Cotton and Sorghum Farmers*** represented a detailed examination of moving from current pest management practices in the U.S. commodity crops to a hypothetical situation where neonicotinoids would not be available. Based on the costs associated with changes in production practices, it was found that growers would accrue $848 million in additional costs. One of the notable findings from the case studies, listening sessions and grower survey was the fact that growers favored neonicotinoids even when alternative insecticides may be available at a lower cost. The next report explores that finding in greater depth. The report ***Value of Insect Pest Management to U.S. and Canadian Corn, Soybean and Canola Farmers*** had two major objectives 1) assess the value of alternative insect management practices to farmers and 2) determine how these values relate to nonpecuniary factors such as simplicity, convenience, yield risk, and human and environmental safety.

Understanding the importance of nonpecuniary factors begins with looking at two recent and notable innovations that were introduced to North American agriculture. There is usually a lengthy period of time between when an innovation is initially introduced to when the majority of growers are using it. For example, moving from open-pollinated corn to hybrid corn began in 1928 in Iowa, but most Iowa farmers did not adopt the new technology until the early 1940s (Ruttan, 1966). That significant time lag did not occur with the introduction of plant-incorporated protectants, such as European corn borer active Bt corn in 1996 and corn rootworm active Bt corn in 2004. An even faster adoption and diffusion process occurred with the introduction of the genetically engineered herbicide tolerant crop, Monsanto's Roundup Ready® soybean, introduced commercially to the U.S. in 1994 and Canada in 1995. A common feature in these recent agricultural innovations was that the rapid adoption patterns could not be explained solely on the basis of profitability. Other forms of value were inducing growers to adopt these products. Exploring those values around insect management practices is the focus of this report.

A professional survey research firm, Market Probe, was contracted to collect a representative sample of growers representing three crops; 622 corn farmers from twelve U.S. states and three Canadian provinces, 622 soybean farmers from fourteen U.S. states and three Canadian provinces and 500 canola farmers from three Canadian provinces. Professional interviewers conducted telephone surveys in 2014.

Two different types of analytical procedures were used to address the objectives in the report. A statistical technique of factor analysis was used to define common dimensions among the nonpecuniary values. Factor analysis is a technique that examines variability among measured variables (in this case the nonpecuniary variables) to determine if there are fewer common dimensions based on these relationships. These fewer common dimensions are called factors. Econometric methods were used to better understand regional difference in pest management practices and the value of these practices, as well as how differences in these pest management practices and the value of these practices related to various nonpecuniary factors. Finally, the results of the econometric analysis were used to estimate the value of these different insect management practices to farmers.

Nonpecuniary connotes a value that cannot be expressed in monetary terms, and therefore the exploration of these values must begin with the grower. A survey instrument was designed and pre-tested that had nine different sections;

1. Operation (e.g., the number of target crop acres, total crop acres, other crops planted, use of conservation tillage practices, number of corn following corn acres for corn farmers, amount of leased land and presence of a livestock enterprise),

2. Actively managed insect pests, including the most important of these pests,

3. Use of alternative pest management practices (e.g., Bt corn, insecticide seed treatments, soil insecticides and foliar insecticides), including specific products and number of acres,

Table 2. Importance of nonpecuniary benefits as percent of growers by crop.

	Not Important			Somewhat Important			Important			Very Important		
	Corn	Soybean	Canola	Corn	Soybean	Canola	Corn	Soybean	Canola	Corn	Soybean	Canola
Reducing equipment wear & tear	8.2	5.9	7.0	28.5	26.8	29.7	38.0	36.7	35.5	25.3	30.6	27.9
Saving time & labor	3.1	3.4	2.4	20.9	20.0	22.1	41.0	40.0	39.2	35.0	36.6	36.2
Replant or other product guarantees	9.3	9.8	8.8	26.4	28.2	28.0	37.1	36.3	37.4	27.2	25.7	25.8
Reduced scouting	13.4	16.2	12.1	31.1	31.1	34.2	38.7	31.9	32.0	16.7	20.7	21.7
Convenience	2.6	3.8	0.8	26.3	26.8	28.4	43.9	40.4	42.5	27.2	29.1	28.2
Flexibility	2.8	2.3	1.0	26.8	27.0	25.2	45.2	41.6	41.7	25.3	29.1	32.1
Simplicity	4.2	4.3	1.8	21.7	25.5	24.3	45.8	40.6	44.5	28.2	29.6	29.4
Cost	1.1	1.6	0.2	15.3	12.2	14.6	33.1	29.6	33.5	50.4	56.5	51.7
Being able to plant early	8.1	9.5	4.8	24.3	24.2	25.7	33.4	31.8	35.6	34.2	34.5	33.9
Family & worker safety	1.6	0.6	0.0	5.2	4.1	2.6	23.3	24.5	16.0	69.9	70.8	81.4
Public safety	2.6	2.1	0.8	11.2	12.2	9.4	34.7	31.2	28.2	51.5	54.5	61.6
Protecting water quality	1.9	1.3	1.8	9.4	9.3	10.6	30.8	31.9	28.9	57.9	57.5	58.7
Protecting wildlife	5.7	4.4	4.0	19.5	21.0	17.6	37.9	36.6	38.4	36.8	37.9	40.0
Protecting beneficial insects	3.9	3.6	2.6	16.7	19.3	12.3	40.5	33.3	32.4	38.9	43.8	52.7
Crop market-ability	5.6	2.8	0.6	12.7	13.8	6.5	32.0	29.4	21.6	49.8	54.0	71.4
Improving plant health	0.5	0.5	0.4	10.4	11.2	9.6	40.2	39.8	35.9	48.9	48.5	54.1
Improving crop stand	0.5	2.1	1.4	8.8	12.6	13.5	38.9	36.7	37.6	51.9	48.6	47.6
Protecting yield	0.3	0.5	0.2	5.8	5.7	4.2	29.0	28.6	25.3	64.8	65.2	70.3
Consistent insect control	2.4	1.1	0.6	8.1	8.2	5.0	37.2	32.1	31.1	52.3	58.6	63.3
Long lasting insect control	3.1	2.0	1.4	14.1	13.1	13.1	35.3	35.4	33.3	47.6	49.6	52.2

4. Average production costs, yields and price received for any marketed crop,

5. Source of insect pest management advice,

6. Most important considerations when making insect pest management decisions,

7. Perceived value of alternative insect pest management practices,

8. Biggest insect pest management concerns in the targeted crop, and

9. Education and farming experience.

The nonpecuniary items that were used in the surveys are listed in Table 2 where the importance placed on each item by the percent of respondents is displayed for each crop. Growers were most likely to give family and worker safety, crop marketability and protecting yield a very important ranking, while reduced scouting, replant or other product guarantees, and being able to plant early had the highest not important scores. The factor analysis generated five factors for corn (1) cost, planting, time and ease, (2) health, environment and marketability, (3) plant performance, (4) yield risk, and (5) marketability versus ease. Soybeans were characterized by four factors (1) cost, planting, time and ease, (2) health, environment and marketability, (3) plant performance and yield risk, and (4) replant guarantees. The factor analysis for the Canadian canola growers generated three factors (1) cost, planting, time and ease, (2) health, environment and marketability, and (3) plant performance and yield risk. It is these values that were used in the factor analysis.

The major insect pests of concern noted by corn farmers were the corn rootworm and European corn borer. While U.S. farmers tended to see the corn rootworm as the most important threat in corn, Canadian farmers saw the European corn borer as the most important threat. U.S. and Canadian farmers both noted that aphids were the biggest threat to soybean production. For Canadian canola farmers, the biggest threat was the flea beetle.

Agricultural retailers and seed/chemical company representatives were the most widely used sources of insect pest management advice for both U.S. and Canadian farmers.

Based on survey responses, Bt corn was the most frequently used management tactic by U.S. and Canadian corn farmers to control insect pests (82.2 percent of U.S. and 90.1 percent of Canadian corn farmers). This was followed by insecticide seed treatments (64.1 percent of U.S. and 79.1 percent of Canadian corn farmers). Soil insecticide use was less common (19.7 percent of U.S. and 3.4 percent of Canadian corn farmers), as was foliar insecticide use (8.2 percent of U.S. and 11.7 percent of Canadian corn farmers). In soybean, a majority of farmers in the U.S. and Canada used insecticide seed treatments to control insect pests (51.4 percent of U.S. and 73.9 percent of Canadian soybean farmers), while fewer than one in four used foliar insecticides (23.0 percent of U.S. and 14.4 percent of Canadian corn farmers). About nine out of ten Canadian canola farmers used insecticide seed treatments with only about one in four using foliar insecticides.

The econometric analysis found a variety of statistically significant differences in farmer responses between the U.S. and Canada, as well as differences within the U.S. and Canada. These differences likely reflect geographical differences in production environments. These differences included not only differences in the use of pest management practices(such as Bt corn, insecticide seed treatments, soil insecticides and foliar insecticides by crop) but also in the per acre value of these practices.

Two types of values were estimated for each crop: the average value per acre treated with the insect management practice ($ per treated acre) and the average value for all the acres of that crop the farmer planted ($ per planted acre). For example, a practice with a value of $20 per treated acre that is used on 60 percent of a farmer's planted acres has a value of $20 x 60% = $12 per planted acre. Multiplying total planted acres by the value per planted acre for a specific insect management practice then gives the total value of that practice for that farmer. All values are in U.S. dollars, with Canadian values converted to U.S. dollars using an exchange rate of $1 Canadian dollar equal to $0.92 U.S. dollar.

The estimated value of Bt corn is about $20 per treated acre in both the U.S. and Canada. The estimated farmer value for insecticide seed treatments is $13.38 per treated acre for U.S. corn farmers and about $12 per treated acre for Canadian corn farmers. The estimated value of insecticide seed treatments for soybean differs in the U.S. and Canada, more than $14.50 per treated acre in Canada but approximately $12 per treated acre in the U.S. The estimated value of insecticide seed treatments is $12.85 per treated acre for Canadian canola farmers, while the estimated value of soil insecticides is almost $13 per treated acre for U.S. corn farmers. The estimated value of foliar insecticides is more than $14 per treated acre for both U.S. and Canadian corn farmers, while the value for Canadian canola farmers is just under $14 per treated acre. Just as for insecticide seed treatments, the estimated value of foliar insecticides for soybean differs substantially for the U.S. and Canada, almost $13.50 per treated acre in the U.S. but about $10 per treated acre in Canada.

The estimated total value of Bt corn in 2013 was $1.25 billion in the U.S. and $56 million in Canada. The estimated total value of neonicotinoid insecticide seed treatments in 2013 was $1.13 billion in the U.S. and $301 million in Canada. The estimated total value of soil insecticide treatments in 2013 was $175 million in the U.S. Too few Canadian farmers reported using soil insecticides to calculate an estimated value. The estimated total value of foliar insecticide treatments in 2013 was $249 million in the U.S. and $57 million in Canada.

Based on these results, neonicotinoid seed treatments were the most valued insect management practice for North American corn, soybean and canola farmers, with a total farmer value of $1.43 billion in 2013. Bt corn was second, with a total farmer value of $1.3 billion in 2013. The total farmer value of foliar and soil insecticides were $306 million and $175 million, respectively. Taken as a whole, the $1.43 billion demonstrate that neonicotinoid seed treatments provide substantial value to North American corn, soybean and canola farmers.

3.3 Managing pest and yield impacts

A Meta-Analysis Approach to Estimating the Yield Effects of Neonicotinoids

Many within agriculture have recognized that neonicotinoids have an impact on crop yields and are thus another value to consider. The statistical technique of a meta-analysis is used with available data to quantify this value. A meta-analysis is based on a set of protocols for bringing together a diverse collection of data sets to seek out common patterns or areas of disagreement. The report, ***A Meta-Analysis Approach to Estimating the Yield Effects of Neonicotinoids*** is based on the aggregation of all publically available documented U.S. and Canada data and reports on the yield impacts of clothianidin, dinotefuran, imidacloprid and thiamethoxam.

The challenge of conducting this meta-analysis was identifying, assembling and validating data sets from three primary sources (1) the published literature, (2) the *Arthropod Management Tests* published by the Entomological Society of America, and (3) what is often called the 'grey literature' that represents legitimate science but is not formally published in a public journal. Many of these studies are efficacy experiments, useful for outreach purposes, commercialization decisions and generating regulatory data, but often not published in traditional peer-reviewed academic journals because they are considered routine.

Using the above sources, significant data sets were assembled for corn, soybean, wheat, cotton, sorghum, canola, potato and tomato. Data were available for these crops for studies conducted from 1993 to 2014 but not for all crops in all of these years. In total for these eight crops, data from a total of 1,550 studies were assembled, generating 3,359 observations of yield for both a neonicotinoid insecticide treatment and an untreated control. In addition, data from a total of 955 studies were assembled, generating 1,611 observations of yield for both a neonicotinoid insecticide treatment and a non-neonicotinoid insecticide treatment. The final data for each study site-year included three types of yields: (1) yield for the untreated control, (2) up to four neonicotinoid yields, one for each active ingredient, and (3) possibly a non-neonicotinoid insecticide yield.

The yield impact of a neonicotinoid insecticide treatment relative to no insecticide treatment is the net percentage increase in yield, calculated for each crop, and the yield impact of a neonicotinoid insecticide treatment relative to a non-neonicotinoid insecticide treatment is the net percentage increase in yield, also calculated for each crop. The average yield benefit of neonicotinoids relative to untreated controls by crop is illustrated in Figure 5, while the benefits relative to non-neonicotinoid insecticides is illustrated in Figure 6. A sufficient number of cases could not be located for tomatoes, and therefore this is left intentionally blank in Figure 6.

There are key caveats relative to these yield benefits. There are differences in yield benefits between geographies for the same crop. These differences are likely due to differences in the pest populations and in the spectrum of pests in the different regions, as well as sampling error. The report also emphasizes that these yield benefits are averages, not certain outcomes. Actual yield outcomes vary across years based on weather, insect pressure and geographies. Report appendices provide histograms and other plots to show the variability in the yield benefit across all the data, plus tables and figures showing how the average varies across geography.

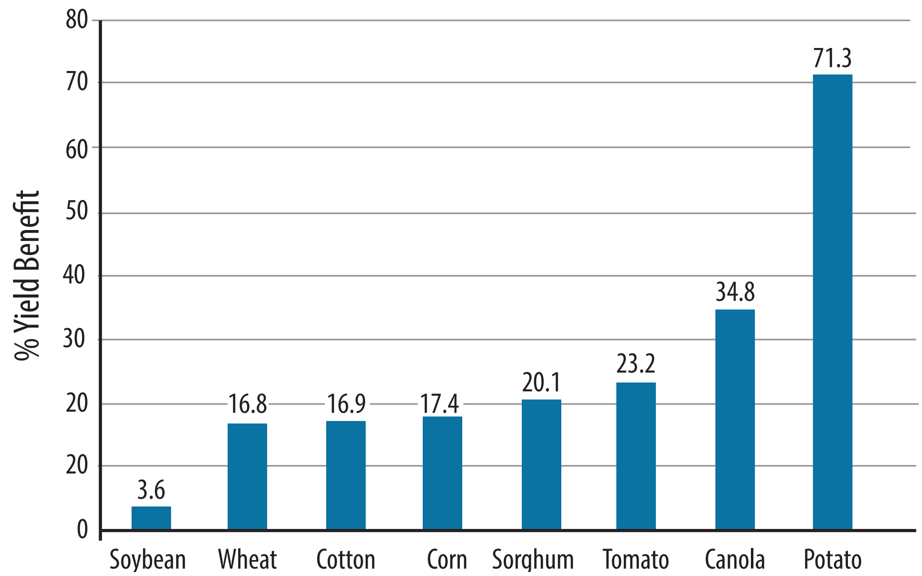


Figure 5. Average yield benefit by crop for neonicotinoid insecticide treatments relative to untreated control treatments.

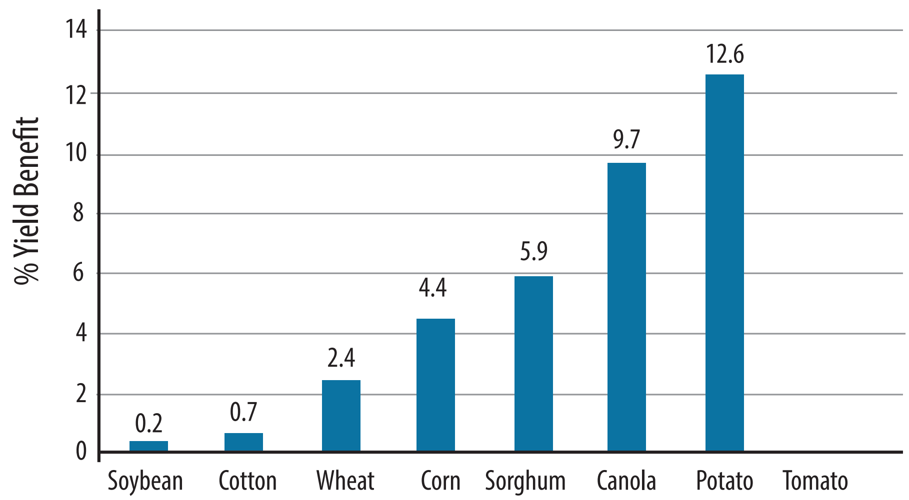


Figure 6. Average yield benefit by crop for neonicotinoid insecticide treatments relative to non-neonicotinoid insecticide treatments.

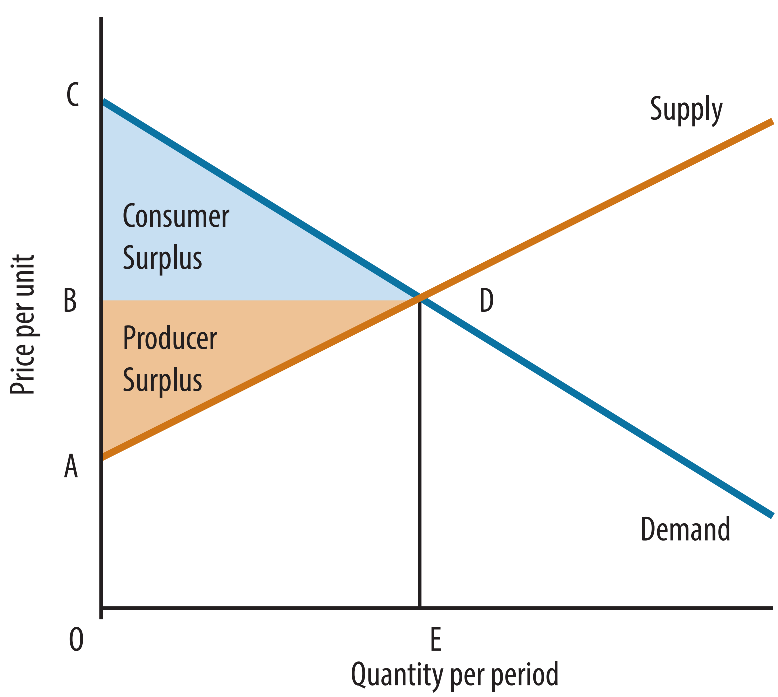
3.4 Overall value

An Economic Assessment of the Benefits of Nitroguanidine Neonicotinoid Insecticides in the United States and Canada

This executive summary is based on providing a synopsis of the multiple types of value associated with neonicotinoids. Some can be quantified, as was the case in the report on the yield impacts of neonicotinoids. Other values associated with convenience, safety or contributions to an IPM program for example, emerged with qualitative techniques represented by the reports on grower listening sessions and the case studies. This report, ***An Economic Assessment of the Benefits of Nitroguanidine Neonicotinoid Insecticides in the United States and Canada,*** quantifies the market-level benefits of nitroguanidine neonicotinoid insecticides to the U.S. and Canadian economies.

The core economic concepts upon which market value is calculated are consumer and producer surplus. Consumer surplus is the total dollar amount consumers would be willing to pay for the market equilibrium quantity above what they actually do pay. Producer surplus is the total dollar amount producers actually receive for the market equilibrium quantity above what they would be willing to accept. These concepts are represented in Figure 7 and are the theoretical foundation for calculating how farmer costs and yields would change if they did not have neonicotinoid insecticides and then estimates the implied changes in the crop supply function and in consumer and producer surplus. The overall value will be the difference between the current situation where neonicotinoids are available to growers and what would happen under the counterfactual scenario where growers would have to shift to alternative insecticides and pest management strategies.

Figure 7. Total Surplus = Consumer Surplus + Producer Surplus.



The challenge is that neonicotinoids are used in multiple crops, and if we assume neonicotinoids are no longer available, then the shifts and changes in these different cropping systems are likely to interact with each other. This means a partial equilibrium analysis will not work as that technique examines each crop in isolation. A multi-market equilibrium analysis models simultaneous changes in costs and crop yields for multiple crops, then shifts crop acreages and prices as farmers seek more profitable crop allocations until prices and acreages settle on a long-run equilibrium. The other advantage of a multi-market equilibrium analysis is that it can also factor in international trade, a critical element for estimated value in North American agriculture. The constraint in employing a multi-market equilibrium model is that they are resource intensive and require relatively current data from agricultural markets. The AGSIM multi-market equilibrium model, developed by Taylor (1993), was used in this report. As noted by the report authors, this selection was made because the AGSIM model has been used by both academics and government analysts and regulators to analyze a wide variety of agricultural policies, including several pertaining to pesticides (e.g., Carlson 1998; Mitchell 2014; Ribaudo and Hurley 1997; Szmedra 1997; Taylor et al. 1991; White et al. 1995; U.S. EPA 1997, 2002).

The analysis begins with the acreage in the crops being considered for U.S. corn, soybeans, wheat, cotton and sorghum. The specialty crops of U.S. potato and tomato (fresh and processing) and Canadian canola, corn and soybeans were also included. The initial step was to calculate the cost and yield impacts of a non-neonicotinoid scenario for each of these crops. No cost change, low cost change and high cost change were calculated along with low or high yield loss. This provides eight different combinations to provide a range of estimates to use in the AGSIM model.

One example of these calculations illustrated in Figure 8 is the low and high yield loss for each crop under a non-neonicotinoid scenario. These losses represent the yield enhancements associated with neonicotinoids and do not include losses associated with greater pest damages or bringing less productive lands into production. The significance of these losses become apparent when considering the acreage in production for each of these crops.

Figure 9 is another example of the input to the AGSIM model where the costs of a non-neonicotinoid scenario are calculated based on dollars per planted arce for each crop being considered. These low and high costs per planted acre are integrated in the AGSIM model with the no, low and high yield losses.

These estimates are critical because the AGSIM does not examine each crop in isolation but models simultaneous changes in costs and crop yields for multiple crops, then shifts crop acreages and prices as farmers seek more profitable crop allocations, until prices and acreages settle on a long-run equilibrium. Changes in acres planted to these crops are reported after equilibrium is reached under the non-neonicotinoid scenario.

Crop acres generally respond to changes in relative profitability – crops more profitable relative to the alternative crops will increase in acres while those less profitable will decrease in acres. Higher costs generally decrease crop acres since these costs do not usually increase prices enough to offset the profit loss from the cost increase, and so relative profitability decreases.

Figure 8. Low and high yield loss for non-neonicotinoid scenario.

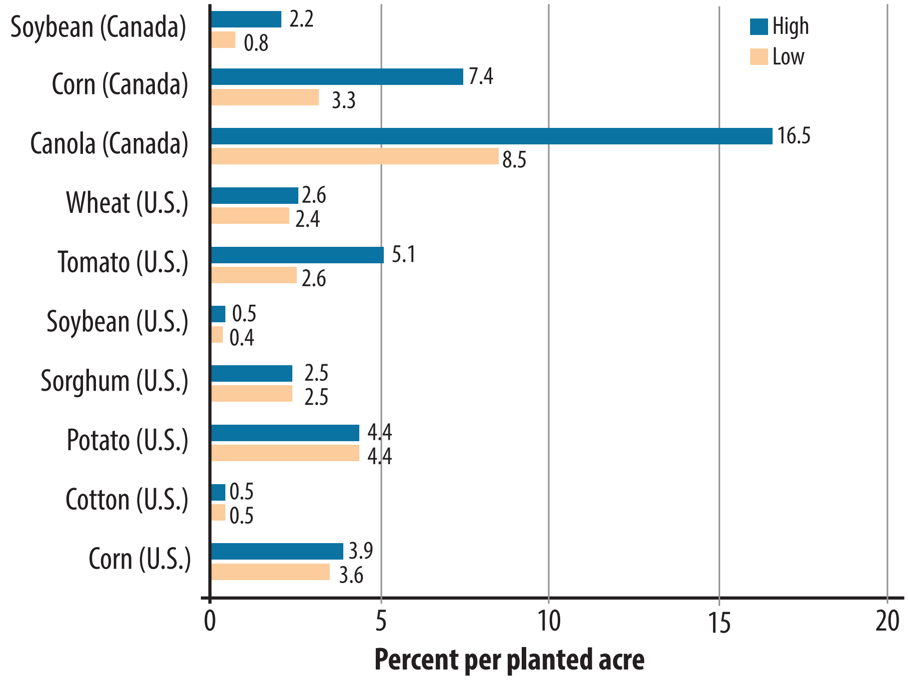
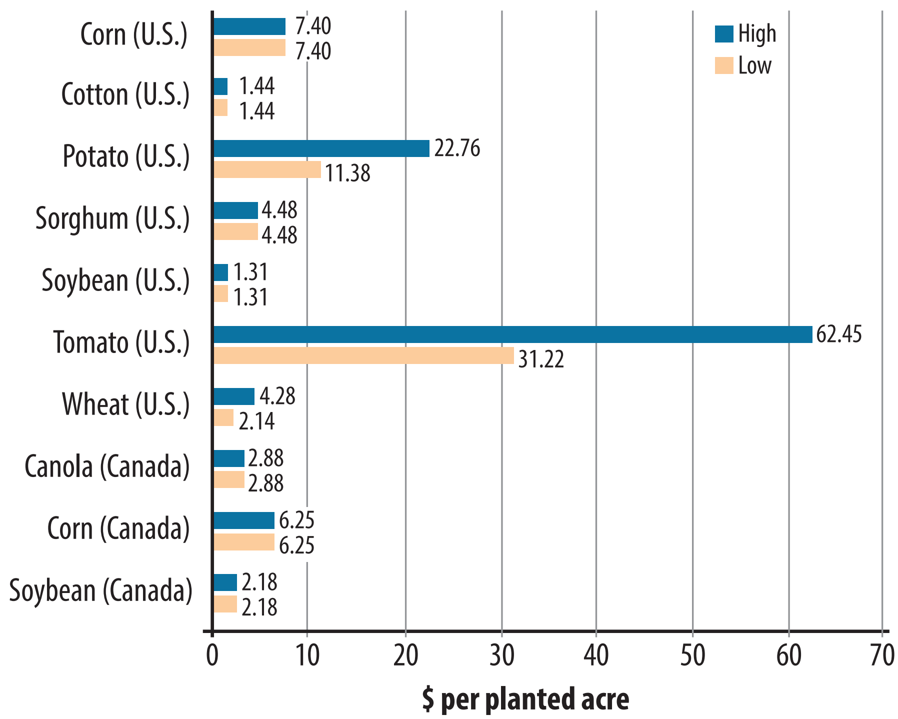


Figure 9. Low and high dollar per planted acre costs for non-neonicotinoid scenario.



However, because industry-wide yield reductions increase crop prices, the price increase can offset lower yields per acre so that relative profitability can increase. As a result, crop acres can increase or decrease when aggregate yield losses are imposed for a scenario, depending on the supply and demand relationships and differences in the magnitude of the cost and yield changes across crops. An example of this is cited in the report is U.S. corn acres. They increase about 450,000 to 525,000 acres in equilibrium once both cost increases and yield losses for the non-neonicotinoid scenario are imposed, since its relative profitability in net increases even with the cost and yield changes as a result of the price increase.

Something worth noting is that the AGSIM model projects a positive increase in farm income for the U.S. commodity crops and the Canadian crops examined. As the price increases due to the reduction in per acre crop yields, this will increase total profit as higher prices are paid for all the remaining crop yields. Consequently, the net surplus changes in the report are the sum of farm income, positive for the non-specialty crops and the consumer surplus that is negative for these crops. The overall costs in the consumer surplus would be paid by commodity crop consumers, which are mostly the livestock, biofuels and vegetable oil industries, and those buying livestock products (meat, dairy, eggs) and using ethanol/biodiesel and vegetable oils.

The estimated value to the U.S. economy (Figure 10) under the high cost and high yield option is $4.34 billion, $4.32 billion with high yield and low cost and $3.35 billion under the high yield and no cost option. The low yield and high cost option still has a cost of $4.04 billion impact on the U.S. economy. The low yield and low cost is calculated to be $4.02 billion, and low yield with no cost option drops this down to a $3.05 billion impact.

The estimated value of the non-neonicotinoid scenario for Canadian corn, soybeans and canola is presented in Figure 11. The no yield with cost is $57 million. The low yield no cost is $91 million, while the low yield with cost increases to $149 million. Finally, the high yield with no cost is $210 million, while high yield with cost is $276 million. It needs to be noted that these estimates of the impacts on the Canadian economy differ from those in a recently released report from the Conference Board of Canada[3] where the estimate was that growers income would decrease by $630 million, resulting in a $440 million reduction in Ontario's GDP. Note that in the short-term, if neonicotinoids were not available, then the cost and yield effects identified in these analyses would reduce farmer income. Multiplying these yield losses by average per acre yields and total treated acres and market prices would give the total value of these yield losses, while multiplying these per acre cost increases by total treated acres would give the aggregate cost increase. These avoided farmer losses are a short-term estimate of the benefits of neonicotinoid insecticides. The estimated economic benefits reported here are not estimates of this sort. Rather, the estimates here assume prices and total production re-equilibrate via market processes over the medium- or longer-term, and then the estimates not only capture the effects on producer income but also consumer benefits.

[3] Grant, Michael, James Knowles, and Vijay Gill. 2014. *Seeds for Success: The Value of Seed Treatments for Ontario Growers*. Ottawa: The Conference Board of Canada.

Figure 10. U.S. net surplus change under non-neonicotinoid scenario.

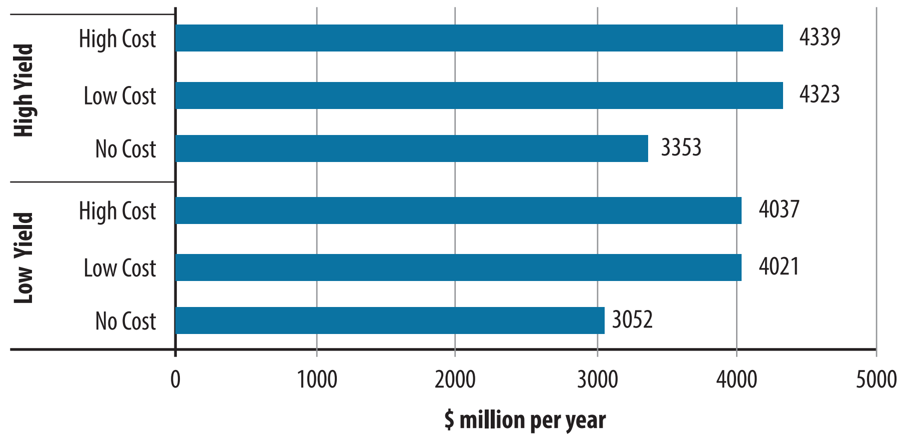
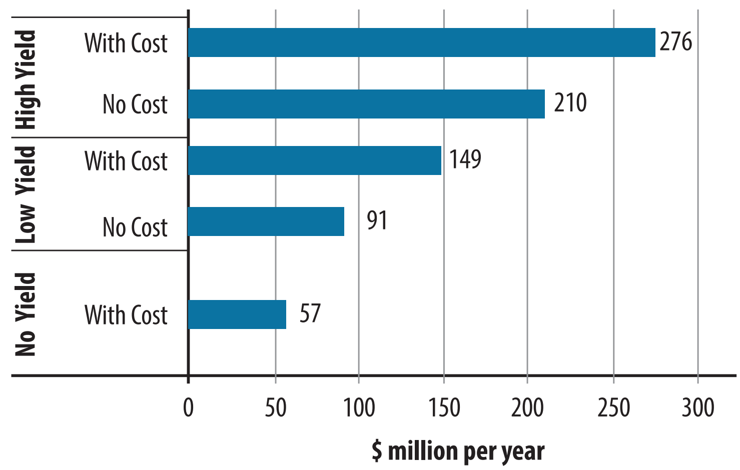


Figure 11. Canadian net surplus change under non-neonicotinoid scenario.



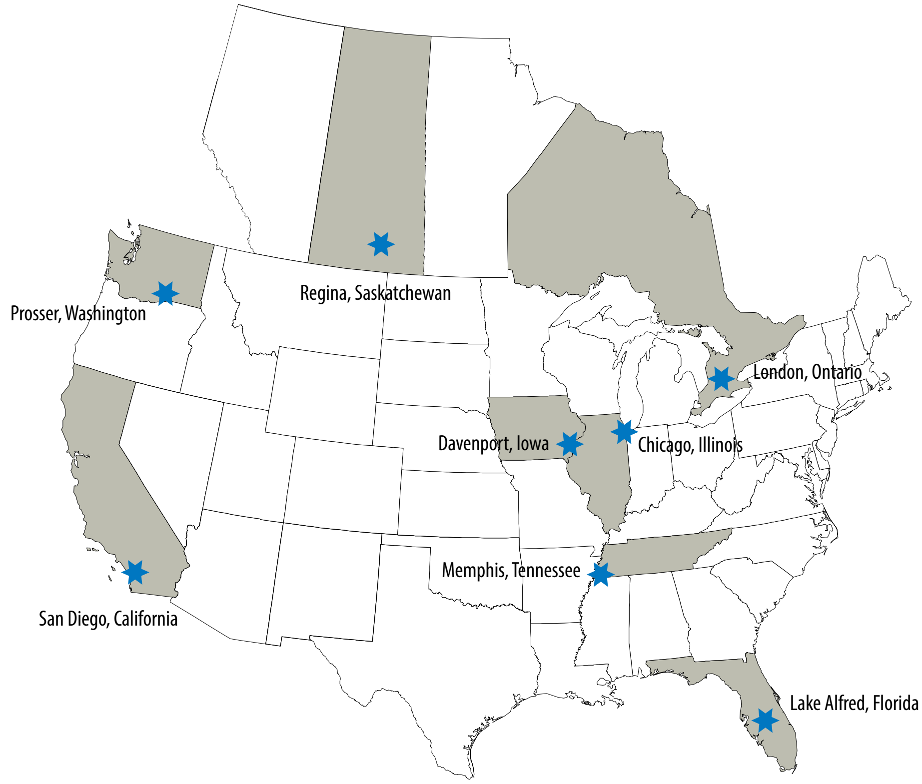
3.5 Grounding the reports

A Summary of Grower and Agri-Professional Perspectives From Regional Listening Sessions in the United States and Canada

An important part of establishing value of neonicotinoids has to be grounded in the knowledge and experiences of the grower. The report, ***A Summary of Grower and Agri-Professional Perspectives From Regional Listening Sessions in the United States and Canada*** is based on a series of listening sessions that were held in the major production areas of North America in the fall of 2013 and winter of 2014. The locations of these meetings are illustrated in Figure 12.

The organization and management of these listening sessions was designed to minimize bias and to represent a spectrum of commercial farms. AgInfomatics staff contacted growers in the selected production regions. These growers were identified as representative producers by local agri-business interests and where applicable, extension specialists. Both growers and a select number of local crop consultants were invited in this manner. Most panels had 7 or 8 growers or consultants, and the audience was AgInfomatics staff, local agri-business representatives and in several

Figure 12. Locations of the listening sessions held in the major production areas of North American in the fall of 2013 and winter 2014.



meetings, researchers and extension specialists. All sessions were moderated and facilitated by AgInfomatics staff. The sessions focused on how insecticides were used in current cropping systems. To illustrate the diversity in the participants, several growers operated part of their operation on an organic basis. The main focus of the approximate 6-hour meeting was to take the understanding of the current situation and then ask the growers to speculate about the implications of the counterfactual scenario of neonicotinoids no longer being available. All the sessions were recorded, transcribed and used to ensure an accurate representation of the ideas and observations being made by the growers.

Two main types of information were sought from these meetings. First, as the title to this section suggests, it was important to 'ground' the entire effort in the knowledge and experience of the grower relative to pest management and farming practices. A number of statements and observations from these meetings have been used to structure our approach to the interpretation of data generated by other efforts. The second type of information sought was themes or issues that ran across the production areas regarding the impacts of the potential loss of neonicotinoids. Reactions to the counterfactual scenario by growers provided an authentic testimony to the value of neonicotinoids.

3.5.1 Major themes

A number of themes and reccurring observations were made at the listening sessions. These are presented in more detail in the report and the appendices. The following eight themes were expressed at all eight of the listening sessions.

1. Higher operating costs associated with more frequent chemical application, more time required for spraying and in some cases, having to reinvest in sprayer equipment.

2. Most stated that loss of neonicotinoids would result in decreased yields and reduced product quality. In some cases, this would lead to lost contracts from purchasers.

3. The loss of effective pest control and a return of episodic pest outbreaks that have been controlled with neonicotinoids.

4. Alternative insecticides would kill beneficial insects (and pollinators) they count on as part of their IPM programs. Growers also expressed concern that the alternatives would not allow them to control invasive pests(especially those without natural enemies) in a way that would not disrupt their IPM programs.

5. Loss of access to neonicotinoids would reduce the available insecticide modes of action, likely accelerating pest resistance.

6. Risk (human health, environment) associated with alternative insecticides was a major and reoccurring concern.

7. A negative impact of higher production costs or inability to manage pests could mean the loss of local jobs associated with production inputs and outputs, and these losses, in turn, would have significant negative impacts on the surrounding rural communities.

8. A common expression of frustration that is relatively few people understand the complexities of food production, and that emotion, rather than science, is dominating the discussion about pollinators and neonicotinoids.

Most participants in these sessions were farm business owners and managers. The decisions they make in response to any future regulatory or policy actions will impact family members, employees, local agri-business, and the local environment and economies. A common sentiment expressed was one of disbelief that an insecticide that is cost-effective, offers selective pest control, preserves beneficial insects for IPM programs, decreases the probability of pest resistance, protects human health and improves food quality could even be considered for restriction when considering the alternatives.

3.6 An in-depth understanding

A Case Study of Neonicotinoid Use in Florida Citrus

An outcome of the listening sessions was an opportunity to hear growers describe the role of neonicotinoids in their current operation and what would be lost if neonicotinoids were no longer available. A Florida grower made an especially compelling case during the first listening session on the importance of neonicotinoids to the Florida citrus industry. Florida citrus growers (orange, grapefruit and specialty fruits) have been fighting for nearly a decade to save their trees from 'citrus greening' disease, also known as Huanglongbing (HLB). Researchers attribute HLB disease to the bacterium '*Candidatus Liberibacter, asiaticus,*' which is introduced to citrus trees (all varieties) by the Asian citrus psyllid when it feeds on citrus leaves and stems.

Figure 13. Communication graphic on HLB importance.

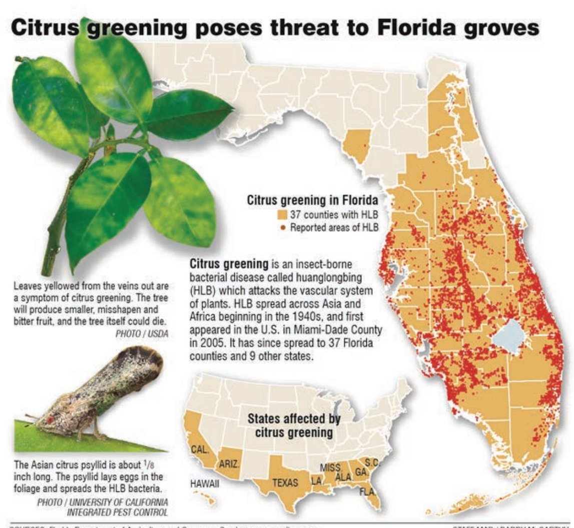
The impacts of citrus greening are dramatic. Based on 2014 data, there are approximately 500,000 acres of citrus in Florida, just over half of the citrus acreage that existed 40 years ago. In 2003-2004, before HLB (and additional hurricane impacts), Florida produced 242 million boxes of oranges (each box consists of two cartons; each carton holds 45 pounds of oranges). By the 2012-2013 growing season, Florida had dropped to 133.6 million boxes of oranges. Initial estimates from the Florida Department of Citrus suggested 115 million boxes for 2013-2014, and preliminary estimates for 2014-2015 predict less than 90 million boxes. The salience of this issue is represented in the following Figure 13.

Lindsay Raley, the citrus grower in our case study, is based in Lakeland, Florida, with roughly 1,200 acres of citrus groves in Polk, Highlands and Hardee counties. He is president of Raley Groves, the family citrus business. Raley's family has been involved with Florida citrus since the 1920s. His mother was among the first women to run a family citrus business in Florida, taking leadership of the operation when her first husband died.

Raley uses a neonicotinoid soil-drench application on his young trees at labeled rates. The application is administered through a hand-held, trigger-controlled spray wand that delivers a pre-measured, 8-ounce mixture per 'shot.' The shot is applied to the ground near the tree. Very small trees receive one shot on the ground near the tree; larger trees get two or three shots depending on size. Raley is confidant the neonicotinoid is working because the trees show no sign of leafminers, which neonicotinoids also control. Although neonicotinoids are registered for foliar applications, he uses that method judiciously out of concern for managing pest resistance.

Raley as well as University of Florida research bulletins point out there are no effective alternatives to neonicotinoids available to citrus growers for protecting young reset trees from psyllid feeding (the route of transmission for the HLB pathogen). Without neonicotinoids, it is unclear how growers would manage the cost and risk of replacing dead and damaged trees. Further loss of citrus acreage and declines in fruit production would be expected to further erode the infrastructure for citrus processing and lead to expansive negative statewide and regional economic impacts, especially in communities dependent on citrus.

Figure 14. HLB in Florida citrus.



3.7 An in-depth understanding

A Case Study of Neonicotinoid Use in Mid-South Cotton

Cotton is a significant crop in the U.S. The USDA estimates $6 billion in sales for cotton. The U.S. cotton industry accounts for more than $25 billion in products and services annually, generating about 200,000 jobs in the industry sectors, from farm to textile mill. The USDA June 2014 acreage report estimated there were 11.4 million acres of cotton planted in the U.S., an increase due to recent higher prices.

Besides the pest management challenges in this crop (and there are many), what caught our attention during the listening session was how cotton cropping is the foundation of the economy of many Mid-South rural communities. Growing cotton provides a significant economic boost to local economies because it is more labor intensive than other crops and involves more businesses and intermediaries in the supply chain before it is shipped to customers.

We had the opportunity to visit the family operation of John Lindamood, a third-generation cotton grower whose operations are based around Tiptonville in Lake County in far northwest Tennessee. They farm approximately 4,200 diversified acres, about half in cotton. The others acres are planted with soybean, corn and wheat. The Lindamood family also owns the Phoenix Gin, which is the only gin in a 45-mile radius and the last remaining cotton gin in the county. Numerous cotton gins have closed down in the area due to economic conditions favoring alternative crops and excess ginning capacity. As a result, some major employers have left the county. The Lindamood family businesses employ 18 people year-round (ten at the farm and eight at the gin) and 20 additional workers on a seasonal basis.

Lindamood relies heavily on neonicotinoids in his farming operations. The seeds he uses for growing cotton, corn and soybean are treated with neonicotinoids, and he uses neonicotinoids as part of early-season foliar treatments in cotton. The neonicotinoids control wireworms, thrips and plant bugs. He rotates his use of pesticides to maximize efficacy and prevent pest resistance problems.

Lindamood pointed out that neonicotinoids provide a number of tangible benefits compared to the alternatives that he could use. He used to employ multiple applications of broad-spectrum insecticides that would kill beneficial insects as well as the target pests. Neonicotinoids changed that by allowing for less frequent spraying and selective targeting of pests. He also observes better health and vigor of seedlings since neonicotinoids were introduced. This translates to lower seeding rates along with healthier emergence, reducing his costs and increasing the yield. Lindamood expressed several times that neonicotinoids are safer for human health compared to other options that are available, both in terms of toxicity to people and the reduced amount of spraying, which offers reduced exposure to workers, family and neighbors.

Lindamood anticipated a number of negative consequences if neonicotinoids were no longer available for use in growing cotton. One immediate impact would be increased business costs in terms of labor (e.g.,

scouting, spraying) and inputs (higher volumes of pesticides sprayed more often, higher seeding rates). More time would be needed for scouting required to monitor insect pressure and spraying more often in the fields. Additionally, because he would have to spray more often to control pests, it would cost more for the higher volume of products he would have to buy. Anticipating lower plant emergence, he would also have to use higher seeding rates without neonicotinoid seed treatments to produce a comparable crop stand.

If neonicotinoids were not available, he would switch to more foliar applications of organophosphates, which he said are broader spectrum, harsher on the environment and need to be sprayed more frequently. Switching to currently available alternatives would be worse for beneficial insects (such as assassin bugs, ladybugs and minute pirate bugs), which are natural predators of some harmful pests (such as spider mites, bollworms, fleahoppers, stink bugs, aphids, thrips and plant bugs). Losing the systemic protection of neonicotinoids would set back his IPM efforts because alternative pesticide options do not provide the advantage of selectively targeting harmful pests without damaging the beneficial insects. A reoccurring theme from Lindamood and others in the local community was the importance of cotton crops to the viability of the local economy. A decline in cotton production would have significant, negative impacts for the local economy. Cotton brings in higher income and is more labor-intensive than other crops. It also involves more businesses and intermediaries in the supply chain, so the money circulates through the economy more times than with other crops, such as corn and soybean.

4.0 Uncertainties, Risk and Unanticipated Consequences

> *There is only one difference between a bad economist and a good one: the bad economist confines himself to the visible effect; the good economist takes into account both the effect that can be seen and those effects that must be foreseen.*
> (Bastiat, 1848)

The reports have uncovered many statistics and findings relative to the value of neonicotinoids in North American agriculture. They have also captured qualitative information that is insightful and illuminating of underlying issues. The significance of these findings is self-evident in most cases. Yet they also bring to light, as the above quote suggests, effects that must be foreseen. The alternative scenario is filled with uncertainty regarding what might happen, and an important way of illuminating the value of neonicotinoids is to consider different types of uncertainty. Sources for uncertainty relative to the alternative scenario are illustrated in Table 3.

Another way to consider the uncertainty surrounding the alternative scenario is to identify potential unanticipated consequences. Merton (1936), an influential social scientist of the last century, identified five sources of unanticipated consequences. The most common are ignorance and error, neither

Table 3. Uncertainties of the alternative scenario (adapted from Klerk et al., 2010).

Type of Uncertainty	Issues Where There is Uncertainty
1. Technological Uncertainty	Cost and performance of alternatives in the context of increased risk of the emergence of pest resistance.
	Uncertainty as to when new insecticides will be registered causing reluctance to invest in changing the infrastructure and market relations needed to deliver the alternatives currently available.
2. Resource Uncertainty	Capacity to meet increased training needs for handling and applying more toxic alternatives.
	Capacity to meet increased scouting requirements coupled with changes in the dynamics of pest ecology in response to shift to alternatives.
3. Competitive Uncertainty	Behavior of (potential or actual) competitors and the effects of this competition on meeting grower needs (e.g., demand for scouting exceeds local crop consultant capacity).
4. Consumer Uncertainty	Consumers and crop aggregators response to the use of alternatives in production of food and fiber.
	Response of local dealers and custom applicators if there is uncertainty in capacity of manufacturers and distributors to meet industry needs.
	Response of interests promoting the alternative scenario when impacts of alternative insecticides begin to emerge (e.g., impact of alternatives on pollinators).
5. Political Uncertainty	Uncertainty on role of science in future changes of pesticide policy.
	The role of government and special interests in this process.

of which should apply to the current situation. However, the third source, 'imperious immediacy of interest,' could play an important role in the future. Imperious immediacy of interest refers to a situation where interests pursue a desired outcome in an almost irrational manner, while purposely ignoring the larger context or unintended effects. The potential of this type of unintended consequence highlights the importance of communicating what might emerge within the alternative scenario. In this case, the importance of pollinators to our food systems are critical. However, eliminating neonicotinoids is likely to have significant unintended consequences as identified in these reports.

The primary function of employing a counterfactual analysis was to identify the value of neonicotinoids by pointing out both the calculated impacts of the alternative scenario and to raise awareness about uncertain or unintended outcomes. A rich set of data from multiple sources have allowed us to present a number of calculated values for neonicotinoids. These are significant. Yet also significant are the insights provided by growers and other agricultural interests on those "*effects that must be foreseen*."

Growers pointed out a number of potential consequences that might occur under the alternative scenario. Less clear is whether any of the following unintended consequences will materialize under a counterfactual scenario, but they are important to consider given the imperious immediacy of interest surrounding this issue. Beyond the possible economic impacts, other significant unintended consequences of a non-neonicotinoid scenario include:

1. An accelerated loss of beneficial insects (including pollinators) under the non-neonicotinoid scenario due to the type and application methods of the alternative insecticides as documented in this report.

2. A loss of neonicotinoids may result in bringing more cropland into production to compensate for lost yields documented in this project. This is likely to come from the same lands in conservation programs that are being identified for future programs to enhance pollinator habitat.

3. A significant decline in the use of cover crops. Cover crops hinder erosion and run-off from farm fields. Both the U.S. and Canada have government programs to promote this practice. The use of cover crops increases a field's soil organic matter. The enhanced soil organic matter is also prime habitat for pests that have been controlled with the use of neonicotinoids. Without neonicotinoids, these pests will cause yield losses resulting in the decreased use of cover crops.

4. Both IPM and pest resistance programs will be significantly impeded, along with increased invasive species concerns. This will result from growers going back to dependence on organophosphates and pyrethroids as documented in these reports.

5.0 A Final Observation

North American agriculture is often cited as being progressive, productive and a dependable source of food and fiber. Growers have come to expect that science will provide the solutions to the complex production and marketing challenges they face. Much of this is due to the ongoing investment in agricultural science, abundant natural resources and a policy process that has considered both the science and natural resource implications of proposed policy changes.

These reports were developed with that spirit in mind. *What can the best available information coupled with a robust scientific analysis tell us about the value of neonicotinoids in North American agriculture?* These reports represent an answer to that question and are summarized in Figure 15.

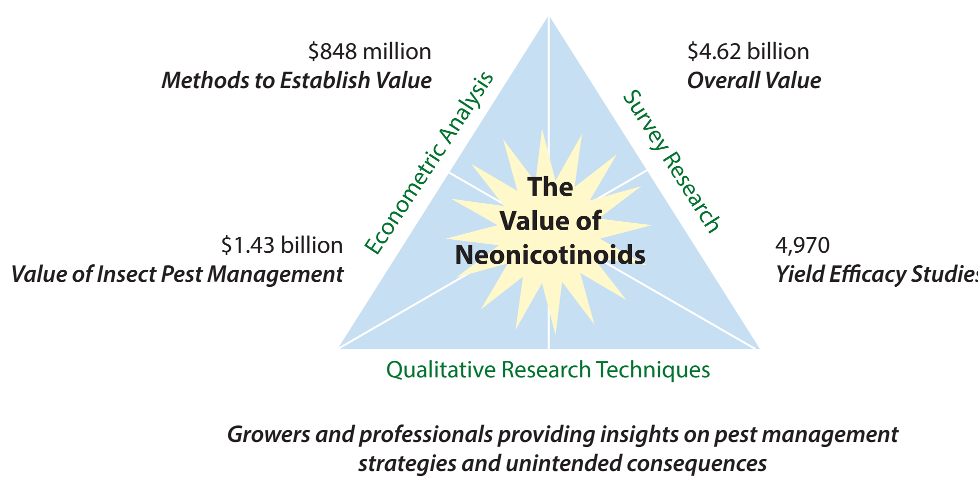


Figure 15. Amalgamation of findings found using the triangulation methodology.

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