UNDERSTANDING THE ROLE OF ENVIRONMENTAL SUSTAINABILITY IN A SOCIAL ECONOMY OF FOOD

A Case Study of IPM in Ontario

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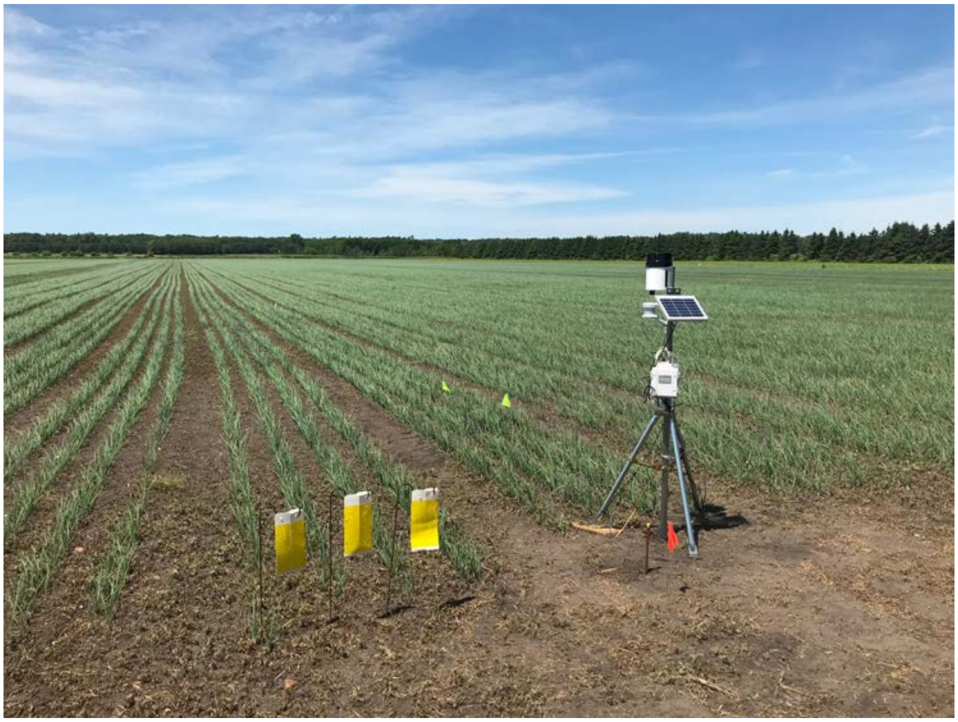
Centre for Sustainable Food Systems

Nourishing

Communities



Yellow sticky traps and weather station for monitoring an onion field in the Holland Marsh, Ontario. Photo: T. Cranmer, OMAFRA

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The Social Economy of Food:
Informal, under-recognized contributions to
Community prosperity and resilience

Project Overview

This case study explores how integrated pest management (IPM) might fit within and serve a social economy of food paradigm that envisions a more sustainable (social, ecological and economic) food system. It considers the role that IPM could play in alternative food systems that emphasize social and ecological sustainability and food security. Envisioning IPM as a sustainable practice within a social economy of food represents a novel approach for several reasons. First, it explores the role of ecological sustainability as a critical element of a social economy of food paradigm. Ecological sustainability is an understudied, but critical aspect within sustainable food systems transition scholarship (Trembley, 2009; Soots and Gismondi, 2008). Second, IPM is considered a highly successful sustainable agriculture practice given its long-term and widespread adoption and effectiveness in reducing the risks of pests and pest management practices to human health, the environment and the agroecosystem (Farrar et al, 2015; Petersen et al, 2018). Findings based on an IPM case study could provide insights for the study of the role of other sustainable agriculture practices within a social economy of food. The case study positions IPM as a sustainable practice and asks how IPM could contribute to a social economy of food. Examining integrated pest management in its eco-social contexts is useful for highlighting some of the barriers to and opportunities for the adoption of integrated and sustainable crop protection approaches within agri-food production systems that advocate a social economy of food paradigm (Letourneau et al 2017).

This case study is part of the *Social and Informal Economies of Food Series* (http://nourishingontario.ca/the-social-economy-of-food/case-studies-subversions-from-the-informal-and-social-economy/), a project funded by the Social Sciences and Humanities Research Council (SSHRC): *The Social Economy of Food: Informal, under-recognized contributions to community prosperity and resilience*. The case study adopts an exploratory approach using documentary and digital sources of data and personal communications with IPM crop specialists from the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), several provincial commodity organizations and independent IPM consultants to describe the different models for and means by which IPM is designed, delivered and practiced across the Ontario agri-food industry. It further draws on the international IPM literature, to identify the benefits and impacts of IPM within the context of a social economy of food by asking can/does IPM 1) build adaptive capacity to increase community resilience; 2) increase social capital; 3) foster innovation, entrepreneurship and economic diversification; 4) increase prosperity for marginalized groups; and 5) bridge divides between elite consumers of alternative food products and more marginalized groups. The analysis provides evidence of how IPM contributes

Yellow sticky tape and traps are used to mass trap pests in the greenhouse. Photo: S. Jandricic, OMAFRA

to ways of overcoming some of the barriers to sustainable food production and food security inherent in conventional agricultural production. It demonstrates how IPM is a promising approach by which alternative food production systems can work towards ecological resilience and how

IPM fits into and advances a social economy of food paradigm. The conclusions reflect on the future of IPM and the policy implications of examining the intersection between IPM and a social economy of food.

Defining Integrated Pest Management

"Integrated Pest Management (IPM) means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human and animal health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agroecosystems and encourages natural pest control mechanisms." (FAO 2019)

IPM is an effective sustainable agriculture practice that has been adopted in both developed and developing countries and in almost every sector of agricultural production (Dixon et al 2014; Farrar et al 2015; Kogan and Jepson, 2007; Petersen et al 2018). Recognition of its advantages and benefits has reached beyond agriculture production to government policy decision-makers, who have acknowledged IPM as potentially the best approach to crop protection and a key element in the transition to sustainable agriculture (Blake et al 2007; Barzman et al 2015; Bottrell and Schoenly 2018). It has evolved over the past 70 years to encompass more than the ecological and human health imperatives of crop protection, but also the societal, cultural and political concerns about the future of agri-food production in meeting food security and sustainability priorities (Dara 2019). The role of IPM in a sustainable agri-food system has taken on greater saliency more recently in the context of concurrent anthropogenic dilemmas, such as climate change, population growth and increasing worldwide standard of living (Kogan and Jepson 2007). Newer and emerging models of IPM embedded in ecological theory and applied at the agroecosystem level represent a sustainability paradigm with the potential to mitigate these socio-ecological-economic challenges (Kogan and Jepson 2007; Levins 2007). IPM plays a role in food security, environmental and public health, the transition to sustainable agriculture and broader resource conservation and sustainability goals. IPM is based on the recognition that a complex array of social, economic, political, ecological, agronomic and scientific factors is involved in shaping sustainable crop protection strategies (Barzman et al 2015; Dara 2019; Letourneau et al 2017; Bottrell & Schoenly 2018).

IPM was first proposed in the late 1950s/early 1960s, as a response to the increasing concerns over the negative impacts of a crop protection model based on prophylactic pest control practices that relied almost exclusively on chemical pesticides to eradicate pests from crops (Stern et al 1959; Geier, 1966; Smith 1962; Van den Bosch and Stern 1962). Stern et al (1959) referred to the apparent benefits of pesticides in public health and agricultural pest control programs as “not an unmixed blessing” (p. 84). They identified the impact of widespread, indiscriminate use of pesticides in drastically altering the complex, interdependent relationships of the diverse components of the agricultural landscape. They described the consequences, which included pest resistance to pesticides, outbreaks of secondary pests, resurgence of primary pest populations, toxic residues on food and forage crops, health risks from direct exposure by farm workers and indirect exposure to pesticide drift by people, livestock and wildlife and the legal issues emerging from these problems (Stern et al 1959). Since that seminal paper, IPM has evolved scientifically, agriculturally and politically to become “the preferred approach to crop protection and…a pillar of both sustainable intensification and pesticide risk reduction” (Vétek et al 2017 p. vii).

The overarching goal of IPM is to reduce the ecological, economic and health risks posed by pests and crop protection strategies (Barzman et al 2015: Farrar et al 2015; Clearwater et al 2016; Farrar et al 2016; Bottrell and Schoenly 2018). Pests represent a serious threat to crops and to food security. Global crop losses due to pests are estimated to be the equivalent of the amount food that could feed 1 billion people (Birch et al 2011). Crop losses from pests are expected to increase due to the impacts of climate change (Lamichhane et al 2015). Crop protection is therefore a vital part of a sustainable agri-food system. But there are risks associated with crop protection that must be minimized to protect human health and the environment. IPM represents an approach to crop protection that mitigates these risks by focusing on growing healthy sustainable crops with the least disruption to the agroecosystem (Barzman et al 2015; Clearwater et al 2016; Bottrell and Schoenly 2018; FAO 2019). The impacts and benefits of IPM include reducing pesticide use, increasing crop yields, improving the economics of crop production, minimizing the development of resistance and enhancing the productivity of agroecosystems through the provision of eco-systems services (Blake et al 2007; Birch et al 2011; Clearwater et al 2016; Letourneau et al 2017).

Banker plants (pots at the end of the bench) are used as refuges for beneficial insects. The plants are 'seeded' with alternative sources of prey to maintain beneficials when pest populations are low. Photo: J. Lemay, Eco-Habitat Agri-Services

Effective IPM programs rely on sound scientific knowledge of pest, crop and natural enemy biology, behaviour, population dynamics and interactions, weather patterns and the dynamics of the agroecosystem. A key element in the success of IPM is its emphasis on adapting scientific advances and innovations to local contexts such as regional cropping systems and practices, available local resources and shifting priorities (Birch et al 2011; Barzman et al 2015; Lamichhane et al 2016; Vétek et al 2017). IPM is a systems-based approach that embeds a complex array of scientific, social, environmental and political factors in its fundamental principles and basic designs (Barzman et al 2015; Dara 2019; Letourneau et al 2017; Bottrell & Schoenly 2018). In practice, IPM combines biological, cultural, physical and chemical options in a crop protection strategy that is environmentally sound, economically viable and socially responsible (Lamichhane et al 2018).

IPM is data-intensive, requiring regular monitoring of pest population levels, activity, crop damage levels and weather conditions to predict and determine if and when crop protection interventions are necessary, based on economic thresholds. Economic thresholds are indicators of the level of

Planting 'cover crops' between rows in the vineyard provides habitat for beneficial insects, enhances biodiversity and increases the capacity of the agroecosystem to provide essential ecosystem services. Photo: J. Lasnier, Ag-Cord Inc.

pests or damage at which the value of crop losses exceed the cost of crop protection interventions. The goal of IPM is to maintain pest or damage levels below the economic threshold. While economic thresholds are an important element of IPM, they are not suitable or applicable for all crops. However, the concept that some level of pest activity or crop damage is acceptable and even beneficial is a foundational principle of IPM that emphasizes prevention and suppression over eradication of pests to maintain crop damage at economically acceptable levels and sustain crop health (Clearwater et al 2016; Vétek et al 2017). In fact, more recent understanding of the agroecosystem has identified the importance of the presence of pests in maintaining the complex dynamics of the ecosystem services provided by the agroecosystem, particularly for sustaining beneficial organisms that serve as biological control agents (Letourneau et al 2017; Bottrell and Schoenly 2018). Moreover, the cost/benefit of IPM includes consideration of the value of the beneficial impacts on the agroecosystem, human health, pest resistance and the long-term sustainability of crop production, which are difficult to calculate and capture in simple economic models based solely on direct, quantifiable monetary costs (Letourneau et al 2017; Federal IPM Coordinating Committee 2018).

IPM is knowledge intensive, requiring on-going basic and applied research in the lab and the field. Photo: VRIC

Early models of IPM were targeted at controlling a single pest in a single field, based on market-driven factors within a pesticide regulatory framework that was aligned with the dominant, mainstream agri-food system (Brewer and Goodell 2012). These nascent IPM approaches were designed and implemented on individual fields targeting a single pest with the primary objective of reducing pest populations below economically damaging levels with reduced pesticide use. Decisions were based on cost/benefit analyses that considered the value of crop losses compared to the cost of control measures. IPM was promoted to farmers as a means of gaining competitive advantage. Those farmers who implemented IPM would save costs on pest management and increase yields, which would have an overall positive economic impact on their operations. These early approaches to IPM were pest-crop centric with economic benefits accruing directly to the farmer (Brewer and Goodell 2012; Letourneau et al 2017).

More advanced models of IPM reflect enhanced understanding of the complex dynamics of the agroecosystem and the potential to go beyond minimizing adverse environmental effects associated with pesticide use to creating resilient agroecosystems that are productive beyond providing a sustainable, secure supply of food (Brewer and Goodell 2012). Advances in

Yellow sticky traps are used for monitoring pests in carrots at the Holland Marsh, Ontario to evaluate risks and provide accurate recommendations. Photo: D. Van Dyk, OMAFRA

fundamental ecological and ecosystems knowledge have led to landscape and agroecosystem scale IPM with public and social benefits in addition to farm-scale economic benefits (Birch et al 2011; Bottrell and Schoenly 2018). This more recent agroecosystems approach has positioned IPM as one of the most promising routes to truly sustainable agricultural production—that is "equitable, secure, sufficient and stable flows of both food and ecosystem services" (Bottrell and Schoenly 2018 p. 411).

IPM is best understood as a continuum of practices that range from simply optimizing the use of pesticides within a conventional production system to adopting non-chemical crop protection approaches to completely re-imagining crop production within a social, ecological and economic sustainability and resilience framework (Lamine et al 2010). Progressing along the IPM continuum is gradual and incremental and shaped by social, cultural, political, scientific and economic factors (Dara 2019). Adoption of advanced IPM practices requires broader engagement from the agri-food value chain and different policies and incentives to promote adoption. The development and implementation of advanced IPM has promise for establishing resilient agricultural landscapes that not only provide secure, sustainable food, but additional public goods through enhanced ecosystem services (Brewer and Goodell 2012). Adoption of advanced IPM strategies is not limited to mainstream agri-food production, it offers the potential for alternative food movements, such as a social economy of food, to be viable and sustainable (Vétek et al 2017).

Context

The case study profiles IPM in the province of Ontario to describe the diversity representative of IPM within an intensive agri-food system. It further draws on the broader international IPM literature to analyse IPM within the context of the five key themes developed for the *Social and Informal Economies of Food* series as an analytical framework for understanding how a social economy of food functions to build more sustainable food systems (Table 1). While recognizing that IPM has a role throughout the agri-food value chain (e.g. food processing, retail) and in other contexts where pests threaten natural resources (e.g. forests), physical infrastructures (e.g. homes) and public health (e.g. hospitals), the case study focuses on IPM in crop production.

IPM in Ontario

Ontario has a highly diverse agri-food sector with areas in the province that have intense production (Dixon et al 2014). With the recognition of the negative impacts on the environment, risks to human health and the rising costs of routine use of chemical pesticides, early forms of IPM were developed and adopted in Ontario during the early-1970s and proved to be highly successful

(McEwen 1978). IPM has been widely adopted by the plant agriculture sector in Ontario over the past 50 years (Canadian Produce Marketing Association 2012). The roles and responsibilities for IPM in Ontario are shared among an interdependent network of stakeholders, including the federal and provincial governments, producer organizations, biocontrol and crop protection product suppliers, farmers, independent IPM consultants and agricultural consultants and post-secondary institutions. IPM is characterized by a range of activities, including research, knowledge mobilization, extension and advisory services, regulatory compliance, pest monitoring and scouting and training (Table 2). IPM is resource intensive and requires the input of financial, human, physical and knowledge resources from all stakeholders.

Table 1. Five themes defining how a social economy of food functions to build more sustainable food systems.

Build Adaptive Capacity to Increase Community Resilience
• Economic resilience
• Ecological resilience
• Food system resilience
Increase Social Capital
• Creating culture
• Creating networks
• Building knowledge
• Social and Political change
Foster Innovation, Entrepreneurship and Economic Diversification
Increase Prosperity for Marginalized Groups
• Addressing inequalities
• Contribution to Canadian economy
• Volunteer labour
• Local economic development
Bridging Divides between Elite Consumers and More Marginalized Groups
• Cross-sector impacts
• Making connections

Table 2. IPM stakeholders and activities.

	Extension	Knowledge Mobilization	Advisory	Regulatory	Research	Monitoring & Scouting	Training
Public Sector							
Federal Government (AAFC, PMRA)		X		X	X		
Provincial Government (OMAFRA)	X	X	X	X	X	X	X
Academia	X	X	X		X	X	X
Non-profit Sector							
Farm Commodity Organizations		X	X		X		X
Non-profit organizations	X	X	X		X	X	
Private Sector							
Farmers		X			X	X	X
Independent IPM Consultants		X	X		X	X	X
Biocontrol Suppliers		X	X		X	X	
Crop Protection Products Suppliers		X	X		X		

IPM Stakeholders and Activities in Ontario

As a dynamic, systems approach, IPM is knowledge intensive and requires on-going **research** to respond to the constantly evolving agroecosystem and changes in the agri-food system. IPM research is highly diverse and generally targets a specific pest or crop. It spans the entire research continuum from basic to applied research with a focus on biological, cultural, mechanical pest management methods, pest identification and biology, behaviour, forecasting, pest resistance, development of biopesticides, semiochemicals, pest-resistant crop varieties, pest-host interactions and development/validation of economic thresholds. **Regulatory** activities are the mandate of the federal and provincial governments. Federally the Pest Management Regulatory Agency is responsible for the importation, registration and conditions of use for crop protection products. OMAFRA regulates the storage, sale, transportation, use and licensing of pesticide applicators. Ontario is the only province in Canada that has made IPM a regulatory requirement. Under recent provincial regulations, corn and soybean producers who intend to plant seeds treated with neonicotinoid insecticides, must successfully complete an IPM training course, have a pest assessment report prepared by a professional pest advisor and sign a declaration that they have considered IPM principles in their decision to use treated seed (MOEE 2019).

Parasitic wasps search for aphids on mint in a greenhouse. Photo: J. Lemay, Eco-habitat Agri-Services

IPM extension services involve on-site visits, farm demonstrations, technical advice and education/training to give farmers the skills and knowledge they need to implement effective IPM strategies and solutions. It is typically a public sector service delivered by government extension specialists and to a lesser degree post-secondary institutions. Extension services have played a key role in the introduction and initial adoption of early IPM programs in Ontario (Dickson et al 2014). IPM extension services are delivered at multiple levels, including field-level advice to individual farmers about specific pest activity and trends. Extension services are often considered the original knowledge mobilization model (Krell et al 2016). **Knowledge mobilization** generally does not involve direct interaction with individual farmers to give custom, real-time pest management advice. It tends to focus on mass communication to target audiences or stakeholders and provides synthesized knowledge rather than field specific recommendations based on real-time data or information. Over the past 30 years, agriculture extension in Ontario has been largely replaced by knowledge mobilization, which has much overlap with extension services, but is still distinct in its mode and scale of delivery. **Advisory services** also have overlap with extension services but tend to be real-time advice based on time sensitive information or data that can be at the individual farm/field level or regionally-based, generally delivered during the growing season. Advisory services include pest management recommendations for specific pests, forecasts and predictions of pest activity and population levels or alerts about new/emerging pests. Both OMAFRA and the private sector provide IPM advisory services.

Monitoring for disease is an important element of IPM. Identifying and removing infected plants early is crucial for minimizing the spread of diseases such as powdery mildew. Photo: J. Lemay Eco-habitat Agri-Services

Scouting and monitoring to forecast current and future pest levels and activity are core elements of IPM. Scouting and monitoring are field-level activities that occur during the growing season. Systematic, regular monitoring of pest populations, weather conditions, plant health and disease symptoms provide the data necessary for making pest management recommendations. Scouting and monitoring are carried out by various stakeholders to varying degrees. OMAFRA provides limited pest scouting and monitoring, which is typically linked to applied IPM research projects or for tracking new, invasive pests. Regular monitoring and scouting over the growing season are carried out by farmers (or their staff), independent IPM consultants and IPM scouts hired by farmers and farm commodity organizations.

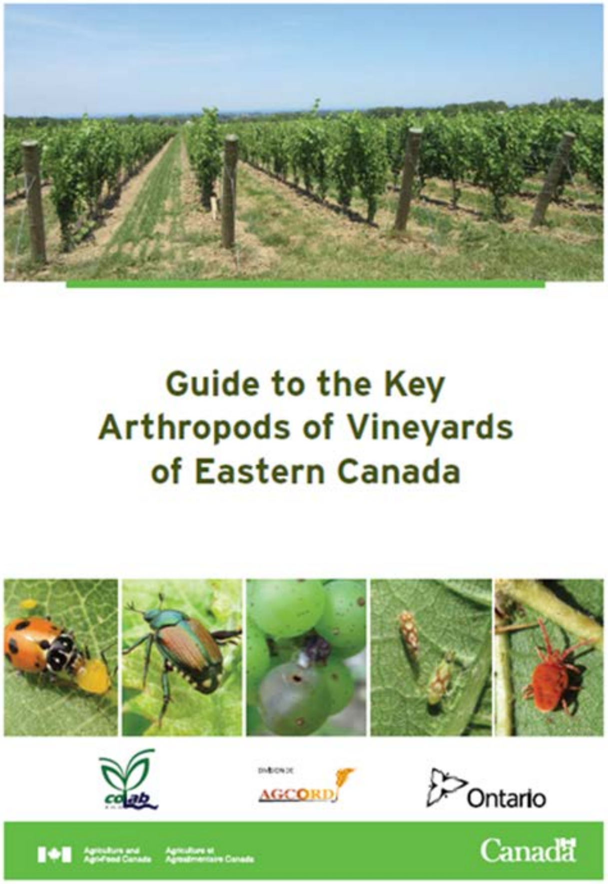
Training is crucial to sustained adoption and effective IPM practices and outcomes (Pinero et al 2018). OMAFRA has taken the lead role in designing and delivering IPM training in Ontario.

Ontario CropIPM (http://www.omafra.gov.on.ca/IPM/english/index.html) is a web-based program that offers basic IPM training in specific crops. Every spring OMAFRA offers hands-on training workshops throughout the key horticultural production regions of the province for most fruit and vegetable crops (Grigg-McGuffin, 2019). There are also on-going webinar series on topics related to IPM for specific crops. IPM training is mandatory for corn and soybean growers; it is offered through the University of Guelph Ridgetown Campus.

IPM Resources

PUBLIC SECTOR

In Canada, IPM is both a federal and provincial priority; it is considered an essential element of sustainable agricultural production and supported through the Canadian Agriculture Partnership, the federal-provincial-territorial agriculture policy framework (Dixon et al 2014).



Collaboration among stakeholders to support knowledge mobilization is critical for successful IPM.

Federal Government Resources

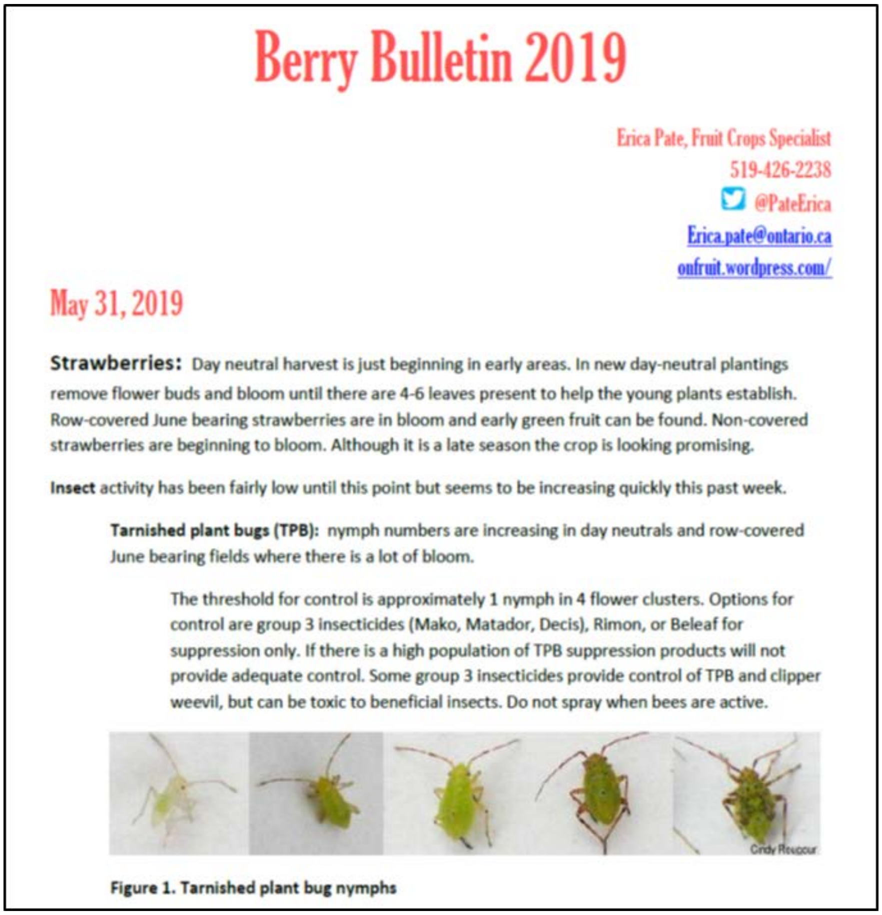
Federally, IPM is supported and delivered jointly by the Pest Management Regulatory Agency (PMRA) of Health Canada and Agriculture and Agri-Food Canada (AAFC) through its research centres and the Pest Management Centre (PMC). Two key IPM-related initiatives of the PMC are the Minor Use Pesticides Program (MUPP) and the Pesticide Risk Reduction Program (PRRP) (AAFC 2018). The PRRP works with various stakeholders to develop and implement IPM strategies and solutions that reduce risks to human health and the environment (AAFC 2018). AAFC does research to understand pest biology and life cycles, pest-host interactions and agroecosystem dynamics and to develop new IPM strategies for specific pests, crops and regions. AAFC also funds external IPM research through CAP programs, such as the Agri-Science Program. While the PMRA's main responsibility is regulating pesticides under the Pest Control Products Act, its mandate is to prevent unacceptable risks to Canadians and the environment from the use of crop protection products. As such, PMRA is involved in non-regulatory activities to develop and promote sustainable agriculture production practices, including IPM.

Joint federal-provincial IPM activities include applied research, forecasting and monitoring, as well as administration of programs that promote the adoption of sustainable practices (Dixon et al 2014). The Environmental Farm Plans and Beneficial Management Practices programs provide incentive payments for producers to implement IPM-related beneficial management practices, such as farm-level IPM strategies, biological control, biodiversity enhancement and cover crops.

Provincial Government Resources

In Ontario, the Ministry of Agriculture, Food and Rural Affairs (OMAFRA) has established a leadership position in IPM over the past 40 years. It is actively involved in IPM, with significant resources committed to basic and applied research, training, education, advisory services, pest monitoring and management recommendations and knowledge mobilization. OMAFRA staff within the Agriculture Development Branch are involved in research and demonstration projects for validating IPM strategies, producing and disseminating resource materials, delivering training sessions, organizing and participating in meetings and events and networking with stakeholders (OMFRA 2019). OMAFRA IPM staff work in most major agriculture regions of the province with a focus on field crops, horticultural crops, greenhouse vegetables and floriculture, nursery and landscape crops, field vegetables, tender fruit, specialty crops and herbs.

Ontario CropIPM (http://www.omafra.gov.on.ca/IPM/english/index.html) is OMAFRA's central website for providing web-based, crop-specific IPM training. The site includes a basic introduction to the fundamentals of IPM, as well as background information about soil diagnostics and weeds and herbicides, highlighting the importance of an overall cropping system approach to IPM. IPM training is available for 13 crops (apples, asparagus, brassica, cucurbits, grapes, onion, peppers, potatoes, raspberries, sweet corn, strawberries, tender fruit and tomatoes).



Berry Bulletin 2019

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May 31, 2019

Strawberries: Day neutral harvest is just beginning in early areas. In new day-neutral plantings remove flower buds and bloom until there are 4-6 leaves present to help the young plants establish. Row-covered June bearing strawberries are in bloom and early green fruit can be found. Non-covered strawberries are beginning to bloom. Although it is a late season the crop is looking promising.

Insect activity has been fairly low until this point but seems to be increasing quickly this past week.

Tarnished plant bugs (TPB): nymph numbers are increasing in day neutrals and row-covered June bearing fields where there is a lot of bloom.

The threshold for control is approximately 1 nymph in 4 flower clusters. Options for control are group 3 insecticides (Mako, Matador, Decis), Rimon, or Beleaf for suppression only. If there is a high population of TPB suppression products will not provide adequate control. Some group 3 insecticides provide control of TPB and clipper weevil, but can be toxic to beneficial insects. Do not spray when bees are active.

Cindy Roucour

Figure 1. Tarnished plant bug nymphs

The Berry Bulletin is one example of how OMAFRA disseminates information and communicates with stakeholders. It is updated regularly on the ONfruit blog (https://onfruit.ca/).

A major initiative that supports and promotes IPM are the crop production and protection guides produced by OMAFRA. Some of the publications are available for free download on the OMAFRA website, while others can be ordered at a small cost. These publications provide recommendations and guidelines for managing pests; the focus tends to be on information on pesticide products that are registered for management of pests and diseases. Most publications provide guidance on how these products can be compatibly used with biological control agents in IPM programs. Several publications outline IPM strategies for specific crops. Most publications are regularly updated. Information about specific pests and recommendations for management are provided through factsheets. OMAFRA staff write articles for newsletters and industry trade journals. OMAFRA has recently launched a blog series (ONvegetables, ONfruit, ONturf, ONnurserycrops, ONspecialtycrops, ONgreenhousevegetables, ONfloriculture) that provides time sensitive information during the growing season about pest activity, identification, monitoring and management recommendations, as well as updates on research related to IPM, training programs and other relevant events. YouTube, Twitter and smart phone apps are also being used as ways to mobilize knowledge and share IPM information.

Academic Resources

Post-secondary institutions contribute key resources to support the development, adoption and implementation of IPM in Ontario, primarily through applied research and knowledge mobilization. The University of Guelph provides the IPM training certification required under the new regulations for neonicotinoid-treated corn and soybean seeds. It delivers the award-winning Muck Crops IPM program for carrots, onions and celery grown in the Holland Marsh through the Muck Crops Research Station (MCRS) in collaboration with a local growers' coop, a local farm commodity organization, OMAFRA, and various private sector organizations. The Muck Crops IPM program provides free scouting services for one 10-acre field. Additional fields can be scouted at a cost of $60/acre. Scouting and monitoring data are provided to member growers through the Agriphone, website postings and via Twitter. The MCRS offers unique physical infrastructure for carrying out on-going applied IPM research, as well as IPM expertise with several staff dedicated to muck crops IPM, including an IPM Coordinator.

NON-PROFIT SECTOR

Involvement in IPM by the non-profit sector comes mostly from farm commodity organizations, who support and promote IPM implementation and adoption through funding and collaborating in applied research and providing training, advisory services and knowledge mobilization to keep producers up to date on new IPM strategies. Most commodity organizations have agronomy staff whose responsibilities include pest management. In terms of a not for profit IPM model, the Niagara Pest Monitoring Club (NPMC) is the only long-standing program in Ontario (http://www.niagaraorchard.com/products-services/niagara-pest-monitoring-club/). It has been operated by Niagara Orchard and Vineyard Corp. since 1993, providing monitoring and scouting services in grapes, peaches and nectarines to members who pay an annual fee. The NPMC hires OMAFRA trained scouts who make weekly visits to members' vineyards and orchards to monitor pest activity and make pest management recommendations. The NPMC is also involved in applied IPM research. The Vineland Research and Innovation Centre (VRIC) (http://www.vinelandresearch.com/program/right-tools-integrating-biocontrol-systems-impact) is a non-profit horticulture research organization that carries out IPM research

IPM research at VRIC. Photo: VRIC

with a focus on the development of biocontrol tools and other pest management strategies that support sustainable, highly productive horticulture production systems. The financial, human, physical and knowledge resources committed to IPM research at VRIC are substantial. There are two research scientists and four research technicians working full-time in IPM research with dedicated laboratory and greenhouse space.

PRIVATE SECTOR

The successful implementation and adoption of IPM in Ontario is dependent on the private sector. With the elimination of publicly funded and delivered IPM services, the private sector has taken up the responsibility for several IPM activities. Farmers have been instrumental in the success of IPM in Ontario; they have overwhelmingly adopted most basic IPM practices. They are directly involved in various IPM activities including scouting and monitoring, collaborating on applied research, training and knowledge mobilization. Certain commodities, such as greenhouse vegetables and floriculture, employ full-time staff dedicated to integrated pest management. A new industry of independent IPM consultants has emerged in Ontario over the past 40 years to provide growers with on-site monitoring, scouting and pest management recommendations. Independent IPM Consultants are typically small, entrepreneurial, single proprietorship businesses that serve a single crop sector (e.g. greenhouse industry, muck crops) within a narrow geographical region. They work closely with their farm-clients and other stakeholders, building long-term, collaborative relationships. While classified as a private sector stakeholder, independent IPM Consultants are typically not profit-driven businesses. Given that their clients have limited resources; they tend to operate on the basis of generating a full-time wage for themselves and sometimes one full-time or several part-time staff. Large, agricultural consultants also provide IPM services as part of a broader package of production advice. Both independent IPM consultants and agricultural consultants collaborate on

Predatory midge larvae (orange bug) feeding on aphids (black bug) on cucumber in the greenhouse. Photo: J. Lemay, Eco-habitat Agri-Services.

applied research and take part in various conferences and workshops. Crop protection product suppliers—companies that sell biological control agents—provide limited scouting and technical advice mostly linked to the sale and use of their products. The private sector contributes financial resources toward IPM research and support for some IPM programs (e.g. MCRS IPM program). It is also involved in contributing knowledge resources through knowledge mobilization activities and IPM training, often in collaboration with other IPM stakeholders.

IPM Delivery Models

Over the past 50 years, different models of IPM have evolved within the different crops and growing regions of the province. With the elimination of publicly funded extension services, delivery of IPM programs is shared among the stakeholders. Few programs are centralized and coordinated through a single organization, such as the Muck Crop Research Station IPM program, the Landscape and Nursery IPM program and the Niagara Pest Monitoring Club. Interestingly, these three programs are the exception to the predominantly private sector-based model for carrying out IPM monitoring, scouting and pest management advisory services for real-time, field-specific recommendations during the growing season. IPM is generally delivered at a field, farm or greenhouse scale with a focus on pest sampling and monitoring that targets a single pest species or species complexes on a specific crop. IPM protection practices are crop-pest specific, but generally are a combination of cultural practices and strategically-timed pesticide applications based on economic thresholds or other monitoring data. Greenhouse IPM (vegetables, floriculture) is dominated by mass trapping using sticky traps and tapes and biological control with some large greenhouse operations spending upwards of $1m a year on biological control agents. Ontario's greenhouse industry has the highest adoption of biological control outside of Europe. The other key elements and activities of IPM (research, knowledge mobilization and training) are delivered through the collective efforts of the stakeholders and are generally based on a cost recovery or not for profit model. An example of collaborative knowledge mobilization and training activities is the greenhouseipm.org website, a collaboration of Flowers Canada Growers, OMAFRA, VRIC and the AAFC-PMC. The website serves both the floriculture and vegetable greenhouse sectors. One of the key mandates of the website is to provide "independent, non-profit driven information resources that improves productivity and the economic bottom-line for growers while helping reduce pesticide risk and promote sustainability" (Greenhouseipm.org 2019).

Envisioning IPM Within a Social Economy of Food: Social Economy of Food Themes

This analysis is derived from the Ontario IPM profile and broader international IPM literature. It uses the five defining themes of the social economy of food (Table 1) as an analytical framework to illustrate how IPM can advance a social economy of food approach to food production. The discussion focuses on the two themes where IPM has the greatest impact: *Building Adaptive Capacity* and *Increasing Social Capital*. The other three themes are briefly discussed.

Building Adaptive Capacity

As a continuously evolving, dynamic approach to crop protection, building adaptive capacity is an inherent element of IPM. Effective IPM programs are constantly updated and revised to reflect new knowledge (both technical and local) and to respond to the continuously evolving agroecosystem, as well as shifting social and political forces that shape sustainable crop protection. All stakeholders who participate in the design, implementation and adoption of IPM develop the capacity to adapt to the complexities of protecting crops from pests, while minimizing risks to humans and the environment. Advanced models of IPM applied at the landscape and agroecosystem scale that focus on public and social goods benefits in addition to farm-level economic benefits have an even greater impact on building adaptive capacity. IPM is a truly sustainable approach to crop protection because it contributes to ecological, economic, social and food system resilience. It is consistent with ecological farming priorities and agroecosystem approaches that are promoted in a social economy of food paradigm (Brewer and Goodell 2012). Envisioned as the dynamic application of principles to local contexts, IPM contributes to the adaptive capacity and thus the resiliency of not only the agroecosystem, but the agri-food system (Barzman et al 2015).

Ecological Resilience

IPM contributes to ecological resilience in two ways. First it reduces the negative environmental impacts and minimizes the environmental risks of pesticide use. Second, widespread, long-term adoption enhances ecosystem services that contribute to ecological resilience. IPM reduces the use of pesticides, both in terms of the amount used and the frequency of application. Reductions in pesticide use translate into reduced negative impacts on water, air and soil quality and on non-target organisms, in particular pollinators, and the rate at which pests develop resistance. IPM strategies also help to minimize the adverse environmental impacts of pests on natural resources, including food crops (Federal IPM Coordinating Committee 2018). The adoption of IPM over the long term enhances ecosystem services of agricultural landscapes contributing to the sustainability of agriculture production and agri-food systems (Lamichhane et al 2018). Certain IPM practices (inter-cropping, trap cropping, minimum/no till, crop rotation) promote healthy crop

Muck Crops IPM Program, Holland Marsh, Ontario: Building Adaptive Capacity for 40 years

The Holland Marsh is one of the most intensive crop production areas in Ontario, producing most of the Province's carrots, onions, lettuce and Asian vegetables. IPM has been practiced in the Holland Marsh for almost 40 years. For the past 15 years, the Muck Crops IPM program has been delivered through the University of Guelph Muck Crops Research Station (MCRS). The program combines twice weekly scouting of individual fields for insects, diseases and weeds, on-going weather monitoring and pest forecasting programs with local research results from the MCRS on cultural controls, host resistance and biological methods. Field-specific recommendations and freely accessible regional scouting data and pest forecasts allow growers to quickly adapt to rapidly changing pest and crop conditions.

Over the past 40 years the IPM program has had an impact on the economic and ecological resiliency of the entire 7000 acre production area by reducing overall pesticide use, facilitating the uptake of reduced-risk strategies, limiting the development of resistance to insecticides and fungicides and most recently considering agro-ecological approaches such as naturalizing non-agricultural areas to enhance biodiversity, improve pollinator health and promote conservation biocontrol. The Muck Crops IPM program has been instrumental in sustaining the resiliency of one of Ontario's most important food production systems.

environments, conserve beneficial organisms (pollinators, natural enemies) within the agroecosystem, enhance biodiversity, and have positive impacts on water and soil quality (Bottrell and Schoenly 2018; Brewer and Goodell 2012; Clearwater et al 2016; Kogan and Jepson 2007)

Economic Resilience

Within a social economy of food paradigm economic resilience is the foundation of farm livelihoods. Farmers must adapt to global and local economic dynamics, often beyond their control, that directly impact the economic viability of their farms and their livelihoods. Economic resilience in the context of IPM is facilitated in several ways: cost savings from reduced use of pesticides, increased yields from more effective crop protection strategies, improved product quality from reduced damage levels and lower pesticide residues, increased competitiveness through access to higher market segments and increased margins/profits from higher prices for sustainably produced crops. Scouting and monitoring in association with economic thresholds reduces the frequency of pesticide applications, which results in a direct cost saving, lowering the overall costs of crop protection. In Ontario, several IPM strategies are eligible under BMP adoption incentive programs, thereby providing an additional direct economic benefit to farmers (Canadian Agricultural Partnership 2019). The increased yields that come from reduced pest damage and improved crop health translate into increased revenues and higher margins. In Germany, where consumers and retailers

Manual removal of pests is an effective IPM strategy, especially when the 'pest' is also a protected species, such as these monarch caterpillars feeding on ornamental milkweed in a nursery. Photo: J. Lemay, Eco-habitat Agri-Services have demanded specific product quality features such as minimal pesticide residues, access to these niche market segments and the associated higher prices is improved through the adoption of IPM (Buurma and van der Velden 2017). Similar recognition from the value chain for the value-added of IPM, such as higher prices, is not yet evident in Ontario. The economic resilience that results from the adoption of IPM is even greater when the marginal costs associated with consumer, worker and environmental health are factored in (Lefebvre et al 2015; Letourneau et al 2017).

Food System Resilience

IPM is widely recognized as one of the most promising approaches for the transition to sustainable agriculture (Lamichhane et al 2018; Kogan and Jepson 2007). The impacts and benefits of IPM can be traced beyond agricultural production throughout the agri-food value chain. IPM has a role to play in protecting public health, which is dependent on a consistent supply of safe, nutritious, affordable food (Federal IPM Coordinating Committee 2018). IPM contributes to food safety by

Biocontrol agents such as predatory mites are used extensively in greenhouse IPM to manage various pests, such as thrips on floricultural crops such as roses and petunia. Sachets containing the mites are clipped to individual plants. Photo: S. Jandricic, OMAFRA

reducing the potential risks of foodborne diseases and pesticide residues. Reductions in pesticide use have impacts on workers' health and welfare with reduced exposure and safer work environments. Worker and family safety is one of the primary reasons why farmers adopt IPM (Bottrell and Schoenly 2018). Reducing pesticide exposure is important in greenhouse production as workers have more frequent and prolonged contact with crops than with most field crops. The

Ontario greenhouse vegetable industry has the second highest use of biological control for crop protection, behind only Europe.

Basic IPM practices have direct benefits to farmers in terms of cost savings from reductions in pesticide use, reduced crop damage, increased yields and quality and potentially increased crop prices and enhanced competitiveness, which makes individual farms more resilient. The collective impacts of widespread adoption of basic IPM contributes to the sustainability of agriculture production at a crop system level. Advanced IPM practices that target broader resource conservation objectives in addition to crop protection at a regional or landscape scale achieve public or societal impacts that contribute to the resiliency of the agri-food system (Brewer and Goodell 2012). Importantly, advanced IPM approaches that go beyond simply reducing pesticide use to build the capacity of agroecosystems to provide critical eco-systems services make agricultural landscapes productive beyond providing food. The multi-functional nature of IPM (e.g. crop protection, ecological services, economic development) (Renting et al 2009) is crucial to its role in building food system resilience and overall adaptive capacity and thus its potential for advancing food systems within a social economy of food paradigm.

Increasing Social Capital

The capacity for building social capital through IPM is well documented (Murage et al 2015; Pretty and Bharucha 2015; Ortiz et al 2019; Palis et al 2002). IPM requires an understanding of the agroecosystem, which involves training, education and knowledge building. Participatory, experiential learning approaches to IPM development and training empower farmers in their decision-making and in taking up leadership roles, which are directly linked to building social capital (Abrol 2017). Sharing data, exchanging knowledge, networking activities, training sessions, grower field days and conferences create opportunities for community connections and relationship building, as well as knowledge building. As a knowledge-intensive practice IPM involves multi-actor interactions, information flows and the production of locally relevant knowledge that take place at multiple levels of engagement, creating trust, reciprocity, social

Apple IPM Groups in Switzerland: Building Social Capital

Apple IPM Groups in Switzerland offer a compelling example of the contribution that IPM makes to building social capital. IPM groups were formed among apple growers, researchers and public IPM advisers. After participating in an apple IPM training course, producers formed sub-groups who were responsible for jointly monitoring apple orchards. The sub-groups met regularly to share data, observations and to discuss crop protection options. The IPM groups allowed growers to implement coordinated, collective activities such as region-wide pheromone trapping. Growers reported that their participation in the Apple IPM group gave them greater confidence in their IPM decisions through the shared learning that occurred in the groups. Growers felt that knowing about the status of many orchards gave them a broader understanding of apple production relative to their own operations. In addition, the large data sets generated by the orchard scouting and monitoring were used by the researchers and IPM adviser to improve IPM recommendations provided to growers. Importantly, the Apple IPM groups were instrumental in the implementation a Swiss agricultural policy that linked state payments to the adoption of IPM. (Lamine et al 2010

connections and norms that facilitate cooperation and result in social, economic and ecological benefits (Barzman et al 2015; Abrol 2017). Access to social capital in the form of networking and improved community organization is a key incentive for farmers to participate in IPM (Ortiz et al 2019). The social capital produced through adoption of and participation in IPM is instrumental in driving further social and political change related to agricultural productions systems and policy (Barzman et al 2015; Pretty and Bharucha 2015).

Building Knowledge

Knowledge building is a foundational element of IPM. It is a knowledge-intensive BMP that requires on-going research and knowledge sharing and exchange among all stakeholders. Practitioners require sound knowledge of pest and natural enemy biology and behaviour, crop biology and development, pest-crop and pest-natural enemy interactions and agroecosystem dynamics (soil, water, weather, climate), as well as the cultural, mechanical, biological and chemical pest management solutions and the associated risks (economic, human and ecological). A key aspect of the knowledge-building element of IPM is its reciprocity. Knowledge building is not limited to farmers. Knowledge-building and learning occur throughout the complex and dynamic network of stakeholders involved in local and regional IPM programs. IPM researchers, government IPM and crop specialists, independent IPM consultants and summer student scouts all benefit from on-going exchanges of knowledge that occur through the engagement of community networks that work toward the development and implementation of IPM programs.

Yellow sticky traps are placed in onion fields early in the growing season to monitor insect populations. Photo: T. Cranmer, OMAFRA

In order for IPM to be effective, the scientific and technical knowledge of pests, hosts, natural enemies, and agroecosystem dynamics must be applied within a local context taking into consideration local knowledge, available resources and production practices. Successful IPM relies on feedback from farmers to document current and futures needs. IPM programs and strategies are increasingly being developed and implemented through participatory action research (PAR) models that include multiple stakeholders throughout the research process and include identifying local priorities, designing studies and applying the results (Horrocks et al 2018). The success of IPM programs is linked to engaging local community networks of knowledge to develop locally adapted solutions (Pérez-Hedo et al 2017). Much of the information provided to farmers through knowledge mobilization and training initiatives is developed in partnership with farmers. Farmers often take a lead role in disseminating and sharing new IPM knowledge and information to other farmers (Carrión Yaguana et al 2016).

Lacewing larvae are predators that are released in the greenhouse to control aphids on vegetables crops such as lettuce. Photo: J. Lemay Eco-habitat Agri-Services

As much of the crop scouting and monitoring during the growing season is done by post-secondary students, IPM provides an excellent opportunity for work-integrated or experiential learning, which allows students to not only gain and apply scientific knowledge and technical skills, but to develop essential social, organizational, communication and entrepreneurial skills and experience in 'real world' settings. Experiential learning has been identified as crucial for preparing the next generation for careers in science-based industries, such as agriculture. Summer student scouts gain considerable social capital through their experiences in participating in IPM programs.

The participatory nature of IPM, the reciprocal learning, the sharing of knowledge and the skills development are powerful means by which the social capital of all stakeholders is increased. The knowledge necessary for effective IPM has implications and impacts far beyond protecting crops from damaging pests. It contributes to the transition to sustainable agriculture and gives farmers a better overall understanding of their own crop production operation, which leads to a more productive, sustainable, resilient food system.

Creating Networks

IPM is fundamentally a network-based BMP; it engages community networks of knowledge and leadership in the design, development, implementation and adoption of programs and strategies (Brewer and Goodell 2012). IPM brings together diverse stakeholders with shared interests, identities and values working towards a common goal. The social capital built within IPM networks has been linked to higher levels of adoption (Barzman et al 2015). Networking at multiple levels is necessary to optimize the resources committed to design, develop, implement, adopt and sustain IPM (Lamichhane 2017). The design, development and implementation of IPM creates networks at multiple levels from the local to the transnational, which are critical for long-term adoption.

As IPM moves toward macro-scale implementation, such as area-wide and landscape-based IPM, networking takes on greater importance. Advanced models of IPM involve many stakeholders collaborating in diverse activities, employing a variety of resources, which need to be coordinated. Furthermore, stakeholders need to be connected in order to share expertise, exchange knowledge and data and learn. Networking is essential for managing these complex interactions and dynamics (Lamichhane et al 2016). It is through networking that advanced IPM models have demonstrated greater social benefits (Lamichhane et al 2016).

Networks facilitate and support key activities that define successful IPM. Networking allows for pooling of social and resource capital that support long-term applied research at a systems level, which is resource intensive, often beyond the capacity of a single stakeholder and requires adaptation to local conditions (Lamichhane et al 2016). Reciprocal learning and knowledge sharing are facilitated through networks that are created by successful implementation and adoption of IPM.

Social and Political Change

Social change in the context of IPM is reflected in changes to agricultural practices, expanded networks of diverse stakeholders that represent the entire food chain/system, a shifting focus on broader ecological, economic and social benefits at more macro-scales (e.g. regions, landscapes) and a recognition of the broader forces that are shaping crop protection. Advanced models that apply IPM at macro-scales such as landscapes and cropping systems that address regional issues with broader public benefits are gaining recognition and capturing the attention of political leaders (Brewer and Goodell 2013; Peterson et al 2018). It is increasingly recognized that IPM represents a promising route to sustainable crop protection, as well as the potential for broader societal benefits (Bottrell and Schoenly 2018; Kogan and Jepson 2007). There is evidence that IPM has contributed to social and political change, both in Ontario and internationally. A key political change is the European Commission Directive 2009/128/EC: *Establishing a Framework for Community Action to Achieve Sustainable Use of Pesticides*, which required Member States to implement IPM as of 2014 (European Commission 2009; Caffi et al 2017). In Ontario, IPM is embedded in the new regulations for the use of neonicotinoid-treated corn and soybean seeds. It is also a key element of the Canadian Agriculture Partnership, the federal-provincial-territorial agriculture policy framework. These shifts in policy are occurring in concert with social changes driven by the recognition that IPM represents a significant shift in crop protection practices with the potential of making a major contribution to the transition to sustainable agriculture (Palis et al 2002; Pretty and Bharucha 2015).

Whiteflies are serious pests of many greenhouse crops, including vegetables and flowers. Photo: J. Lemay, Eco-habitat Agri-Services

IPM and a Social Economy of Food

The strength of IPM in supporting a social economy of food is its potential for increasing social capital and building adaptive capacity. It does, however, also show promise for fostering innovation and entrepreneurship, increasing prosperity and bridging divides between stakeholders. IPM is directly linked to a vast range of scientific, technological and agronomic innovations, for example pheromone-based monitoring and management techniques, novel biological control agents, computer-based models for predicting pest activity and timing crop protection interventions and ecosystem level approaches that deliver environmental public goods. As a knowledge-intensive practice, the future of IPM depends on continued advances and innovation from multidisciplinary and participatory action research. The widespread acceptance and adoption of IPM worldwide across myriad crop and production practices has led to the emergence of new occupations and high-quality employment opportunities. As seen in Ontario, employment opportunities for private IPM consultants and summer-student IPM scouts are a direct result of the wide-spread adoption of IPM across the province's agri-food system. New and nascent forms of IPM emphasize the importance of integrating agricultural, environmental, social and policy interests to address multiple issues at broader scales that achieve long-term sustainable crop protection and deliver agroecosystem benefits (Brewer and Goodell 2012). Because it is accessible and available to all production approaches and can be practiced regardless of socio-economic status, IPM can contribute to increasing prosperity for marginalized groups, specifically addressing inequalities by leveling the

Maintaining a healthy agroecosystem that conserves naturally occurring beneficial species is an important element of IPM. Hawks are effective predators of rodent pests in nurseries. Photo: J. Lemay, Eco-habitat Agri-Services playing field between conventional production and alternative food production approaches advocated within a social economy paradigm.

The Future Role of IPM in a Social Economy of Food

IPM is widely recognized as a highly successful agriculture beneficial management practice, serving as a model for sustainable agriculture (Peterson et al 2018). Over the past 50 years, IPM has advanced and responded to the shifting needs and priorities of agricultural production in regions and countries with vastly different natural resources and social, economic and political conditions (Vétek et al 2017). It has proven to be effective across a diverse range of agri-food systems. Evolving perspectives of IPM and ongoing advances have positioned IPM to serve a broader social and public goods vision: a vision that is aligned with the objectives of a social economy of food to address inequalities and gaps of conventional agri-foods systems. IPM is an accessible crop protection approach that is not limited to the formal economy. As demonstrated in the case study of Ontario, IPM is designed, supported, delivered and implemented by a diverse range of stakeholders representing all sectors (formal and informal) of the economy.

Pheromone traps are used to monitor and track population levels of some moth and beetle pests in vineyards and orchards. Pheromones are a form of chemical communication among insects. Photo: J. Lasnier, Ag-Cord

IPM is an adaptive, dynamic model of crop protection that has significant potential to contribute to the development of alternative models of food production that emphasize social and environmental values. Its foundational principles are aligned with those of a social economy of food paradigm. Another strength of IPM is its capacity for multi-functionality in serving multiple purposes beyond sustainable crop protection, such as food safety, enhanced agroecosystem services, high quality employment opportunities and improved human health and well-being (Renting et al 2009). In the future, advanced forms of IPM will have an integral role in the transition to a model of sustainable agriculture that integrates social values, alternative economic models and ecologically sound practices. Advanced IPM approaches, which recognize and reflect the value of public goods, in addition to private benefits, serve as a model for using market economy resources in new ways within new socially-conscious, business models (Dara 2019). Such modes of IPM delivery contribute to advancing alternative methods of agri-food production that increase prosperity, build adaptive capacity, increase social capital, bridge divides by connecting diverse stakeholders and foster innovation and entrepreneurship.

IPM is well suited to a social economy of food paradigm, both from the perspective of supporting alternative crop production and food systems models and as a service delivered under a social economy model. Exploring IPM within the context of a social economy of food brings to light opportunities for advancing and expanding activities for both approaches. The principles of IPM are aligned with, complimentary to and supportive of various alternative food system approaches that privilege ecological and social sustainability on par with or prior to economic sustainability (e.g. organic production, ecological farming and community-based farming). IPM offers an effective strategy for crop protection that is accessible regardless of socio-economic status or demographics, making it a promising approach for food systems that emphasize food security and food sovereignty. In addition, in terms of a delivery model, IPM is well suited to a social economy-based model, such as the not for profit services offered by the Muck Crops Research Station IPM program and the Niagara Pest Monitoring Club. Envisioning the delivery of IPM within a social economy of food paradigm has compelling implications for the transition to advanced, ecosystem, public good-based IPM models that warrant further consideration.

Challenges & Constraints

IPM faces a variety of political, social, economic and scientific challenges and constraints. In the Ontario context, IPM is clearly a priority with the extensive public resources committed to supporting, promoting and advancing adoption and implementation. IPM is constrained by the lack of an overarching policy directive. While the diverse delivery models reflect the crop and site-specific dimensions of IPM, a single vision and strategy for guiding provincial activities would provide a valuable coordinating element to the province's IPM efforts, as well as link to other provincial policy priorities, such as sustainable agriculture production, local food and public health. Social challenges for IPM are related to the adoption and implementation of advanced models that shift the focus away from individual/farm-level, market-driven benefits towards agriculture landscape/community scale, public good objectives. Crop production approaches within a social economy paradigm already operate under this public goods imperative and, therefore, would likely find the adoption of advanced IPM practices less challenging. The transition to advanced IPM will also require cooperation among an expanded stakeholder base to reconcile the market-based and public-based interests, thus re-enforcing the capacity for IPM to bridge divides. IPM faces economic challenges such that current incentives for implementation are based on the private returns to individual farmers. In future, new policy driven incentives will be necessary to ensure

Establishing biosecurity protocols and physical barriers to prevent pests are important elements of greenhouse IPM programs. Photo: J. Lemay, Eco-habitat Agri-Services the adoption of ecosystem-based IPM approaches that target public goods (Brewer and Goodell 2012). There are two primary scientific challenges that constrain IPM. First, as a knowledge-intensive practice, advances in and adoption of IPM are heavily dependent on research and knowledge mobilization, which requires significant funding. Both public and private sources of funding have been declining over the past several decades. Lack of funding for research and knowledge mobilization is a challenge that needs to be addressed if IPM is to continue to support multiple functions. The second scientific challenge that is limiting IPM is the sheer complexity of the agri-food "macro" system and our capacity and ability to truly understand and make sense of the vast, interdependent variables, factors and entities that comprise the multiple systems that represent the agri-food system. Finally, probably the greatest challenge for IPM is human-generated, including increasing global market demands for food, cultural and societal biases and anthropogenic disasters (Kogan and Jepson 2007). Continued disregard for the impacts of human actions on the environment threaten the capacity of IPM to support sustainable agriculture production. Ignorance and entrenched beliefs about pests and pest management have set back well-established IPM programs and pose further barriers for widespread implementation and adoption of advanced IPM systems at the agroecosystem that show promise for making a significant contribution in the transition to sustainable agri-food systems (Kogan and Jepson 2007).

Greenhouse vegetable crops are scouted on a regular basis to monitor for insects and diseases and evaluate the effectiveness of pest management strategies. Photo: VRIC

Implications for Policy

While IPM is widely supported in Ontario, its design, delivery and implementation are fragmented among diverse stakeholders. The lack of an overarching IPM policy or strategy leaves Ontario at a disadvantage compared to jurisdictions such as the European Union, which has embedded the adoption of the IPM in transnational policy and regulation and the United States, which has a Federal IPM Coordinating Committee and several dedicated, regional IPM centres. The EU's recent pesticides package, which includes two Directives and two regulations has catalyzed coordination of IPM research and knowledge mobilization among EU countries and triggered several new programs and initiatives that promote and support the development and implementation of advanced, agroecosystem based IPM (Barzman et al 2015).

Specific to the Ontario context, envisioning IPM within a social economy of food has implications for several of OMAFRA's current agri-food and rural policy priorities, including enhanced environmental sustainability and performance through the adoption of environmental beneficial management practices, enhanced plant protection through innovation in IPM, and the expansion of local food to improve the health of Ontarians (OMAFRA 2018). Moreover, examining the intersection between IPM and a social economy of food opens opportunities for expanding the reach of the province's local food strategies, for supporting the growth of local food markets and for contributing to rural community development. Connecting policies for IPM and a social economy of food represents a novel policy approach for supporting the transition to sustainable agriculture through food production systems that are socially acceptable, ecologically responsible and economically viable.

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