Vermont Envirothon – 2019 Current Issue

Agriculture and the Environment: Knowledge and Technology to Feed the World

Welcome to the 2019 VT Envirothon Current Issue, ***Agriculture and the Environment: Knowledge and Technology to Feed the World.*** While exploring this year's topic, you will learn about many of the connections between agriculture and the environment and how innovative technologies are being implemented to make the quality and quantity of our food safer while maintaining or improving the environment. You'll dig a bit deeper into what's happening in your local area to find out if some existing technology could be implemented nearby or if new technology could be created. We all want to enable farmers to work in ways that are more sustainable -- for them, for us and for the natural resources we all depend on. Maybe you'll dream up the next technological advance to make farmers' lives easier and all our lives better!

I. Introduction and Challenge

We've got a problem: The planet has a growing population but a finite set of natural resources. Add to that an increasingly erratic climate. The outlook for sustaining human populations while maintaining a healthy, resilient ecosystem is a bit unnerving. Farmers are trying to make sure we have enough food and that it's safe and nutritious. Meanwhile, we are expecting them to produce it with less impact on the environment. Seems like a daunting situation.

Many people are pinning their hopes on technology – current and future – to help solve these issues. Farmers have long used new ideas to develop practices and tools to make their task easier, whether it was the John Deere steel plow that helped mid-western farms turn over prairie soils in the mid-1800's or the milking parlor nearly a century later. Many technological advances have occurred in the past century, and in the past decade alone, there have been huge changes in equipment, technique, systems and thinking. Modern technology is being applied widely to agriculture, food safety and natural resources, as well as on how they impact each other. Technology is being utilized in ways not dreamed of only a few years ago. A word of caution, however. First of all, technology isn't always the best or only solution; sometimes returning to past practices could be the answer. And sometimes our ability to invent technology gets ahead of our scientific understanding; what seems like a solution may itself become a problem. It's important for us to think carefully about possible repercussions and side effects of new technologies *before* we utilize them rather than quickly latching onto them as silver bullets. We've implemented the use of agricultural chemicals like DDT and Alar only to later ban them. We used to advocate digging out and straightening stream channels to promote rapid drainage; now we've realized that natural debris is important

for fish habitat and winding streams help prevent flooding. In some places, farmers have attempted to maximize yield by plowing as much of a field as possible. As a result, vegetated buffers between fields and streams or roads are minimal. This frequently leads to increased soil loss and decreased water quality, wildlife habitat and wildlife corridors. One way to respond to these impacts is to look for technology to solve them; another way is to replant the buffers and make them as large as feasible. However, when "old school agriculture" just doesn't work, technological advances may help solve big problems surrounding agriculture in its relationship to a growing population and a fragile ecosystem. Just as there seems to be no end to the real and potential problems in this regard, there seems to be no end to potential solutions. What is required is thoughtful science-based knowledge, know-how, and imagination.

Just like everywhere else, Vermont's agriculture and natural resources are linked. A decrease in water quality, the loss of soil through erosion and flooding, and a decline of pollinators are among the issues that impact Vermont farmers and are impacted by them. Harmful microbial contamination of the food supply is also a big concern. Agricultural regulations have been put into place to help insure food safety and better protect the environment but these regulations also may increase a farm's operating costs. At the same time, many farmers, especially dairy farmers, are getting less money for their products. Also, farmers are having to change long-used systems and practices to cope with Vermont's changing climate: warmer temperatures, fewer but stronger rain events and late frosts.

Technological innovations have enabled farms throughout Vermont to adopt more efficient, safer, and seemingly more environmentally friendly systems. Precision agriculture is the overarching term for new methods of implementing and monitoring many different practices on farms. Precision agriculture on cropland, for example, uses equipment fitted with GPS/GIS systems. Tools equipped with these systems let farmers collect and manage a wide variety of data in the field, allowing them to understand variability throughout their farm and also within a field. This helps them make management decisions for growing the best crops at the least cost to the farm and the natural resources around it. One benefit of precision agriculture is more accurate nutrient and pesticide applications with less potential loss to the environment. Another is the ability to monitor the quality and quantity of crops from field to store.

Technology is being employed by agriculture all around Vermont. The list below mentions one type of technology being used in one area of the state although most of these uses are widespread. We hope the list will give you a sense of how extensive the use of technology is already and get you ready to explore many of the ways it's being utilized near you:

- Precision crop-management in Washington County
- Precision feed-management in Grand Isle County
- Robotic milkers in Franklin County
- Drone field assessments in Rutland County
- New sugaring technologies such as variable frequency drive, in Essex County.

- Mobile applications and software for record keeping on farms in Chittenden County.
- Methane digester in Orange County
- New rinse technology systems (for produce) in Windham County
- Modern temperature-relative humidity sensors in Orleans County

There are plenty of gaps in the technology, plenty of farms that don't have access to what's available and plenty of problems that still need tackling. That's where we hope you'll step in. Can you come up with an idea to help farmers address these challenges?

Your Challenge:

A. Classroom research:

1. Research some of the connections between agriculture and the natural resources we all depend upon: soils, aquatic systems, forest resources and wildlife.
2. Spend some time learning about food safety, food borne illness, and the federal Food Safety Modernization Act, especially the Produce Safety Rule. (More on this in the background information section.)
3. Learn about some of the impacts climate change is having on agriculture and the environment.
4. As agriculture expands and changes to feed more people at less cost, are the connections between it and the above topics strained? Are there old methods that could be used to ease the problems?
5. Find out what technologies are being employed by farmers to help mitigate some of these issues. Get a sense of the situation globally, nationally and broadly in Vermont.

   Note: Although this write-up doesn't contain any information about gene technology, Genetically Modified Organisms (GMOs), or how this technology is being applied to agriculture, your group may include that area if you want, as long as you consider it in light of protecting natural resources, food safety and/or climate change. The same is true for sugaring. While not really covered in this write-up, sugaring is considered agriculture (as well as forestry,) so if you'd like to look at sugaring as agriculture and explore the technologies being developed, please do so. Once again, you must consider it and any technologies you work on in light of protecting natural resources, food safety and/or climate change.

B. Personal Interview(s):

Interview one or more people in your area who are involved in agriculture, an agricultural business, an agricultural related technology or someone from an agency with knowledge of what's happening in agriculture in your area. The focus of your research can be narrow (one farm) or broad (a couple of farms or your community.) You can limit it to one of the three key areas (natural resources, food safety, and climate change) or you can include more than one idea/area.

1. What are the major natural resource concerns for farmers in your area?
2. Are there farms nearby who have to follow new practices due to the Food Safety Modernization Act Produce Safety Rule?

3. How is the changing climate affecting farmers locally? What are they doing to deal with it?
4. What kinds of agricultural technologies are being used locally to assist farmers?
5. What are the local technology gaps – either existing technology that isn't being used or places where a new technology would help?
6. What resources are available for farms when trying to incorporate new technologies into their current management?
7. Are there non-technological methods that might help?

C. Based on these conversations and your classroom research:

1. What local farm issues seem like they could have a technological fix but don't at the moment? Is the gap because the technology doesn't exist, or because it does exist but hasn't yet made it to your area or "your" farm? If it already exists elsewhere, what's delaying its use here? Is there technology that was created for another purpose that could be applied? How would the technology help farmers address the natural resources, climate, or food safety issue you identified above? What are the pros and cons of using it? Think about these seriously.
2. If no technology currently solves the problem you identified, can you imagine what such technology might do and look like?
3. Can you take your ideas further?

On the day of the Envirothon…

On the day of the Envirothon, your team will have 20 minutes in front of a panel of judges. 15 minutes is for you to present your work and the last five minutes are to answer questions from the panel. Everyone on your team should help present your work and be able to answer questions. Although you can't use any electronics during the main part of your talk, *because of this year's topic, <u>if you want to</u>, you may use electronics for the last few minutes of your presentation*, before the questions. That way, you can use technology to show the judges what technology you are researching or inventing. (You will have to set this all up before you start your presentation so you can go seamlessly into it from the main part of your talk.) (At a later date, we'll tell you what equipment we will have on hand and what you'll need to bring yourself.) As in the past, you may use electronics at school to prepare a map and/or any other displays. A month or two before the Envirothon, your team will receive a copy of the rubric the judges will use to assess your work. This will help you fine-tune your efforts – but don't wait for it to get started!

Your presentation should include:

A. Information from your research on the impact of today's agriculture on the four Envirothon natural resource areas: soils, aquatic systems, forest resources and wildlife as well as your research on the Food Safety Modernization Act Produce Safety Rule and risks to our food supply. Also include information on the impact a changing climate is having on agriculture.

B. Information from the conversation(s) you had with people involved in local agriculture, agricultural business or agriculture-related technology. Did you talk in person or interview them by phone?
    1. What are the natural resource, climate and/or food safety issues that farmers in your area are most concerned about?
    2. How are farmers in your area employing technology to help them in their work, especially in regards to these issues?
    3. What resources are available to farmers to assist in getting and using agricultural technologies?
    4. What *existing technologies* would they like to employ but haven't yet? What's keeping them from doing so? What resources are available to them to help them take that next step?
    5. What *technologies are missing*? What would they like someone to invent to help them do their work?

C. Your ideas to help solve some of these problems.
    1. Are there old methods you think could be used rather than relying on a technological fix? If not, what types of technology would you design or bring to a local farm? You can limit your focus to one of the three areas (natural resources, climate change and food safety) or you can include more than one idea/area.
    2. What natural resources would be improved or protected with these technologies or how would our food supply be safer?
    3. What are the pros and cons of using these technologies?
    4. Have you taken your ideas further? If so, present what you've done so far.

D. A visual aid – The type of visual aid you use will really depend on the direction your research takes.
- If you decide to create some new technology, provide a sketch/design plan or a prototype of your invention.
- If you are not creating a new technology, and you interviewed a farmer, make a map that shows that farm in relation to your community and to the issue you focused on. Indicate how/where a technological innovation is helping or would help to address that issue. For example, if the issue is water quality, show the farm in relation to nearby wetlands, streams, ponds etc. If you've focused on pollinators, include the areas of good pollinator habitat that do exist or would exist.
- If you have talked with someone about agricultural technology in your broader community, rather than on one farm, your map should show multiple farm locations and what is happening on them.

There is a lot of leeway as to what your visual aid is so if you have questions about what you should produce, ask at Training Day or before.

II. Background

The following three sections describe in more depth the three areas of exploration for this Envirothon: natural resources, climate change and food safety. All are considered in relationship to Vermont agriculture and some of the problems farmers face. Following the descriptions are some examples of technology being used to solve or mitigate some of these problems. Remember that the science and our knowledge continue to change. There are pros, cons and many unknowns to using every technological solution. There are many other issues and unfulfilled needs – that's where we hope you will step in and step up. We're counting on you!

A. Major natural resource issues

Vermont's agricultural community faces many natural resource issues. This section focuses on managing cropland and farmsteads to protect soils, nearby waters and pollinators and the technological innovations that are already helping farmers to do so. Two types of systems you'll hear a lot about in the course of your research are Global Positioning Systems (GPS) and Geographic Information Systems (GIS). Very briefly, GPS is a satellite-based navigation system developed by the Department of Defense. It uses satellites to find and track the positions of GPS receivers, one of which is in your cellphone. GPS is what allows you to use your phone for getting directions and finding nearby businesses etc. It has many, many other uses, many applicable to agriculture. GIS is a way to visualize and analyze geographic data from maps. It's like looking at an area through layers of maps. You might have a road map superimposed on a topographic map and then another layer that shows the vegetation and another with soils. You can add layers with natural and/or human features; you can use GIS on a small scale or a large scale. Like GPS, the uses of GIS are vast. You'll want to learn more about them on-line or by talking with experts.

Although this year's Current Issue focuses on technology, it's worth remembering that non-technological methods can also help farmers. For example, reducing field size and increasing forested land can improve water quality, wildlife habitat, soil health and resiliency. The importance of forested buffers should not be overlooked. However, smaller fields may not be cost-effective in today's agriculture so in addition to advocating for larger buffers, people are looking for other ways to mitigate or prevent some of these natural resource issues.

1. Water Quality

a. Background

Clean water is crucial to Vermont, its natural resources, its agriculture and our quality of life. Many factors help determine the quality of our waters; the most important is the quantity of nutrients such as phosphorus and nitrogen that get into them. Agriculture is a big contributor of these nutrients but the problem is shared by forestry, industry, municipal sewage treatment plants, parking lots, roads and even our own yards and

driveways. There is evidence that, at least in many areas, pollution is rising and water quality decreasing.

Phosphorus and nitrogen, in fertilizers and also occurring naturally in manure, bind to soil particles in our fields, lawns, forests and dirt roads. When there is run-off and erosion, some of the soil ends up in waterways releasing the nutrients it carries. In water, as on land, these nutrients spur plant growth – but we don't want extra plants/algae growing in our rivers and lakes. They decrease water clarity, change the usual composition of species, and can disrupt the habitat and health of many things, including people and our pets. Certain types of algae, like blue-green algae, produce toxins that can be dangerous to us in high concentrations. The blue-green algae blooms in numerous lakes are caused, at least in part, by phosphorus-laden runoff.

Vermont's 2015 Clean Water Act was enacted to help enhance water quality and to help meet the goals of a federal program, a "pollution budget" called Total Maximum Daily Load (TMDL). As a result, there have been revisions and updates of regulations for many sectors, including roads, wastewater treatment facilities, developed lands including paved roads, forestlands, unpaved roads, river corridors and floodplains, wetlands and agricultural lands. The regulations that impact the agricultural community are called the Required Agricultural Practices (RAPs. reducing erosion and reducing runoff of manure and fertilizer from agricultural fields and barnyards are among their aims; the RAPS will help decrease the amount of phosphorus and nitrogen entering our waterways. Many farms are already implementing Best Management Practices (BMPs) to comply with or exceed these requirements to address water quality concerns on their farms.

b. Examples of Technology and Innovations for Water Quality

Below are just a few examples of technologies and innovations farmers are using to protect and improve water quality in their watersheds. Water quality practices often have indirect benefits to a variety of natural resources, such as soil health and climate change. The technologies being utilized are expansive, but gaps do remain for our local farmers.

- Precision Nutrient Management: Many farms are adopting computer software and mobile technology to implement precision nutrient management on their crop fields. This includes flow meters on manure spreading equipment that records the volume of manure being applied, record keeping and GPS tracking software in equipment that can record and map data such as crop yields, and mobile applications that allow farmers to update crop information in real time. This software and technology can help farmers better utilize their nutrients, improving crop yields and reducing application of excess nutrients beyond crop needs which may contribute to nutrient runoff.

- Precision Manure Management: Many farmers are investing in modern manure spreading equipment, such as drag lining, subsurface injection, and highly specialized manure sensing systems, to reduce the risk of manure runoff from crop fields to surface waters. Drag lining systems apply manure directly and more uniformly to crop fields, reducing compaction from heavy equipment and allowing farms to be more precise with application rates and locations. Subsurface injection systems use shallow discs to first create an opening for manure to be injected and then close the opening after. This method applies manure directly into the soil, allowing nutrients to be more readily available to the crop and reducing manure runoff from the surface of the crop field to surface waters. A highly specialized manure sensing system has been developed and uses near infrared (NIR) sensors that are mounted on a slurry tanker to achieve precise control of manure application rates. The NIR sensors would be able to measure nutrient content of the manure as it is being field applied. Using computer technology mounted in the tractor, the manure analysis information is combined with yield, soil, and N-Sensor nitrogen management technology, and the required manure application rate can be calculated. Once the information is available the manure application system adjusts the manure slurry flow to deliver the exact quantity of nutrient required.

- Precision Feed Management: Precision feeding (PFM) is all the buzz in the dairy industry as it works to combine feed management and environmental sustainability. Farmers use forage analysis, computer systems, and technical service providers to develop and feed animals a diet that meets their nutritional requirements exactly preventing excess nutrients from being brought onto the farm. Radio control collars, precise equipment scales, and often NIR technology are used to make these precision diets for the cows!

- Phosphorus Removal Technology: In Vermont, farms and agricultural companies have started to explore phosphorus removal and remediation systems. Although phosphorus remediation technologies are not widely utilized currently, Vermont has a Phosphorus Innovation Challenge (VPIC) designed to identify and develop technologies to capture phosphorus prior to reaching our state's surface waters while also creating a business opportunity.

- Whole Farm Mass Nutrient Balances: Farmers are managing a complex ecosystem and require a diverse set of knowledge and tools to do so in an economically and environmentally sustainable way. Understanding nutrient flows onto and from the farm is a critical component to managing their farms. Farmers are starting to develop whole farm nutrient balances using computer software to allow them to track and monitor if nutrients are in excess or shortage on the farm as a whole. Managing nutrient build-up on the farm is a critical component to managing soil, water, and animal health.

2.Soil Health

a. Background

Soil health is a building block in food production around the world so improving and managing it is an important part of agricultural systems. Unhealthy soils lead to poor crop production, soil erosion, lack of biodiversity, and disease and pest problems. Unhealthy soils can also increase the need for fertilizers and pesticides. There are many practices and technologies that can help build and maintain a healthy soil on farms.

Managing and improving soil health is one of the ways farms of all sizes, from large scale corn fields to small vegetable fields, improve and protect the environment, increase crop productivity and profitability, and protect other natural resources such as air, water, and wildlife habitats. Healthy soils hold more water, decreasing the need for irrigation and increasing availability of water during droughts and reducing runoff and erosion. Healthy soils also have good infiltration systems and other physical properties as well as increased biological activity and diversity. As a result, healthy soils need fewer fertilizers and pesticides which in turn reduce the risk of nutrient loading in groundwater, rivers, lakes, and ponds. Also, fields with healthy soils often need fewer passes of a piece of equipment, reducing air emissions. Building high functioning soils can also help farmers mitigate and adapt to a changing climate.

Overall, healthy soils are an important natural resource providing benefits to farmers, ranchers, gardeners, and environmental benefits to everyone. It is important to improve and protect soil health throughout our communities.

b. Examples of Technologies and Innovations for Soil Health

Below are just a few examples of technologies being utilized to protect soil health. Soil health practices often have indirect benefits to a variety of natural resources, such as water quality and climate change. The technologies being utilized are widespread, but gaps do remain for our local farmers.

- Conservation Tillage: No Till corn planting and other conservation tillage practices are examples of innovations that are gaining popularity in Vermont to improve soil health. These practices work to improve soil health by reducing soil erosion, maintaining crop residue, and minimizing or eliminating soil disturbance to build organic matter. With no-till planting, farm equipment plants seed directly into the existing residue. Benefits include increasing soil organic matter, improving water retention, and reducing soil erosion.
- Cover Cropping: Cover cropping is another example of an agronomic practice that can benefit soil health. Cover cropping is not a new practice, but the means of establishing and managing a cover crop have evolving innovations and technologies – such as new equipment technology for establishment and

management, genetic and/or species variety, and mobile apps to calculate and plan cover crops all with the aim to improve soil health.

- Crop Management: Technology and new innovations can also help improve crop harvests. New software and mobile applications paired with soil testing can provide farmers with a full picture of their soil health, guiding management decisions such as nutrient applications and harvest dates. Some software and mobile applications can track soil type, weather, soil moisture, growing degree-days, and much more. Accessibility to this information can help guide crop management decision-making.
- Drone Technology: Some farmers in Vermont are adopting drone technology to check on the health of their crops, identify problem areas and monitor grazing cows. Drones provide farmers with an efficient way to check all their crops and assess harvest dates, crop needs, and livestock needs, which can help guide management decisions.

3. Pollinator Protection

a. Background

Pollinators, such as birds, bees, butterflies, and many other insects, are a crucial part of our environment. Many of them are also crucial to our agricultural system; about 35 percent of the world's food crops depend on animal pollinators. However, within the last decade certain types of pollinators have declined both in North America and throughout Europe. Honey bees, the most widely used managed agricultural pollinator in the United States, have declined from a high in 1947 of about 6 million colonies to about 2.5 million managed hives in 2012. There are many reasons behind the drop in these numbers, including a change in the way colonies are counted, social changes and pollinator health. Other pollinator populations have had recorded declines as well. The development of millions of acres of land that was vital wildlife habitat has contributed to negative impacts on pollinators like bees and monarch butterflies. Protecting and restoring these areas is critical to the survival of the insects that ensure our crops are pollinated. These pollinators are vital to our food supply.

The following factors, in some combination, are suspected to be influencing the decline of pollinators and what's known as Colony Collapse Disorder (CCD.)

- Pollinator pests (e.g., mites) and diseases
- Nutrition issues
- Loss of habitat (agricultural practices, urbanization)
- Management practices of beekeepers
- Pesticide exposure
- Change in methodology of counting of colonies in the US

Vermont's pollinators, honeybees as well as wild pollinators, face these same issues. Although there has been an increase in annual honeybee losses, Vermont beekeepers are trying to stay ahead of the decline by splitting up their hives and by purchasing more bees. Since pollinators and the agricultural community have a

close-knit relationship, pollinator decline is a natural resource issue on the farm. Below are two examples of how pollinators are affected by agriculture.

Habitat:
As agricultural and other land uses have changed in Vermont over the past century, so has the available nutrition and habitat for honeybees. Available habitat has declined due to urbanization of former farms, increased acreage planted in corn and harvesting pastures before flowering. This decrease is being somewhat offset by initiatives such as solar-friendly pollinator habitat, increases in farm field buffers and no-till agriculture which can protect habitat of ground burrowing pollinators.

Pesticides:
Pollinators are exposed to pesticides in a variety of ways. Sometimes, it's intentional, for instance when the hives are treated with pesticides to kill parasitic mites. More often, the exposure is unintentional and is due to the nature of pollinator activities. When pollinators forage in an area that has been treated with a pesticide, they come in contact with treated plants, soil, nectar, pollen and water. Additionally, sometimes, pesticides migrate off treated application sites in the form of application drift by dust from seed planter lubricant having direct contact with treated seed, or particles of windblown soil or run-off from fields planted with treated seeds. Also, new classes of registered pesticides pose further problems for pollinators.

Native pollinators are vital to Vermont's agricultural community, so providing healthy habitats for both managed and native pollinators should be considered wherever possible, including in agricultural conservation practices.

b. Examples of Technologies and Innovations for Pollinator Protection
Different technologies, innovations, or new ways of thinking are important for pollinator protection. Below is just one example. Continued research and monitoring in Vermont is important to help guide best practices for pollinators.

- Pollinator Habitat: Like innovations and new practices being implemented by landowners and farmers to protect water quality and soil health, farm field practices can also protect and restore important pollinator habitat. Innovative buffer designs, crop management such as no-till planting, and harvest timing are just a few examples of management shifts and strategies to protect pollinator habitat.
- Pesticide Drift: Many commercial controllers have been developed to deliver agrochemicals on a site-specific basis using GPS guided prescription maps within a field. New technology is being developed that does not use prescription maps, but relies on sensors to provide real-time sensing information which is used to dispense the agrochemical at the correct target within the field. These types of variable rate sprayers consist of ultrasonic sensors and/or "seeing eye" digital color cameras that sense or feel pests (i.e. weeds) and release chemicals in a precise manner. This reduces over application and misplacement of chemicals.

B. Climate Change Resiliency

In 2017, Vermont created the Vermont Climate Action Committee because of the observed and projected impacts of climate change. In 2018, the committee released a report containing strategies and recommendations to help build climate change resiliency throughout the state. Four main sectors identified by this Committee as contributing to climate change in Vermont are: transportation, building thermal (heating), electricity, and agriculture. Based on the Vermont Greenhouse Gas Emissions Inventory, agriculture, apart from its energy use, is responsible for about 10% of Vermont's greenhouse gas emissions (GHG). The agricultural sector was also identified as being quite vulnerable to the impacts of climate change. Therefore the Climate Action Committee suggested two strategies for the agricultural community: mitigating the amount of greenhouse gases produced on the farm and adapting to the altered weather patterns.

1. Climate Change Resiliency Through Adapting to Altered Weather Patterns
a. Background

Since our climate helps determine the types of crops, crop productivity, and agricultural economy in Vermont, changes in Vermont's climate will result in various changes throughout the agricultural community and food systems. Vermont studies and research projects of weather patterns over the last century observe more frequent, heavier rainstorms and temperature increases.

Projected impacts of climate change on the agricultural community include:

- Increased likelihood of damaging floods
- Increased soil erosion and runoff from fields
- Reduced yield and quality of cool season crops
- Wet soils leading to reduced yield or sub-optimal timing of crop management, e.g. delayed plantings due to wet fields
- Increased need for irrigation
- Increased risk of heat stress in livestock
- Increased risk of spring frost damage to fruit growers
- New opportunities and crops with extended growing seasons

As climate patterns change, farmers are starting to explore and implement new practices to adapt to the changing weather patterns. Due to fewer but more intense rain events, farmers have to think about drought as well as storm run-off and flooding. Storm run-off can mean loss of soils and also pollution of local watersheds due to the nutrients that the eroded soil carries. These farmers might shift to more grass-based agriculture and use farm agronomic practices to retain soil and improve its health. Farmers whose land is subject to flooding and inundation have another

set of problems and potential solutions. They may consider using better riparian buffers and different crops in those areas to reduce crop loss and runoff. Some farms are increasing their tile drainage systems to get rid of standing water, however when that water is moved rapidly by the drains from field to nearby waterbodies, it can increase their nutrient load. In some instances, tile drainage may solve one problem but lead to another. Drought is also now an issue, especially in certain parts of Vermont and especially on farms that rely on cool season perennial forages, an important feed source. These plants become dormant during dry and hot weather conditions. Without them, farmers are at significant risk of losing their operation. As a result, irrigation systems are being deployed more frequently, however it is difficult to "fit" standard irrigation systems into small and often remote fields. Farmers are already adapting practices to improve soil health, which can help to retain water within the soil. They may also need to consider plant varieties that can handle a July drought. Increased risk of heat stress in livestock is also a projected issue. Farmers will need to protect animals, especially pregnant and lactating livestock, from the heat. Another impact farmers may face from climate change is shorter winters. Due to shorter cold periods and a longer growing season, insect and disease pressures on crops will be higher. Types of infestations normally found in southern New England may shift to different crops or varieties in Vermont. Farmers may have to anticipate and adapt management practices for these insects and diseases. In all these situations, improving soil health is a primary means to help farmers become more resilient to changing climate.

b. Examples of Technologies and Innovations for Climate Change Resiliency through Adaptation Many strategies are being researched to allow farmers to adapt to the demands of a changing climate. UVM and UVM Extension are working with farmers to cope with these altered conditions.

- Crop Management: Like new practices being implemented to protect other natural resource issues, farm field practices can also provide climate change resiliency. Practices such as no-till cover cropping and crop rotations can improve soil health, crop health and crop resiliency to adapt to changing weather patterns.
- Irrigation systems: Pod irrigation systems are gaining in popularity and tend to be more cost effective and water efficient than standard systems.
- Crops more suited to the altered conditions: Understanding crops that can thrive in a "new" Vermont climate is an ongoing process. We must first understand how current crops will be impacted by increased precipitation and warmer temperatures. Understanding if we can adapt our practices to still grow the same crops is important. Will new varieties perform in a new climate? Will there be new pests to manage and can we do so in a realistic means that doesn't harm the environment? It is true that new crops may be a part of how farmers adapt to climate change. Will warm season grasses replace cool season grasses? Will farmers be able to grow longer season crops as the climate warms? Of significant concern is the maple industry and if these prized VT trees will be able to adapt quickly enough to overcome the pressures of a changing climate.

2. Climate Change Resiliency: Mitigating some of Agriculture's Impacts
a. Background

Most greenhouse gas emissions (GHG) from farms come from cows' belching and flatus. Many farms are researching or have already implemented practices to help reduce these and other GHGs. Farmers are experimenting with and changing feed to improve their cows' digestion. Unfortunately, wet weather makes it difficult to get the feed harvested in time so devising methods to speed up the process will be important. Optimization of milk production may also lower the GHG per gallon of milk produced. Many farms in Vermont are capturing and burning emissions of gasses from manure pits in methane digesters or even just covering manure pits. With crop management, farms can implement better manure management and soil health to reduce nitrogen emissions from soils. Carbon loss can be reduced by using cover crops (vegetated fields all the time) and by decreasing or eliminating tillage.

Overall, the agricultural community can more than offset its emissions through conservation practices. The Climate Commission recommendations show how various conservation practices improve not only climate change resiliency, but also water quality, environmental stewardship, and the viability of farming.

b. Examples of Technologies and Innovations for Climate Change Resiliency through Mitigation. Below are just a few examples.

- Milk Production: Some farms are experimenting with and implementing innovative practices to change livestock feed to improve cows' digestion. Farms are also working on practices to optimize milk production. If successful, these innovations would lower GHG emissions per gallon of milk produced.
- Methane Digesters: Many large-scale dairy farms in Vermont have installed anaerobic digester technology on their farms. Anaerobic digestion is a natural process that creates biogas. Digester technology on farms help capture methane gas from livestock manure and convert it to energy. Digesters can also reduce odor and pathogens, and separate solids that can be recycled as livestock bedding.
- Crop Management: Changes in crop management can also help build climate change resiliency through mitigation. For example, drag lining can reduce carbon emissions by reducing the amount of passes the tractor needs to make across the field.

C. Food Safety Modernization Act – Produce Safety Rule

While agricultural producers work to produce enough food for our growing population and protect our natural resources, an important component to the system is food safety. The U.S. Food and Drug Administration (FDA) Food Safety Modernization Act (FSMA) is the most comprehensive reform of our federal food safety laws in over 70 years. Its intent is to ensure a safe food supply by shifting the focus from *responding* to microbial contamination to *preventing* it.

One part of FSMA is the Produce Safety Rule (PSR.) The PSR will affect Vermont produce growers who have more than $25,000 in annual produce sales. The rule includes tiered compliance dates based on their annual produce sales. Farms with more than $500,000 in produce sales had to comply with the new rule in January of 2018; those selling $250,000 to $500,000 have to comply by Jan. 2019; smaller farms have an additional year. Based on 2012 census figures, Vermont had about 1,444 farms selling produce. Of these, about 10% would be affected by this new regulation. The Vermont Agency of Agriculture, Food & Markets (VAAFM) expects that the PSR will have an even greater impact when the data is updated.

The PSR sets new standards for growing, harvesting, packing, and holding produce to reduce the risk of microbial contamination. The standards apply to fruits and vegetables normally consumed raw, such as, but not limited to, apples, carrots, lettuce, onions, strawberries, and tomatoes. The rule does not apply to produce that is considered "rarely consumed raw", such as winter squash, eggplant, pumpkins and potatoes, or produce grown for personal consumption.

The Produce Safety Rule establishes standards for:

- Agricultural Water: Farmers must ensure that water that is intended to or is likely to contact produce or food-contact surfaces is safe and of adequate sanitary quality, with inspection and periodic testing requirements.
- Biological Soil Amendments of Animal Origin: This part of the rule hasn't been finalized yet but it will specify types of treatment, methods of application, and time intervals between application of certain soil amendments - including manure and composted manure - and crop harvest. These requirements are currently under review and are subject to change.
- Health and Hygiene: Farm personnel must follow hygienic practices, including hand washing, not working when sick, and maintaining personal cleanliness.
- Domesticated and Wild Animals: With respect to wild animals, farmers must monitor for wildlife intrusion and not harvest produce visibly contaminated with animal feces. Domesticated animals are not prohibited in the FSMA Produce Safety Rule, however, their presence should be monitored and a corrective action plan established for their presence. Again, produce visibly or likely contaminated with animal feces must not be harvested.
- Equipment, tools, and buildings: This sets requirements for equipment and tools that come into contact with produce, as well as for buildings and other facilities.
- Training: This requires training for supervisors and farm personnel who handle produce covered by the rule.

- Sprouts: This establishes separate standards for sprout production, including treatment of seed before sprouting and testing of spent irrigation water for pathogens.

Produce farms that are covered under the PSR will need to invest time, money, and resources to ensure they are in compliance with the rule. The produce industry has not had a mandatory federal rule like this before, and significant challenges are expected including, but not limited to, infrastructure and equipment, agricultural water testing, cleaning and sanitizing routines, and recordkeeping.

Produce Industry Equipment & Tools. Currently, wooden barrel washers and harvest bins are common industry tools. However, wood poses a greater risk for microbial contamination because it can be difficult to adequately clean and sanitize. The implementation of equipment and tools, such as stainless-steel washing systems that can be effectively and efficiently cleaned and sanitized, will be encouraged on farms.

Farm Recordkeeping. The PSR requires farms covered under the rule to keep records of Worker Training, Cleaning and Sanitizing practices, and Water System analysis. Meanwhile, many farms are also involved in voluntary audit programs such as Vermont Organic Farmers Certification, Good Agricultural Practices, Good Handling Practices, and the Vermont Vegetable and Berry Growers Association Community Accreditation for Produce Safety. These programs have recordkeeping requirements that often don't align with one another, nor with the requirements of the PSR. This means growers need to juggle a handful of different recordkeeping documents.

b. Examples of Technologies and Innovations for Food Safety

Below are a few examples of where technology is helping out already. These are "home-grown" solutions to local problems. Someone saw a need and figured out how to fill it. There is plenty of room for additional innovations in these applications as well as others you identify through your research.

- FarmOS, a project that aims to help with the multiple record keeping requirements. Learn more: http://blog.uvm.edu/cwcallah/produce-tracking-and-traceability/
- AZS Rinse Conveyer This is a new technology produced by UVM Extension's Agricultural Engineering team as they investigate materials to make cleaning and sanitizing equipment easier and more effective.
- The DewRight RH sensor, developed by a UVM professor, and its associated Vesta environmental control system, developed by Vermont Energy Control Systems. These help farmers with accurate temperature and relative humidity measurements. The information can help reduce spoilage while increasing yield and quality, thus saving farmers money and effort.