

A Summary of Climate Change Impacts and Preparedness Opportunities for the Agricultural Sector in New Jersey

This report is one of a series of working briefs prepared by the New Jersey Climate Adaptation Alliance to provide background information on projected climate impacts for six major sectors in New Jersey, including agriculture, built infrastructure (utilities and transportation), coastal communities, natural resources, public health, and water resources. These working briefs present information to be used throughout the Alliance's deliberations to develop recommendations for state and local public policy that will enhance climate change preparedness and resilience in New Jersey. These briefs are living documents that are periodically updated. This document updates a prior version from January 2013. For more information about the Alliance and its activities, visit <http://njadapt.rutgers.edu>.

This report provides an assessment of agriculture-based perspectives, including farms, nurseries and fisheries, on the topic of adaptation planning for climate change in New Jersey. Current New Jersey efforts as well as current and planned adaptation practices and strategies in other states are presented as the basis for a series of recommendations which serve as a starting point for discussion and prioritization of comprehensive adaptation planning for New Jersey.

Agriculture in New Jersey

The agricultural community in New Jersey consists of farmers, service providers, regulators and other organizations responsible for growing crops, livestock, and nursery plantings. In addition, the agricultural community considered here will also include those entities involved in aquaculture (e.g. shellfish growing and harvesting) and commercial fishing. Additional agencies supporting agriculture in the state include those agencies that are responsible for the optimal use

and preservation of farmland. Each stakeholder group has a unique perspective on climate change adaptation and the policies that could be set forth to improve preparedness in New Jersey.

Traditional agricultural products in New Jersey include crops that are farmed for commercial sale, such as tomatoes sold at a farmer's market or grain sold to a feed mill. Farmers produce more than 100 different kinds of fruits and vegetables. New Jersey ranks among the top ten states for production of blueberries, cranberries, peaches, tomatoes, bell peppers, snap beans, cucumbers, spinach, and squash.¹ In 2012, 10,300 farms generated cash receipts totaling \$1.12 billion, with the nursery/greenhouse/sod industry generating cash receipts of \$453.6 million. Cash receipts for fruits and vegetables totaled \$428.8 million, followed by field crops with \$112.2 million. Equine brought in \$46 million, while the sale of poultry and eggs generated \$30.7 million. Dairy industry sales were valued at \$27.5 million.² In addition, growers produced hundreds of thousands of dollars of specialty crops, including the state's 46 vintners. Fish and seafood are also a valuable commodity adding another \$211.7 million to the value of agriculture in New Jersey.³

Farms in New Jersey cover 800,000 acres in fertile areas such as the Wallkill and Delaware Valleys, the Highlands region, and the Pinelands bogs. Agricultural practices are governed by a number of state agencies in New Jersey. The New Jersey Department of Agriculture's (NJDA) Division of Agricultural and Natural Resources (DANR) is responsible for a variety of services and programs for agriculture and related agribusinesses. The DANR also coordinates between various state and federal agencies and provides assistance in the development of policy positions on land use planning issues on the State Planning Commission. It administers programs to conserve soil, water and related natural resources

¹ NJDA (2012)

² NJDA (2012)

³ NJDA (2012)

through the State Soil Conservation Committee and the 15 local soil conservation districts, and provides and oversees the administration of financial cost-share assistance to farmers for soil and water conservation projects. Federal agency involvement includes the United States Department of Agriculture and United States Environmental Protection Agency (USEPA), while additional support and regulation at the state level is provided by the New Jersey Department of Environmental Protection (NJDEP), particularly for management of water quality and resources.

Fisheries off the coasts of New Jersey are regulated under the National Marine Fisheries Service through the Mid-Atlantic Fishery Management Council. The council, along with NJDEP and NJDA are responsible for managing different aspects of the fisheries population, habitat, commercial fleet operations, and other aspects. The NJDEP also works to protect habitats for aquatic species, in conjunction with regional and federal fisheries management agencies and the USEPA.

Aquaculture is viewed and regulated as an agricultural pursuit, as opposed to a natural resource in the way wild fisheries are managed. The NJDA is the lead state agency responsible for aquaculture. In 2004, the NJDA initiated the New Jersey Aquatic Farmer License (AFL) program. The NJDEP is responsible for the leasing of shellfisheries and permitting for aquaculture operations along the New Jersey coast in conformance with the Coastal Zone Management Program. The New Jersey Department of Health is responsible for guidance for processors, along with the NJDEP who jointly monitor shellfisheries for food safety. Federal oversight and support for aquaculture comes from the USDA through various sources such as the Conservation Loans, Beginning Farmers Loans, or other funding vehicles.

Potential Sector Impacts

Weather and climate factors such as temperature, precipitation, CO₂ concentrations, and water availability directly impact the health and well-being of plants,

pasture, rangeland, livestock and fisheries. Climate affects variation in yield, insects, disease, and weeds, which in turn affect agricultural production. Farmers in the Northeast may face increasing uncertainty and risk as they attempt to adapt to the effects of climate change relate to:

1. Warming temperatures and drought
2. Extreme weather events and flooding
3. Sea level rise
4. Increasing Carbon Dioxide (CO₂)

Warming Temperatures and Drought

Warming temperatures will have significant effects on the agriculture sector. Impacts from climate change for crops include decreasing yield, obsolescence of certain varieties, and increased needs for both land conservation and water management strategies. For livestock, decreases in production and yield are also expected. A predicted increase in pests and insects, as well as the migration of invasive plant species, will threaten both crops and livestock.

Temperature increases will cause the optimum latitude for crops to move northward. Where plants can be efficiently grown depends upon climate conditions, of which temperature is one of the major factors.⁴ Higher temperatures will mean a longer growing season for crops that do well in the heat, such as melon, okra, and sweet potato, but a shorter growing season for crops more suited to cooler conditions, such as potato, lettuce, broccoli, and spinach. Parts of the Northeast are projected to become unsuitable for growing certain popular varieties of apples, blueberries, and cranberries by late this century, since these plants require long winter-chill periods to produce fruit.⁵ Warming temperature may affect the maturity and yield of certain crops. Exposure to high temperatures during the grain, fiber, or fruit production period leads to lower productivity and decreased quality.⁶ Shifts in plant productivity and type will likely also have significant impact on livestock operations as a foraging input

⁴ USGCRP (2009)

⁵ Frumhoff et al. (2007)

⁶ USGCRP (2013)

for feeding livestock.⁷ Higher temperatures also cause plants to use more water to keep cool.⁸ A longer growing season may allow farmers to experiment with new crops, but many traditional farm operations in the region will become unsustainable without adaptation strategies that could be quite costly.⁹

Temperature extremes will also pose problems. Even crop species that are well-adapted to heat, such as tomatoes, can have reduced yield and/ or quality when daytime maximum temperatures exceed 90° F for even short periods during critical reproductive stages. For many high-value crops, just hours or days of moderate heat stress at critical growth stages can reduce grower profits by negatively affecting visual or flavor quality, even when total yield is not reduced.¹⁰

Weeds, diseases, and insect pests benefit from warming, and weeds also benefit from a higher carbon dioxide concentration, increasing stress on crop plants and requiring more attention to pest and weed control. One concern with continued warming is the northward expansion of invasive weeds, such as kudzu. Controlling weeds currently costs the United States more than \$11 billion a year, with the majority spent on herbicides. As temperatures and carbon dioxide levels rise, higher concentrations and more frequent spraying of herbicides will be needed, increasing economic and environmental costs associated with chemical use.¹¹ Many insect pests and crop diseases thrive due to warming, increasing losses and necessitating greater pesticide use. Warming aids insects and diseases in several ways. Rising temperatures allow both insects and pathogens to expand their ranges northward. In addition, rapidly rising winter temperatures allow more insects to survive over the winter, whereas cold winters once controlled their populations.¹²

Higher temperatures will very likely reduce livestock production during the summer season, but these losses

may be partially offset by warmer temperatures during the winter season. For ruminants, current management systems generally do not provide shelter to buffer the adverse effects of changing climate; such protection is more frequently available for non-ruminants (e.g., swine and poultry).¹³ Disease pressure on domestic animals will likely increase with earlier springs and warmer winters, which will allow proliferation and higher survival rates of pathogens and parasites. Regional variation in warming and changes in rainfall will also affect spatial and temporal distribution of disease.¹⁴

Regarding aquaculture and fisheries, the distribution of marine fish and plankton are predominantly determined by climate, so marine species in U.S. waters are moving northward and the timing of plankton blooms is shifting. Commercial fishermen and researchers have already observed shifting distributions of fish and invertebrates as ocean temperatures change.¹⁵ Warm surface waters are also pushing some fish towards deeper waters.¹⁶ Species that were previously unable to establish populations because of cold winters are likely to find the warmer conditions more welcoming and gain a foothold, particularly as native species are under stress from climate change and other human activities. Intense human uses have taken a toll on coastal environments and their resources. Many fish stocks have been severely diminished by over-fishing and large “dead zones” depleted of oxygen have developed as a result of pollution by excess nitrogen runoff. Coastal dead zones in places such as the northern Gulf of Mexico and the Chesapeake Bay are likely to increase in size and intensity as warming increases, unless efforts to control runoff of agricultural fertilizers are redoubled.¹⁷

Drought frequency and severity are projected to increase in the future over much of the United States, making irrigation essential for most high-value crops. Increased drought will be occurring at a time when

⁷ Hatfield et al. (2008)

⁸ USGCRP (2009)

⁹ Frumhoff et al. (2007)

¹⁰ USGCRP (2009)

¹¹ USGCRP (2009)

¹² USGCRP (2009)

¹³ Hatfield et al. (2008)

¹⁴ Hatfield et al. (2008)

¹⁵ Pinsky et al (2013)

¹⁶ USGCRP (2013)

¹⁷ USGCRP (2009)

crop water requirements also are increasing due to rising temperatures. Water deficits are detrimental for all crops.¹⁸ An increase in dry spells, heat waves, and sustained droughts could result in major impacts on crop and livestock growth and productivity.¹⁹

Extreme Weather Events and Flooding

Extreme weather events may cause destruction and degradation of farmland and aquaculture habitats. Extreme events such as hurricanes and heavy downpours reduce crop yields because excesses of water have negative impacts on plant growth. Additional consequences of excessive rainfall include crop damage (also caused by wind), delayed spring planting, field flooding, increased susceptibility to root diseases, and increased soil compaction due to the use of heavy farm equipment on wet soils. In spring 2008, heavy rains caused the Mississippi River to rise to about 7 feet above flood stage, inundating hundreds of thousands of acres of cropland, with agricultural losses estimated around \$8 billion.²⁰

Extreme events impact fisheries as well. Greater spring runoff into East Coast estuaries and the Gulf of Mexico would flush more nitrogen into coastal waters stimulating harmful blooms of algae and the excess production of microscopic plants that settle near the seafloor and deplete oxygen supplies as they decompose. More extreme weather events, including intense rainfall, floods, and tropical storms will also alter freshwater flows into estuaries and lagoons, affecting salinity.²¹ These changes are likely to affect the composition and distribution of important commercial fisheries and aquaculture.

Sea Level Rise

Sea level rise may damage bivalve habitat as salt water reaches farther up estuaries and alters salinity levels, a

problem compounded by the reduced flow of freshwater streams. The intrusion of salt water into coastal aquifers may diminish the availability of freshwater at the same time that warming temperatures are generating a greater demand for irrigation and human consumption.²² Additionally, a rising sea level will increase the base for storm surges,²³ elevating the risk of saltwater inundation of agricultural areas near the coast during flood events. Dehydration and salinity decrease the productivity of agricultural crops.²⁴

Increasing Atmospheric Carbon Dioxide (CO₂) Concentrations

Increasing atmospheric carbon dioxide (CO₂) concentrations affects both terrestrial agricultural harvests and marine fisheries. Terrestrial agriculture is affected by weeds, as most weeds respond more positively to increasing CO₂ than most cash crops, particularly “invasive” weeds. Recent research also suggests that glyphosate, the most widely used herbicide in the U.S., loses some of its efficacy on weeds growing at the increased CO₂ levels likely in the coming decades.²⁵

Increasing CO₂ also causes the acidification of the ocean. When carbon dioxide reacts with water to produce carbonic acid, the increased ocean acidity reduces the availability of carbonate, making it more difficult for organisms to build their shells. The process damages oyster and mussel populations as well as phytoplankton and zooplankton. Many of the organisms affected are either at the base of the food chain or provide critical habitat for other forms of marine life.²⁶

Particularly Vulnerable Groups

Increased agricultural productivity will be required in the future to supply the needs of an increasing population.

¹⁸ USGCRP (2009)

¹⁹ USGCRP (2013)

²⁰ USGCRP (2009)

²¹ USGCRP (2009)

²² Frumhoff (2007)

²³ Broccoli et al. (2013)

²⁴ Pitman (2002)

²⁵ USGCRP (2013)

²⁶ Hoegh-Guldberg and Bruno (2010)

Table 1: New Jersey Impacts and Risk for Water Resources as a result of climate change

<i>Climate Impacts</i>	<i>New Jersey Risks</i>
Warming Temperatures	<ul style="list-style-type: none"> • Unsuitable conditions for some crops such as blueberries and cranberries • Higher operational costs due to irrigation and pest management • Decreased milk production in livestock • Shift in distribution of commercial fish stocks • Ocean acidification
Extreme Weather Events and Sea Level Rise	<ul style="list-style-type: none"> • Inundation and periodic flooding of farmland and habitat • Decrease in crop quality
Increasing Atmospheric Carbon Dioxide Concentrations	<ul style="list-style-type: none"> • Damages to shellfish and estuarine environments from ocean acidification
Drought	<ul style="list-style-type: none"> • Decline in water availability requiring alterations to irrigation practices.

Throughout history, agricultural enterprises have coped with changes in climate through changes in management and in crop or animal selection. However, projected climate changes are likely to increasingly challenge U.S. capacity to as efficiently produce food, feed, fuel, and livestock products.²⁷ Given the potential effects of climate change on agriculture, certain disadvantaged groups have been identified as at risk communities.²⁸ These groups include:

- Farmers specializing in cool-season crops or distinct crop varieties
- Smaller farms with less capital to invest in experimenting with new crop varieties or equipment

New Jersey Specific Impacts

The agricultural sector is likely to experience uneven impacts throughout the country. Initial economic gains from altered growing conditions will likely be lost as temperatures continue to rise. Regional droughts, summer water shortages, excess winter precipitation,

and spread of pest and diseases will negatively impact agriculture in most regions.²⁹

Warming Temperatures

An extended frost-free period may benefit peach, melon, and pepper farmers, whose crop requires a long growing season. But increases in the frequency of short-term drought, along with warmer temperatures, could necessitate increased irrigation and operational costs. Moreover, northern blueberries and cranberries require long periods of winter chill for optimum flowering and fruit development.³⁰ Many of these at risk crops, including blueberries and cranberries, are substantial portions of the New Jersey agricultural economy. While berries in New Jersey still meet chilling requirements, the Rutgers Philip E. Marucci Center for Blueberry and Cranberry Research is monitoring these temperatures in addition to the effects of heat stress on the crop.³¹ Research efforts are also underway to mitigate risks due to temperature fluctuation, including the development of heat tolerant cranberry cultivars, and developing a better understanding of responses to heat stress to identify crop management decisions.³²

²⁷ USGCRP (2009)

²⁸ NYSERDA ClimAID Team (2010)

²⁹ CIER (2008)

³⁰ USGCRP (2009)

³¹ Vorsa (2012)

³² Xu et al. (2012)

Increasing summer temperatures and heat stress are expected to depress the yields of a number of other economically important crops adapted to cooler conditions (e.g., spinach, lettuce) by mid-century, while rising winter temperatures are expected to drive the continued northward expansion of agricultural pests and weeds (such as kudzu). This would further impede crop production and potentially pressure farmers to increase their herbicide and pesticide use.

Additional economic losses in the agriculture sector likely will result from decreased dairy production. When temperatures exceed 75° F, dairy cows produce less milk as their bodies work to stay cool. Researchers predict that milk production across much of the region could decline 5 to 20 percent in certain months. A 10 percent loss in milk production by 2100 was estimated to translate to a \$3.3 million loss for New Jersey.³³

Warming waters have contributed to a dramatic reduction in landings of surf clams from waters off the Jersey shore,³⁴ which represent one of New Jersey's most valuable fisheries. Shifts in other marine species have also been observed as ocean temperatures warm.³⁵

Extreme Weather Events and Flooding

Extreme weather events such as hurricanes, heavy precipitation events, and other strong storms can have significant impacts on terrestrial and marine habitats. During Hurricane Sandy, several farms had crops flooded or blown down, and had their planting or harvesting schedules altered.³⁶ After the storm, shellfish gathering was off-limits throughout the Garden State for several months because of elevated bacterial and viral levels in coastal waterways.³⁷ The NJDEP conducted an assessment of the economic impacts of Sandy to the fishing and aquaculture industries with assistance from the National Marine Fisheries Service and the Atlantic States Marine Fisheries Commission and concluded that

the industry experienced a loss of approximately \$272 million dollars as a result of Sandy, accounting for the for-hire vessel, bait & tackle, commercial fishermen, shellfisheries/aquaculture, commercial dealer, and marina sectors.³⁸

Sea Level Rise

Less acute damages may occur to bivalve shellfish from sea level rise which will cause salinity changes to the estuary as tidal volumes bring saltwater farther up the estuary. One-third of the commercial fish and shellfish species harvested off the Northeast's coast depend on estuaries and wetlands for food or protection during their juvenile or adult stages. These include such key species as lobster, clams, bay scallop, conch, winter flounder, menhaden, alewife, herring, and several species of shark.³⁹ Sea level rise, and the resulting saltwater intrusion issues, may also result in demands to change agricultural and irrigation management strategies as freshwater supplies decrease and the potential for human and crop consumption increases from rising temperatures.⁴⁰

Increasing Atmospheric Carbon Dioxide Concentrations

Increasing carbon dioxide will impact both marine and terrestrial environments in New Jersey. Elevated concentrations of CO₂ can increase plant growth and yield, but the effect varies tremendously among plant species. Some weed species will benefit more than crops and be more resistant to herbicides.⁴¹

Ocean acidification caused by elevated concentrations of CO₂ has been shown to damage oyster and mussel populations, and many phytoplankton and zooplankton species that form the base of marine food webs.⁴²

³³ CIER (2008)

³⁴ Weinberg (2005)

³⁵ Pinsky et al. (2013)

³⁶ Forand (2012)

³⁷ NJDEP (2013)

³⁸ NJDEP (2013b)

³⁹ Frumhoff et al. (2007)

⁴⁰ Frumhoff et al. (2007)

⁴¹ USGCRP (2013)

⁴² Hoegh-Guldberg and Bruno (2010)

Impacts on the marine food web will also create impacts on fisheries. Given the importance of shellfisheries and aquaculture in New Jersey, it is evident that ocean acidification could represent a significant risk to these species.

State Benchmarking

Several states in the Northeast have formalized processes that account for climate adaptation at the state agency level. Entities in New Jersey have undertaken some initiatives to understand and plan for the impacts of climate change and how they might adapt to such changes. In 2009 a report from the New Jersey Department of Environmental Protection (DEP) containing mitigation strategies for reducing greenhouse gas emissions from all major sources to achieve New Jersey's 2020 and 2050 goals was released.⁴³ However, there are currently no formal and ongoing processes for addressing climate adaptation for agriculture at the state level. Other states have succeeded in formalizing these approaches and measuring resilience and adaptation actions.

In Pennsylvania, as part of the Climate Change Action Plan completed in 2009, the Climate Change Advisory Committee decided to create a companion state adaptation plan. The Pennsylvania Climate Adaptation Planning Report, released in January 2011, should serve an integral role in planning for and updating the Action Plan every three years as required by law. The adaptation plan identifies a number of risks and adaptation actions to assist the agricultural community in Pennsylvania. Actions recommended included greater research efforts in understanding the vulnerability of economically important species and the potential to develop or utilize alternative species. In addition, a number of conservation efforts were proposed in order to sustain agricultural uses, in addition to preventing agricultural uses from polluting other areas because of chemical runoff. Monitoring efforts also appeared to be a focus for the adaptation planning in order to establish baselines and monitor changes to species health, crop yield and

other indicators that could trigger the need for actions by agricultural stakeholders.⁴⁴

Section 9 of the Global Warming Solutions Act in Massachusetts required the Secretary of Energy and Environmental Affairs (EEA) to create an advisory committee responsible for developing a report for the legislature to analyze adaptation strategies for the predicted impacts of climate change. The report was completed in 2011, and entailed several recommendations for the legislature regarding impacts and adaptation strategies related to agriculture.⁴⁵ The agriculture recommendations were focused on research for adaptive plant varieties and monitoring for insects, weeds, pathogens, and other effects of climate change on crops, livestock, and fisheries. In addition, management strategies for runoff to prevent degradation of water quality were also seen as a major initiative for mitigating risk from climate change in the future. Recommendations were also made to support financing programs to assist farmers in the changeover to new equipment or for experimenting with new varieties of more climate resilient crops.

The Maryland Commission on Climate Change (MCCC) was established in 2007 by Executive Order and charged with developing an action plan to address the causes of climate change and prepare for the likely impacts. The Adaptation and Response Working Group developed several recommendations for creating resilience in the agricultural sector, including increasing crop diversity, protecting against pests and disease, and intensifying water management.⁴⁶ In order to execute those recommendations, resources were identified to strengthen applied research, risk communication and technical support and to identify opportunities to support the transition of farm and agricultural practices. Additional recommendations were made to enhance existing Best Management Practices (BMPs) and revise land conservation targets based on likely climate change scenarios.

The State of New York's report cites a number of adaptation strategies to be pursued by the State.⁴⁷ Strategies recommended were focused primarily on the

⁴³ NJDEP (2009)

⁴⁴ PDEP (2011)

⁴⁵ EEEA and the Adaptation Advisory Committee (2011)

⁴⁶ ARWG (2011)

⁴⁷ NYSERDA ClimAID Team (2010)

livestock and fruit industries that comprise a significant portion of the New York agricultural economy. Explicit recommendations focused on minimizing water consumption, developing varieties that take advantage of the effect of increases of carbon dioxide concentrations, increased weed control and new approaches to minimize chemical inputs.

Discussion and Recommendations

Warming air and water temperatures could create significant challenges for the agriculture industry in New Jersey. Such challenges might require researching and replacing current crop varieties with those better suited for warmer temperatures, managing pests and invasive species, and addressing the potential of decreasing productivity across many agricultural sectors. The nature of agricultural entities (i.e. small businesses) may not allow for the capital investment or willingness to experiment with new technologies needed because of limited resources. Increasing levels of carbon dioxide in the atmosphere are also likely to cause ocean acidification, which researchers have determined to have detrimental effects to shellfish. While warming

and increases to carbon dioxide levels will occur over the next 50 to 100 years, extreme weather events are already prevalent in New Jersey, causing damages to both maritime and terrestrial agriculture environments. Given the variety of species and the uncertainty of impacts from warming, experts feel that more research is needed in order to understand more about the impacts on specific crops and fisheries, and on the impacts of alternative agricultural practices.

Some states and regions have been successful at incorporating climate change into official farmer education and outreach, especially in land use practices that affect runoff pollution. Leading states are focused on implementing additional data collection plans, monitoring, and research in order to gain more certainty about the effects of climate change impacts in addition to being able to identify detrimental effects in a timelier manner. It is perceived that this focus on data collection and research could lead to future investments in new management initiatives or technologies that will help agriculture stakeholders adapt to the changing climate. The Alliance and its partners have compiled additional leading practices for investigation in Table 2 below for consideration.

Table 2 : Specific areas for investigation based on leading practices

<i>New Jersey Adaptation Need</i>	<i>Potential Initiatives for Investigation and Projects</i>
Understand vulnerability and resilience of current crops and fisheries to climate change	<ul style="list-style-type: none"> • Work with local and regional scientists to improve understanding of climate change and projections. • Quantify the vulnerability of the system to risks such as saltwater intrusion, storm surge and inland flooding. • Promote the diversification of crop types and varieties to limit risk • Provide directed research and monitoring funds to increase knowledge of the effects of ocean acidification at varying carbon dioxide concentrations. • Invest in new climate science research to determine current trends and develop early-warning systems for farmers. • Encourage the development and implementation of monitoring technologies
Integrate Climate Adaptation with Planning and Regulation Processes	<ul style="list-style-type: none"> • Develop an agriculture stakeholder group to organize and coordinate state-level adaptation planning and implementation • Evaluate incorporating flexibility into fisheries management systems to accommodate species shifts through updated cross-jurisdictional management mechanisms, and incorporate triggers and methods for adjustments based on evolving knowledge and information. For example, fishing regulations, such as catch number and length, and fishing season dates may need to change in order to support a more sustainable fishery in the face of climate change. • Improve shellfish management and aquaculture by incorporating predictions of harmful algal blooms, marine pathogens, and rainfall. • Assess and revise targets for agricultural land preservation, including an analysis of future water resource and drainage issues. • Identify opportunities to support the transition of farm and agricultural practices. • Protect terrestrial and marine habitats against incoming pests, weeds, invasive species and disease. Incorporate regional management strategies and pursue minimization of chemical inputs where possible.
Invest in technology adaptation to encourage resilience	<ul style="list-style-type: none"> • Investigate incentives and financing programs for implementing new technologies and crops, especially for small farms with limited funds. • Develop cooler and less energy intensive shelters for livestock. • Explore new varieties, new crops; develop markets for new crops to take full advantage of any beneficial effects. Develop varieties that take advantage of the effect of increases of carbon dioxide concentrations and minimize water and nutrient constraints. • Research new innovative and cost-effective strategies for improved water management systems and design. • Proactively pursue, design, and construct habitat restoration projects to enhance the resilience of bay and aquatic ecosystems to the impacts of climate change. • Prepare for new or expanding ranges of invasive species. • Adjust bay and watershed restoration priorities in light of a changing climate.

Sources

Adaptation and Response Working Group (ARWG), MCCC. 2011. Comprehensive Strategy for Reducing Maryland's Vulnerability to Climate Change—Phase II: Building Societal, Economic, and Ecological Resilience. Available at: http://dnr.state.md.us/climatechange/climatechange_phase2_adaptation_strategy.pdf

Center for Integrative Environmental Research (CIER). 2008. Economic Impacts of Climate Change on New Jersey. Available at: <http://www.cier.umd.edu/climateadaptation>

Executive Office of Energy and Environmental Affairs (EEEA) and the Adaptation Advisory Committee. 2011. Massachusetts Climate Change Adaptation Report. September 2011. Available at: <http://www.mass.gov/eea/air-water-climatechange/climate-change/climate-change-adaptation-report.html>

Forand, R. November 27, 2012. Superstorm Sandy leaves late-fall crops struggling. South Jersey Times. Available at: http://www.nj.com/gloucester-county/index.ssf/2012/11/superstorm_sandy_leaves_late-f.html

Frumhoff, P.C., J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis report of the Northeast Climate Impacts Assessment (NECIA). Cambridge, MA: Union of Concerned Scientists (UCS). Available from <http://www.climatechoices.org/assets/documents/climatechoices/confronting-climate-change-in-the-u-s-northeast.pdf>

Kreeger, D., J. Adkins, P. Cole, R. Najjar, D. Velinsky, P. Conolly, and J. Kraeuter. 2010. Climate Change and the Delaware Estuary. Available at: http://delawareestuary.org/pdf/Climate/Climate%20Change%20and%20the%20Delaware%20Estuary_PDE-10-01.pdf

Hatfield, J., K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, and D. Wolfe. 2008. Agriculture. In: The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Available at: <http://www.climatescience.gov/Library/sap/sap4-3/final-report/#EntireReport>

Hoegh-Guldberg, O., and J.F. Bruno. 2010. The impact of climate change on the world's marine ecosystems. *Science*, 328(5985), 1523-1528.

Maryland Department of Planning. 2011. PlanMaryland Revised Draft Plan. September 2011. Available at: http://www.plan.maryland.gov/PDF/draftPlan/PM_revisedDraft.pdf

New Jersey Department of Agriculture (NJDA). 2012. Overview of Agriculture in the Garden State. Available at: <http://www.state.nj.us/agriculture/about/overview.html>

New Jersey Department of Environmental Protection (NJDEP). 2009. Meeting New Jersey's 2020 Greenhouse Gas Limit: New Jersey's Global Warming Response Act Recommendations Report. Available at: http://www.nj.gov/globalwarming/home/documents/pdf/njgwra_final_report_dec2009.pdf

New Jersey Department of Environmental Protection (NJDEP). 2013. Shellfish Classifications of New Jersey's Coastal Waters. Available at <http://www.nj.gov/dep/bmw/waterclass.htm>.

New Jersey Department of Environmental Protection (NJDEP). 2013b. 2012 Fishery Disaster Declaration - Hurricane Sandy: Assessing the Impacts to NJ's Marine Fishing Industries. Presented at the New Jersey Fisheries Disaster Funding Meeting on August 12, 2013.

New York State Energy and Research Development Authority (NYSERDA ClimAID Team). 2010. Responding to Climate Change in New York State, the Synthesis Report of the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State. Available at: <http://www.nyserda.ny.gov/Publications/Research-and-Development/Environmental/EMEP-Publications/Response-to-Climate-Change-in-New-York.aspx>

Pennsylvania Department of Environmental Protection (PDEP). 2011. Pennsylvania Climate Adaptation Planning Report: Risks and Practical Recommendations. Available at: <http://www.depweb.state.pa.us>

Pinsky, M.L., B. Worm, M.J. Fogarty, J.L. Sarmiento and S.A. Levin. 2013. Marine taxa track local climate velocities. *Science* 341, 1239-1242.

Pitman, M. G., & Lauchli, A. 2002. Global impact of salinity and agricultural ecosystems. *Salinity: environment–plants–molecules*. Dordrecht: Kluwer, 3-20.

U.S. Global Climate Change Research Program (USGCRP), 2009. *Global Climate Change Impacts in the United States*. Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). New York: Cambridge University Press. Available at: <http://globalchange.gov/publications/reports/scientific-assessments/us-impacts>.

U.S. Global Climate Change Research Program (USGCRP), 2013. Draft National Climate Assessment Report. Available at: <http://ncadac.globalchange.gov/>

Vorsa, N. 2012. Personal communication. Director Philip E. Marucci Center for Blueberry and Cranberry Research and Extension, New Jersey Agricultural Experiment Station. Rutgers University.

Weinberg, J.R. 2005. Bathymetric shift in the distribution of Atlantic surfclams: response to warmer ocean temperatures. *ICES J. Mar. Sci.* 62:1444-1453.

Xu, C., J. Johnson-Cicales, N. Vorsa and B. Huang. 2012. Genotypic variation and irrigation effects on canopy temperature and photosynthesis of cranberry under heat stress. 2012 Annual Winter Meeting of the American Cranberry Growers Association. Rutgers University, New Jersey Agricultural Experiment Station.