The Impact of Climate Change on Agriculture: Harvard, Massachusetts

June 2019

Funded by the Massachusetts Executive Office of Energy and Environmental Affairs: Municipal Vulnerability Preparedness Program

Prepared for the Town of Harvard

Prepared by Harriman and
Daniel Cooley, Professor of Plant Pathology
at the Stockbridge School of Agriculture
at the University of Massachusetts-Amherst

Town of HARVARD Massachusetts

ACKNOWLEDGMENTS

Thank you to the Core Group members for planning and facilitating the MVP process and for attending the workshops:

- Christopher Ryan, Director of Community and Economic Development
- Liz Allard, Land Use Administrator/Conservation Agent
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- Eric Broadbent, Harvard Energy Advisory Committee (HEAC)
- Kerri Green, Agricultural Advisory Commission (AAC)
- Justin Brown, Planning Board
- Jarrett Rushmore, Planning Board

Special thanks to the members of the Harvard agricultural community who contributed their time and expertise during the workshops to make this a comprehensive document:

NAME	ORGANIZATION	FARM SIZE	COMMERCIAL / RECREATIONAL	AGRICULTURAL WORKSHOPS ATTENDED
C. Ron Ostberg				Ag1/Ag2
David Durrant	Micheldever Farm	5-29.9 acres	Commercial	Ag1
Erin McBee	Planning Board	5-29.9 acres		Ag2
Fred Honchelle		5-29.9 acres	Commercial	Ag1
George Watkins				Ag1/Ag2
Jim Burns	Conservation Commission/ Harvard Maple	0-4.9 acres	Recreational	Ag1
Joan Eliyesil	Harvard Press			Ag1
Laura McGovern	AAC/Dunroven Farm	5-29.9 acres	Commercial	Ag1
Libby Levison	Board of Health	0-4.9 acres	Recreational	Ag1/Ag2
Linda Hoffman	Old Frog Pond Farm	0-4.9 acres	Commercial	Ag2
Matthew Varrell	Harvard Alpaca Ranch	5-29.9 acres	Commercial	Ag1/Ag2
Nicky Schmidt	AAC	0-4.9 acres	Recreational	Ag1/Ag2
Pam Durrant	Micheldever Farm	0-4.9 acres		Ag1
Pam Lawson	Doe Orchards	30+ acres	Commercial	Ag1
Rene, Christiane Turnheim		5-29.9 acres	Commercial	Ag1
Rob Traver	AAC	0-4.9 acres	Recreational	Ag1
Stacia Donahue	Planning Board	0-4.9 acres		Ag1
Stephanie O'Keefe	Westward Orchard	30+ acres	Commercial	Ag1/Ag2
Tom Cotton	Harvard Cons. Trust	30+ acres		Ag1/Ag2
Vicky Lochiatto		5-29.9 acres	Commercial	Ag1
Wendy Sisson	Conservation Commission/ Land Stewardship Subcommittee			Ag1
Chris Green	Westward Orchard	30+ acres	Commercial	Ag1/Ag2

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Front Cover: Image Credit: Westward Orchards

Frank W. Carlson finds no surviving peaches on his 25-acre farm
Credit: *The Boston Globe - Jonathan Wiggs*

1 Agriculture and Climate Change: Harvard, MA

Agriculture is an integral component of Harvard's economy, character, and sense of community. Agriculture in Harvard consists of commercial farmers and hobbyists, is plant-based and animal-based, is conducted at large scales and small ones. As such, the Massachusetts Executive Office of Energy and Environmental Affairs (EEA) provided additional funding in the Municipal Vulnerability Preparedness Grant to address the impacts of climate change on agriculture in the Town of Harvard.

This report is a companion to the *Community Resilience Building Workshop Summary of Findings* (June 2019) which describes the overall planning process for the Municipal Vulnerability Preparedness (MVP) Program and provides a summary of the results from the workshops. This report will focus on agriculture: the concerns raised during the process, the data collected, and the preferred actions identified by participants in the process. Both reports will be provided to the EEA to aid in their understanding of climate-related needs and their ability to provide MVP grants to communities to address those needs.

Notwithstanding the purpose of the MVP Program, **the key takeaway from this process is that climate change is not the only pressure on agriculture in the Town of Harvard, and by extension, the Commonwealth of Massachusetts, and is not the current immediate pressure.** While the variations in both temperature and precipitation were identified as the highest hazards, farmers are well used to dealing with extremes in both. However, the cost of strategies to adapt to or mitigate the impacts of climate change on farming operations adds pressure to the limited resources, particularly financial, that farmers have.

There is no single solution to these stresses. Addressing climate change, food security, and sustainability requires a partnership among state agencies, municipalities, and the farming community, and this is critical to the success of agriculture at all scales in the Commonwealth. Harvard should form partnerships with the Commonwealth and other municipalities who rely on agriculture as part of their economies and their communities.

Discussions among members of the MVP Core Group indicated a dissatisfaction with the standard components of the MVP process as this program relates to the needs of the agricultural community. Some of this dissatisfaction also applied to the larger process. The MVP process seeks to identify community-sourced vulnerabilities and strengths, and community-sourced actions to address the vulnerabilities. However, there is little room in the process for discussing the best practices of other communities in dealing with similar vulnerabilities. The Town of Harvard was part of the second group of communities to go through the MVP process and, to the community's knowledge, the only one to date to address agriculture. As EEA continues this program, and more communities complete both the planning for and implementation of specific mitigation/adaptation actions, it would be helpful to compile and distribute a record of successful actions throughout the state. This would address the MVP Core Group's concerns about the lack of information about best practices.

This report provides information in several different formats. The remainder of this section is a summary of the planning process and the prioritized hazards and actions related to the data collected at the two workshops.

Sections 2 and 3 contain additional data about the threat of climate change to agriculture and actions to adapt to or mitigate the projected impacts. These sections, with resources, are provided by Dan Cooley, Professor of Plant Pathology at the Stockbridge School of Agriculture at the University of Massachusetts Amherst. Section 4 contains additional resources.

The Appendices supplement this information with the raw data from the pre-workshop survey, the information collected from the two workshops, and the maps, presentations, and materials completed at the two workshops.

Build-out Scenario: The Loss of Agricultural Land

As a land use, agriculture contributes to the quality of life in the Town of Harvard, including the economy, the sense of community, and the visual aesthetic. One reason for understanding the impact of climate change on agriculture is to also understand the impact to the Town if agriculture disappeared as a significant land use.

As noted in Figures 3A and 3B, over 735 acres of land in Harvard have either a conservation restriction or an agricultural preservation restriction.[1] However, not all agricultural land is protected in this way. In addition, the agricultural restriction program is voluntary. 330 CMR 22.12 provides guidance on the release of land from an agricultural restriction; this can happen at the request of the owner of the land, who must provide consideration for the release of the land. Consideration may include the placement of other land under an agricultural restriction. Release requires a two-thirds vote of both houses of the General Court of Massachusetts. If the owners of agricultural land were unable to continue their operations and decided to sell, the impact to the Town of Harvard of other land uses could change the

[1] Further details can be found here: https://www.mass.gov/service-details/agricultural-preservation-restriction-apr-program-details

Table 3-1: Harvard's Estimated Future Development Potential

	Potential New Development	Existing Development	Build-Out
Developable Land Area (sq. ft.)	278,131,911		
Residential	266,021,711	133,169,170	399,190,881
Commercial	12,110,200	3,275,152	15,385,352
Developable Land Area (acres)	6,385	3,132	9,517
Total Residential Lots	2,564	1,730	4,294
Total Residential Dwelling Units	2,564	1,911	4,475
Residents	7,333	5,230	12,563
Population <18	1,769	1,588	3,357
Comm./Ind. Buildable Floor Area (sq. ft.)	1,295,791	253,449	1,646,233
Comm./Ind. Water Use (GPD)	97,184	19,009	123,467
Residential Water Use (GPD)	549,983	392,250	942,233
Municipal Solid Waste (tons)	3,762	2,683	6,445
Non-Recycled Solid Waste (tons)	2,675	1,908	4,583
Roads (miles)	58.27	64.82	123.09

Figure 1. Harvard's Estimated Future Development Potential
Source: *Town of Harvard Master Plan (2002), page 3.8*

physical and economic character of the Town.

In 2002, The Town of Harvard completed a build-out scenario as part of their master planning process. The *Harvard, Massachusetts Master Plan*, November 2002, (the "2002 Master Plan") contains a build-out analysis that estimates the amount of development that could occur under the regulatory structure in place at that time, based on the amount of undeveloped but buildable land available. The methodology is described in Appendix E of 2002 Master Plan. Figure 1 is a table extracted from the 2002 Master Plan and shows the estimated impact of a maximum build-out under the zoning regulations in place at the time. Figure 2 is a map of the protected and potentially developable land in 2002.

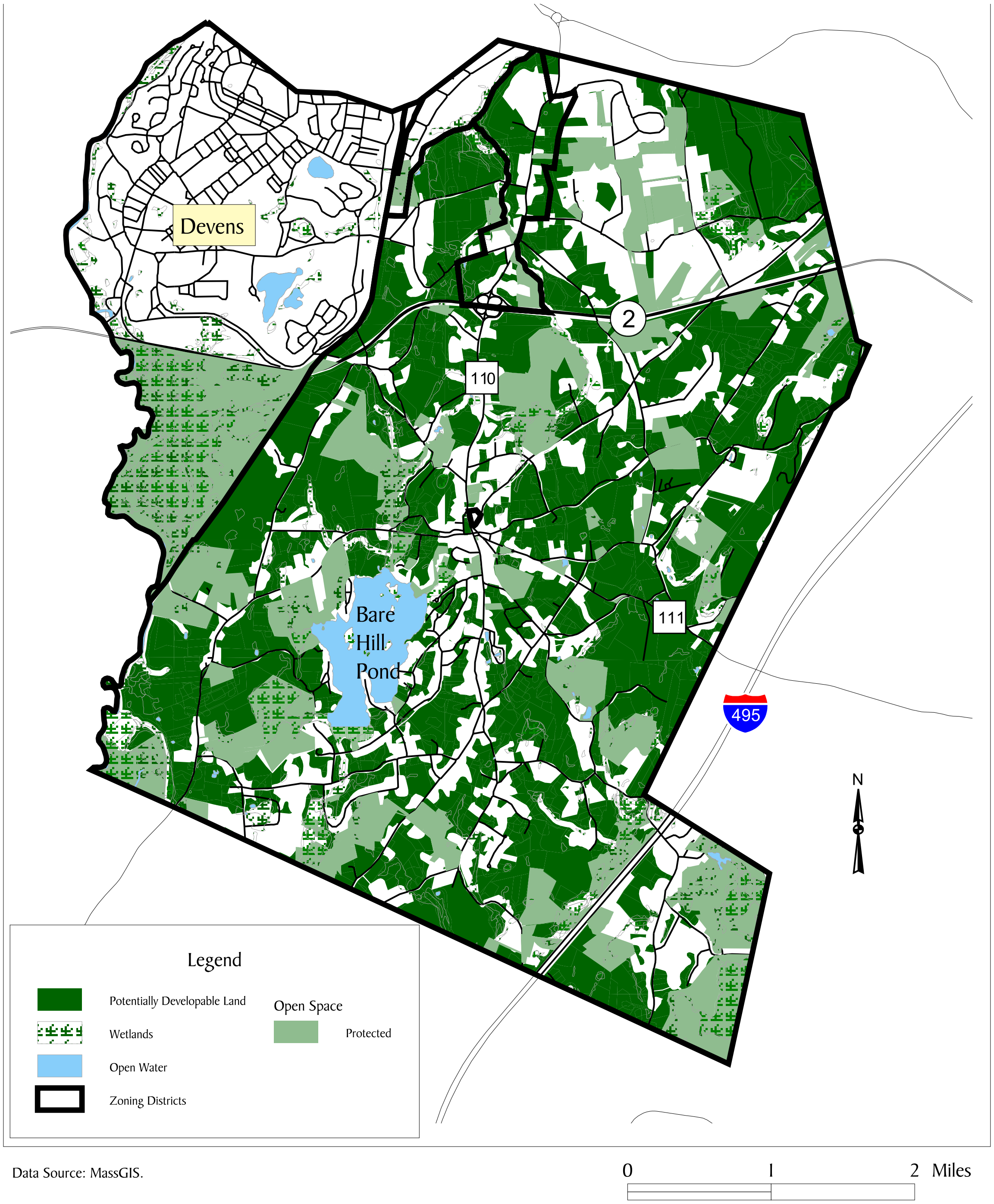


Figure 2. Map 3-A: Potentially Developable Land
Source: *Town of Harvard Master Plan (2002)*

The 2002 Master Plan estimates an additional 2,600-2,700 housing units on land that was then undeveloped.[2] The build-out analysis includes and estimate of an additional 1.1 to 1.2 million square feet of new business growth along Ayer Road.[3] The discussion notes that only half of the land commonly referred to as open space is protected. These estimates do not include an analysis of future development capacity for Devens; this information is provided in a separate chapter and could be in the range of 5-8 million square feet of industrial, office, and retail.[4]

The 2002 Master Plan also references an earlier build-out study (completed around 1999/2000) by the Montachusett Regional Planning Commission (MRPC). This study found that the Town had sufficient undeveloped land for 3,203 additional housing units and 11.8 million square feet of commercial development in the C District on Ayer Road.[5]

Since these completion of these two studies – and the 2002 Master Plan explains the different methodologies behind the differing numbers – the country and the state have gone through a significant recession, and the conversation about how development can and should be accomplished to meet community needs and goals has changed.

The methodology described in Appendix E of the 2002 Master Plan does account for wetlands, steep slopes, and the need for septic for residential lots. The lack of a municipal sewer system for Ayer Road does not seem to have been included in the calculations and may reduce the amount of commercial square footage that may be developed. The estimated housing units assume all single-family homes; both this estimate and the estimate of commercial space may be further reduced by a number of factors, including any changes to the delineation of wetland areas since 2002, land that has been put into protection since the master plan was written, modifications to zoning or other regulations, and land that has been developed after the completion of the build-out analysis.

As the Harvard community uses the two reports from this MVP planning process to launch a series of discussions, a key element of that discussion should be the land use policies that will govern future development of the approximately 6,385 acres of developable land.[6] How that land is developed has important implications for the environmental, cultural, and economic health of the community. The success of agricultural operations within Harvard will have a significant impact on the future use of agricultural land. Recommendations in this report will contribute to the discussion of how to strengthen farms; the Town should consider the impact of its current land use policies and regulations if those efforts are not fully successful.

Part I: Agricultural Survey

The first step in this process was to understand is what "agriculture" means in Harvard. The MVP Core Group worked with the consultant team (Harriman and Professor Cooley) to develop a survey designed to get a sense of which agricultural activities were happening and how climate change has already impacted or is expected to impact those activities. This questionnaire was distributed by the MVP Core Committee to those who were producing agricultural products and those interested in agriculture.

The complete data from the survey is provided in *Appendix A: Agricultural Community Survey*. Note that the respondents were self-selected; the members of the MVP Core Group attempted to reach as many people who were related to agriculture as possible, but the results of this survey should be treated

[2] Community Opportunities Group, Community Planning Solutions, and Abend Associates, *Harvard, Massachusetts Master Plan*, November 2002, page

[3] Ibid.

[4] Ibid., p. 2.49

[5] Ibid., p. 3.6

[6] Ibid., p. 3.8

as a snapshot of the community rather than a scientific survey.

Clear differences in the responses to the survey were also apparent in the workshops. Respondents differed in the scale of their operations (large/small), the type of operations (commercial /noncommercial), the structure (income-producing/hobby), whether the farms were crop-based, animal-based or a mixture, and whether the farms were organic or non-organic. These differences have implications for climate change in that the vulnerabilities to climate change, the potential mitigation or adaptation actions, the resources available to undertake those actions, and the implications for failure differ based on farm type, operations, and goal. Note that the number of respondents does not equal the number of farms; a few farms may have had more than one respondent.

The following is a summary of the results:

Farm Size

- **The majority of respondents did not have sufficient acreage to qualify for the tax benefits under Chapter 61A of the Massachusetts General Laws.** 38.57% of the respondents had farms of less than one acre (twenty-seven respondents). 20% had farms of ten to just under thirty acres (Fourteen respondents) and 11.43% had thirty acres or more (Eight respondents).

Members of the MVP Core group noted that the survey was not representative of the commercial agricultural operations and the list of Chapter 61A land would be a better representation of agricultural land in Harvard. The *Town of Harvard Open Space and Recreation Plan* (2016) identifies the land then under Conservation Restrictions (CR) and Agricultural Preservation Restrictions (APR). (See Figures 3A and 3B.) Land under either a CR or an APR may be used for agricultural activities.

Agricultural Production

- **The main focus of farming in Harvard is fruit and vegetable production, primarily orchards.** Thirty-one respondents produced tree fruits, including one with a farm over thirty acres and one with a farm over fifty acres. Forty respondents produce berry crops, but no respondents had more than five acres devoted to berries. Other crops included grapes (fourteen respondents) and cool-weather crops (thirty respondents).
- **Smaller farms were more likely to have livestock**: No respondents with farms thirty acres and more reported acreage devoted to livestock. Livestock included poultry and eggs (fifteen respondents); apiculture (ten respondents); horses, ponies and mules (ten respondents); sheep and goats (five respondents); hogs and pigs (one respondent); and cattle and calves (one respondent).
- **Other than hay, field crops are not significant within the Town.** One respondent over thirty acres reported producing hay. Under thirty acres, eighteen respondents reported producing hay; six respondents reported producing corn; four respondents produced grains, oilseeds, dry beans, and dry peas; and one respondent produced wheat.
- **Forest-related products are mostly focused on firewood** (thirty-three respondents). Maple syrup (ten respondents all under three acres), lumber (six respondents), and Christmas trees (two respondents each under one acre) were not significant.
- **Hydroponics and Aquaponics have little presence in Harvard.** Aquaponics had only two respondents, both with farms under one acre; hydroponics had one respondent, also under one acre.

Conservation Restriction and Agricultural Preservation Restriction Land
Conservation Restrictions (CR) are deed restrictions that provide perpetual protection of privately owned open space. They are intended to keep the land in a natural, open, or scenic condition or in farming or forestry. Agricultural Preservation Restrictions (APR) occur when the development rights to a property are bought by a government agency or private, non-profit organization with the purpose of keeping the land in agriculture in perpetuity.

Owner	Location	Acres	Use	Restriction Held By	Public Access
Barrett	Littleton County Road	20.86	CR	HCT	Limited
Bilodeau	Murray Lane	6.60	CR	Town	None
Bilodeau	Murray Lane	16.88	CR	HCT	None
Camel Needle Eye Corp.	Ayer Road	31.3	APR	Town	Limited
Carlson Orchards	Old Littleton Road	12.77	APR	Town	Limited
Carlson Orchards	Old Littleton Road	17.56	APR	Town	Limited
Carlson Orchards	Oak Hill Road	18.90	APR	Town	Limited
Carlson Orchards	Pinnacle Road	7.00	CR	HCT	None
Coleman	Poor Farm Road	11.90	CR	HCT	Limited
Dickason	Still River Road	10.44	CR	Town	None
Dean's Hill	Depot Road	32.00	CR	HCT	Trails
Deer Run Realty Trust	Lancaster County Road	20.91	CR	Town	Limited
Dunlap	Old Littleton Road	4.40	CR	HCT	Trails
Dunlap	Old Littleton Road	29.28	CR	HCT	Trails
Dunlap	Old Littleton Road	3.54	CR	HCT	None
Endicott	Littleton County Road	30.66	CR	HCT	None
Ernst	Murray Lane	50.00	CR	HCT	None
Ernst	Murray Lane	13.50	CR	HCT	None
Fairway Partners	Trail Ridge Way	28.00	CR	Town	Limited
Franzen	Woodside Road	7.15	CR	Town	Trails
Fuller Dudley Woods (fka Dunlap)	Old Littleton Road	10.21	CR	HCT	Trails
Guswa	Old Meadow Lane	2.49	CR	HCT	None
Hoch	Still River Road	11.41	CR	HCT	Trails
Harvard Conservation Trust	Harris Lane	13.74	CR	HCT	Trails
Harvard Conservation Trust	Slough Road	3.08	CR	Town	Trails
Harvard Conservation Trust	Slough Road	4.19	CR	Town	Trails
KWW Harvard LLC	East Bare Hill Road	10.52	CR	HCT	None
Magoun	Old Meadow Lane	1.50	CR	HCT	None
Maxant	Willard Lane	2.67	CR	Town	None
Maxant	Willard Lane	20.47	CR	HCT	None
Mayerson/Shulman	Stow Road	9.05	CR	Town	Limited
Moran	Shaker Road	7.30	APR	Town	None
Moran	Shaker Road	27.70	APR	Town	None
Muller	Shaker Road	2.53	CR	HCT	None
Muller	Shaker Road	4.38	CR	HCT	None
Murphy	West Bare Hill Road	1.50	CR	HCT	None
New England Forestry	Shaker Road	24.32	CR	HCT	None
Pinnacle Hill Realty Trust	Old Meadow Lane	3.00	CR	Town	None
Saalfield	Woodchuck Hill Road	7.89	CR	Town	None

Figure 3A. Conservation/Agricultural Production Properties in Harvard
Source: *Town of Harvard Open Space and Recreation Plan (2016), page 94*

Owner	Location	Acres	Use	Restriction Held By	Public Access
Smith	Littleton County Road	12.61	CR	Littleton Conservation Trust	None
Thayer	South Shaker Road	5.50	CR	HCT	None
Town of Harvard, Smith	Oak Hill Road	2.51	CR	HCT	None
Town of Harvard, Tripp	Brown Road	44.00	CR	HCT	Trails
Town of Harvard, White Lane	White Lane	19.97	CR	Town	Trails
Westward Orchard	Oak Hill Road	34.00	APR	Town	Limited
Westward Orchard	Littleton County Road	75.32	APR	Town	Limited
TOTAL		**735.51**			

CR= Conservation Restriction
APR = Agricultural Preservation Restriction

Figure 3B. Conservation/Agricultural Production Properties in Harvard
Source: *Town of Harvard Open Space and Recreation Plan (2016), page 95*

Image Credit: Westward Orchards

Sales and Income

- **The majority of respondents do not sell their products** (thirty-seven respondents or 52.86%). However, of those that do, 35.71% (twenty-five respondents) sell direct to consumers. The remainder either sell wholesale (nine respondents), to processing (three respondents), or have other means of distribution (twelve respondents) including but not limited to trade, distribution to non-profits, and self-production of feed for livestock.
- **Unsurprisingly, the majority of respondents did not use farming to support their household income.** Only three respondents identified that all household income was from their farms; one had most of their income from their farms, twenty-eight respondents had less than half or almost none, and thirty-nine respondents had no income from their farms. Note that Chapter 61A, in addition to a size restriction, requires at least $500 in annual income in order to be eligible for tax relief.

Impacts of Success

The survey asked two questions about the success of farming: the first, a quantitative question about which items were more likely to have an impact on a farm's success and the second, a qualitative question about what the Town could do to help.

The potential impacts were rated on a scale of 1 (Most Important) to 5 (Not Important). The top five impacts that were identified as Most Important were as follows:

- Extreme and variable weather (thirty respondents)
- Land use regulations, such as zoning (twenty-two respondents)
- Local tax structure (fourteen respondents)
- Crop failure (thirteen respondents)
- Pest control (twelve respondents)

Of the topics rated as Not Important, the following five impacts received the most responses:

- Full-time labor shortages (thirty-eight respondents)
- Recruitment, retention, and retraining of seasonal employees and Insecure land tenure (tied at thirty-seven respondents each)
- Part-time labor shortages (thirty-four respondents)
- Market volatility (thirty-three respondents)

However, it is important to remember the distribution of responses; these six items are less important to the smaller, non-cash producing farmers that make up the majority of the respondents. Knowing that eight respondents have thirty acres or more of land, and twenty-six respondents have farms of ten or more acres, it is worth evaluating those items that may be of concern to larger farms.

The following additional non-climate impacts are more specific (although not exclusive) to large farms:

Table 1: Non-climate Impacts

Impact	Most Important (# of Respondents)	Important (# of Respondents)
Land use regulations, such as zoning	22	12
Labor regulations	2	6
Food safety regulations	6	6

Impact	Most Important (# of Respondents)	Important (# of Respondents)
Pesticide notification laws	9	8
Weekend weather conditions*	9	17
Market volatility	2	7
Insecure land tenures	1	5
Local tax structure	14	15
Increase operation costs	7	10
Cost of mitigation	4	14
Succession planning	3	7
Full-time labor shortages	1	3
Part-time labor shortages	2	4

*Note that poor weather on the weekend reduces direct sales to consumers.

The impacts listed in the table above are consistent with the conversations with farmers between the two workshops. Appendix A has a consolidated summary of those comments.

When asked how the Town could help farmers, the survey produced almost as many ideas as there were respondents. However, the options, which are provided in full in Appendix A, can be grouped into the following categories:

- Tax relief for farms of all sizes (the most responses). This would require both local and state changes.

Image Credit: Westward Orchards

- Regulations, including use of home kitchens vs. commercial kitchens for farm stands; not applying local site regulations to farm stands; expanding the agritourism district; ensure zoning promotes agriculture. These actions are primarily Town actions although state health restrictions might be involved.
- Minimizing pesticide use and using best practices in the application (impact on pollinators); minimizing salt use; measures to test and conserve water; air quality concerns such as idling vehicles and the impacts of snowmobile use on conservation land (which have other impacts). These actions may require policy changes by the Town and would require educational outreach to residents.
- Requested recognition for horses as a form of agriculture; requested support for commercial hemp and cannabis production. These would require policy changes by the Town.
- Increased availability of conservation land for farming and firewood harvesting. These would require policy changes by the Town or other bodies that hold conservation land in trust.

Agriculture and Climate Change

The survey asked six questions about the concerns about climate change, impacts of climate change on operations to date, and recent or anticipated changes to operations.

The top five concerns, rated from 1 (No Concern) to 4 (Highly Concerned), were as follows:

- More frequent or new pest pressures related to weather (e.g. insects, fungus, or disease) (thirty-one respondents)
- Longer dry periods or drought (twenty-three respondents)
- More frequent or new weed/invasives pressure related to weather (twenty-two respondents)
- More frequent/unpredictable seasonal temperatures (early bud break, early or late frosts) (twenty-one respondents)
- More frequent crop diseases related to weather (twenty respondents)

Again, it is possible that some of the concerns for the larger, commercial farmers (such as stress on cold storage equipment) were not picked up in this survey due to the number of non-commercial respondents.

The majority of respondents (thirty-eight or 65.52%) noted they had not made any changes because of an experience or concern about the weather challenges identified. Of those that had made changes, many can be grouped into the following broad categories:

- Field rotation and resting
- Changes in crops or varietals
- Soil and drainage improvements
- Diversification of farm activities
- Infrastructure improvements (electrical supply, wells, cisterns)

The survey also asked whether respondents planned to make any changes. Responses can be grouped in the following categories:

- Changes in crop types and varietals
- Infrastructure and equipment (greenhouse, well, aquaponics, raised beds, drip irrigation, low-impact logging equipment)

- Forestry plan to deal with invasive [species]
- More spaying from one respondent vs. need to keep pollinator-attracting plants from another
- Drainage improvements

Respondents were asked to identify changes they wanted to make but could not. Cost was an issue for some; other changes/problems included the following:

- Infrastructure (solar panels, barn with running water and electricity, irrigation, access to water)
- Equipment (update with more energy efficient models)
- Ability to take advantage of the agritourism overlay district
- Restriction on biomass energy plants reduce ability to see low quality wood
- Certain invasive are important for beekeeping (loosestrife, black locust) and should remain in controlled areas

The penultimate question asked whether respondents believe that extreme weather events had affected their long-term goals. Twenty-eight respondents responded Somewhat; nine felt there had been Moderate Impact; six felt there had been a Frequent Impact and only one felt there was an Extreme Impact. Eleven chose the response: Not at All. Of those who had seen an impact, ice storms, wind, late freezes, and increased rain were listed in the comments section.

Finally, respondents were asked if they would like to share any other information. Responses ranged from additional concerns about climate change to the need to look at non-climate change related agricultural issues within Harvard. Climate change concerns include the loss of habitat for pollinators, particularly bees, the loss of trees, and erosion. Non-climate change concerns include the need to support historic or heritage farms as a cultural resource, codify water use guidelines, support agritourism and reduce regulations.

This pre-workshop survey provided a useful snapshot of agriculture in Harvard today and a good base for the discussions in the workshops. Future research could focus on the needs of large and/or commercial growers vs. small and/or noncommercial producers. The survey also indicated some areas of disagreement, such as spraying invasives (pests and plants) against the need to protect pollinators and their preferred plants.

The survey results began the identification of actions that are individual to the farms, but may be informed by a set of best practices, and those that require collective actions, whether formal local or state interventions (regulatory, policy, and tax relief) or more informal (community discussions and education). These themes will be present during the second stage of this process.

Part II: Agricultural Workshops

Post-Survey, the MVP process began by following the standard CRB format as described in the *Community Resilience Building Workshop Summary of Findings* (May 2019) that accompanies this report. After Agricultural Workshop 1, the process took a different direction, based on the results of the workshop.

Agricultural Workshop 1 (February 2, 2019)

The Town held two workshops specific to agriculture. The first workshop followed the CRB process, introducing the MVP process and provided a general introduction to climate change. The presentation transitioned to a more specific discussion of the projected impacts on the Town of Harvard, including projections for changes in temperature and precipitation. Professor Cooley presented a summary of the survey results and the impacts of climate change on agriculture. This served to inform the second part of the workshop, which was to define the specific hazards relative to agriculture and identify strengths and vulnerabilities related to those hazards.


Agricultural Workshop 1

Participants identified several hazards, but most could be grouped into two categories:

- Variability in temperature; including extremes and variability within seasons
- Variability in precipitation, including extremes and the shift of precipitation patterns to different seasons

Afterwards, both the MVP Core Team and the consultant team agreed that the information gathered at that workshop did not easily fit the CRB categories of Infrastructural, Societal, and Environmental. Key immediate stresses on agriculture were not directly climate-related, and the ability to address climate-related impacts was interlinked with the ability to address other, more immediate, stresses.

Interviews

The consultant team conducted interviews with specific farmers between the first and second workshops to gather additional information about the needs of the farming community. The farmers who participated in the interviews were:

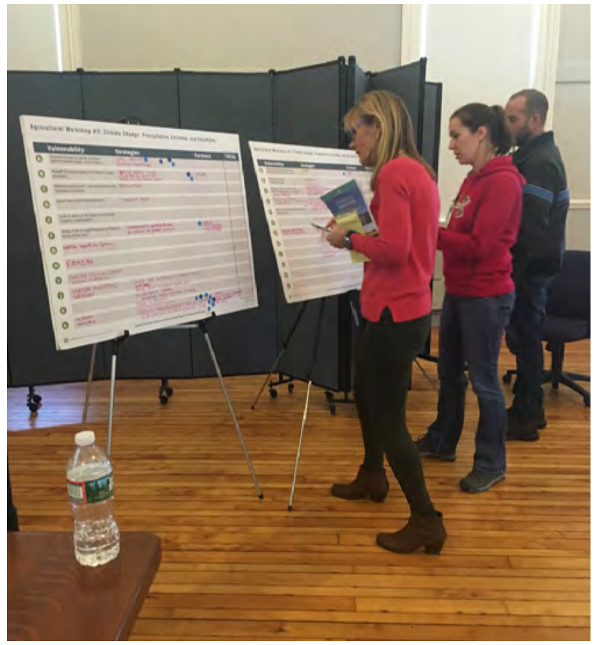
- Frank Carlson, Carlson Orchards
- Chris Green, Westward Orchards
- Linda Hoffman, Old Frog Pond Farm
- Laura McGovern, Dunroven Farm
- Paul Willard, Willard Farm

Pam Lawson of Doe Orchards was contacted, but a mutually convenient time to talk was not agreed upon prior to the second workshop.

The results of these interviews were kept confidential, but the conversations informed the structure of Agricultural Workshop 2 and the subsequent discussion of non-climate change related stresses. See Appendix A for a summary.

Agricultural Workshop 2 (March 9, 2019)

After the first workshop, the MVP Core Team and the consultant team decided that the focus of the second workshop should be on capturing both climate-related and non-climate related vulnerabilities, and identifying strategies and partnerships. The focus of the second agricultural workshop was on prioritizing strategies for climate change mitigation and adaptation. The workshop opened with a presentation by Harriman which provided overviews of the MVP process and climate change, concepts related to risk and risk management, a summary of the first agricultural workshop as well as the farmer interviews that took place afterward. There was a pause in the presentation to allow participants an opportunity to add to the list of vulnerabilities that was generated at the first workshop.



Agricultural Workshop 2

After that discussion, Professor Cooley gave a presentation on climate change mitigation and agriculture in Harvard which provided information on temperature and precipitation extremes. He discussed potential adaptation strategies and tactics to address soil health, irrigation, erosion control, temperature variability and extremes including frost and heat, growing-season length, chilling, and challenges in pest management.

Professor Cooley also provided tools, such as the Northeast Climate Hub, the UMass Center for Agriculture, Food, and the Environment, and other online and easily accessible sources of information. The consultant team distributed printed copies of *Adaption Resources For Agriculture: Responding to Climate Variability and Change in the Midwest and Northeast* to all participants in the second workshop and left additional copies with the Town for further distribution.

The discussion after the presentation began with reviewing the vulnerabilities identified at the last meeting, which had been divided into those related to climate change and those that were not, and adding those that were identified at the start of the workshop. Participants broke into two groups and switched half-way though the discussion. This allowed all participants to contribute to both discussions.

The facilitators asked them to identify strategies for each of the vulnerabilities and then identify partners who could help implement the strategies. In the climate-change discussions, the initial vulnerabilities were divided between those that were temperature-related and those that were precipitation-related.

In the non-climate change discussion, vulnerabilities were divided among regulatory, economic/market, and other.

After the matrices were filled out, each participant was given five sticker dots to place on the strategies that they felt should be given the highest priority. The following discussion questions guided participants through the activity:

- Vulnerabilities: How are you vulnerable to these pressures?
- Strategies: How could you mitigate/adapt to these pressures?
- Partners: Whose help do you need and what is that help?
- Prioritize: What are the five most important strategies to you?

At the end of the discussion, participants were given five green dots and five blue dots and asked to prioritize their top five strategies across the two discussions.

Part III: Findings from the Agricultural Workshops

The purpose of the MVP Program is for the participating town to identify the top actions that the town needs to take to address existing vulnerabilities to climate change. As noted above, a key finding of the agricultural workshops and planning process is that climate change is not the immediate concern of the farmers who participated. The findings from these two workshops therefore identify the priority actions related to climate change, for which the Town of Harvard could apply for the MVP grants that are the second stage of this process, and the priority actions that are not specific to climate change, but address other needs for agricultural producers.

Top 5 Priority Actions at Workshop 2

The actions below were identified and prioritized by the participants at Agricultural Workshop #2 and may not be representative of the entire agricultural community. In some cases, identified partners were added by the MVP community after the workshop based on their knowledge of the community. Some additional context has also been provided to clarify the conversations at the workshop. The data from the workshops are provided in Appendices B and F.

Climate-Related Priority Actions (Temperature and Precipitation)

1 State regulations for grants for forestry management plans require a minimum of ten contiguous acres. That leaves many smaller parcels unmanaged, with the risk of invasive (pest and plant) and forest fires. Participants recommended that **adjacent property owners with less than ten acres each but ten or more acres together work with the state to create a shared forestry management plan**, including managing forests for CO2 an the integration of carbon sequestration. *Identified partners: Town, Public/private partnerships, UMass Amherst,*[7] *DAR/DEM, Commonwealth of Massachusetts* (Twelve votes)

2 Projected impacts of climate change lead to increased threats to plant and animals from diseases. Participants noted that organic farms have greater difficulties addressing some of these threats. The first recommended action was a **focus on soil health and inter-planting techniques**. *Identified partners: UMass Amherst, Town (Agricultural Commission, Board of Health)* (Eight votes)

3 Because some solutions to invasives create additional problems, such as the threat to pollinators from pesticides and herbicides, the third recommended action was to **create a public education program, including recommendations for the timing of spraying and the spread of pollinator gardens**. *Identified partners: Town (Agricultural Commission, Board of Health, Harvard Public Schools), UMass Amherst* (Seven votes)

4 The fourth action is also related to invasive insects and disease; participants recommended **education around systems** (e.g. the link between deer, mice, bird feeders, and ticks) and **comprehensive regional strategies for collective land stewardship**. 3 *Identified partners: Town (Board of Health, Agricultural Commission), Commonwealth of Massachusetts, Property owners, UMass Amherst* (Six votes)

5 Participants identified land use and settlement patterns (particularly those that allow greenfield development) as a threat to the continuity of agriculture in the state and recommended that

[7] Note that the references to the UMass Amherst refer to The Center for Agriculture, Food, and the Environment at the University of Massachusetts Amherst. UMass Amherst is the center for the State Agricultural Extension Service.

the **state coordinate strategies for small New England Towns to address the pressures of development on agricultural land**. As part of this conversation, participants mentioned Ayer Road as an example. Ayer Road (Route 111) stretches from the heart of the town north to the town line just south of Route 2A. The C District is the primary commercial district in the Town of Harvard and is located between Route 2 and Myrick Lane on Ayer Road. The *Town of Harvard Master Plan 2016* (the 2016 Master Plan) notes that 60.9% of the acreage within the C District is noncommercial (conservation, agricultural, recreation, or residential).[8] This noncommercial land includes William Park Farm, and provides frontage for Ayer Road Meadows, Maxant Land, and Blomfelt Land. *Identified partners: Commonwealth of Massachusetts, Planning Board* (Seven votes for development patterns; six for Ayer Road)

Non-Climate Related Priority Actions (Economic/Market, Regulatory, Other)

1 Local property taxes contribute to financial stress for farms with small profit margins. In some cases, land is assessed at agricultural rates but buildings are assessed at commercial rates. Participants suggested several strategies, including **land banks, preservation, and evaluating the property tax structure**. Such evaluation would assess the property tax structure as it relates to agricultural lands and determine if modifications or updates based on best practices in the state. Massachusetts General Laws Section 3, Chapter 61A provides tax relief for agricultural and horticultural operations, but applies only to the valuation of land of five acres or more actively devoted to agricultural or horticultural use. To address the need for additional relief, Bill S.1792 *An Act Relative to Exemptions From Taxation of Structures and Buildings Essential to the Operation of Agricultural and Horticultural Lands* seeks to reduce the tax on buildings and structures. *Identified partners: Town (Select Board, Agricultural Commission), Commonwealth of Massachusetts, Farmers* (Nine votes)

2 Participants recognized the promise of agritourism to help farms with additional income streams, educate residents and visitors about the importance of agriculture and local products, and contribute to the local economy and culture. Questions arose about whether agritourism would be regulated by the Commonwealth or locally, or both. Participants recommended **support for agritourism locally and the creation of a strong information flow between the Commonwealth and municipalities about agritourism regulations** and also recommended that **communities lobby the state** for their interests. The 2016 Master Plan notes that local regulations do not promote tourism;[9] the Town may also wish to evaluate how its zoning regulations and other local strategies could support agritourism which would have the benefit of increasing flexibility for farmers and supporting economic development within the Town. *Identified partners: Town (Select Board, Planning Board), Chamber of Commerce, Commonwealth of Massachusetts, Residents* (Seven votes)

3 A common discussion was the general lack of awareness about agriculture and agricultural needs in Harvard. Participants recommended a robust outreach program to **educate more people about the unique benefits afforded to the Town by its orchards and farming operations**. Participants also identified a lack of a shared information base about agriculture for the entire community and **recommended facilitation to connect the community to agriculture**. *Identified Partners: Town (Select Board, Agricultural Committee, Harvard Public Schools), UMass Amherst* (Six votes for education and five votes for facilitation)

4 Considering how building codes should be applied to agricultural buildings was an issue under the regulatory discussion. The concern was that commercial standards were applied to agricultural buildings and that not all of these standards were appropriate. Participants

[8] Town of Harvard Master Plan, 2016, p. 71
[9] Town of Harvard Master Plan 2016, p. 76

recommended **lobbying the Commonwealth for building codes specific to agricultural uses**. *Identified Partners: Farmers, Commonwealth of Massachusetts* (Five votes)

5A Another priority requiring state action were the regulations on farm stands that serve food, particularly food that had been grown and/or prepared on-site rather than brought in from an outside supplier. Participants recommended **lobbying the Commonwealth for appropriate regulations for farm stands selling products produced on-site**. *Identified Partners: Farmers, Commonwealth of Massachusetts* (Four votes)

5B Tied for the fifth priority was the need to consider succession planning. Participants noted that Chapter 61A enhances the economics of succession planning by keeping land values lower, but that the **Town should explore other strategies such as the transfer of development rights (TDR) and open space design development**. A strategy for TDR would require a receiving zone, which could be the C District identified by the 2016 Master Plan as underutilized. *Identified Partners: Farmers, Town (Select Board, Planning Board)*

Part IV: Beyond the Town of Harvard

Agriculture in the Town of Harvard is part of a wider network of farms throughout Massachusetts. In 2017, Worcester County had 1,598 farms with a total of 95,308 acres and produce approximately $65 million in sales.[10] Worcester County has the highest number of farms per county in Massachusetts and the highest number of acres in production; however, Franklin and Plymouth Counties have higher sales. Massachusetts has 7,241 farms overall, with 491,653 acres of farmland and $475,184,000 in market value of agricultural products sold.[11]

Consistent with the pressures identified in the two Agricultural Workshops, the Massachusetts Department of Agricultural Resources notes that 94.2% of farms in Massachusetts are small farms (those with agricultural sales below $250,000).[12] Supporting the concern about succession, 79.7% of farms in Massachusetts are family or individually owned and the average age of a principal operator is

[10] Snapshot of Massachusetts Agriculture, Massachusetts Department of Agricultural Resources, https://www.mass.gov/info-details/agricultural-resources-facts-and-statistics, last accessed May 27, 2019.
[11] Ibid.
[12] Ibid.

Image Credit: Westward Orchards

59.1 years old.[13] All numbers are from 2017.

Agricultural production in Massachusetts is subject to existing stresses beyond climate change. In fact, the information gathered from the survey, interviews, and workshops suggest that for the larger farmers, climate change is seen as an aspect of something they already deal with – fluctuating temperatures and precipitation. The impacts are either viewed as too far in the future when compared to current financing needs or labor shortages, or too expensive to contemplate, such as changing varietals now or refitting the farm to grow an entirely new crop. This may represent an opportunity for further discussion and education to assist in planning for future impacts.

The United States Department of Agriculture (USDA) just completed its *2017 Census of Agriculture, Massachusetts State and County Data,* issued in April 2019. A review of its Profile of Massachusetts' Agriculture indicated the following:[14]

- The number of farms between 500-999 acres increased from 2012 to 2017; the numbers of all other farms over 10 acres decreased.
- The average market value per farm increased from 2012 to 2017; but the market value of livestock, poultry, and their products increased while the market value of crops decreased.
- Of the selected expenses surveyed, most expenses decreased in prices except for fertilizer, lime, and other conditioners, which increased. Taxes were not included in this survey, but hired farm labor was. Of the expenses that decreased, hired farm labor decreased the least; interest expense decreased the most. However, the cost of hired labor has increased significantly since 2007 and 2002.
- The market value of land and buildings increased significantly between 2012 and 2017, with the implication that the annual cost of property taxes may also have increased (depending on the tax rate in each community).
- In 2017, 614 farms had 4,704 acres in orchards; this is an increase since 2012 (456 farms, 4,146 orchards). The number of farms has increased since 2007, but the number of acres has decreased (458 farms, 5,416 acres).[15]
- However, the total market value of agricultural products in Massachusetts decreased; $492 million in 2012 to $475 million in 2017. The average market value of products per farm increased, but the number of farms decreased from 7,755 (2012) to 7,241 (2017).[16]

It is not within the scope of this study to undertake an exhaustive analysis of the USDA's census data. However, a few high-level questions should be considered as farmers, municipalities, and the Commonwealth seek to support and promote agriculture in the state.

- How does the impact of local taxes on the market value of land and buildings impact the overall finances of farms, especially as the value of that land increases as a result of development pressures around the state?
- Is 61A as currently structured the most effective means of addressing property tax pressures and will Bill S.1792 help?
- Should municipalities consider additional regulatory strategies to promote the preservation of agricultural lands? These could include the transfer of development rights to allow higher densities elsewhere within a municipality or cluster/open space developments to preserves some land for agricultural use while allowing development elsewhere. Such strategies could

[13] Ibid.

[14] United States Department of Agriculture, *2017 Census of Agriculture, Massachusetts State and County Data, Volume 1, Geographic Area Series, Part 21*, April 2019 https://www.nass.usda.gov/Publications/AgCensus/2017/Full_Report/Volume_1,_Chapter_1_State_Level/Massachusetts/mav1.pdf, last accessed May 27, 2019, pp 7-16.

[15] Ibid., p. 8

[16] Ibid., p. 9

work in partnership with prohibiting the development of prime farmland and farmland of statewide importance as defined by the US Natural Resource Conservation Service.

- As farmers look to agritourism, including farm stands, events such as weddings or farm-to-table meals, classes, and tours, state and local regulations may not be keeping up with the demand. The Massachusetts Department of Agricultural Resources promotes agritourism, providing a list of farms, classes for farmers, and access to the relevant sections of Massachusetts General Laws. However, there are anecdotal reports of conflicts in some communities between farms seeking to diversify their income streams and neighbors who are experiencing conflicts from agritourism, especially those based on events. Local Boards of Health, Conservation Commissions, Planning Boards and the executive bodies of municipalities also have roles in regulating this use. The balance of a consistent policy across the state and the need for local control needs to be considered.
- The majority of farms are family or private; the average age of the principal farmer is approaching what would be a traditional retirement age in an office environment. Succession planning will be a key concern of many farms and the results of that planning may have an impact on the communities those farms serve.
- Interviews with farmers indicated that the availability and cost of seasonal labor is also a concern.

The Town of Harvard received additional funding from the MVP Program to address the impact of climate change on agriculture, not only because of its own needs, but because the information gathered from this process can help address the needs of farmers throughout the Commonwealth and can help the Commonwealth target funding and policies to support agriculture. As such, the Town of Harvard serves as an important case study in this process.

To address agricultural vulnerabilities statewide, both those related to climate change and those that are not, three actions should be undertaken within the next 12 to 24 months:

1. **Develop a state-wide program to bring state officials, local officials and farmers together to discuss the impact of climate change on already stressed budgets and to determine how some of the agricultural strategies mentioned in this report could be disseminated along with appropriate funding sources for experiments in adaptation or mitigation strategies**. Long-term funding is key to some of these strategies; for example, an orchard cannot plant a new varietal of apple trees hoping that in ten years time it will be appropriate for the climate conditions at that future date. Grants and loans to help smaller operations should also be considered. Mitigation/adaptation measures will vary based on local conditions – soil types, water tables, elevation, and hyper-local precipitation and temperature patterns. The need to test strategies now to identify best practices is critical as some strategies may take time to evaluate. *Identified partners: Commonwealth of Massachusetts, University of Massachusetts, Towns, Farmers*

2. **Reconsider the regulatory structure around agriculture as a land use. Consider flexibility for multiple income streams (defining and allowing agritourism) and creative thinking around the tax structure.** State-wide data that evaluates the impact of agriculture on the culture, economy, and physical characteristics of a community is critical to creating a property tax that is consistent across municipalities and is fair to both farmers and the municipal budget. Regulatory structures, such as zoning, health codes, and building codes require a balance between state standards and local control; between farming needs and community safety and comfort. For example, food production regulations that require transport across long distances may not be appropriate for food produced and sold on-site on the same day. *Identified partners: Commonwealth of Massachusetts, Town (Select Board, Planning Board)*

3 **Create education programs at the local and state level that address two levels of need. The first is outreach to farmers to help integrate best practices in farming that can also set the stage for future adaptation to/mitigation of climate change.** These programs should be open to commercial farmers and those who are not reliant on farming for an income. The best practices to adapt to/mitigate may not yet exist, and state agencies and UMass Amherst need to be clearinghouses for reviewing, testing, and distributing the successful interventions by farmers through the state. **The second level of education requires a partnership among state agencies, municipalities, and farmers themselves and should be targeted to the residents of agricultural communities.** As one person noted in the data gathered, the Right to Farm legislation is not enough to inform people about the needs of and stresses on agriculture and the benefits that farms bring to communities. *Identified partners: Commonwealth of Massachusetts, University of Massachusetts, Towns, Farmers*

There are other stresses that can and should be addressed by partnerships among state agencies, local government, nonprofits, the educational community, farmers and residents. However, the combination of policy shifts and related funding mechanisms, flexibility in regulations and tax structures, and education for a variety of audiences are critical to understanding the importance of, and supporting the future of, agriculture within Harvard – and beyond.

Image Credit: Westward Orchards

2 General Hazards and Implications for Agriculture

Climate change will create unprecedented challenges for farmers in Massachusetts, including those in the Town of Harvard. In general, climate change will produce more extreme weather (Frumhoff et al., 2008; Horton et al., 2014; Tobin et al., 2015; Walthall et al., 2013) These include more extremes in precipitation (Guilbert et al., 2015), particularly high rainfall events and prolonged drought periods, more variability in temperatures including high nighttime temperatures (Hatfield et al., 2011; Kunkel et al., 2013). The impacts of climate change on agriculture in the Northeast have already been seen. Weather-related crop losses in the region from 2013 through 2016 have been summarized in Figure 4 (Wolfe et al., 2018).

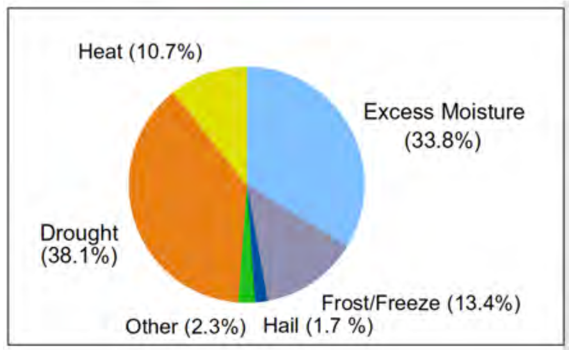


Figure 4. Categorization of weather-related crop losses in the northeastern U.S. from 2013 through 2016 (Wolfe et al., 2018)

Precipitation

Extreme precipitation events cause soil erosion and runoff of fertilizer, manures and pesticides into surface water. The Northeast has already seen an increase of 71% in the heaviest precipitation events since 1958 (Walsh et al., 2014). They also waterlog soils, increasing damage from root asphyxiation and soil-borne diseases. Wolfe and colleagues (Wolfe et al., 2018) predict 1.5 to 2 times as many 4+ precipitation events in Harvard by 2055 (Figure 5). In general, wet weather would increase plant diseases, because fungi and bacteria grow best under wet conditions, and can be more easily spread in rainy weather.

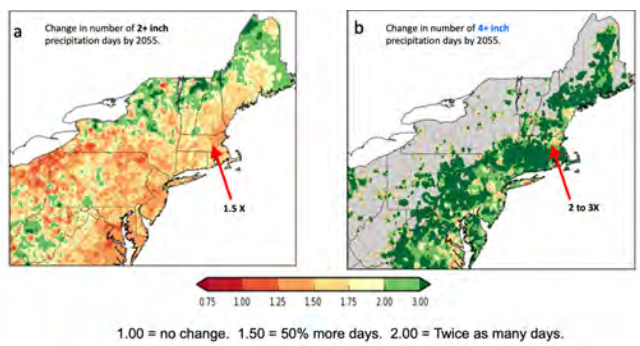


Figure 5. Change in the number of days with 2 or more inches of precipitation (a) and the number of days with 4 or more inches of precipitation (b) by 2055. Arrows show Harvard. Adapted from Wolfe et al. 2018, Supplemental Material.

Wet weather is not just a preferred environment for plant diseases, but it also makes pest management more difficult. More intense rainfall washes pesticides from plants, and prolonged rain makes it difficult to apply pesticides. The situation is even more difficult for organic growers, because organic pesticides generally do not adhere as well to plants, nor are they generally as effective as conventional pesticides.

For livestock, hay production becomes much more difficult with prolonged rain events. Accessing fields with heavy equipment, and having sufficient time for hay to dry becomes more difficult. While using plastic wrapped bales has improved the speed with which hay can be cut and put into storage, horse owners prefer lower-moisture hay that requires longer drying.

Prolonged rain severely damaged crops in the late summer and early fall in Massachusetts in 2018. Annual vegetable crops suffered significantly more disease damage, and were difficult to harvest.

Perennial crops such as apples were also damaged by diseases that normally cause problems in more southern regions, but not New England. The combination of prolonged rain, increased humidity and warmer temperatures are apparently allowing pathogens and other pests from the South to move into our region (Figure 6).

In the spring, more rain prior to the first frost-free day is predicted, which indicates that while it may be possible to plant crops earlier because the last frost will come earlier, this may be offset by wet soils which can't be cultivated or planted. The "growing season" and the number of frost-free days are not necessarily the same thing.

Similarly, periods of extreme precipitation do not necessarily mean that overall precipitation is expected to increase. While winter and spring (December – May) overall precipitation in eastern Massachusetts is predicted to increase 10% to 20% over the period 1994 to 2055, summer and fall precipitation is predicted to stay the same or rise by about 5%. This means that during most of the growing season, the amount of rain in Harvard will be about the same as it is now, but rainy and dry periods will probably be more extreme. Short-term drought will also be an issue, and water management over the year will become more important.

Much of the crop loss (38%) over the 2013 to 2016 in the Northeast was attributed to drought. For high value fruit, vegetable and nursery crops, irrigation will be critical, and require new investment. For forage crops, farmers will need to look to more drought tolerant varieties and crops for livestock.

Temperatures

Overall, average temperatures in Harvard have increased and will continue to increase with climate change. Seasonal changes will not be the same, but will be greater in winter than in spring, summer and fall. Winter minimum and summer maximum temperatures will increase, and there will be from 10 to 20 more days a year over 95ºF by 2055. Higher temperatures during the growing season will generate more evaporation (Figure 7), and that coupled with no to little increase in summer precipitation (0 to 5%), the potential for short-term drought and water stress will increase. Higher temperature extremes will also generate more heat-related problems, including reduction in growth, sunscald on fruits and vegetables, and changes in the timing for production of cool-season crops, perhaps eliminating some.

Figure 6. Fruit rots on apples 2018 (top); apple tree killed by root rot 2017 (center); grower surveys flooded field in western MA 2018 (bottom; Boston Globe).

Overall warming will also change the length of growing seasons. The average number of frost-free days from 1991 to 2012 compared to 1901 to 1960 increased by 10 in the Northeast, and is projected to increase by an additional 30 to 40 days by 2070 (Walsh et al., 2014). While this increases the growing season for many crops, it will introduce changes in development of perennial crops. In particular, the development of tree fruit will begin earlier (Figure 8).

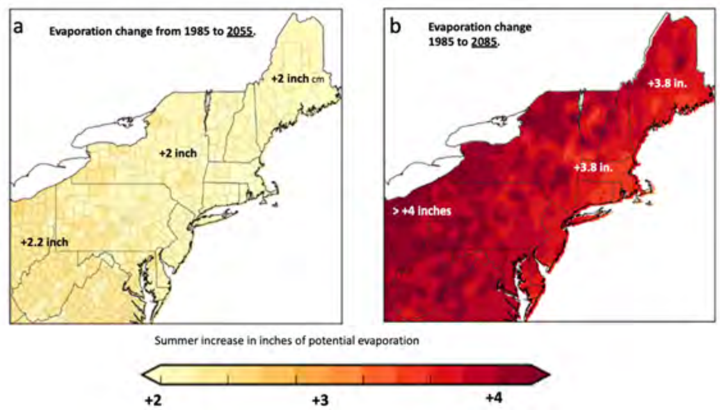


Figure 7. Change in the potential evaporation during June, July, August from 1985 to 2055 (a) and 1985 to 2085 (b). When combined with little to slight change in overall precipitation over these months this indicates an increased risk of short-term drought. Adapted from Wolfe et al. 2018, Supplemental Material.

Warmer weather for a longer period will probably allow insect pests to complete more life cycles per year, which means populations can grow to higher levels, potentially causing more damage. Other pests that normally die off due to cold winter temperatures may survive. For example, the hemlock wooly adelgid aphid has expanded its range in the Northeast, causing forest owners to cut hemlocks before they are killed by the pest. Codling moth, one of the most important apple insect pests, will likely be able to complete a third generation in the near future, requiring additional insecticide sprays.

Fruit Trees

The relationship between temperature changes caused by climate change and potential damage to tree fruit and other perennial crops is complicated. Deciduous tree fruit, such as apples and peaches, become cold-tolerant, “hardy”, during the fall as days shorten and frosts occur. They can withstand most extremes common in Massachusetts, though peaches are less hardy than apples. While apple buds can withstand -20ºF or lower in winter, peaches start to die at -12ºF. Minimum tolerance temperature goes up if there are warm days, above freezing, in winter. The entire peach crop in Harvard and much of southern New England was killed in February 2016 by record low temperatures, around -15ºF, following prolonged abnormally warm weather.

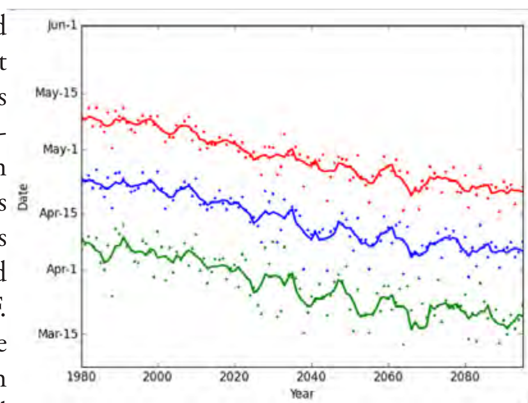


Figure 8. Projected change in the dates of critical stages in apple tree development, green tip (green), tight cluster (blue) and bloom (red) in Geneva, NY, similar to Harvard MA. Wolfe et al. 2018, Supplemental Material.

Temperature fluctuations in spring are also problematic. Once deciduous fruit trees have experienced a sufficient amount of cold weather, they can start to grow when the weather warms. As trees begin to flower, the flowers are sensitive to freezing damage. Studies estimating changes in damage to apples during bloom have mixed results, but the Wolfe study indicates a slight increase in risk up to 2039, followed by a decrease. Overall warming, particularly in winter, will decrease the number of chilling hours in Massachusetts, which may mean some apple varieties which require more than 1,200 chilling hours cannot be grown in Harvard. In addition, varieties such as McIntosh that have traditionally ripened well in the cold fall nights of New England, will be less colorful and less crisp as temperatures warm.

Agriculture and Harvard

As described in Chapter 1 of this report, while there are a few larger farms of 50 or more acres in Harvard (still relatively small compared to the United States as a whole), there are many more people farming on 10 or fewer acres. Most people who responded are not farming commercially and are managing small areas, but want to make changes to adapt to climate change. A study of small-scale farmers in the Pacific Northwest and the Northeast noted that the majority of these farmers "are unfamiliar with institutional suggestions for climate adaptations – and these institutional discourses seem to clash with small-scale farmers' climate narratives and priorities – perhaps pointing towards a disconnect between small-scale farmers and knowledge-producing institutions" (Baranow, 2018). Presumably this would extend to people involved in non-commercial agriculture. A primary goal of this report is to connect growers of all scales with methods that have been developed in the region and nationally to help agriculture reduce the impact of climate change. These approaches will be described in Chapter 3.

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3 Strategies to Address Climate Vulnerabilities

Agriculture in the Town of Harvard faces significant challenges from climate change as described earlier. This chapter presents potential adaptation strategies, tactics, and tools to address these challenges. The effects of climate change are already present; impacts will continue to increase over decades.

Over the next 1 to 5 years, **short-term adaptation tactics** allow farmers to use their same basic management approaches, adjusted to deal with current climate change challenges. A recent survey of farmers in the Northeast taken November 2017 through March 2018 showed that many are already using new production methods in an effort to adapt to climate change. The nearly 200 respondents, primarily producing vegetables, berries and tree fruit, listed a number of practices discussed here. A list of practices reported to mitigate heavy precipitation and drought are at the end of this chapter (figures 19 and 20). The full report is at https://adaptationsurvey.files.wordpress.com/2018/10/new-england-adaptation-survey-report-updated-10-22.pdf.

Dealing with the magnitude of change after the next 5 to 20 years or more will require more significant actions. **The long-term adaptation will most likely require fundamental changes in farming systems and probably the larger food system.** This chapter emphasizes short-term approaches.

Adaptation to Precipitation: Healthy Soils

Soil and water are basic to farming. The changes in precipitation predicted to come with climate change will lead to greater potential erosion, more prolonged droughts, and more soil saturation and flooding. **Improving soil health can help growers adapt to climate change impacts.** Building soil health is worthwhile regardless of climate change, but will reduce the impacts precipitation changes have on agriculture and horticulture.

Figure 9. Healthy soil is a living soil. (Photo Texas Wildlife Association)

Modern agriculture has tended to treat soil as an inert substance, minerals that primarily serve to hold plants in place. Typically, production relies on frequent plowing and tilling, and on purchased fertilizers, particularly nitrogen, to improve plant growth. These practices degrade soil quality over the long run, making them, among other things, more susceptible to erosion and less able to absorb and retain water. Far from being inert, a healthy soil is actually a complex living ecosystem made up of microbes, animals, plant roots, and significant amounts of organic matter, as well as mineral soil particles. **Maintaining appropriate levels of organic matter in soils is critical to reducing the impact of extremely wet and excessively dry weather.** Healthy soil addresses important problems brought about by climate change, including more frequent dry periods or drought, more frequent saturated soils and ponded water, runoff of fertilizers and pesticides due to heavy precipitation, and soil erosion. An excellent book on how to develop and maintain healthy agricultural soil is available to download for free: *Building Soils for Better Crops. Sustainable Soil Management, 3rd ed., by Magdoff and van Es* at https://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition.

Understand Your Soil

Soil health is made up of many components, and gaining a basic understanding of the soil for a specific farm will require accessing different resources. The soils in Harvard vary, but there are many examples of soils classified as Paxton, the state soil of Massachusetts, and Woodbridge, the soil shown in Figure 10. Created by the movement of glaciers thousands of years ago, these soils can be found throughout New England and are exemplified by scenic rolling hills also formed by glaciers. They are considered one of the most productive soils for agriculture in New England. A good basic description is available here https://www.soils4teachers.org/files/s4t/k12outreach/ma-state-soil-booklet.pdf.

Figure 10. Woodbridge soil (common to Harvard, MA)

It is beyond the scope of this report to review the details of soil classification in Harvard, which have been mapped by the USDA Natural Resources Conservation Service, with the most recent published maps for Harvard available in the Soil Survey of Worcester County Massachusetts Northeastern Part, 1985. This data gives information on soil texture and basic composition as well as slope. Massachusetts has incorporated this data in the state's MassGIS system, which can give landowners information on their property through interactive maps on OLIVER or via downloadable data files (https://www.mass.gov/orgs/massgis-bureau-of-geographic-information).

Soil Health Assessment

The quickest way to understand the soils on your farm is to get an assessment of soil health (Figure 11). The assessment can point growers towards specific practices they can use to improve soil. This is useful even without the complications introduced by climate change. Cornell University offers such an assessment for a fee; information is available on the **Comprehensive Assessment of Soil Health (CASH)** web site, https://soilhealth.cals.cornell.edu. An associated manual giving an excellent overview of the basics of soil science is also available.

Figure 11. Taking soil samples in an orchard

The CASH system uses several types of data, including factors such as pH, soil hardness, water holding capacity, organic matter to generate an overall soil health index. More importantly, the assessment identifies specific areas where improvements should be made, and general recommendations as to how to make them. For example, a soil may have a very low aggregate stability, meaning that the soil particles don't hold together well, making the soil more susceptible to erosion and less able to store and release water slowly. The CASH recommendations to remediate this problem would be to incorporate fresh organic materials, use shallow-rooted cover/rotation crops, add manure, green manure, mulch, reduce tillage, use a surface mulch, rotate with sod crops and mycorrhizal hosts, and use a cover crop whenever possible.

Short-term Solutions

Covering soils with organic matter, either living plants or mulches, is critical to building and maintaining soil health. While the standard is changing, growers usually till and plow soils at least before every planting. This often comes at a time of year when precipitation is heavy, exposing soils to erosion and allowing excessive water runoff. Cover cropping and mulches can solve the issue in the short term (Figure 12).

Figure 12. Cover crop and productions crop to keep soil covered

Most growers and gardeners are familiar with organic mulches, such as straw and woodchips. These are simply used to cover bare soil around crop plants. Integrating cover crops and ground covers into plantings is more involved, but can help with erosion control, build soil organic matter, and help with carbon sequestration. There are many kinds of cover crops recommended for use in Massachusetts. A description is available in the New England Vegetable Guide https://nevegetable.org/cultural-practices/cover-crops-and-green-manures and the New England Small Fruit Management Guide https://ag.umass.edu/fruit/ne-small-fruit-management-guide/general-information/cover-crops-green-manures.

Longer-term Solutions

No-till, intercropping, polyculture and permaculture offer longer term solutions. Such planting systems require different equipment and a completely different approach to management. No-till is most often associated with field crops such as corn, but can be used in vegetables. The Northeast Sustainable Agriculture Research and Education (SARE) program has put together an excellent site describing no-till methods at https://notillveggies.org/about/. UMass also offers guidance on transitioning to no-till at http://bit.ly/no_till_transition_UMass.

Intercropping and polyculture are very similar, and are terms that mean growing two or more crops in close proximity. **Intercropping tends to refer to growing in adjacent rows or beds, while polyculture generally implies a more thorough mixing of different species of individual plants.** Some plant combinations work well together, and others do not. SARE offers guidelines for intercropping in organic systems, which of course could also be used in conventional production (http://bit.ly/intercropping_SARE). The National Center for Appropriate Technologies offers guidelines for a small charge at http://bit.ly/intercropping_AATRA.

The most radical solution is **permacultures**. Definitions of permacultures vary, but in their purest forms, they are an attempt by farmers to mimic the diversity and interactions found in natural ecosystems using harvestable plants. The diversity can be more resilient and stable than typical monocultures. Permacultures can be adopted by non-commercial growers, and small-scale commercial production, but it is not clear that they can be adapted to large-scale farming. There is an active group working on permacultures in the Northeast, the Permaculture Association of the Northeast (http://northeastpermaculture.org/about/), for those interested in exploring this option.

Permacultures are part of a more general approach to farming, **agroecology**. Simply put, agroecology applies ecological principles to farming, often including social and political dimensions of food systems. While agroecology is predominantly promoted as a solution of small farmers in less developed parts of the world, the principles of agroecology have relevance to adaptation to climate change. Agroecology is a broad topic, inspiring textbooks (e.g. http://bit.ly/Gliessman_agroecology_3), though a SARE site gives a quick overview of aspects of the topic http://bit.ly/Ecological_ag_SARE. While it would be a major undertaking, it would be groundbreaking work for Harvard to explore developing adaptation of the town's agriculture and forestry using agroecological principles.

Adaptation to Precipitation: Managing Excessive Precipitation and Drought

Too much rain, too little rain: managing excessive rainfall and dealing with drought are different sides of the same coin. As noted, healthy soils can significantly help both issues. In addition, physical changes to production areas can reduce impacts. Large-scale projects may impact more than one property owner as well as public land, and need to be designed in the context of town and regional water management.

Erosion Control

For erosion control, in addition to keeping soil surfaces covered, it may be necessary to add structures that slow runoff. These may either be **"hard" or "soft" engineering solutions**. Hard engineering involves bringing in heavy equipment and material to build structures, such as stone water bars or trap rock, to deal with areas prone to erosion. A soft engineering solution to address the same problem might involve using trees or brush cut from the area to slow water flow. While hard engineering usually has been proven to work and tends to last longer and require less maintenance, it costs more and may destroy soil structure. Soft solutions (Figure 13) have less impact on the environment, but may require more maintenance and manual labor to construct.

Figure 13. Using logs and brush, a "soft" engineering solution, to control erosion in a maple woods in VT. (Photo Cornell Small Farms Program)

A case study of erosion control on a Vermont farm is available here: http://bit.ly/gully_erosion_control_vt. The economic analysis of this work show that there is a net benefit to both society and the farm to implement the control.

Flooding

To reduce the impacts of flooding in level areas, **raised beds** used in conjunction with mulch can reduce direct impacts. Raised beds are increasingly used in commercial agriculture, and can are very useful in small-scale gardening. Mechanical bed shapers make them relatively easy to make on commercial farms (Figure 14). Home gardeners, and even some small-scale commercial operations, use beds bounded with boards. Raised beds offer several benefits, such as warming soils more quickly in spring, improving air circulation in plants and reducing wind damage. Raised beds will also reduce the incidence of root diseases that often develop when plants are flooded for brief periods. At the same time, raised beds should generally be used in conjunction with irrigation, as they dry relatively quickly. General guidelines for building raised beds are available at https://nevegetable.org/cultural-practices/raised-beds.

Drainage

Agricultural drainage is a major issue, and must be addressed in any water management plan for agriculture in the town. Issues such as **wet sites that need drainage, water runoff from agricultural sites, and construction of ponds for water storage** need to be considered. To deal with drought, growers should develop the capacity to store runoff from tiles and excessive precipitation in general, so that it may be used for irrigation when needed. Building surface ponds to store water may be more important as climate change impacts increase. Harvesting rainwater from the roofs of buildings will also both reduce runoff and, with adequate storage, provide a source of irrigation water. USDA/NRCS is the agency charged with developing plans for drainage in agriculture and communities. The Massachusetts NRCS home page is https://www.nrcs.usda.gov/wps/portal/nrcs/site/ma/home/. While there are regulations regarding water quality used for commercial agriculture, Massachusetts encourages homeowners to use rainwater (http://bit.ly/MA_rainharvest).


Figure 14. Raised beds keep plants and roots from standing water.

Irrigation

Irrigation will be increasingly important in an age of climate change. Irrigation technology has improved. Modern trickle or drip systems are 90 to 95% efficient, while older overhead sprinklers waste 25 to 30% of the water applied. However, for perennial crops, and particularly berries, overhead irrigation can provide spring frost protection, which may outweigh lower efficiency. UMass has guidelines for irrigation in vegetables, which apply to other crops as well, at https://ag.umass.edu/vegetable/fact-sheets/irrigating-vegetable-crops. Guidance for drip irrigation is available at https://ag.umass.edu/vegetable/fact-sheets/irrigation-drip. The USDA Climate Hubs offer an overview of irrigation in the Northeast at http://bit.ly/climate_hub_NE_irrigation.

Adaptation to Temperatures

Freezing and Frost

While a Massachusetts winter challenges this idea, warmer weather in Massachusetts will not necessarily be better. As climate change advances, Massachusetts will warm, potentially extending the growing season and increasing the minimum winter temperatures, which both suggest that farming may be more productive. However, along with these general changes come **increased extreme high temperatures, more variability in winter and spring temperatures, a decrease in the number of chilling hours**. These changes will require growers to make **changes in the kinds and varieties of crops they grow**.

New Cultivars and Crops

Increased variability of temperatures could increase the risk of freeze damage in apples and other tree fruit. Short-term methods that can be adopted to mitigate spring frost damage remain much as they have been for recent decades: **select sites that have good air drainage, row covers and overhead irrigation for low-growing crops, wind machines for air circulation, and supplemental heat** (Figure 15). Winter freeze damage, such as that which hit peaches in southern New England in 2016, is a more intractable problem **for which there is no solution at present**. Cornell offers a list of frost protection tactics for fruit at https://fruit.cornell.edu/frost-protection/.

Figure 15. Ice on blueberries protected from frost at bloom by overhead irrigation. (Photo Brookside Farms, Michigan)

Some researchers have suggested that apple growers in the Northeast should select cultivars which require fewer chilling hours, because models suggest that some areas, including eastern Massachusetts, will not reach 1,000 chilling hours in 30% of years by 2070. However, more recent research suggest that chilling hours will reach 1200 in 99% of years. Cultivar selection for perennial crops, particularly tree fruit, is a long-term decision and a major investment. **Until the agriculture community has a clearer idea of whether cultivar changes are needed, growers should not replant to low-chill varieties.**

Dealing with increased heat stress presents a difficult problem. For annual crops, growers may select longer growing-season, heat-resistant, or drought-resistant varieties. For home landscapes, UMass, Penn State and Michigan State have lists of plants at http://bit.ly/heat_landscape_umass, (http://bit.ly/heat_landscape_psu, and http://bit.ly/heat_landscape_msu, respectively. Unfortunately, few such lists exist for horticultural or agricultural crops.

Growers can also **adjust planting time** to avoid mid-summer heat, planting earlier in spring or later in summer. **Overhead misting or irrigation** can provide cooling, but will require adequate water supplies. The effectiveness of mist cooling of both crops and livestock in Massachusetts, where the summer humidity is generally high, may be limited.

High Tunnels

Growers around the Northeast and U.S. in general have been adopting high tunnels for production of fruit and vegetable crops (Figures 16 and 17). High tunnels are essentially greenhouses without a foundation that enable farmers to extend seasonal production. They can also provide a buffer from weather extremes in general, including heavy rainfall. For example, high tunnels have been adapted to cherry production, because excess moisture causes cherry fruit to split. Tunnels also provide protection from hail. **Using high tunnels for a portion of production can make overall production and sales less subject to variable weather.** It is critical that tunnels be designed and managed appropriately in order to make them profitable. UMass and Cornell have sites that offer a good start, at http://bit.ly/high_tunnel_UM2 and http://blogs.cornell.edu/hightunnels/.

Figure 16. High tunnel production of spinach

Hail

Figure 17. High tunnel production of cherries. (Photo from Cornell Extension)

Increased intensity of storms is expected to increase the frequency of hail. Hail is particularly damaging to high-value fruit and vegetable crops, where severe storms can destroy a year's production in a matter of minutes. Crops can be protected from hail using netting, though the cost for protecting tree fruit is high. As a result, **hail nets** are not used in apple production in the Northeast, although the idea is being explored (https://cce.cornell.edu/newsarticles/28221).

Livestock

Sufficient drinking water is critical for livestock. Livestock producers can rotate grazing sites more frequently to allow forage recovery. Shade for livestock is also critically important with increasing heat extremes.

Managing Pests and Diseases

As Harvard's climate increasingly looks more like that in more southern states, pest pressure from insects, diseases and weeds will change, and potentially increase. It is critical that growers remain aware of arising new problems. For example, in recent years over much of the country including Massachusetts, fruit and vegetable growers have had to deal with the invasive spotted-wing Drosophila. This pest has forced growers to significantly change pest management in some crops, such as raspberries and blueberries. To stay abreast of best management methods, including integrated pest management (IPM), growers can use Extension resources.

IPM Resources

Figure 18. Weather station, solar powered, connected to the internet, a must for managing climate change.

UMass Extension has developed broad Integrated Pest Management (IPM) and related crop management resources via the Center for Agriculture, Food and the Environment (CAFE; http://ag.umass.edu), including agriculture and commercial horticulture information (http://ag.umass.edu/resources/agriculture-resources) with specific IPM guidelines for crops important in the state (http://bit.ly/UMass_Ag_Ext).

Accurate Weather Data

With climate change, **having accurate weather information will be more important than ever**. Ten years ago, UMass CAFE initiated a partnership with Cornell which was developing a network of on-farm weather stations (Figure 18) coupled to pest and disease forecast models, the Network for Environment and Weather Applications (NEWA; http://newa.cornell.edu). As a result, growers in Massachusetts can link a weather station to NEWA, and get real-time evaluations and forecasts for weather-related management decisions for several crops, including apples, grapes, blueberries, tomatoes, potatoes, onion, corn, and turfgrass. This decision support system enables growers to access accurate weather information for their farms. Owning and maintaining a weather station is moderately expensive, with an initial investment of $1,500 to $2,000, and annual maintenance and repair costs of $300 to $500. An alternative to an on-site weather station is so-called gridded weather data, information for a specific farm extrapolated from actual ground observations.

Other decision support options are available. **The important point is that growers need to monitor weather and pest conditions daily to make good management decisions**, and this will only become more critical in the future.

Crop Insurance

A major tool for managing risk in agriculture, including climate change, is crop insurance. UMass Extension in collaboration with USDA Risk Management Agency offers growers both risk management education and crop insurance programs (https://ag.umass.edu/risk-management).

Additional Tools

A useful web site which contains several tools to help farmers in adapting to climate change is **Climate Smart Farming**, particularly the Decision Tools available on the site (http://climatesmartfarming.org). For example, using one tool, growers can calculate the daily risk of freeze damage to apple flowers. The site offers links and other tools to help farmers adapt to climate change.

A potentially useful tool in developing actions related to agriculture and forestry, including urban/suburban forests, is the **Adaptation Workbook** (https://adaptationworkbook.org), an interactive web site that guides users through the process. This is designed to be used in agriculture with an accompanying book, *Adaption Resources for Agriculture*, available online (http://bit.ly/Ag_Adapt).

Summary of Actions

Soil Health

- Undertake a Comprehensive Assessment of Soil Health process.
- Enhance organic matter to reduce impact from pests, provide nutrients, and address water absorption.
- Consider the use of alternative techniques such as no-till, intercropping, polyculture and permaculture. Evaluate appropriateness for farm size and crop types.
- Use mulches, cover crops, and other means of keeping soil covered.

Addressing Precipitation

- Develop appropriate erosion control methods for vulnerable areas.
- Evaluate use of raised beds for certain crops.

- Investigate need for drainage to address standing water.
- Investigate options for storing water and/or adding drip irrigation as drought cycles increase.

Addressing Temperature

- Consider frost protection tactics.
- Research and experiment with new cultivars; do not remove current ones until research is more certain.
- Consider adjusting planting times.
- Investigate use of high tunnels for vegetable crops and fruit trees.
- Consider need for hail nets for fruit trees.
- Investigate additional sources of water and shade for livestock.

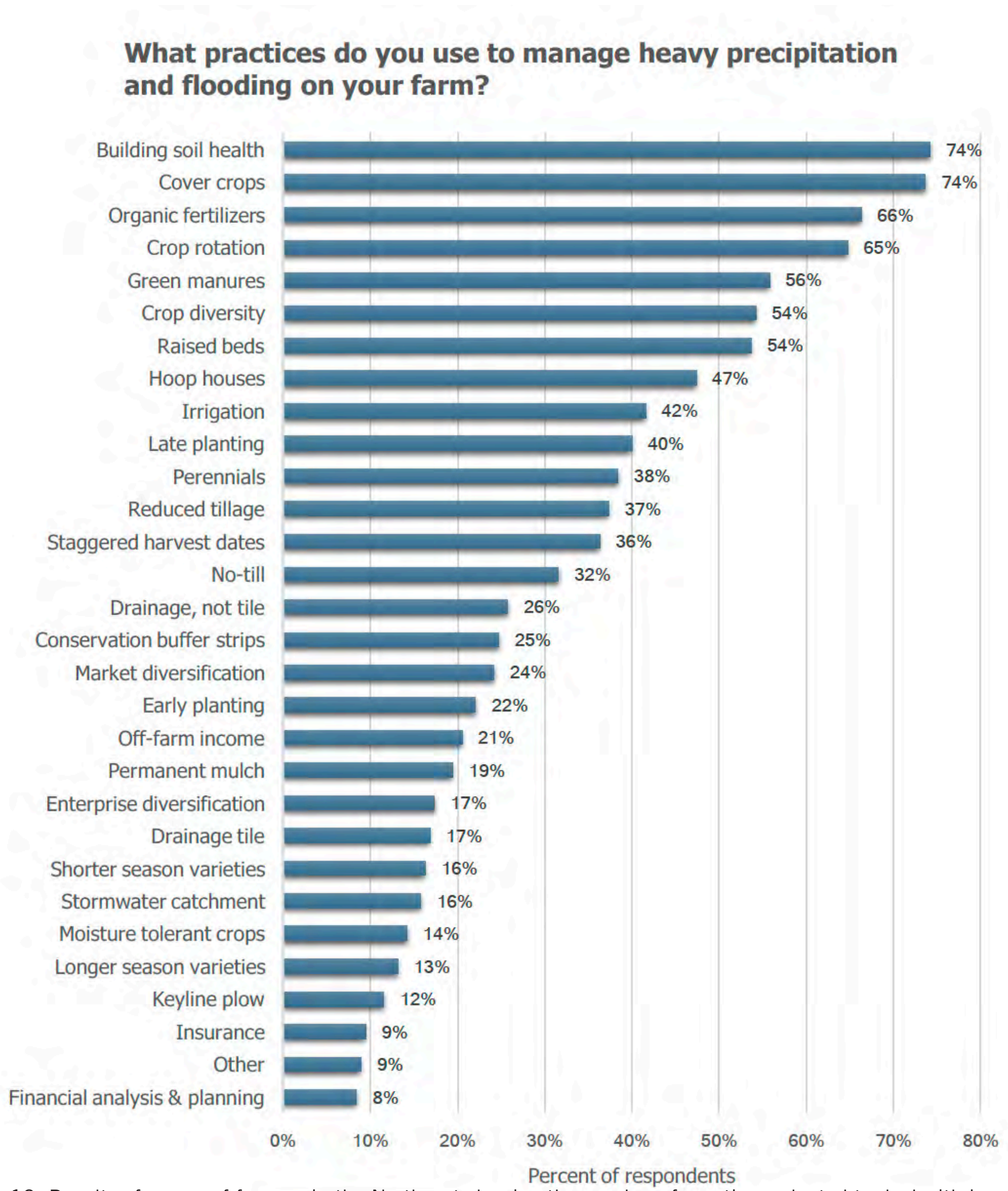

Figure 19. Results of survey of farmers in the Northeast showing the number of practices adopted to deal with increased heavy precipitation. From White et. al, UVM, 2018.

Managing Pests and Diseases

- Invest in appropriate weather monitoring systems.
- Investigate IPM resources at UMass for strategies appropriate to the type of crop and pest.
- Obtain crop insurance.

Additional Tools

- Investigate online tools and workbooks to plan for and implement strategies appropriate for a variety of crop types.

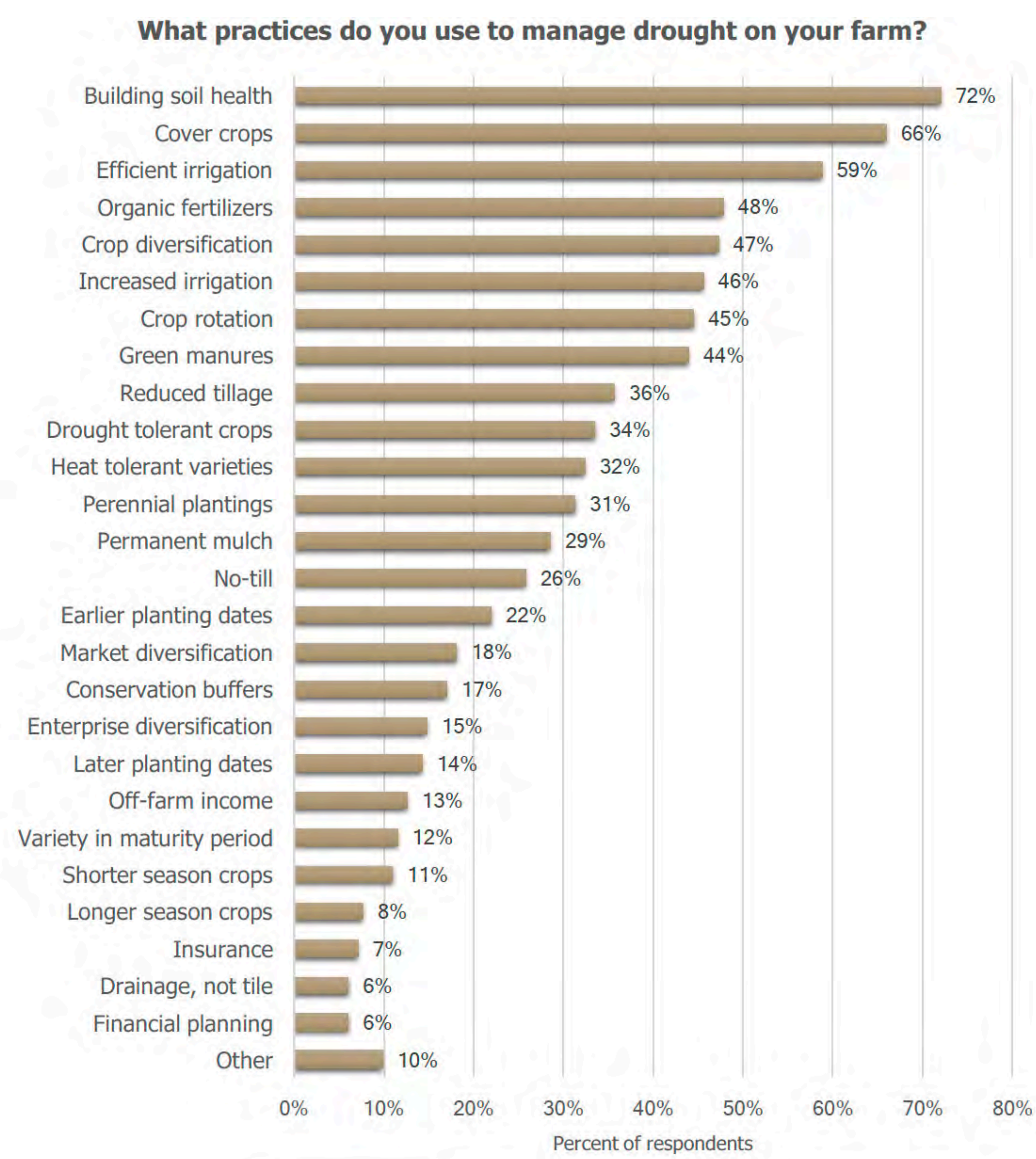

Figure 20. Results of survey of farmers in the Northeast showing the number of practices adopted to deal with drought. From White et. al, UVM, 2018.

4 Resources

Prepared by Daniel Cooley, Professor of Plant Pathology at the Stockbridge School of Agriculture at the University of Massachusetts-Amherst

Government

Climate Change Adaptation Workshops: A Planning Guide for Local Govt. Need to register. https://www.cakex.org/tools/climate-change-adaptation-workshops-planning-guide-local-government-staff

Commonwealth of Massachusetts, resilientma.org

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USDA Climate Hubs. https://www.climatehubs.oce.usda.gov. A wealthy of resources developed by a collaboration of USDA and Land Grants. There are Regional Hubs, one in the Northeast.

U.S. Climate Resilience Toolkit - Northeastern agriculture. General information on potential impacts of climate change. Part of a national set of resources. https://toolkit.climate.gov/regions/northeast/ecosystems-and-agriculture

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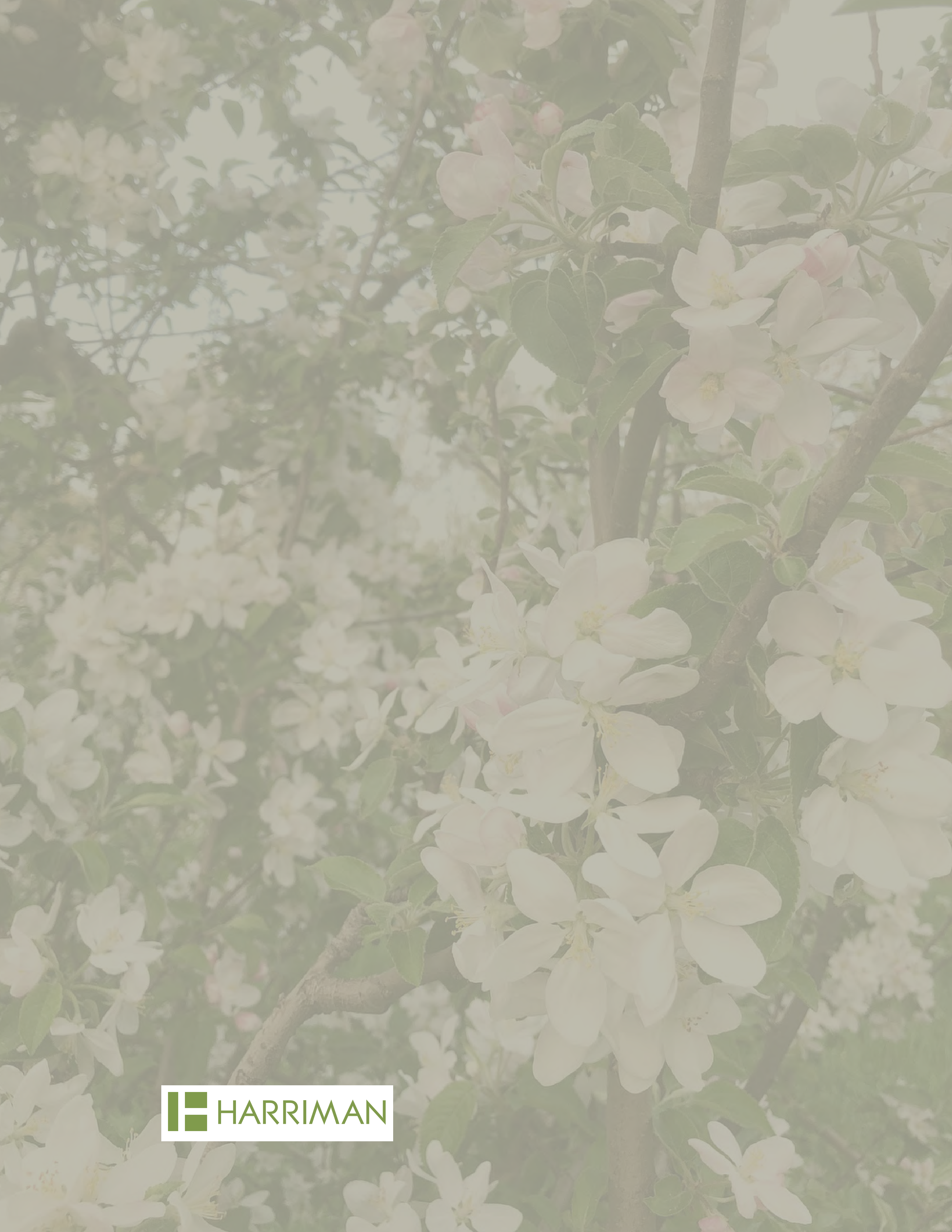
Image Credit: Westward Orchards



HARRIMAN