ENVIRONMENTAL SUSTAINABILITY — STATE OF RESEARCH

Nutrient Transport

UNIVERSITY of GUELPH

IMPROVE LIFE.

Supported by the Ontario Agri-Food Innovation Alliance's Environmental Sustainability Research Theme

Ontario

The Environmental Sustainability (ES) Synthe

The Ontario Agri-Food Innovation Alliance is an innovative government-university collaboration delivering high-quality, high-impact research results that strengthen Ontario's agri-food and rural sectors and improve the health and prosperity of the province's citizens and environment.

Environmental Sustainability (ES) is one of eight research themes funded by the Alliance, supporting research that ensures the sustainability of Ontario's agricultural and agri-food sectors, promoting environmental health while maintaining profitability. The goal of this synthesis was to capture information about the impacts of ongoing and completed ES research projects and their interrelationship at a farm scale.

Taken together, this project documents a dedicated and comprehensive research effort by the Alliance to increase the environmental sustainability of Ontario's agri-food industry.

Ontario

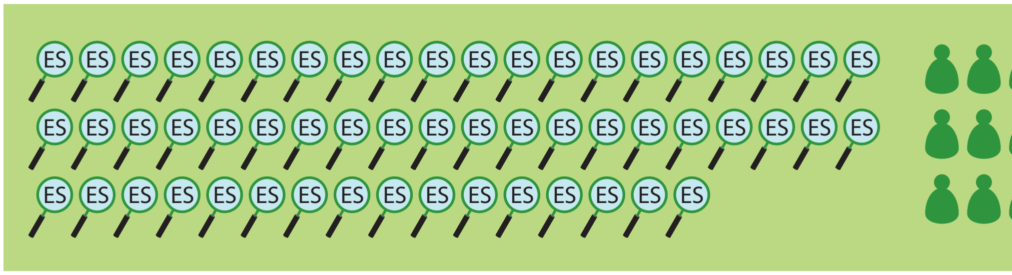
UNIVERSITY of GUELPH

IMPROVE LIFE.

Process to create a farm-scale view of the ES research

56 ES projects starting between 2008 and 2015 were examined

27



Investment

$4.9 Million invested by OMAFRA + **$7.5 Million** leveraged from 77 partners

(**1:1.53** leveraging ratio)

Return on Investment

16 commodity group programs or government policies supported

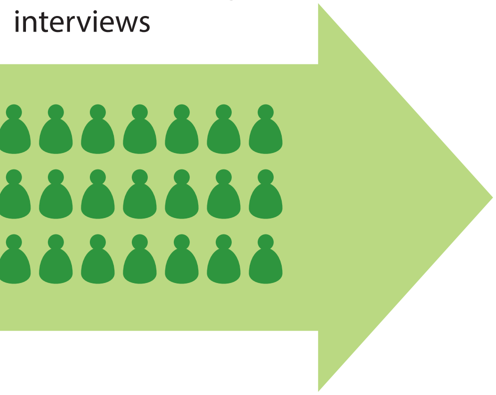
14+ new technologies produced

6 online ... crea...

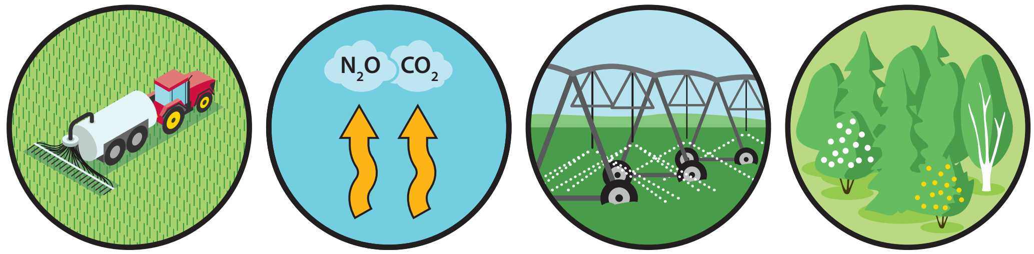
esis Project

Summarizing research supported by the Ontario Agri-Food Innovation Alliance

principal investigator interviews



4 case studies created for compiling projects and interviews

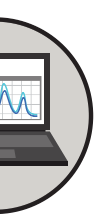


Nutrient Transport | Climate Change | Wastewater | Biodiversity

Partnerships

77 Partners

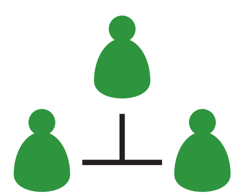
- **30** Industry
- **21** Government or conservation authorities
- **17** Commodity groups
- **9** Granting agencies



tools
ted

122
papers published
in **75** scientific journals

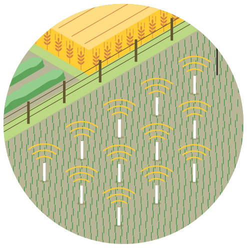
149
highly qualified
personnel trained



130
research collaborators
(**3:1** U of G to external institutions)

Contents

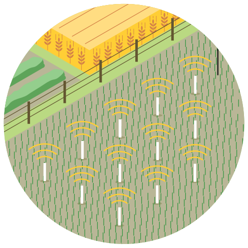
Introduction



Nutrients are an important part of farm management, playing a key role in crop health, productivity and soil health. Nutrients such as phosphorus and nitrogen are contained in manure, fertilizer, compost and biosolids, which are all applied to land to improve crop growth. However, if not properly managed, nutrients can move off-farm resulting in a variety of issues, including impacting water quality and increasing costs for farmers.

Nutrients can leach into groundwater and surface water sources, where they may eventually meet up with lakes and rivers. In high levels, nitrogen and phosphorus in surface water can harm aquatic life and promote growth of oxygen-depleting algae. This can lead to decreased biodiversity and declining fish populations, among other concerns. Some species of blue-green algae also produce toxins harmful to humans and aquatic wildlife. The loss of nutrients through runoff incurs additional costs for farmers as more fertilizer or manure is needed to maintain proper nutrient levels. Understanding how to best keep nutrients on-farm to prevent these possible environmental impacts is an equally important component of agricultural nutrient use.

The Ontario Agri-Food Innovation Alliance supports research and knowledge mobilization to help producers reduce the transport of nutrients off-farm through evidence-informed policies, programs, best management practices (BMPs) and the development of new tools and technologies.



Foreword

A competitive agri-food sector is built on a sustainable environment. From farm to fork, every step in food production has an impact on the environment. Research supported through the Ontario Agri-Food Innovation Alliance's Environmental Sustainability research theme is helping maintain and enhance our natural resources, while also ensuring that our agri-food sector remains sustainable and profitable. As we look forward to our renewed partnership with the Ontario Ministry of Agriculture, Food and Rural Affairs, it is important to also look back at what our researchers have accomplished over the past eight years: creating online tools to improve sustainable agricultural operations; developing technologies and models that help address nutrient runoff from farms; influencing government and commodity group policies with evidence-informed research; and training 149 skilled students to meet the changing demands of the agri-food sector. Research supported by the Alliance is helping farmers and agri-business deal with some of the most pressing challenges of our time, including climate change, nutrient transport and biodiversity conservation.

This project represents the first effort to tell the story of how individual research projects are contributing to the sustainability of both our environment and our agri-food sector. Even as each project increases our knowledge, the entire program illustrates the interconnectedness of the research at the farm level and how that research helps us understand the influence of agricultural drivers on our environmental systems.

Bill Van Heyst
PhD, P.Eng.

Environmental Sustainability Theme
Research Program Director, 2011-2018

University of Guelph

Long-term sustainability and profitability of the agri-food sector is increasingly dependent on the preservation of the productive capacity of natural resources. Stewardship of these resources is essential for capitalizing on growth opportunities and protecting agricultural land for future generations. The Ontario Agri-Food Innovation Alliance provides a unique capacity to address the agri-food sector's research and innovation needs and agri-environmental issues to drive long-term sustainability for the sector. OMAFRA's environmental sustainability research theme has supported research at the University of Guelph to maintain the ability of our natural resources to support and strengthen agricultural, food and bioproduct sectors and rural communities. Over the last 10 years, OMAFRA invested $7.4 million in 70 agri-environmental sustainability research projects through the Alliance. Research has focused on important environmental issues to encourage nutrient management best practices, enhanced biodiversity and reduction of greenhouse gas emissions from the sector. These research projects are yielding exciting new knowledge, innovative technologies, partnerships and new production systems, and contributing to the training of the next generation of trained personnel for the sector. It is essential that this research be shared in formats that are widely accessible to farmers, agri-businesses and other partners across the province, providing evidence to guide decision-making related to agricultural lands and to inform adoption of innovation and best practices on the landscape. This synthesis report is another step toward this goal. Through the recent renewal of the Alliance, we look forward to continued collaboration with the University to further strengthen our partnership and the outcomes achieved.

Colleen Fitzgerald-Hubble

Environmental Sustainability Theme
Director Champion

Ontario Ministry of Agriculture,
Food and Rural Affairs

Keeping Nutrients On-farm

A farm-scale view of research su

Nutrients such as phosphorus and nitrogen are key to crop health and productivity. But if allowed to move, nutrients can travel off-farm, reduce water quality and increase costs for farmers.

The Ontario Agri-Food Innovation Alliance helps keep nutrients on-farm by supporting research that advances our understanding of the nutrient transport system – from application and retention to transportation and mitigation – and to develop evidence-informed best management practices, tools and technologies.

Taken together, these projects create a tool kit for producers to reduce on-farm nutrient loss, enhance productivity and contribute to a healthier environment.

Mitigation and Water Treatment

Adoption of Nutrient Management and Land Use BMPs

Researcher: John FitzGibbon

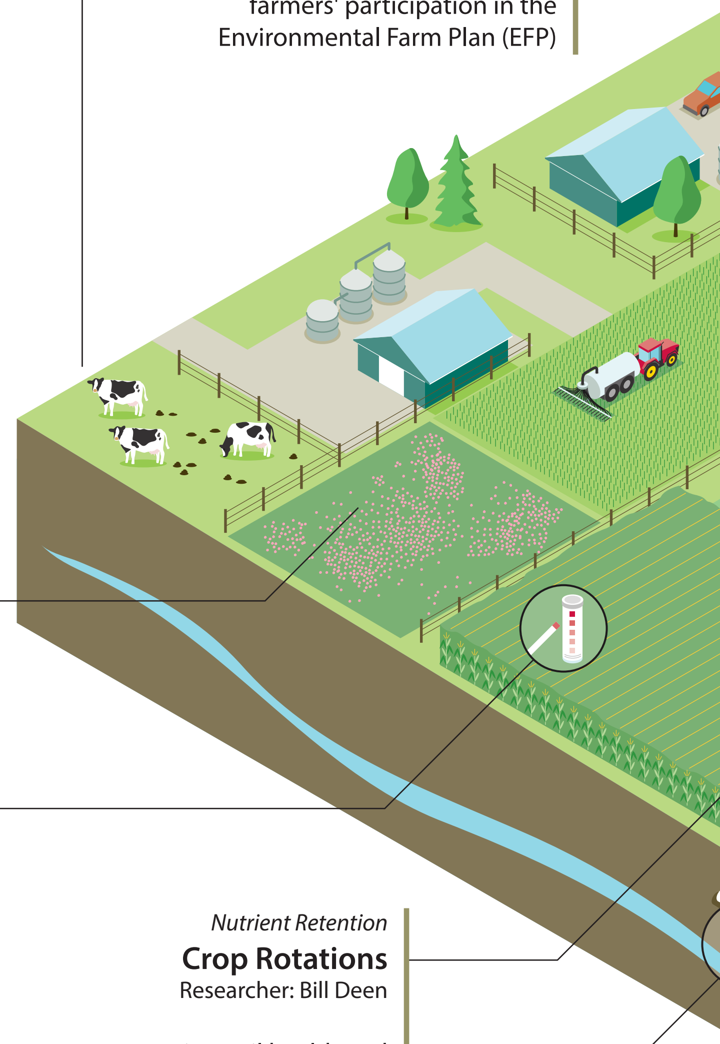
Increasing environmental awareness: Research to increase farmers' participation in the Environmental Farm Plan (EFP)

Nutrient Application

Anaerobic Digestion

Researcher: Anna Crolla

Evidence to help farmers on-farm: Comparing the benefits and costs of anaerobically digested manure to those of raw manure



Nutrient Retention

Red Clover Drought Resistance

Researcher: Ralph Martin

Optimizing fertilizer use by studying red clover growth

Nutrient Application

Nitrogen Tests and Biopesticides

Researcher: Manish Raizada

Optimizing fertilizer and pesticide use by developing a new nitrogen test and biopesticide

Nutrient Retention

Crop Rotations

Researcher: Bill Deen

Improving soil health and crop yield using diverse crop rotation

Transport Through Soil

Geology and Groundwater

Researcher: Emmanuelle Arnaud

Reducing nutrient transport through soil by identifying areas at risk of groundwater contamination

Nutrient Retention

Practices on Phosphorus

Researcher: Ivan O'Halloran

Reducing soil phosphorus loss by evaluating the effectiveness of best management practices

Mode

Guiding source water
the movement of w
flow of nu

Ontario

University of Guelph

Improve Life.

pported by the Ontario Agri-Food Innovation Alliance, Environmental Sustainability research theme

Nutrient Retention

Cover Crops

Researcher: Laura Van Eerd

Improving soil health by using cover crops to keep nutrients in the field

Transport Through Soil

Managing Surface Transport

Researcher: Ramesh Rudra

Tracking nutrient and sediment runoff into surface water using wireless sensor networks

Transport Through Soil

Mapping Watersheds

Researcher: Aaron Berg

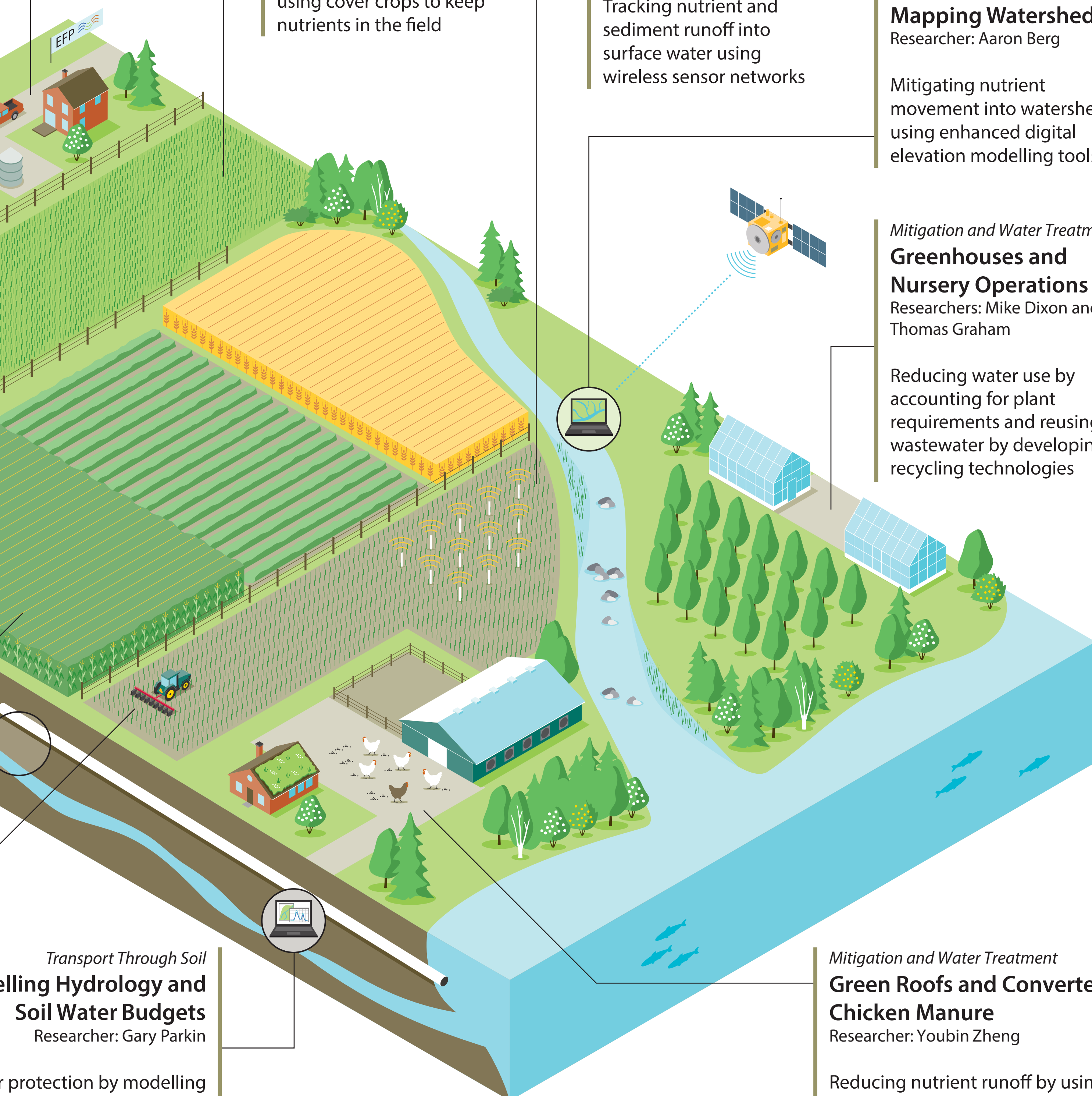
Mitigating nutrient movement into watersheds using enhanced digital elevation modelling tools

Mitigation and Water Treatment

Greenhouses and Nursery Operations

Researchers: Mike Dixon and Thomas Graham

Reducing water use by accounting for plant requirements and reusing wastewater by developing recycling technologies



Transport Through Soil

elling Hydrology and Soil Water Budgets

Researcher: Gary Parkin

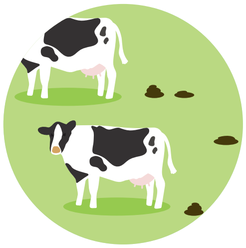
r protection by modelling
vater through soil and the
utrients into groundwater

Mitigation and Water Treatment

Green Roofs and Converted Chicken Manure

Researcher: Youbin Zheng

Reducing nutrient runoff by using fly larvae to convert chicken manure into dry organic fertilizer



Comparing the costs and benefits of anaerobic digestion

Researcher: Anna Crolla

Problem Addressed

Anaerobic digestion, a process that uses microbes to break down organic matter (in this case manure and off-farm waste substrates) in the absence of oxygen, produces digestate and biogas. Digestate can be applied to fields as fertilizer and biogas can be converted to electricity or heat. This process can reduce greenhouse gas emissions and odours, improve the quality of fertilizer and produce energy. Different types of manures contain different levels of nutrients. Questions remain about how nutrients from land-applied digestate act in soil compared to those from raw manure, and what types of manure and co-substrates can effectively be broken down through anaerobic digestion.

Digestate tends to contain higher ammonium concentrations than raw manure, contributing to increased crop yields, but could lead to greater nitrate losses to drainage water.

Project Findings

Anna Crolla, formerly of Campus d'Alfred, compared the land application of digestate and raw manure on agricultural plots. Digestate tends to contain higher ammonium concentrations than raw manure, contributing to increased crop yields, but could lead to greater nitrate losses to drainage water. Compared to control plots with no manure, both digestate and raw manure application increased pathogen indicator levels in drainage water, with digestate having lower pathogen indicator levels than those of raw manure. Pathogen indicator levels were not concerning for either of the digestate- or raw manure-treated plots. Although digestate had greater nitrate loss than raw manure, anaerobic digestion has the added environmental benefit of producing methane in a controlled environment that can be used for energy or heat production, making it the more sustainable option overall. Farmers can use this information to compare the nutrients' costs and benefits, knowing the challenges associated with their application.

Reducing nitrogen fertilizer loss with a low-cost test

Researcher: Manish Raizada

Problem Addressed

The amount of soil nitrogen gives farmers a guide to how much fertilizer needs to be applied for optimal crop growth, but nitrogen testing can be costly. Several soil samples are required at a cost of $10–15 each. Farmers often test less due to the cost and add more fertilizer or manure than crops actually need to reduce risks. This contributes to nutrients being applied at higher levels than needed and results in loss. A cheap, easy-to-use test would help farmers determine how much fertilizer they need to optimally grow crops and prevent excess runoff.

Project Findings

Prof. Manish Raizada, Department of Plant Agriculture, and his team have developed a low-cost test for detecting nitrogen levels in crops that requires only a bit of the plant leaf to determine whether fields need an extra dose of fertilizer. The test uses a strain of modified bacteria with a gene that glows in the presence of the amino acid glutamine — an important source of nitrogen for plants and a good indicator of soil quality. Using side-by-side tests, this technology performed better than any others, and at a fraction of the cost ($1 per sample). After several years of greenhouse and field trial validations, negotiations are under way to bring the new nitrogen test to market.

Developing biopesticides to reduce pesticide use

Researcher: Manish Raizada

Problem Addressed

Fusarium — a major issue for Ontario grain farmers — is a fungus that produces disease-causing toxins that affect humans and cattle that consume infected wheat or corn. The fungus can produce toxins before there are visible signs of infection and cause significant profit loss through control efforts with synthetic fungicides. Dollar spot disease in turfgrass is another costly infection that can cost $20,000 per year per golf course in synthetic pesticides to control. However, runoff of synthetic fungicides and pesticides can harm other organisms in the field or surrounding environment. Biological control methods that use bacteria, viruses or fungi to control pathogens and pests could be a sustainable alternative to synthetic control.

Project Findings

Prof. Manish Raizada, Department of Plant Agriculture, led another team that used beneficial bacteria and fungi called endophytes to help protect crops against *Fusarium*. The endophytes are coated on seeds before they are planted. Field tests show the coating can significantly reduce levels of *Fusarium* toxin in corn. Wheat trials are still underway. The microbes grow a protective layer around the roots, preventing fungal infections without harming other organisms. Endophytes also reduce the amounts of fertilizers and fungicides required, helping lower the concentrations of these substances in the environment. Microbes are found naturally in the environment, so this technology can also help farmers meet the demand for organic crops. The team also developed a biocontrol spray to help suppress dollar spot disease in turfgrass.

Red clover drought resistance

Researcher: Ralph Martin

Problem Addressed

Farmers often choose red clover as a cover crop. As a legume, red clover adds nitrogen and organic matter to soil, improves water use efficiency, reduces weed biomass, mitigates erosion and increases yields. Red clover typically grows evenly across the field, but growth can become patchy under drought conditions. Patchy red clover stands create a need for farmers to fertilize their crops, producing high nitrogen areas around the remaining red clover. This increases nitrate leaching and nitrous oxide emission, resulting in extra work and additional costs for farmers. The reasons for this patchy growth behaviour are unknown, but the answer could produce uniform red clover stands and reduce environmental impacts.

Project Findings

Prof. Ralph Martin, Department of Plant Agriculture, has focused on growing consistent red clover stands, and determining whether factors such as drought or competition with other crops lead to irregular stands. Results showed that with uniform stands, any variation in growth seems mainly due to soil moisture. There was no competition between the plants, indicating competition is not a reason for irregular growth.

The team also found that red clover may become dormant during droughts. Survival depends on the type of clover (single or double-cut), with single-cut red clover faring better under drought conditions. Red clover's ability to recover after dormancy from drought is based on the amount of water stored in the plant's crown. These findings will affect what genes researchers look for when determining the best lines of clover for cover crops.

Improving soil health using cover crops

Researcher: Laura Van Eerd

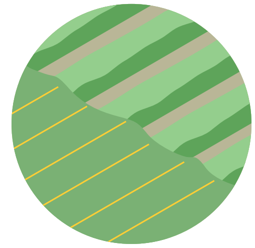
Problem Addressed

During non-growing seasons, bare soil is exposed to wind and water erosion. With nothing to keep soil or nutrients in place, nutrients are easily transported off the field, especially during the spring thaw. Cover crops protect the soil from these effects while helping to retain or even provide nutrients, such as nitrogen. By keeping nitrogen trapped in a plant rather than remaining in the soil, less nitrogen is lost during the winter and at spring thaw. Although there are soil health benefits to cover crop utilization, farmers would like to know short-term and long-term effects on soil and economic returns. Research currently focuses on how cover crops benefit grain and vegetable crops, how profitable they are and the long-term impacts of these rotations.

Project Findings

Prof. Laura Van Eerd, School of Environmental Sciences, designed and maintains two long-term cover crop field trials at U of G's Ridgetown Campus to determine the benefits of different cover crops. From 2008 to 2014, two projects found that cover crop planting date did not impact crop yields, but August planting created higher cover crop biomass and nitrogen content than September planting, so earlier planting is still recommended. All cover crops tested (oat, cereal rye, oilseed radish, forage pea and hairy vetch) provided better nitrogen retention and equal or better profit margins than no cover crop treatment.

Improving soil health and yields through diverse crop rotation



Researcher: Bill Deen

Problem Addressed

Many farmers in Ontario use a corn/soybean rotation or a monoculture of one crop. However, simple crop rotations are associated with a range of agronomic issues, including soil erosion risk, nutrient depletion, pest infestation and poorer soil structure. Historically, these have been addressed through nutrient application and pesticide use. Using a diverse crop rotation increases crop yields and yield stability against pests and disease, and the stronger soil structure reduces nutrient loss, requiring fewer added nutrients. Data that clearly communicate the environmental and economic benefits of diverse crop rotations are needed to encourage farmers to adopt these practices.

Project Findings

Studies at U of G's Elora Research Station run by Prof. Bill Deen, Department of Plant Agriculture, use long-term crop trials to determine benefits of diverse versus simple crop rotations. One trial, initiated in 1980, reveals the long-term effects of different crop rotations, cover crops and tillage vs. no-till practices on yields of corn, wheat and soybeans. The benefits of more diverse rotations include greater yield stability and resilience under moisture extremes, increased nutrient use efficiency, soil structure benefits and altered microbial populations. Adding cover crops such as winter wheat and legumes also improves soil health and nutrient retention. In field studies, Deen found that as rotation diversity increased, fewer tillage-associated benefits were seen, indicating the benefits of reduced or no-till systems can be more attainable if complex rotations are adopted.

Mitigating phosphorus loss

Researcher: Ivan O’Halloran

Problem Addressed

Phosphorus fertilizers and manures are frequently used to increase crop yields, but phosphorus runoff can negatively impact water quality. Algal blooms caused by eutrophication due to phosphorus transport have recently led to water quality issues in waterways, particularly Lake Erie. Best management practices (BMPs) have been recommended by the provincial government to reduce phosphorus loss, but continued investigation is needed to ensure they effectively mitigate nutrient loss. Environmental impacts from phosphorus loss occur before agronomic repercussions are observed, so BMP recommendations are developed with research done through an environmental lens.

Incorporating phosphorus manures into soil lowered phosphorus, ammonia and pathogen runoff when the time between incorporation and first rainfall was short.

Project Findings

In 2008, Prof. Ivan O’Halloran, School of Environmental Sciences at Ridgetown Campus, gathered data to modify an Ontario P Index, a tool to help farmers determine potential phosphorus lost from the soil based on field conditions and nutrient use practices. The study found that different manure and soil types affected the amount of phosphorus at risk of being lost to runoff — liquid hog manure was most at risk of phosphorus loss, with a risk similar to that of synthetic fertilizer. The research also suggested that measuring the soil’s degree of phosphorus saturation using Ontario’s recommended agronomic soil test, the Olsen-P test, helped to better estimate losses.

Another study examined how incorporating phosphorus manures into soil changes the amount of phosphorus lost in runoff compared to leaving manure on the soil surface. Incorporating phosphorus manures into soil lowered phosphorus, ammonia and pathogen runoff when the time between incorporation and first rainfall was short. Depending on the timing of rainfall, incorporation appears to be a good practice for reducing phosphorus runoff.

Using geology to monitor groundwater

Researcher: Emmanuelle Arnaud

Problem Addressed

Manures and fertilizers are applied to agricultural lands to supply crops with nitrogen. Nitrogen can move through the ground into rivers and lakes. Nitrate is a water-soluble form of nitrogen. It binds less tightly to soil and moves through soil easily. Nitrate in groundwater at high levels can contaminate drinking water sources in rural areas or in private wells. Management practices influence how much nitrate is lost from the soil into groundwater. However, a lot of research has focused on the surface transport of nutrients and pathogens in agricultural systems or in urban industrial settings. Less is known about how the deeper subsurface environment may affect the transport of nitrate and pathogens in fields under different land management practices. Research is needed to better manage groundwater sources in rural communities and understand how land management practices affect the fate of pollutants.

Project Findings

Prof. Emmanuelle Arnaud, School of Environmental Sciences, conducted a study that found the highest nitrate levels in agricultural soils beneath outwash plains and where manure and fertilizer had been applied. The next highest levels occurred when synthetic fertilizer was applied to an agroforestry plot (located on a drumlin). The nitrate was present only in top portions of the subsurface. The research results showed that undetectable levels of nitrate were found under soils with no agricultural practices located at a site on the Paris Moraine. Samples were taken from various sites with different sediment and soil layers that affect how nitrate moves in the subsurface. Tree roots may have contributed to the decrease in nitrate at the agroforestry site. The team found that liquid hog manure application resulted in *E. coli* populations in the bedrock aquifer despite the 12-metre depth of sediments overlying that aquifer.

Data gathered in this project provide an indication of areas that may be susceptible to groundwater contamination, adding to this body of knowledge.

Modelling hydrology and soil water budgets

Researcher: Gary Parkin

Problem Addressed

A variety of factors influence nutrient loss from leaching (downward movement of nutrients through the soil) such as groundwater recharge, shallow groundwater levels and soil water budgets (input and output of water through a region). Understanding these factors can help predict nutrient loss and aid in developing region-specific practices for mitigating nutrient transport. Along with knowledge of local trends and soil management practices, computer modelling can help predict water movement and nutrient leaching through soil. Accurate data are needed to provide farmers and researchers with forecasts of soil drainage and nutrient loss, without running full-scale experiments.

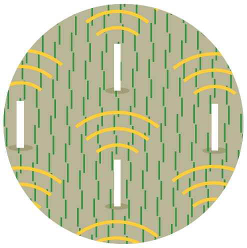
Project Findings

Now retired, Prof. Gary Parkin, School of Environmental Sciences, uses computer modelling to show how water moves through soil. He has collected field data on different soils' hydraulic properties and used this information to create and validate models predicting soil water budgets, groundwater recharge and existing BMPs' utility. He has also modelled potential future climate change effects on these variables. His research employed a soil water budget model to demonstrate that yearly water table variations in different regions of Ontario significantly change groundwater recharge, evapo-transpiration and runoff. This work gathered the data to model the intricate relationship between these variables, based on climate and soil type inputs.

Parkin has also completed modelling to estimate tile drainage volumes under different potential future climatic conditions. The results indicate how a changing climate will affect soil hydrology under various farming practices.

Monitoring surface transport

Researcher: Ramesh Rudra



Problem Addressed

During rainfall and snowmelt events, not all water is absorbed by the soil. Water runoff travels down slopes on the field, which can be a key form of nutrient movement. These slopes, called variable source areas, are potential sources of runoff, transporting both nutrients and sediments from the field into waterways. Variable source areas transport nutrients more easily and with even less precipitation than other areas of the field. To mitigate this non-point source pollution (pollution from many diffuse sources), variable source areas must be identified, monitored and properly managed. BMPs such as setback distances (from waterway to field) and vegetative filter strips can help reduce the transport of nutrients and sediment from the variable source areas off-farm. Tools are needed to help farmers identify where these setbacks and strips should be placed.

Project Findings

Prof. Ramesh Rudra, School of Engineering, assessed how to reduce runoff from variable source areas on a watershed scale using non-point source modelling approaches. Using a wireless sensor network developed by the research team, Rudra monitored variable source areas to track where runoff was generated in a watershed. This novel system has the capability to continuously track multiple hydrologic variables in a watershed, such as soil moisture and runoff, before, during and after rainfall.

In another project, Rudra's team created a computer tool kit to assist in planting vegetative filtration strips. The tool kit determines the size of the vegetative filter strip to be planted and type of plants to include to produce a desired percentage reduction in nutrient and sediment runoff for rainfall. This tool kit can also be used to evaluate the effectiveness of existing vegetative filter strips to trap sediment and nutrients.

Mapping watersheds

Researcher: Aaron Berg

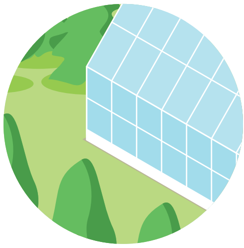
Problem Addressed

Watershed sustainability can be threatened by excess nutrient flow from agricultural fields into bodies of water. Topographic maps provide large-scale information on nutrient flow through watersheds. Digital Elevation Models (DEMs) are 3-D models of the terrain that provide large-scale information of nutrient flow through watersheds. DEMs represent the land elevation needed to assess large-scale soil hydrology, soil moisture and drainage for several hydrology models. DEMS can be collected from multiple sources, including photogrammetric and RADAR, and then require processing to remove the noise within derived DEMs to ensure the product is useful for hydrological modelling. Research was needed to evaluate various approaches for merging DEMs created by multiple sources and to investigate issues with post-processing to improve confidence in the DEM accuracy for runoff modelling, groundwater recharge and characterization of variable source areas.

Project Findings

Profs. Aaron Berg and John Lindsay, Department of Geography, Environment and Geomatics, led a research project to collect DEMs using Synthetic Aperture RADAR for a 625-square-kilometre area north of Guelph. The team developed an approach for merging multiple DEMs of varied quality to produce a more accurate final DEM. A tool was developed in “Whitebox GAT” (open-source desktop GIS and remote sensing software for geospatial analysis and data visualization) to perform the DEM merge operations. These tools helped select the best DEMs and reduce the error in the DEM creation. A master’s student evaluated the impacts of DEM conditioning procedures used to ensure that DEMs function appropriately for hydrological simulations (e.g., filling depressions, breaching depressions, burning streams into DEM). Results demonstrated that the choice of conditioning technique significantly impacts watershed delineation, particularly in high-resolution DEMs such as those available in LiDAR.

Greenhouse and nursery operations



Researchers: Mike Dixon and Thomas Graham

Problem Addressed

Runoff from greenhouse and nursery irrigation contains nutrients and other biological and chemical contaminants that could be detrimental to the receiving ecosystems. Reducing the amount of water applied — and capturing and reusing the runoff — would help decrease this burden and could reduce production costs. Greenhouse producers are reluctant to reuse irrigation water as it is a potential source of pathogens and other contaminants that can negatively impact production. In nursery production, water availability and quality are becoming significant challenges that threaten to limit production and diminish product quality. Many growers err on the side of caution and irrigate to excess, in part due to the lack of automated systems attuned to the actual water needs of the crops. New and improved technologies and management practices are needed for greenhouse growers to recycle irrigation water and for nursery growers to use water resources more efficiently.

Project Findings

Profs. Mike Dixon and Thomas Graham, School of Environmental Sciences, used stem psychrometers (sensors that attach directly to the tree's water-conducting tissue) to measure plant water stress. They found that nursery water use can be reduced by 40-60 per cent without any effect on tree growth (*Pyrus calleryana* and *Thuja occidentalis*), reducing the environmental demands of nursery production and allowing for expanded production with the same baseline water allocation. Data collected from this project were used to create an irrigation schedule based on weather conditions and soil moisture, which were tracked alongside water stress.

To address barriers to reusing greenhouse irrigation runoff, the team focused on the application of advanced oxidation processes (technologies that use ozonation or electrochemistry to produce short-lived free radicals that break down resistant contaminants), expanding the options available to growers to better manage their water resources.

Green roof technologies for Northern climates

Researcher: Youbin Zheng

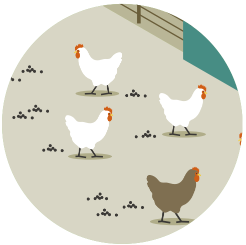
Problem Addressed

In urban areas, roofs and roads prevent rainwater from reaching the soil. The drainage and sewage systems transport the excess water away. When rainwater collects as runoff, it accumulates chemicals from urban environments, including chloride, sodium, lawn pesticides, and nutrients like nitrogen and phosphorus. This runoff eventually reaches rivers and streams, where these chemicals can harm aquatic organisms. Green roofs can serve to hold water and prevent it from accumulating as runoff, reducing harmful substances' movement into surface water. But there was little research available about formulating growing substrates and producing and maintaining plants for green roofs that can withstand Canada's colder climate. Research was needed to provide guidance for both green roof plant producers and green roof installation companies.

Project Findings

Prof. Youbin Zheng, School of Environmental Sciences, develops horticultural technologies to improve the environment, specifically through green infrastructure. Canada's colder climate means plant and substrate (the engineered soil that the plants grow on) options are limited, so Zheng's lab created an array of technologies to help this industry. Their research resulted in soil-free substrates that are lightweight and lower cost, use waste materials such as crushed bricks and are able to retain nutrients such as phosphate. They also developed a patented technology that gets green roof plants ready within 4-6 weeks, compared to the usual full year. Another patent resulting from the research is a brick system that makes the installation much easier on sloped roofs. Zheng's program was one of the first green roof research programs in Canada and remains unique today.

Converting poultry manure into value-added products using fly larvae



Researcher: Youbin Zheng

Problem Addressed

An average Ontario chicken farm produces about one ton of manure every day. Regular composting can take months to complete and, during that time, rain washes nutrients and pathogens out of the manure. That contributes to harmful runoff, especially since poultry manure is high in available nutrients like ammonium and phosphate. A fast, easy way to convert manure into usable fertilizer is needed to reduce runoff and the environmental impacts of poultry and other animal production.

Project Findings

Prof. Zheng, along with Profs. Steve Marshall and Mike Dixon, collaborated with an industry partner, EcoSpace Engineering, to build a converter that uses fly larvae to quickly (about a week) convert chicken manure into a usable, stable form. The research identified BMPs related to ideal depth, moisture and number of fly eggs to optimize device operation. The final products are a non-synthetic fertilizer and animal feed made using the larvae. Zheng hopes to use fly-converted manure as organic fertilizer to supply nutrients in the urban green industry, including green roof applications.

Adoption of nutrient management and land use BMPs

Researcher: John FitzGibbon

Problem Addressed

The Environmental Farm Plan (EFP) is a voluntary assessment that farmers conduct on their farm. They attend a workshop, develop a plan based on identified environmental strengths and weaknesses on their farm, submit a plan for review by the workshop leader, and have an opportunity to receive funding in a cost-share program to improve their farm's sustainability. Funding is available in 23 areas, including fertilizer storage and handling, water efficiency and field crop management. To continually improve the program and attract more participants, it is necessary to understand farmers' motivation for participating or not. Identifying these factors will help program developers tailor programs to increase farmer participation.

Project Findings

Prof. John FitzGibbon, School of Environmental Sciences, interviewed Ontario farmers to understand their motivations for participating in the Environmental Farm Plan. The interviews showed that level of participation reflected a farmer's specific values — environmental stewardship, training and education, financial incentives, time, confidentiality, etc. Those who completed the program multiple times were primarily from family farms, and the EFP's workbook was useful for making decision about major investments. Those who attended once, but stopped after funding reductions, still adopted practices that improved production and/or modified some of their existing practices. Those who never participated did not understand the program and its privacy policies, did not want government involvement or wanted more assurance they would receive incentive money. Approximately 70 per cent of the non-participating population were age 65 or older and felt they had little to gain from major investments. Lack of funds and communication were seen as major drawbacks to participation in the EFP.

Research at a glance

The economics of cover crops

In her most recent project, Prof. Laura Van Eerd examined the benefits of cover crops to crop yield and collaborated with economics Prof. Richard Vyn. Yields and profit margins on four-year rotations of sweet corn, wheat, tomatoes and field corn with cover crops (oat, cereal rye, radish and a mix of radish and rye) provided a 5.9-per-cent increase in yields and a 6.6-per-cent increase in profit margins (adding an extra $104/acre with cover crops).

Over a decade of cover crop plantings, 121 of the 122 trials resulted in equal or better crop yield. While cover crops do not guarantee a yield boost, the added benefits of retaining nutrients in the field highlight the overall advantages of their use.

From the lab to Mars

U of G's Controlled Environment Systems Research Facility, directed by Prof. Mike Dixon, works on nutrient recycling and growing food for long-duration human space missions.

Resources are limited off-Earth, so the lab employs bio-regenerative life-support technologies (i.e., plants and supporting biological systems that recycle resources) that will allow people to work and live in space and on other planetary surfaces. The "recycling" and crop production challenges of space drive the development of new greenhouse and nursery production technologies on Earth.

The Ontario Agri-Food Innovation Alliance funding has helped drive these terrestrial developments, which are improving the sustainability of the greenhouse and nursery industry sectors.

Acknowledgments

Many thanks to all of the researchers who took part in this project for taking the time to tell the stories of their research and to create a large-scale picture of the work being done to support environmental sustainability in Ontario.

Thanks as well to Darryl Finnigan, Elin Gwyn and Rajib Hazarika from OMAFRA for their invaluable help in shaping the goals, structure and findings of the project.

The research in this document was supported by the Ontario Agri-Food Innovation Alliance.

uoguelph.ca/research
Published by the
Office of Research
(Agri-Food Partnership)

Compiled by Cole Heasley
and Shannon Brown

Editorial Coordination:
Shannon Brown
and Rebecca Moore

Electronic version available
in PDF format at
uoguelph.ca/alliance

UNIVERSITY of GUELPH

IMPROVE LIFE.

Ontario