WHY DO WE CARE ABOUT CLIMATE CHANGE IMPACT IN OUR FOOD SECTOR?

MA food system employs approximately 426,000 people (about one of every ten workers residing in the State) and accounted for $24,434,046,000.00 of economic activity in 2017. (4.5% of 2017 GDP of $542,978,800,000.00)

For perspective- 2018 BLS numbers for the larger employment sectors in MA:

- Manufacturing - 247,500;
- Trade, Transportation, and Utilities - 585,000;
- Financial Activities - 222,500;
- Professional & Business Services – 602,500;
- Government – 452,600,
- Education & Health Services- 811,200;
- Leisure & Hospitality- 375,600

Top 50 employers in MA employ a total of approximately 300,000 workers or just 70% of food system sector.

Ecosystem services provided by agroecosystems include:

Provisioning services, which provide food, pharmaceuticals, fiber, and fuel products.

Regulating services, which regulate ecosystem processes such as groundwater flow; erosion control; flood protection; water purification and temperature control; pollination, weed, insect, disease, and parasite pest control; air quality and greenhouse gas emission control; carbon sequestration; local climate modification; and biodiversity.

Cultural Services, which provide non-material benefits such as spiritual enhancement, tourism and recreational opportunities, and aesthetic experiences.

Supporting Services that include basic soil aggregate arrangement, hydrological cycling, atmospheric and mineral nutrient cycling, and wildlife habitat

Our Food Plan asks us to work on:

- Increasing production, sales, and consumption of Massachusetts-grown foods.

- Creating jobs and economic opportunity in food and farming, and improve the wages and skills of food system workers.

- Protecting the land and water needed to produce food, maximize environmental benefits from agriculture and fishing, and ensure food safety.

- Reducing hunger and food insecurity, increase the availability of healthy food to all residents, and reduce food waste.

FOOD PLAN RECOMMENDATIONS THAT MAY IMPACT CLIMATE CHANGE RESPOSNSES

The Food Plan notes that

- Public investment in State agency services for agriculture, especially UMass Extension, has not kept pace with needs of the agricultural and seafood sectors and recommends providing resources for farming and fishing with research, technical assistance, and other resources that help them remain viable and competitive.
- The theme of economic viability runs through all of the plan's recommendations.
- The need for more education throughout all sectors of the food system figures prominently in the plan and it states: "strengthened educational services and training, coupled with applied research and targeted technical assistance, should be key tools to advance the state of practice in all sectors of the Commonwealth's food system… Farmers, fishermen, and processors need access to training on the latest management and production technologies, support in understanding and complying with regulations, and research and training that helps them to produce food economically, in an environmentally supportive manner, and safely… As stewards of land and sea, food producers of all types need support in employing sustainable management practices and adopting energy efficiency and renewable energy generation techniques while remaining economically sustainable."
- There is a significant shortage of technical assistance to inform and educate farmers and landowners about existing services financial and business planning services or to meet the demand for them. The fishing industry lacks sufficient technical assistance resources for management practices to protect the sustainability of fish stocks and the marine environment.
- There are a growing number of opportunities to divert food waste to energy production through the use of anaerobic digestion, as well as to home and community composting. Yet these initiatives have not yet received enough support to appreciably reduce the food waste going into landfills. Food waste decomposition in landfills produces large quantities of methane, a greenhouse gas with 25 times the climate change accelerating impact than carbon dioxide.

The Plan recommends:

- Funding infrastructure development - Support investments in modern equipment that facilitates safe, efficient food production and processing.
- Providing business supports - Expand the range of financial and business planning services for farms and food businesses.
- Improving soil health - Incentivize best practices for farmers around cover crops and other management techniques that maintain soil organic matter. Facilitate better access to conservation programs.
- Providing resources for fisheries -Support and educate the fishing industry on sustainable management practices that protect stock and habitat.
- Protecting water resources. -Provide incentives and technical assistance for increasing water conservation and decreasing water pollution in food processing and on farms.
- Increasing energy efficiency and sustainable practices in food production - Streamline processes for participation in public programs that provide financing and technical assistance for energy efficiency upgrades, and investing more public resources in these programs.

- Ensuring food safety - Ensure that regulations are science-based, effective, and appropriate for Massachusetts businesses size and complexity, and that technical assistance and education to help facilitate compliance is readily available. Regulations and their enforcement should, above all, foster the production of better and more food while managing risk responsibly, not impose new management practices that producers and processors are unable to implement if they are to remain viable.

THE FOLLOWING SECTIONS ARE COMPILATIONS OF INFORMATION FOUND IN NUMEROUS PUBLICATIONS AND WEBSITES INCLUDING:

- USDA: 4th National Climate Assessment, Volume ll,
- The institute for Agricultural and Trade Policy: From the Ground Up: The State of the States on Climate Adaptation for Agriculture,
- SARE: Cultivating Climate Resilience on Farms and Ranches,
- SARE: Report of the 2017-2018 New England Adaptation Survey for Vegetable and Fruit Growers,
- USDA: Adaptation Resources for Agriculture – Responding to Climate Variability and Change in the Midwest and Northeast,
- http://www.climateactiontool.org/,
- Massachusetts Climate Action Plans: https://www.mass.gov/topics/climate-action , https://www.mass.gov/files/documents/2017/12/06/Clean%20Energy%20and%20Climate%20Plan%20for%202020.pdf, https://www.mass.gov/service-details/massachusetts-integrated-state-hazard-mitigation-and-climate-adaptation-plan , https://www.mass.gov/municipal-vulnerability-preparedness-mvp-program ,
- NOAA Northeast Fish & Shellfish Vulnerability ,
- Food & Agriculture Organization of the United Nations Impacts of climate change on fisheries and aquaculture ,
- Northeast Climate Adaptation Science Center ,
- The UN Intergovernmental Panel on Climate Change (IPCC),
- MAPC's MAGIC Climate Resilience Plan

SUMMARY OF CONDITIONS AND PREDICTIONS FOR THE NORTHEASTERN US:

Because of their inherent connection to, and dependence on the land, farmers, ranchers, and rural communities will most suffer the consequences of climate change.

- Vegetable and berry farmers are among the most vulnerable to the impacts of severe precipitation and drought due to the intensive soil and crop management strategies that characterize this kind of production.
- Small-scale fishers and small scale aquaculture are particularly vulnerable to climate change as a result of both their geographical location as well as financial situation. Fishing and fishfarming communities are exposed to climate related extreme events and natural hazards such as hurricanes, sea level rise, ocean acidification, floods, and coastal erosion.
- Plant and insect species migration and population growth, and new diseases will compromise crop productivity.
- The climate change impacts which farmers are most concerned about are unpredictable spring temperatures, increased incidence of drought, new pest and disease pressures, and loss of nutrients due to heavy and abundant precipitation.
- Majority of growers believe that they do not have the financial capacity, knowledge or technical skills to deal with the expected level of weather-related threats to the viability of their farm operation.

Increasingly severe and erratic precipitation events pose significant risks to every sector of agricultural production.

- Extreme precipitation events have increased in frequency and severity. The Northeast has already experienced an increase in severe tropical storms and hurricanes compared to other regions and can expect the risk of hazards from them to continue increasing.
- More intense and concentrated precipitation events create wetter soils at those times.
- Severe snow and ice storms currently occur in the Midwest and Northeast.
- Areas of the Northeast are vulnerable to increased flooding due to changes in the frequency or intensity of extreme precipitation events including thunderstorms, tropical storms, and coastal storms.
- The frequency and intensity of flooding and flood damage will increase, especially in winter and spring. Terrestrial connectivity loss (roads and infrastructure) may result.
- Rainfall intensity has increased notably: 71 percent increase in extreme precipitation since the mid-1900s. Total annual precipitation is projected to increase up to 6 inches. Precipitation during winter and spring is expected to increase, while precipitation during summer and fall is expected to decrease. By mid-century, the state can expect to receive greater than 1 inch of rain on an average of up to 10 to 11 days per year, an increase of 4 days from the observed average between 1971 and 2000.
- The Food Plan notes some communities charge farmers stormwater and flood water utility fees, which can range from relatively small for farmland to significant for farm buildings, and can include land eligible for Chapter 61A.

Challenges to human, plant and livestock health growing due to the increased frequency and intensity of high temperature extremes.

- Temperatures have risen across all seasons, growing seasons have become longer, there are more hot days and fewer cold days.

- The number of hot days and hot nights are increasing. Nighttime temperatures have persistently increased during the 20th century.
- Extreme high temperatures (defined as greater than 90 F) and heat waves are also projected to increase.
- The average, maximum, and minimum temperatures in Massachusetts are likely to increase significantly.
- Average annual temperature increase of greater than 6 degrees F and up to 10 degrees F is projected.
- Projected 32 to 64 days per year over 90 (now 10) and 6 to 24 days per year over 100.
- Seasonal temperature increases greatest in winter and summer, least in spring. Winter temperatures are projected to increase at a greater rate than spring, summer, or fall.
- Winter snow cover of 30 days or more only in northern ME, and far northern NH, and VT.

Other temperature related conditions may alter production and/or production practices.

- The length of the frost-free season has increased by 9 to 10 days and it is expected to increase by 18 to 30 days by 2055 and up to 60 days thereafter.
- The number of days per year with daily minimum temperatures below freezing (32°F) is projected to decrease by 19 to 40 days.
- The number of growing degree days is projected to be 23 to 52 percent higher relative to 1971-2000 average.
- 1st bloom dates ½ week earlier.
- plant emergence, pollination, blooming - depends on the synchronous response of diverse organisms. With early blooming and flowering pollinator insects for those plant species may or may not emerge in time to pollinate them.

Marginalized populations living in risk-prone rural areas have a higher propensity for heat related health consequences.

A large amount of agriculture in the Midwest and Northeast is not irrigated, increasing vulnerability of these crops to summer drought and associated economic impacts.

- Increased temperatures and evapotranspiration leading to drier soil conditions between precipitation events. More intense summer water deficits and droughts predicted.
- The number of continuous dry days is projected to increase to nearly 20 days per year at the end of this century, compared to the observed average of 16.64 days per year from 1971 to 2001.
- The eastern half of the state is expected to experience a greater number of consecutive dry days than the western side of the state.

Current weed distributions will likely shift north, changing the mix of weed species on farms and ranches.

- Invasion of about 900 plant species.
- Kudzu and privet are expected to gain a foothold in the Northeast by 2100.

Shifts in insects, and disease infestation, and their range, frequency, and intensity.

- Rising temperatures will increase the disease and pest populations already in Massachusetts, and will lead to a greater diversity of disease and pests as conditions become more habitable. Milder winters will exacerbate these trends, and warmer temperatures will do less to interrupt pest life cycles.
- Spotted wing drosophila became pervasive in Massachusetts and the Northeast generally only after Hurricane Irene in 2011.

Significantly higher concentrations of atmospheric carbon dioxide.

Changing precipitation, temperature and climatic patterns and the melting of snow and ice affect the quantity, quality and seasonality of water resources, leading to inevitable changes in aquatic ecosystems.

- Lower salinity (resulting from ice melt and/or excess precipitation) exacerbates water acidification by diluting the concentration of substances acting as buffers. Acidification is corrosive to calcium carbonate shells and skeletons.
- General degradation of freshwater and marine ecosystems due to flooding and sediment and nutrient loadings.

The rate of sea level rise is projected to increase.

- Along the Boston coast, sea level rise is expected to reach 2.4 feet by 2050 and 7.6 feet by 2100 under a high scenario.
- Similar relative mean sea level and future scenarios at Woods Hole, and Nantucket.

Federal fishing quotas let commercial fishermen from the south catch more black sea bass and other previously southern species in northern waters than local fishers are allowed, because they registered in southern ports where the fisheries were concentrated decades ago when the federal quotas were set. They must unload their haul in their legal home ports.

ANTICIPATED IMPACTS OF PROJECTED CLIMATE CHANGE (and Justification)

Reduced Agricultural Productivity

- Higher temperatures will lead to higher frequency of droughts, lower crop yield, depletion of surface and groundwater resources, increased risk of wildfires, and overall lower soil health.
- Floods may render crops unsuitable for market, delay planting, and damage young plants. They may also increase risks of soil compaction from using heavy equipment on wet soils.
- Increased frequency of soil moisture stress (wet and dry) suppresses crop yields.
  Although plants have evolved many effective responses to maintain growth and development under conditions of variable soil water, many have critical growth phases during which too much or too little water can cause irreversible damage that greatly reduces crop quality and yield. Critical periods can be as little as days or hours.
- Floods increase the risk of transport of sediment, nutrients, and pesticides, and contamination of agricultural fields with pollutants carried from upstream sources.
- Severe wind and storm hazards/damage may increase. -Thunderstorms, tornadoes, hail, lightning, strong winds.
- Without a cooling off period at night, animals become more subject to heat stress, especially when coupled with higher relative humidity. Livestock can acclimate to gradually changing temperatures, but long periods of temperature extremes or extreme or rapid fluctuations in temperature will reduce productivity and can sometimes result in death.
- High nighttime temperatures can adversely affect plant biomass accumulation, crop yields, and quality.
- High temperatures reduce the quality and yield of annual crops and tree fruits.
  For most crops, growth and development is more rapid as temperatures increase, but only until the upper limit of the optimum range.
- Earlier spring thaws can be detrimental to fruit production if early bud development increases exposure to late spring frosts.
- Populations of many damaging insects increase.
  - Insects that overwinter in the Northeast, such as corn earworm, flea beetle, and the spotted-wing Drosophila, are already present at higher levels earlier in the season and this trend is expected to continue.
  - Shorter winters bring an earlier arrival of migratory insects, allowing more generations of pests to develop within a season.
- Management of insect pests will almost certainly become more challenging and costly as pest populations increase, generation times decrease and ranges expand northward.
- With unpredictable temperatures and varying water availability, weed management will become more difficult, especially in seasons that become warmer and wetter, because weed growth will speed up while the period in which soil conditions permit cultivation will become narrower and more variable.
- Herbicides may also become less reliable because increasing atmospheric CO_2 levels have varying effects on herbicide efficacy. Longer growing seasons have made weed management more difficult.
- Disease management is likely to become more difficult and costly. Changes in seasonal weather patterns, more extreme weather events and increasing atmospheric CO_2 levels are likely to cause changes in the timing, spread and ability of disease organisms to cause infection.

- The risk of plant pathogens rise. Increased temperature can increase pathogen survival over winter, can increase the period of infectivity, allow for more infection cycles in season, and result in pathogen populations expanding into new areas.
  - Stewart's wilt is a bacterial disease that can devastate sweet corn crops; cold winters can keep the disease in check, but the projections for generally warmer winters suggest there will be more outbreaks of Stewart's wilt in the future.
  - Sooty blotch, a fungal disease that affects apples has become more prevalent in Massachusetts. Conventionally a summer disease common only in southern states, Massachusetts' warmer, more humid weather is now creating conditions favorable for this disease's proliferation.
- The introduction of new crops and livestock that can better deal with climate risk may also have the unintended consequence of increasing the risk of introducing new diseases, and may create new opportunities for existing diseases as well.
- The risk of pressure from pathogens and parasites of livestock may rise. Earlier springs and warmer winters may allow for greater proliferation and survivability of animal pathogens, parasites, and disease vectors. Hotter weather has the potential to increase the incidence of several health issues affecting dairy cows or increase the potential of toxin-producing fungi in forage. Bacterial tick born-illnesses do better under warmer conditions. Will incidents of illness increase?
- Regional warming and variability in seasonal rainfall patterns may change the spatial and temporal distribution of livestock diseases sensitive to temperature and moisture, such as anthrax, blackleg, and hemorrhagic septicemia, as well as increased incidence of ketosis, mastitis and lameness in dairy cattle.
- Reduced efficacy of existing cultural and biological pest-management strategies. Changing seasonal weather patterns have disrupted the synchrony between pest and control agent. In theory, if predator and prey respond to different cues—one to changing temperatures, the other to changing day length, for example—then the chance of a mismatch is high. If the predator is a specialist, then there is a greater chance that a timing mismatch will reduce predator populations. Agricultural scientists expect that these sorts of mismatches in agricultural crops will grow more common in the future.

Earlier spring thaws and later first frosts in autumn could result in greater growth and productivity, but only if temperatures do not exceed upper limits for growth, there is enough water (and not too much), and nutrients, and disease and pathogens are not constraints.

Degradation of Soil and Water Resources Soil and Water Resources.

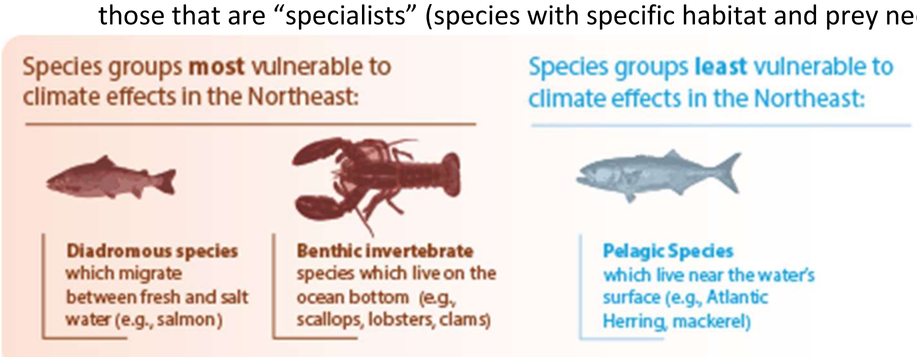
- Soil health and the quantity and quality of water resources are extremely sensitive to climatic changes.
- Climate change will increase the frequency of extreme precipitation events which in turn will lead to further soil erosion on working farmlands (wind and water erosion).
- As more variable precipitation narrows the window for time-sensitive fieldwork such as planting, cultivating and harvesting, the risk of soil degradation increases because producers may be forced to carry out operations when the soil is too wet or too dry.
- Along with the potential to degrade soil health, longer growing seasons and warmer winters also increase the potential for soil nutrient losses by extending active nutrient cycling by soil microorganisms into the winter months.
- Droughts affect water supplies, resulting in water use restrictions in metropolitan areas and may result in competition of limited water resources by urban and agricultural users.

Higher concentrations of atmospheric carbon dioxide may disproportionately benefit plant species.

- More than 95 percent of the world's plant species assimilate carbon dioxide from the atmosphere using the C3 pathway, while the rest use the C4 pathway. C4 category includes sugarcane and corn.
- Under elevated carbon dioxide concentrations, C3 plants are often better able to increase production in response to additional carbon dioxide than C4 plants.
- Competition from weeds and invasive plant species may increase.
  Complex interactions between elevated carbon dioxide, higher temperatures, and altered precipitation may influence the success of weedy and invasive plant species within plant communities

Species productivity and fish growth are already changing with consequences for fishing and fishfarming yields.

- Large nutrient-rich sediment loadings, coupled with global warming has caused increases in the duration, intensity, and extent of hypoxia (low-oxygen conditions) in coastal and freshwater systems over the past century.
- Warming reduces the solubility of oxygen in water. There have been widespread decreases in oxygen concentrations in coastal waters since the 1960s.
- The presence and expansion of low oxygen in the water column reduces vertical migration depths for some species (e.g. tunas and billfishes), compressing vertical habitat and potentially shoaling distributions of fishery species and their prey.
- For freshwater systems, an increase of water temperature is expected to occur in most areas, as a result of an increase of air temperature.
- Shifts in the distribution of fish, alteration of larval transport, or thermal tolerance of farmed fish.
- Operations of fishing and fishfarming activities affected by short-term events such as extreme weather events or medium to long-term changes such as lake levels or river flow that could affect the safety and working conditions of fishers and fishfarmers.
- Food control procedures will undergo major reshaping to protect consumers from potential increase in contaminants and toxin levels resulting from changes in water conditions.
- Approximately half of the 82 species assessed are estimated to have a high or very high vulnerability to climate change in the region including species like sea scallops, lobster, and winter flounder.
- In general, diadromous fish and benthic invertebrate species are predicted to be more vulnerable to climate effects in the ecosystem, and pelagic species are predicted to be the less vulnerable. The method tends to categorize species that are "generalists" as less sensitive to climate change than are those that are "specialists" (species with specific habitat and prey needs).



See: https://www.st.nmfs.noaa.gov/ecosystems/climate/northeast-fish-and-shellfish-climate-vulnerability/index

- Atlantic Sea Scallop fishery yields are projected to decrease in the coming decades owing to the effects of ocean acidification.
- Consistent negative impacts of ocean acidification on mollusc larvae. This should be interpreted cautiously, and highlights the need for more research on species specific impacts of ocean acidification.
- Some species may respond positively to projected climate-related changes, such as Atlantic croaker, spot, and black sea bass, among others.

Changes in the selection of perennial crop species and varieties, livestock species and breeds, engineering design criteria for livestock building construction, and energy supply.

GENERAL ADAPTATION STRATAGIES

Managing for persistence - generally focuses on maintaining the current system by reducing the climate change impacts that are pushing it in an unproductive direction. This includes actions to increase the resistance of a system to change, as well as actions that increase its resilience (i.e., ability to bounce back) from disruptions.

Managing for change - moves activities toward the new conditions created by climate change. Managing for change can range from small changes such as trying out new crop or livestock species that are better suited to warmer climates, to major changes that fundamentally transform operations.

Managing for persistence and for change are not mutually exclusive ideas. Any enterprise may do some of both.

One form of adaptive management that producers can use is whole-business planning. Managing an operation to enhance adaptive capacity or resiliency is complex. It requires making strategic management decisions that take into account many factors, some relatively simple and stable, and many others that are complex or can change rapidly. When faced with such challenging conditions, adaptive management has proven to be a useful tool. A key strategy in whole-business planning is to regularly monitor production system conditions in order to evaluate and modify management actions to meet sustainability and resilience goals.

Many producers say the record-keeping required for effective monitoring is a barrier to adopting the management strategy; however, in recent years, new record-keeping tools that use smartphones and other digital technologies have made record-keeping easier, and whole-farm planning is a key feature of many beginning-farmer training programs.

Key sustainable agriculture principles that have proven useful in managing production risks created by weather variability and extremes include an emphasis on soil health, diversified production systems, ecological design and diversified, high-value marketing.

- Healthy soils buffer the farm or ranch from the increased variability and extremes in precipitation that currently challenge farmers and ranchers throughout the country.
- Diversified production systems build soil health and spread climate risks through the growing season, reducing potential losses from any single weather event.
- Ecological design reduces climate risk by creating production systems that are well adapted to the local landscape and climate. Ecological design also enhances ecosystem services that buffer production from weather-related disturbances and reduce costs.
- Diversified, high-value marketing spreads climate risks across multiple markets, improves profitability and produces social capital, all of which enhance capacity to respond to challenging climate conditions and to recover from climate-related damages.

Adaptive management strategies like whole-farm/whole business planning are likely to become more important as climate risk adds increasing uncertainties and complexities to the challenges of managing agricultural and fishing businesses.

MID LEVEL ADAPTATION STRATEGIES

Sustain fundamental functions of soil and water.

- Maintain and improve soil health.
- Protect water quality.
- Match practices to water supply and demand.

Reduce existing stressors of crops and livestock.

- Reduce the impacts of pests and pathogens on crops.
- Reduce competition from weedy and invasive species. Monitoring weed populations and the efficacy of weed- management efforts will also become important under changing weather conditions.
- Maintain livestock health and performance.

Reduce risks from warmer and drier conditions.

- Adjust the timing or location of on-farm activities.
- Manage crops to cope with warmer and drier conditions.
- Manage livestock to cope with warmer and drier conditions.
- Reduce the risk and long-term impacts of extreme weather.
- Reduce peak flow, runoff velocity, and soil erosion.
- Reduce severity or extent of water-saturated soil and flood damage.
- Reduce severity or extent of wind damage to soils and crops.

Manage farms and fields as part of a larger landscape.

- Maintain or restore natural ecosystems.
- Promote biological diversity across the landscape.
- Enhance landscape connectivity.
- Alter management to accommodate expected future conditions.
- Diversify crop or livestock species, varieties or breeds, or products.
- Diversify existing systems with new combinations of varieties or breeds.
- Switch to commodities expected to be better suited to future conditions.

Alter agricultural systems or lands to new climate conditions.

- Minimize potential impacts following disturbance.
- Realign severely altered systems toward future conditions.
- Alter lands in agricultural production.

Alter infrastructure to match new and expected conditions.

- Expand or improve water systems to match water demand and supply.
- Use structures to increase environmental control for plant crops.
- Improve or develop structures to reduce animal heat stress.
- Match infrastructure and equipment to new and expected conditions.

Soil building.

- The use of cover crops, reduced tillage, incorporating residues, and other organic matter sources.
- Hugelkulture.
- Low and no till. Mulching with organic materials or with plastic mulch.

Identified need: how to use low and no till practices for: vegetables and within organic systems, consistent soil cover to limit the evaporation of moisture from bare soil and permanent bed systems with mown paths.

Holding some critical resources in reserve.

Key to the recovery capacity. These reserves can be natural (feed and forage, soil health, biodiversity), human (management experience, ease with loss and change), social (community support, knowledge, skills, public assistance), financial (insurance and disaster payments, savings, access to capital) or physical (backup and alternative energy sources, storage, shelf-stable products). Resilient farms and ranches accumulate reserves across the full range of resources under management.

ADAPTIVE STRATEGIES FOR PRECIPITATION EXTREMES

Adaptive management strategies for heavy precipitation and flooding highlight the use of raised beds, investments in storm water management, adjusted locations of crops based on site and soil characteristics, new high tunnels, perennial plants, reduced tillage, and soil building.

- Cover crops and soil heath strategies to manage for the risks of heavy precipitation (and drought).
- Understanding of the flow of water on a site and using a whole systems perspective on farm planning informs long-term adaptation to heavy precipitation (and drought).
- Storm water management: new or deepened ditches to control the flow of water across the site. Increased or new drainage strategies to improve water infiltration and flow through their soils, such as deep tillage and specifically using subsoil plow implements in wheel tracks to counter soil compaction and allow water infiltration between raised beds. Other: swales, terraces, berms, trenches or pond systems to slow, control and catch water movement.
- Site planning for heavy soil and flood risks: transitioning flood prone fields and heavy soils to perennial plants, pasture, reduced tillage or permanent cover crops. Planting lower value crops, short duration crops or “vegetables that tolerate poor drainage in the sections of our fields that flood.”
- Raised or permanent beds. Raised beds one of the most highly reported changes that farmers made in response to an experience with heavy precipitation or flooding.
- Protection: Adopting mulch or reduced tillage to protect soil from heavy precipitation or flooding risks. Uncultivated “idle strips” or sod between plots and beds to protect soil from erosion.
- Investing in high tunnels, greenhouses, hoop houses and caterpillar tunnels to protect plants and soil from rain and moisture. This strategy has tradeoffs, in terms of investment costs and irrigation needs, but offers additional protection from cold weather.

- Soil health. Improving soil characteristics primarily though using cover crops, incorporating organic matter and keeping the soil covered. Reduced and no-till strategies. Keyline plowing, or subsoiling on contour to increase water infiltration into soil and slow erosion. Perennial plantings, both as primary crops and as perennial borders or buffers around fields especially planted in areas which would have left annuals more vulnerable, such as on slopes and areas prone to more moisture or flooding.
- Agroforestry and the inclusion of more trees and deep-rooted perennials. "intersperse rows of perennial and nursery crops with annuals. "
- Crop planning. multiple plantings, alley cropping, strip cropping, and "planned succession in case of failures."
- Crop timing. From general planting date changes to very precise planting dates based on the locations of beds. This included later planting dates due to wet soils, cooler wetter weather, and flood risk. Some crops are also being planted early when grown under protection of hoop houses.
- Plant selection. changing crops and diversifying crops, and interest in species and cultivars that are more tolerant of extreme weather conditions and excess moisture.
- Crops that are native, moisture tolerant, and even "suitable for heavy rains" are increasingly considered.
- Reduce crops that "expose bare ground for too long, such as potatoes," and add crops that consume a lot of water.

Adaptive management strategies for drought highlight the importance of water harvesting, efficient irrigation systems, mulch, soil health, reduced tillage, and crop planning.

- Systems level water planning: Taking a bigger picture perspective on farm landscape and water flows with the goal of understanding how to make sure water was conserved and available when needed.
- Paying attention to soils and contours and using them to manage water availability on site with both passive water delivery systems and pump powered irrigation systems.
- Drought tolerant plants. Selecting drought tolerant crops as a promising Often used strategically in more drought prone climates where growers use conservation irrigation strategies to train roots to go deep for water.
- Save seed and select for locally adapted varieties
- Diversity of cultivars and crops as insurance against extreme weather and drought.
- Water source development. Growers reported investing in additional water sources, including additional on-farm wells and retention ponds. Infrastructure to access water from existing ponds, nearby springs, rivers and waterways.
- Water harvesting. Collection using roofs, gutters, rain barrels, swales, ditches. System for collecting dew and atmospheric moisture.
- Water storage and access. Investing in increasing their water storage capacity and placing it in new locations around the farm or near fields. In addition to ponds, water storage containers mentioned by farmers included tanks and cisterns.
- Improved water delivery systems. New, updated and expanded irrigation systems; importance of water conservation and streamlined irrigation systems for time efficiency.
- The creation of shade to conserve water, both in the practice of setting up large shade cloths over plants, or planting more trees into the landscape strategically.
- Question: how can wash and pack areas could use water more efficiently and recycle water?

MITIGATION:

Greenhouse gas mitigation presents opportunities for agriculture to sequester more carbon in healthy soils, which regulate water and nutrient cycling, buffer against adverse impacts such as erosion, and ultimately increase plant biomass production. Greenhouse gas mitigation is a necessary component of an integrated climate change response sometimes referred to as climate smart agriculture. It can help to reduce the amount of adaptation needed in the future by reducing the degree to which greenhouse gases disrupt the climate system.

Solar

Wind

Bio-mass

Anaerobic Digestion

Carbon Sequestration

Composting

RESOURCES

The Massachusetts Climate Adaptation Partnership http://www.climateactiontool.org/ and U-Mass/The Department of Interior's Northeast Climate Adaptation Science Center (NE CASC) https://necsc.umass.edu/

Farm Viability Enhancement Program (FVEP), the APR Improvement Program (AIP), and the Matching Enterprise for Agriculture (MEGA) Program – provide business planning, technical assistance, and grants to help improve the productivity and profitability of Massachusetts farms.

Solar Massachusetts Target (SMART) Program	Massachusetts Department of Energy Resources	
Agricultural Business Training Program	Business Training	MDAR
Agricultural Best Management Practices	Informational	MDAR
MA Farm Energy Program:	Technical Resources, Informational	MFEP
Incentives for Energy Efficiency	Rebate	MFEP
Net Metering		DPU
Solar Renewable Energy Certifications: RPS Solar Carve Out		DOER
Farm Energy Discount Program Discount	Discount	MDAR
Dairy Farmer Tax Credit Program	Tax Credit	MDAR
Farm Viability Enhancement Program	Business Planning/covenant/grant	MDAR
Agricultural Energy Grant Program	Grants	EEA
Agricultural Composting Program	Technical Assistance	MDAR
Ag. Environmental Enhancement Program	Reimbursement Grant	MDAR
APR Improvement Program	Grant	MDAR
Farm Energy Best Management Practices	Informational Documents	MFEP
MFEP Custom Audits	energy audit	MFEP
MFEP renewable Energy Assessments	Energy Assessments	MFEP
Farm Technology Review Commission	Informational	MDAR
Ag. Climate Resiliency & Efficiencies (ACRE) Program	Reimbursement Grant	MDAR
Agriculture Preservation Restriction (APR) Program	Payment for Deed Restriction	MDAR
Introduced Pests Outreach Project	Educational	MDAR, UMass Ext.
Matching Enterprise Grants for Agriculture (MEGA)	Grants	MDAR
MassCleanDiesel Clean Markets Program	Grants	MDEP

Commonwealth Organics-to-Energy	feasibility studies, implementation grants, technical assistance	MassCEC

Residential Renewable Energy Income Tax Credit

Renewable Energy Equipment Sales Tax Exemption

Renewable Energy Property Tax Exemption

Excise Tax Exemption for Solar or Wind Powered Systems

Excise Tax Deduction for Solar or Wind Powered Systems

Alternative Energy and Energy Conservation Patent Income Tax Deduction (Corporate)

Alternative Energy and Energy Conservation Patent Income Tax Deduction (Personal)

Renewable Energy Trust Fund

Holyoke Gas & Electric - Residential Energy Conservation Loan Program

Holyoke Gas & Electric - Commercial Energy Conservation Loan Program

Wakefield Municipal Gas & Light Department - Residential Conservation Services Program

Chicopee Electric Light Department - Residential Energy Efficiency Rebate Program

Concord Municipal Light Plant - Residential Energy Efficiency Rebate Program

Concord Municipal Light Plant - Commercial Energy Efficiency Rebate Program

Federal programs:

USDA - RMA (crop and farm income insurance)

FSA - NAP non insured crop disaster assistance program

FSA- ARC/PLC (Agriculture Risk Coverage & Price Loss Coverage)

FSA - CRP (Conservation Reserve Program)

FSA - BCAP (Biomass Crop Assistance Program)

FSA - ECP/ EFRP (Emergency Conservation Program & Emergency Forest Restoration Program)

FSA - ELAP (Emergency Assistance for Livestock, Honey Bees, and Farm-raised Fish)

FSA – LFP (Livestock Forage Program)

FSA – LIP (Livestock Indemnity Program)

FSA - TAP (Tree Assistance Program)

NRCS- AMA (Ag Management Assistance)

NRCS - CTA (Conservation Technical Assistance)

NRCS - ACEP (Agricultural Conservation Easement Program)

NRCS- HFRP (Healthy Forest Reserve Program)

NRCS - EWP (Emergency Watershed Protection Program)

NRCS- CSP (Conservation Stewardship Program)

NRCS – EQUIP (Environmental Quality Incentives Program)

Rural Development - REAP (Rural Energy for America Program Renewable Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants)