Cornell's Climate Smart Farming Program

Resources, Tools, and Extension Support for Farmers in the Northeastern United States

©George Shinn, 2013

Case study

The present case study explores a new research and extension outreach program that is providing resources, training, and decision support tools for farmers in the NE USA. The program is built on trusted, two-way feedback between researchers, extension staff, and farmers.

GACSA
GLOBAL ALLIANCE FOR CLIMATE-SMART AGRICULTURE

Jonathan Lambert, Allison Chatrchyan, Savannah Acosta

SECTIONS

Cornell University

CSF
Cornell Climate Smart Farming

Table of Contents

1 Overview: Agricultural Context and Climate Impacts in the Northeastern United States and New York State

1.1. Agriculture and Forestry in the Northeast

The region known as the "Northeast" in the United States sits on the western shore of the North Atlantic. It is a dense and diverse region containing 20% of the US population on less than 6% of the land area, and produces, processes, and markets agricultural goods for major cities in the region such as New York, Philadelphia, Boston, Washington DC, as well as for areas across regional and international borders (Tobin et al., 2015).

Figure 1. Map of states included in the Northeast U.S. as defined by the USDA Northeast Climate Hub, with Durham, NH as the location of the Hub headquarters and other cities marked as satellite affiliates (Horton et al., 2014).

Agriculture and forests are the dominant land uses in the Northeast, especially in the more northern and inland parts of the region (Tobin et al., 2015). Unlike other agricultural regions of the U.S., the topography, landscape and agricultural production of the Northeast is varied, from small organic farms, to large dairy production. The sale of agricultural commodities in the region totaled $21 billion in 2014, and the value of forestry in the most productive states exceeds $19 billion per year (NASS, 2014; Shifley et al., 2012). The most important agricultural commodities in the Northeast are dairy and poultry, but production of other products such as vegetables, ornamentals and fruits, livestock, and field crops are also economically important (NASS, 2014).

1.2 Climate of the Northeastern U.S.

As a region, the Northeast's climate is diverse, however some generalizations can be made. Average annual temperatures in the region range from approximately 60°F in the south, to as cold as 35°F in more northern, land-locked areas away from the coast, and toward higher elevations. Precipitation varies throughout the region by about 20 inches a year, with the highest amounts of approximately 60 inches observed in select coastal and mountain areas. There is also strong seasonality in the region, with frequent winter storms bringing wind, cold, and frozen precipitation, and summers being warm and humid, especially farther south. Large temporal and spatial variability in weather conditions are observed in the Northeast, especially as related to extreme events such as heavy precipitation, extreme temperatures, and Atlantic storms (Horton et al., 2014).

1.3 Effects of Climate Change in the Northeast

Climate change has had a significant impact on the Northeast. Average annual temperatures in the region have risen 2.4°F within the last 120 years, with 1.5°F of this occurring in the last 30 years alone. In addition to this increase in temperature, there has been a 4.9-inch increase (approximately 10%) in average annual precipitation over the same time period (NOAA NCDC, 2017).

From 1958-2012, there has also been a 71% increase in the occurrence of heavy precipitation events in the Northeast, which is the highest observed increase in the entire United States (Figure 2) (Horton et al., 2014).

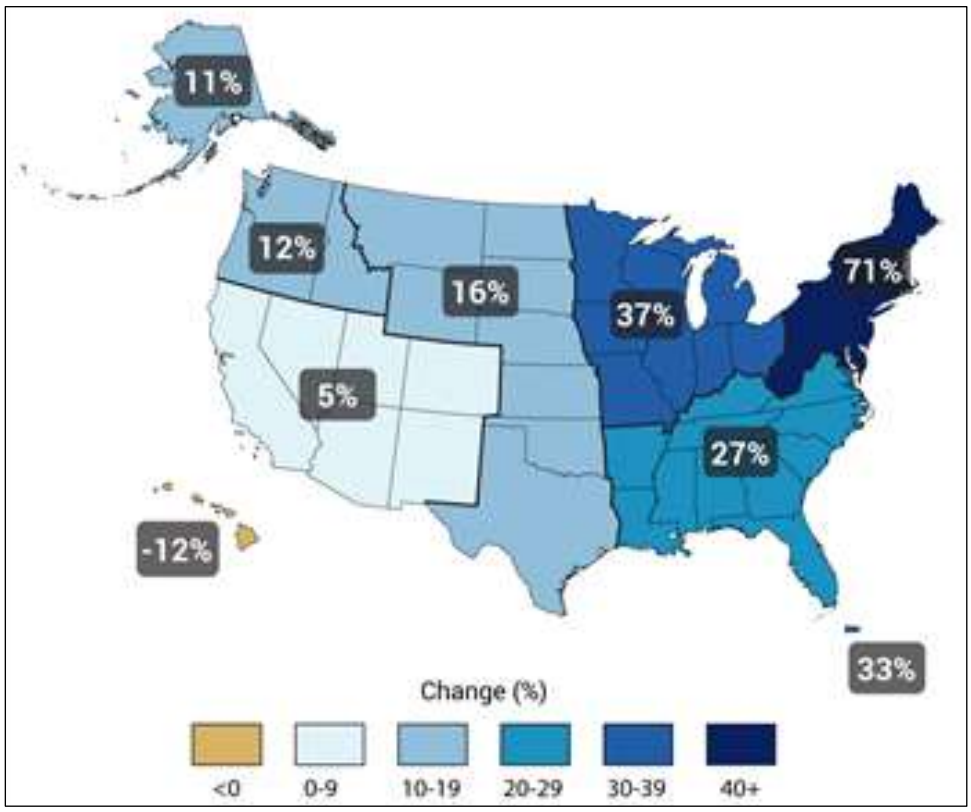

Figure 2. Observed percentage increase in heavy precipitation events (highest 1% of all daily events) by US region from 1958-2012. (Horton et al., 2014).

Native plants and agricultural crops have responded to these changes in climate with a northward shift (observable in recently updated maps of Plant Hardiness Zones from the US Department of Agriculture (USDA) as plants have been emerging, flowering, and producing fruit earlier than in the past. This is in part a product of increasing length of the growing season due to approximately 10 more frost-free days in the year (Kaplan, 2012; Horton et al., 2014). Pests, weeds, and other diseases have also responded, with new pests entering the Northeast due to warmer temperatures, as well as some species being able to sustain multiple generations in a season or overwinter when they were unable to before (Northeast IPM Center, 2017).

1.4 Agricultural Impacts of Climate Change in the Northeast

These changes have had significant effects on agriculture. Heavy precipitation floods fields and leads to erosion, soil loss and compaction, and can prevent farmers from accessing their fields at critical junctures in the season. Excessive heat causes stress to both plants and livestock, creating

dangerous and unhealthy living conditions for animals, and reducing productivity and reproductive capacity. Warmer temperatures combined with longer time periods between rainfall events contributes to short-term droughts, which can cause significant crop loss for regions like the Northeast, where irrigation is not highly prevalent (Wolfe, 2014). Additionally, an increase in freeze risk and damage is also associated with climate change due to earlier flowering and bud-break as a result of warmer winters, coupled with regular freeze events later in the spring after loss of bud hardiness. Farmers in the Northeast have experienced considerable losses to their fruit crops and grapes as a result of freeze damage after warmer winters. Pest and disease pressures are also shifting due

Figure 3. Flooded farm in Spencer, NY (Photo: A. Timm, 2015).

to more favorable summer and overwintering conditions. There is also the possibility for other impacts and feedbacks that have not already been observed as the climate continues to change. However, recent precipitation trends are expected to continue (with an increase of between 5 and 10% by 2100). Temperatures are also expected to warm by up to 8.5°F above late 20th century averages, and changes in extreme precipitation, season length, and extreme heat will follow (Tobin et al., 2015). These effects are impacting farm operation costs due to money lost from crop loss/damage, lack of productivity, higher costs of labor and inputs due to shifting seasons, and unplanned investment in repairs. Additional costs are also incurred in reacting to more extreme events. However, investments to mitigate and adapt proactively and strategically can benefit farmers in the long-run by increasing resiliency and reducing risks.

While it is important to focus on and prepare for the possible detriments to agriculture due to climate change, it is key to note that there are also agricultural opportunities that come along with adaptation and mitigation.

Longer growing seasons will allow farmers to experiment with new crop types as well as with multiple plantings of crops in a year. Additional precipitation during some parts of the year may also be used strategically. In terms of mitigation, the increasing installation of renewable energy, or more efficient nutrient management, can help farmers take advantage of cost savings for their farm. Farmers may be able to increase production in some areas or increase cost savings, but they need to understand the impacts, and adaption and mitigation practices, and have the capacity to make changes on their farms. It is essential, therefore, to provide farmers with the tools and training to help them make more climate-smart decisions.

2. Climate Change Research and Extension to Support Farmers

2.1 Climate Change Research

Cornell University is the land grant university for New York State, working toward the national land grant mission of undertaking meaningful, relevant, and applicable research in order to raise public access and education around the most pressing issues of our time.

Each state in the U.S. has a land grant university, which are supported partially by federal capacity funds, such as Hatch and Smith-Lever funds, allowing for research and extension surrounding important issues such as climate change. Cornell is one of the strongest and most well-equipped institutions in the world for climate change research, with over 150 researchers

working on some aspect of this issue, from climate modelling and agricultural/land-use responses to communications and social science research. The Climate Smart Farming (CSF) Program relies on this expertise in climate change research, and advances Cornell's land grant goal by translating climate science into useful decision tools and resources for stakeholders to utilize.

2.2 Climate Change and Agricultural Extension

A great deal of the information that farmers use in order to inform best management practices (BMPs) in agriculture and address climate change comes from the U.S. Cooperative Extension System, with programs that exist in every state in the U.S. that are connected to the land grant universities. The goal of Cooperative Extension is to "provide research-based information and tools to individuals, to help them improve their lives and communities" (USDA NIFA, 2016). Cooperative Extension has been recognized as a trusted resource for disseminating valuable agricultural information and research to farming communities. Trained Cooperative Extension educators can provide farmers with information to improve their understanding of climate change impacts on farms, ultimately leading to behavior change.

2.3 Farmers' Views and Decisions on Climate Change in the U.S.

As opposed to many other countries where the science of climate change is well accepted, many farmers in the United States, like the general public, remain skeptical of the science of climate change, and fearful of the impacts of regulations or costs of adaptation and mitigation. In order to best determine strategies for outreach, education, and climate change action in agricultural communities, it is necessary to understand the views and perceptions of farmers when it comes to the changing climate. Researchers from Cornell University in Ithaca, NY and Pennsylvania State University conducted a comprehensive literature review focusing on the studies that have been conducted on U.S. agricultural stakeholder views and actions toward climate change from 1997 to 2015 (Chatrchyan et al., 2017). The review finds that:

- U.S. farmers have noticed changes in weather patterns and an increase in extreme weather, but many remain skeptical about climate change and its long-term risks.
- While climate change belief varies among farmers by region of the United States, the majority of U.S. farmers do believe the climate is changing. However, far fewer farmers believe that climate change is human-caused than those who believe it is naturally occurring.
- Farmers more widely accept adaptation than mitigation measures, and farmers are more likely to adopt adaptation practices if they have personally experienced an extreme weather event on their farm.
- Farmers' likelihood of supporting mitigation practices seems to be related to factors such as belief in human causation, concern for negative impacts, and the presence of economic incentives.

With a clearer understanding of farmers' belief and willingness to act on climate change in a region, agencies, researchers, and extension services can design more effective programs to educate farmers and encourage them to change their behaviors and practices to support on-farm climate change mitigation and adaptation.

2.4 Supporting Changes in Farmers' Attitudes & Practices

At their core, Cooperative Extension programs are based on theories of reasoned action and planned behavior, such as those developed by Fishbein and Azjen (2011). They argue that an individual's willingness to adopt new behaviors (such as climate change mitigation and adaption) will be largely determined by their beliefs, attitudes, and intentions. The goal of Cooperative Extension outreach therefore is often to provide stakeholders with research-based information and support to help them change their behaviors to better their farms, environment, and communities.

However, because of the polarization around the issue of climate change in the United States, there is a great deal of misinformation and uncertainty surrounding the issue.

Therefore, climate change education and outreach requires strategic communication and framing of messages for youth and adult audiences. Specifically, due to the political polarization of the issue between major political parties, providing stakeholders with more scientific facts, or trying to simply change their beliefs, may not significantly alter behavior (Leiserowitz et al., 2009; Kahan, 2015). Therefore, initiatives such as the Cornell CSF Program and the USDA Climate Hubs are working to develop specific research-based resources and decision-support tools to help farmers address the particular climate impacts they are experiencing, rather than trying to change their general climate change beliefs per se.

3. Cornell's Climate Smart Farming Program Goals

3.1 Program Formation and Goals

In response to the increasing climate pressures in the Northeast and the necessity for strategic interactions with farmers in the face of climate change, the Cornell Climate Smart Farming (CSF) Program was established by the Cornell Institute for Climate Smart Solutions (CICSS) in 2015. The Program is specifically designed with profitability, mitigation, and adaption in mind to help farmers in New York and the Northeast: (1) sustainably increase agricultural productivity, (2) reduce greenhouse gas emissions and increase energy efficiency, and (3) build resilience to extreme weather and climate change/variability through best mitigation and adaptation practices.

Figure 4. Example of a typical small NE Farm: Common Thread Farm in Madison, NY (Photo: A. Chatrchyan, 2014).

These pillars of the CSF Program mirror those of the Food and Agriculture Organization's (FAO) Climate-Smart Agriculture program (FAO, 2013). Support from the CSF program is aimed at helping farmers accomplish the following through research and extension support, decision tools, and useful resources:

- Identifying on-farm vulnerabilities to extreme weather and variability; inventory energy use and greenhouse gas (GHG) emissions on the farm; set goals and plan for adaptation and mitigation changes
- Increasing on-farm adaptation through BMPs, including cropping systems, IPM, land-use planning, and water resource management
- Upgrading infrastructure such as cooling, irrigation, drainage, and waste management systems for increased resiliency
- Increasing farm energy efficiency and installing renewable energy systems on the farm, which can contribute to cost savings
- Adopting BMPs to reduce GHG emissions and sequester carbon through Cornell-recommended practices (e.g. soil health, cover crops, low-till practices)
- Improving on-farm recycling, solid waste disposal, nutrient management practices
- Utilizing new climate-smart agricultural decision support tools with Cornell University
- Supporting local food and climate-smart initiatives in the surrounding community
- Informing and inspiring other farmers to be leaders and innovators through peer-to-peer information exchange and recognition

3.2 Stakeholder-Driven Research and Extension

Cornell's CSF Program is rooted in the stakeholder-driven research and extension approach detailed in Figure 5. Research and information from Cornell's College of Agriculture and Life Sciences and other institutions and organizations is used to inform useful and usable decision support tools, which the CSF Extension team trains and educates farmers and communities on and receives feedback to improve the CSF program and associated tools, resources, and BMPs. The continued proliferation of this approach, as well as monitoring and evaluation to assess effectiveness, is necessary in order to sustainably grow the CSF program.

3.3 Partnerships and Collaboration

With a growing focus on the impacts of climate change on agriculture among private industry, government organizations, and NGOs, partnerships and collaboration will be paramount in order to successfully and efficiently drive the field and the Program forward. A particular emphasis of the CSF Program's partners is placed on the sustainability of decision support tools through funding and creation of repositories for shared data.

In establishing the CSF Program, CICSS strove to facilitate an interdisciplinary focus through strategic collaborations with the Northeast Regional Climate Center (NRCC)[1], the USDA Northeast Climate Hub[2], and other organizations such as NEWA[3] (Network for Environment and Weather Applications), Cornell Cooperative Extension[4] (CCE), and additional state and federal agencies. The USDA Northeast Climate Hub has been a particularly instrumental partner for the Program, especially with dissemination of tools and resources, as well as in evaluation, feedback, and research to support the mission of healthy and resilient agricultural and natural resource production in the face of climate variability and change. The Northeast Hub is one of seven Climate

[1] http://www.nrcc.cornell.edu/
[2] https://www.climatehubs.oce.usda.gov/northeast
[3] http://newa.cornell.edu/
[4] http://cce.cornell.edu/

Hubs and three Sub-hubs throughout the United States hosted by the Forest Service and Agricultural Research Service.

With their focus on decision tools, the NRCC and NEWA have also been valued partners, and their role is discussed further in the following section.

CICSS also focuses on regularly interacting with Canadian researchers and agricultural specialists in order to bridge the border gap in these two areas of the world that will be similarly impacted by climate change.

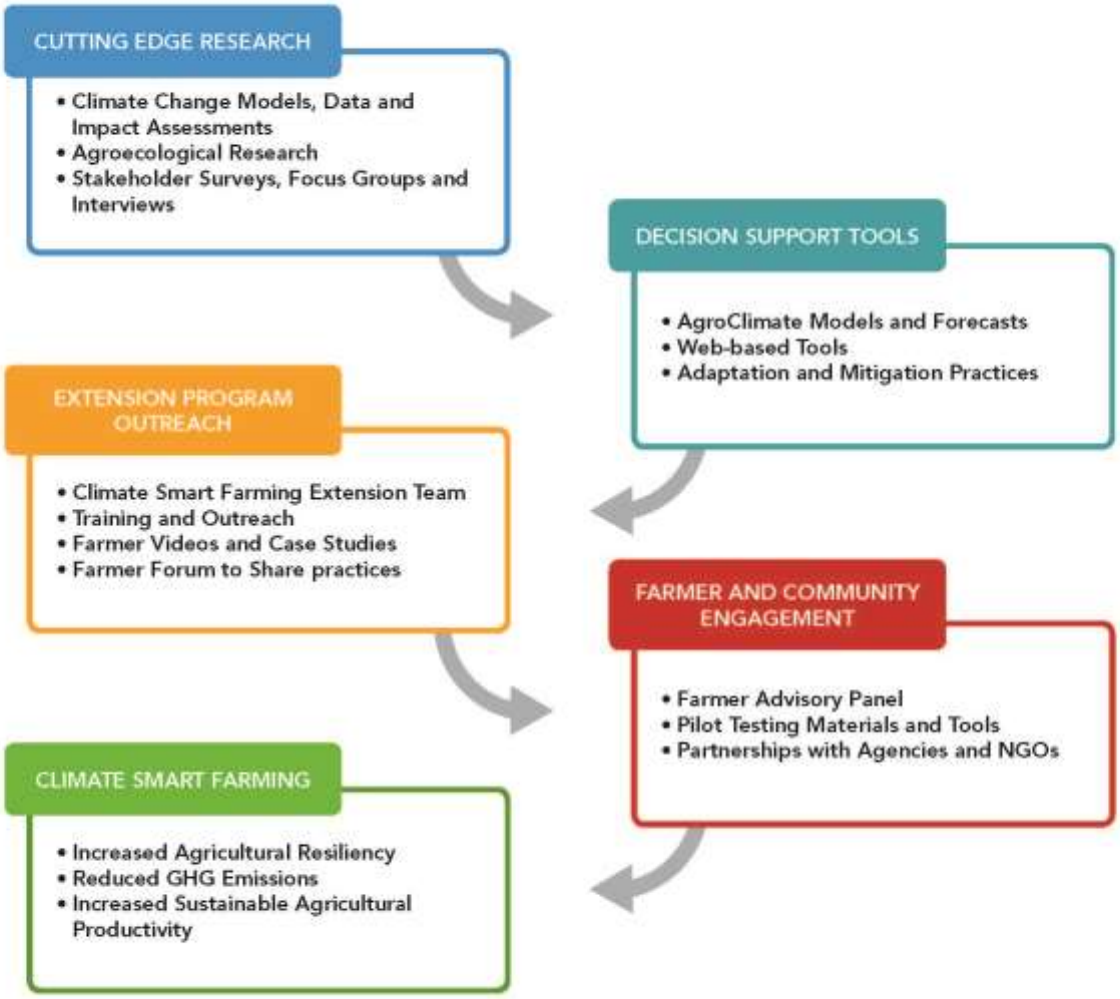

Figure 5. The Cornell CSF Team's Stakeholder-Driven Research Approach Flow Chart (Cornell CSF Program).

4. Cornell CSF Website, Tools, and Extension Team

4.1 The CSF Website

The Cornell CSF website[5] is the focal point for the Program's decision tools, resources, BMPs, and other CSF-specific information. The website features background Northeast-specific climate information, and is separated into individual sections focused on: decision tools, resources and BMPs, the CSF Extension Team, the online farmer forum, and various multimedia. Development of the CSF website and online decision-support tools, which are a key part of the Program, were made possible largely due to the partnership with the NRCC, which provided programming support for the tools as well as the high-resolution data backbone through the Applied Climate Information System (ACIS), which is maintained by all of the NOAA-administered regional climate centers (RCCs) throughout the county. The RCCs also play a key role in similar decision-tool based groups throughout other regions in the United States, such as AgroClimate[6] in the Southeast, Useful to Useable[7] in the Midwest, and NEWA in the Northeast. The CSF Program's tools can also be used in combination with the NEWA pest management tools in the Northeast in order to build a perspective of on-farm management decisions from the weather/climate view, as well as the biotic view.

4.2 CSF Decision Tools

The CSF tools are online resources aimed at helping farmers make more informed decisions in the face of climate variability and change. They are built by combining weather and climate data with agricultural models to provide accurate, daily-updated, and location-specific short-term outlooks that are useful for farm management and planning. Any farmer in the Northeastern U.S. can use the tools free of charge, and can enter their specific farm location into the tools, which provide them with a graphical output of weather and climate information at 2.5 X 2.5-mile grid resolution via the interpolation of modeled and observed data. Specific tools were developed based on the major climate impacts to agriculture in the Northeast, and through collaboration with the NRCC. The initial CSF tools available on the site include Apple and Grape Freeze Risk Tools, a water Deficit Calculator, and a Growing Degree Day (GDD) Calculator. The tools are updated regularly based on farmer and extension feedback, and new tools such as a cover crop GDD calculator and heat stress tool are being planned for the future. These tools were developed using federal research dollars and foundation funds, and are usable by farmers throughout the Northeast. In order to give a perspective on the tools designed by the CSF Team and shown in Figure 6, the next section includes a brief discussion on each tool, including its relevance for Northeast farmers. Other third-party tools such as those from NEWA, the US Drought Monitor, NOAA Seasonal Forecasts, greenhouse gas accounting tools, renewable energy tools, etc. are also available on the site.

Apple Stage/Freeze Damage Probability Tool

With climate change, abnormally warm days are occurring earlier and more frequently in the late winter and early spring in the Northeast, causing some fruit crops to bud earlier, placing them at risk for damaging freezes. For example, apples require a certain number of chilling hours throughout the winter, which is still consistently met in the Northeast, however they are coming out of dormancy earlier upon receiving greater amounts of warmth/growing degree days in late winter/early spring. Killing freeze events have been seen relatively frequently in the past few years, placing the utility for an online tool for assessing freeze risk on both researchers' and farmers' minds, and prompting the CSF Team to build a spring freeze risk tool.

[5] http://climatesmartfarming.org/
[6] http://agroclimate.org/
[7] https://mygeohub.org/groups/u2u/tools

Figure 6. Cornell's Climate Smart Farming Decision Tools Webpage[5].

To provide a forewarning for freeze events, the Apple Stage/Freeze Damage Probability tool on the CSF website provides a graphical output of the phenological stage of three apple varieties (Red Delicious, McIntosh, and Empire) versus observed and forecasted minimum temperature, providing an estimate of lethal freeze damage at 10%, 50%, and 90% levels. The six-day forecast provided in the tool also gives farmers sufficient time to take action to prevent bud damage and crop loss. With sufficient notice, farmers can implement actions to protect their fragile apple buds, such as: covering trees with tarps, setting burning bins (smudge pots) between rows, creating temperature inversions and moving air via wind machines, misting, etc. As with all of the CSF Tools, farmer feedback is critical to the sustainability and utility of them, and is gathered through focus groups, surveys, and informally at field days and conferences. As a result of this feedback, the next update to the Apple Freeze Tool will be to have users directly input phenological stage of the apples on their farm, which should lead to greater accuracy of outlooks.

Grape Hardiness and Freeze Risk Tool

As with tree fruit such as apples and stone fruit, the economic viability of some regions of the Northeast is greatly tied to grape production, and with climate change, grape growing may become even more lucrative due to the prospect of longer growing varieties or warmer weather varieties. However, the risk of killing freezes during the depth of winter is not completely reduced with climate change. To address this risk, the CSF Team designed the Grape Hardiness and Freeze Risk Tool, which aims to capture the risk of possible freeze events for growers' specific grape varieties up to six days in advance. The Grape Tool is very similar in functionality to the Apple Freeze Tool and displays forecasts and risk by graphing hardiness temperature versus observed and forecasted minimum temperature for 3 common New York State grape varieties (Riesling, Cabernet Franc, and Concord). This lead time gives the opportunity to take preparative methods similar to those used in the apple industry to prevent crop loss. Additionally, site selection and variety selection are key to reducing grape freeze risk throughout the winter.

Water Deficit Calculator

We have noted that with the increasing effects of climate change, short-term droughts will become more frequent in the Northeast. In fact, in the summer of 2016, farmers in the region experienced the worst short-term drought in over two decades (Sweet and Wolfe, 2017). The CSF Program developed a Water Deficit Calculator that was released in the beginning stages of this 2016 drought that proved very useful for extension specialists and farmers. The tool estimates soil water content and displays probable plant stress levels to inform farmers and water managers about potentially detrimental current and forecasted (3-day) water deficits. The tool is also unique in that it is the first of the CSF tools to incorporate longer-term climate probabilities by providing a 30-day outlook based on historical water deficit data. As with all the tools, the Water Deficit Calculator will eventually incorporate downscaled climate model data to inform decisions on the decadal timescale. However, the tool is currently useful in informing decisions about frequency and duration of watering necessary to avoid plant stress. If farmers have warning of an impending dry spell or drought, they can make sure to consider if their water sources will be adequate, may consider irrigating crops when most needed, and may consider investing in highly efficient irrigation systems.

Growing Degree Day Calculator

Growing degree days (GDD) are a common metric used in agriculture to measure heat accumulation. The metric helps agricultural producers estimate when crops (or pests) may reach important developmental stages. GDD calculators are prevalent throughout many climate and agriculture organizations, but the CSF GDD calculator is unique because it incorporates climate changes into its modelling of long-term climate information and its 6-day forecast The CSF calculator displays average GDD over the current climatological normal (1980-2010), but also includes a moving 15-year average of the most recent climate

Figure 7. Adaptation to a late-winter freeze by creating a temperature inversion in the apple orchard – Fishkill Farms in Hopewell Junction, NY (Photo: K. Ross, 2016)

data, which captures the signal of climate change more accurately (Wilks and Livezey, 2013). This tool allows farmers to contextualize the current year's GDD accumulation versus these climate conditions, giving them the ability to make important decisions related to planting, harvesting, fertilizers, and pest management, based on the most accurate assessment of the current season, recent seasons, and 6-day forecast. In 2016, the tool indicated a much warmer growing season than the historical average, leading to quicker accumulation of GDD.

4.3 CSF Resources and Best Management Practices

Another goal of the CSF program is to serve as a clearinghouse for resources and information related to the pertinent aspects of climate change and agriculture in the Northeast. In order to accomplish this, a "Resources and Best Management Practices" page was created on the CSF website, which catalogs specific reports, documents, webpages, etc. from climate and agriculture-related organizations such as the USDA Northeast Climate Hub, Cooperative Extension, NOAA, NASA, and other state and regionally-based efforts. Users can sort these resources by agricultural sector, specific climate vulnerability (i.e. drought, flooding, frost risk, etc.), mitigation/adaptation resources, and resource type (webpage, video, map,

etc.). Within each resource, there are also additional links that are being organized and categorized further. These direct the user to fact sheets, online courses, decision support tools and other resources, providing copious information to educate farmers on their climate change options and allow them to adequately analyze the risks their farm may face.
Currently, one of the most important resources available in this section of the website is the USDA Adaptation Resources for Agriculture document shown in Figure 8. This workbook was specifically designed for use by farmers and other agricultural stakeholders in the Northeast and Midwest, and was released in late 2016. An online interactive version of the workbook is also available[8]. The CSF program has played a large role in promoting this workbook throughout the Northeast with the help of the USDA Climate Hubs, CCE, and an "Intro to Climate Smart Farming" course through the Cornell Small Farms Program. Tangible resources and workbooks such as these, which allow farmers to see adaptation as a major focus for farm sustainability and profitability via defined chapters, practices, and case-studies are paramount in the adoption of these practices.

4.4 CSF Extension Team

The Cornell CSF Program established the first Climate Smart Farming Extension Team in the United States. The team of four educators from across New York State are experts in dairy, field crops, vegetables, berries, and tree fruit, and are hired to devote a small percentage of their time to work on climate change issues. They work directly with farmers to answer their questions and help educate farmers on the agricultural issues and responses germane to climate change. The CSF Team helps farmers make more climate-smart decisions by using new decision-support tools, resources, and best management practices. Members of the Team are spread throughout New York State with various regional extension teams and counties, and are supported by CSF to incorporate climate change into their daily extension activities and represent CSF at events such as conferences, meetings, and field days. While the Team is currently only focused on NYS, replicas of this model could be applied to other states with strong agricultural extension systems, given funding and commitment from other land-grant institutions.

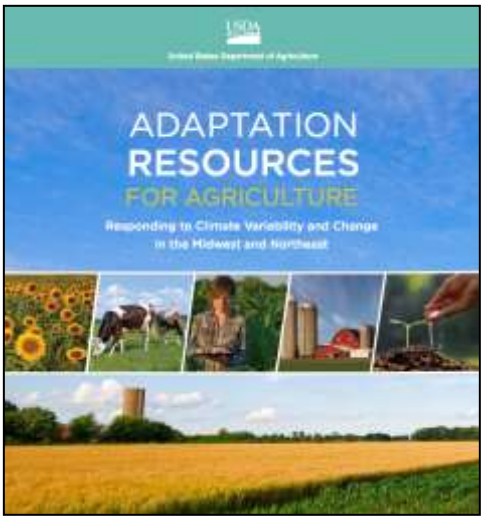

Figure 8. Front page of USDA Adaptation Resources for Agriculture Document[8].

4.5 CSF Farmer Forum and Videos

Aside from Extension, farmers place significant trust in other farmers and are eager to hear what their peers are doing to increase their bottom line or respond to difficult situations. The CSF Program facilitates this dialogue by maintaining an online "Farmer Forum" where farmers can ask questions online and have them answered by any user of the Forum (Extension, researchers, peer farmers, etc.) in any state. The CSF website also includes over a dozen facilitated farmer interview videos focusing on responses of NYS farmers to aspects of climate change such as extreme precipitation, drought, and freeze risk.

[8] https://adaptationworkbook.org/

5. Conclusions

Climate change impacts to agriculture are already being experienced by farmers in the Northeastern U.S., with an increase in average annual temperatures, an increase in extreme weather events, and changes in seasons and in pest and disease pressure. However, there are also potential opportunities for agriculture due to adequate water supplies in the region and longer growing seasons, but farmers need specific information, tools, and resources to help them adapt to, and mitigate, climate change. Despite the critical impacts of climate change to agriculture, the issue is not as high a concern to farmers as are other on-farm issues such as fear of regulation, access to labor, and profitability, with many Northeastern famers struggling to break even in the current farm economy. Most farmers in the Northeast do not have an excess of funds to invest in adaptation and mitigation measures, and greater government support of climate change research, extension programs and incentives are needed for farmers. Integrated climate-smart farming programs that can combine climate and agricultural modelling research, social science research on farmer needs, development of decision tools, and dedicated climate-smart extension programming can be effective in reaching farmer audiences. A growing focus among researchers should be on the connections between climate change impacts to agriculture and the impacts to nutrition and global food security in the face of climate change. A systems approach of mitigation, adaptation, and modelling and assessment is critical in order to increase the resiliency of the global climate-smart agriculture system.

References

Chatrchyan, A.M., Erlebacher, R.C., Chaopricha, N.T., Chan, J., Tobin, D., Allred, S.B. 2017. United States agricultural stakeholder views and decisions on climate change. WIREs Clim Chang. doi: 10.1002/wcc.

FAO. 2013. Climate-Smart Agriculture Sourcebook. Rome.

Fishbein, M., Ajzen, I. 2011. Predicting and Changing Behavior: The Reasoned Action Approach. Taylor & Francis.

Horton, R., Yohe, G., Easterling, W., Kates, R., Ruth, M., Sussman, E., Whelchel, A., Wolfe, D., Lipschultz, F. 2014: Ch.16: Northeast. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn.

Kaplan, K. 2012. USDA Unveils New Plant Hardiness Zone Map. (available at: https://www.ars.usda.gov/news-events/news/research-news/2012/usda-unveils-new-plant-hardiness-zone-map/). Accessed on 15 May 2017.

Leiserowitz, A., Maibach, E.W., Roser-Renouf, C. 2009. Climate Change in the American Mind: Americans' Climate Change Beliefs, Attitudes, Policy Preferences, and Actions (SSRN Scholarly Paper No. ID 2667029). Rochester, NY: Social Science Research Network. (available at: http://papers.ssrn.com/abstract=2667029).

Kahan, D.M. 2015. Climate-Science Communication and the Measurement Problem: Climate-Science Communication and The Measurement Problem. Political Psychology, 36, 1–43.

National Agricultural Statistics Service (NASS). 2014. 2012 Census of Agriculture. Washington DC. (available at: http://www.agcensus.usda.gov/Publications/2012/).

NOAA (National Oceanic and Atmospheric Administration) NCDC (National Climate Data Center), Climate at a Glance. 2017. (available at: https://www.ncdc.noaa.gov).

Northeast IPM Center. 2017. News and Information. (available at: http://www.northeastipm.org/about-us/signature-programs/climate-change-and-pests/).

Shifley, S.R., Aguilar, F.X., Song, N., Stewart, S.I., Nowak, D.J., Gormanson, D.D., Moser, W.K.; Wormstead, S.; Greenfield, E.J. 2012. Forests of the Northern United States. Gen. Tech. Rep. NRS-90 (pp. 202). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. (available at: https://www.nrs.fs.fed.us/pubs/40189).

Sweet, S., Wolfe, D. 2017. Anatomy of a Rare Drought: Insights from New York Farmers. CICSS Research and Policy Brief: Issue 3. (available at: https://blogs.cornell.edu/cicca/files/2015/02/CICSS-RPB-Drought-Survey-v3-126h0si.pdf).

Tobin, D., et. al. 2015. Northeast and Northern Forests Regional Climate Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies, United States Department of Agriculture, 65 pp. (available at: https://www.climatehubs.oce.usda.gov/sites/default/files/Northeast%20Regional%20Hub%20Vulnerability%20Assessment%20Final.pdf).

USDA NIFA. 2016. Extension - National Institute of Food and Agriculture. (available at: https://nifa.usda.gov/extension).

Wolfe, D. 2014. Farming Success in an Uncertain Climate. (available at: https://blogs.cornell.edu/cicca/files/2015/02/CornellClimateChange_Farming-Success-in-an-Uncertain-Climate_FINAL-2l8vftg.pdf).

Wilks D.S., Livezey R.E. 2013. Performance of Alternative "Normals" for Tracking Climate Changes, Using Homogenized and Nonhomogenized Seasonal U.S. Surface Temperatures. Journal of Applied Meteorology and Climatology 52(8): 1677–1687.

CORNELL'S CLIMATE SMART FARMING PROGRAM: RESOURCES, TOOLS, AND EXTENSION SUPPORT FOR FARMERS IN THE NORTHEASTERN UNITED STATES

The case studies are aimed to give insights on specific experiences to be possibly reproduced and scaled up to foster the adoption of climate-smart agricultural practices.
Please visit GACSA website for more information: www.fao.org/gacsa/en/

Authors
Jonathan Lambert, Program Manager at Cornell Institute for Climate Smart Solutions
Allison Chatrchyan, Director of the Cornell Institute for Climate Smart Solutions
Savannah Acosta, Research Assistant at Cornell Institute for Climate Smart Solutions

Editor
Bianca Dendena, Consultant for FAO

Funding
The Cornell CSF Program is supported by federal capacity funds from the USDA, federal contracts, and foundation funding.

Publishing date: July 2017

Cover Photo: A flooded corn field in New York State. Increased flooding is one of the most severe climate change impacts for NE farmers.

Cover photo credit: George Shinn, 2013

Acknowledgements
GACSA deeply thanks all the authors and their institution, who kindly contributed to the development of this Case Study.