Agriculture and Forestry in a Changing Climate:
Adaptation Recommendations

A Product of the 25x’25 Adaptation Initiative
April 2013
About the Adaptation Work Group

The 25x’25 Alliance Adaptation Work Group is a collaboration of leaders from the agriculture, forestry, business, academic, conservation, and government sectors. Their mission has been to explore the impacts of a changing climate on the United States agriculture and forestry sectors and to develop recommendations to address its related opportunities and challenges.

First convened in September of 2011, the Adaptation Work Group divided into four teams focusing, respectively, on production systems, risk management, ecosystem services, and communications. This document is the second in a series from the Adaptation Work Group and presents the key recommendations from these teams based on their expertise and on feedback from surveys of producers and supporting groups nationwide. While it also offers background into the anticipated impacts of climate change on agriculture and forestry, more detail on this topic can be found in “Agriculture and Forestry in a Changing Climate: The Road Ahead,” a report published by the Adaptation Work Group in February of 2012.
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“We tend not to think long-term. But we need to try to peer over the horizon and figure out where we are going to be in the country in terms of our natural resources. We need to ask ourselves what we should be doing today to prepare for the next decade and beyond.”

– Steve Irsik, Kansas Rancher

“While I am able to cope with short-term changing climatic conditions in my cattle operations, my greatest dilemma is how to change my forestry practices today to result in forests that will survive to economic maturity in the new climatic conditions which will exist fifty years from now. While political leaders and agencies will eventually get climate change adaptation polices right, history says they will get it right too late to affect the outcome.”

– Producer Response to Anonymous 25x’25 Alliance Adaptation Survey

“We seem to be in a cycle of extreme weather and rain events. We need to adapt our management and conservation practices to what is happening in our fields.”

– Ray Gaeber, Iowa Grain Farmer

“Adapt or retire. Those are the options as I see it.”

– Jim Gray, North Carolina Forester
Executive Summary

Agriculture and Forestry in a Changing Climate: Adaptation Recommendations

A Product of the 25x’25 Adaptation Initiative / April 2013

Adaptation is nothing new to those who produce food, feed, fiber, and fuel, along with a host of ecosystem services. Wet and dry seasons come and go. And from the time the very first seeds were planted in the ground, producers have been making adjustments to meet the many challenges of an unpredictable Mother Nature. In fact, the history of United States agriculture is a tale of adaptation and remarkable progress in the face of these challenges.

Yet recent years have demonstrated just how vulnerable our production system remains to changing weather. The year 2012, with its historic national drought, was one of the most expensive years for weather-related disasters in United States history. As many scientists look ahead, these once occasional or rare events are expected to grow more common and more intense in many parts of the country, throwing into question whether “business as usual” will suffice for the future of agriculture and forestry.

And farmers, foresters, and ranchers are adjusting their operations to much more than changing weather. They also face unprecedented economic, social, and environmental pressures that require balancing for multiple outcomes. These challenges include meeting the needs of a rapidly growing world, making decisions in increasingly volatile local and global markets, and managing to continually renew and protect soil, water, and air resources.

The 25x’25 Alliance Adaptation Work Group is a collaboration of agriculture, forestry, business, academic, conservation, and government leaders who are exploring the impacts of a changing climate and other variables on United States agriculture and forestry and developing recommendations to address it. Their work has focused on production systems, risk management, ecosystem services, and communications. This document presents the key recommendations in these areas.

The impacts of changing weather patterns vary by region, but include higher temperatures; changing precipitation patterns; new threats from weeds, pests, and diseases; increased humidity; and stronger storms. But our nation is not solely at the mercy of these trends. Rather, there are many options available to address
this uncertainty and mitigate risks while strengthening productivity, cutting input costs, and improving the quality of the land. This document explores many of these options through a series of recommendations for producers, researchers, policymakers, and supporting groups. The Adaptation Work Group believes that with forethought, leadership, and the right priorities, our nation’s agriculture and forestry systems can not only meet future challenges, but thrive in the midst of them.

**Adaptation Recommendations**

Adaptation strategies come in many different forms, but typically fall into three major categories: actions to increase *resistance* to changes in climate in order to maintain existing practices; actions to improve *resilience* by investing in steps that preempt disasters and restore systems in the wake of them; and actions to *transform* operations. Examples include planting drought-resistant hybrids to resist the impacts of decreased precipitation; extending rotations of corn and soybeans to include wheat and cover crops to build resilience to extreme weather; and diversifying production systems to incorporate ecosystem services that would transform the landscape and protect producer incomes in the face of significant changes in climate.

The recommendations of the Adaptation Work Group are designed to reflect this range of activities and have been placed into five distinct, yet overlapping categories: research, production systems and practices, risk management, decision-making tools, and communications, outreach, and education. The overarching recommendations for each of these categories are summarized below and discussed in detail in the full report.

**Research**

From pest-resistant hybrids to powerful data systems enabling precise targeting of irrigation and other inputs, a firm foundation of public and private research lies beneath the incredible success of American agriculture. In the future, this research base, whether it be in new technologies or best practices, must be expanded and refined to provide producers with the tools and information they need to succeed. The following research areas should be prioritized to aid producers in adaptation:

a) Support governmental, academic, and private research designed to create more accurate climate forecasting and scenarios at the spatial and time scales needed to inform producer decisions.

b) Engage in public and private research on the impact of anticipated changes on crops and animals.

c) Examine the economic, political, and social barriers to adaptation facing producers.

d) Expand private research into new bioengineered species more resilient to anticipated changes while preserving heritage varieties.

e) Develop new crop management tools, such as pesticides and herbicides, for anticipated changes.

f) Design and manufacture new equipment and facilities to meet the changing needs of producers.
Production Systems and Practices

The history of agriculture and forestry is one of constant change and continuous improvement. Producers will need to adapt many products and supplies to maintain viable operations. The following are recommendations for strengthening production systems, conservation, ecosystem services, and infrastructure:

a) Implement conservation practices designed to maintain the productive capacity of land.
b) Adopt new production practices to address climate-related challenges.
c) Develop new private and public sector programs and markets for creating additional value for ecosystem services.
d) Create new and upgrade existing infrastructure to meet climate challenges.

Risk Management

The Adaptation Work Group recommends using risk management to address climate challenges at both the producer and policymaker levels. Risk management is the systematic strategy of managing uncertainty to minimize potential losses. Producers are no strangers to this. After all, it comprises all of the decisions they make on a daily basis. However, this approach should be broadened to include the short- and long-term risks associated with climate changes. Doing so will lead to more resilient agricultural and forest systems.

a) Maintain a robust federal crop insurance program.
b) Ensure that there are adequate disaster relief programs available to producers for natural disasters.
c) Provide multiple avenues for funding adaptation measures.

Planning and Decision Support Tools

In the context of this report, tools are defined as devices, methods, or rules that assist producers in making decisions. Our nation’s producers already have various decision tools created by private companies, universities, and government agencies at their disposal for a wide range of purposes such as detecting invasive species, determining when to spray, and weighing diversification options. As the past becomes a less reliable predictor of the future, decision tools will be all the more important.

a) Develop new tools to take advantage of how producers will use and access information in the future.
b) Provide regular updates to decision tools dependent upon climate data.
c) Incorporate climate change information and data into existing tools.
d) Integrate tools to provide a more comprehensive picture for decision-making.
e) Engage in local- and watershed-level planning with all relevant stakeholders.

Communications, Outreach, and Education

The best technologies, groundbreaking studies, and decision tools in the world will matter little if we cannot effectively get information into the hands of producers. Recognizing this, the Adaptation Work Group has developed recommendations to strengthen outreach to farmers, foresters, and ranchers.
a) Engage in producer-to-producer dialogues to connect producers in areas experiencing changing conditions with those already accustomed to addressing similar challenges.

b) Encourage ongoing dialogue between scientists, policymakers, and agricultural organizations.

c) Involve producers and trade associations in research decisions and implementation.

d) Address the challenges of reaching landowners.

e) Conduct cross-disciplinary efforts in researching and communicating adaptation measures.

f) Provide additional support for existing outreach networks such as agricultural extension, government agencies, and universities.

**A Path Forward**

Though the recommendations included in this document are the result of a year of work with various stakeholders from agriculture, forestry, and supporting groups, they mark the beginning rather than the end of a conversation. This report is intended as a living document, to be revised and expanded upon as new information from a wide range of sources is brought to light. As such, we not only welcome, we encourage your feedback on the types of adaptation measures needed to enable our nation’s producers to succeed in the context of a changing climate.

Over the course of 2013 and 2014, 25x’25 Alliance staff members and volunteers will be offering presentations, workshops, webinars, and other forums to discuss the ideas found within this report and to gather feedback on what we got right, what we missed, and what is needed for individual crops and communities to adapt. In doing so, we invite agricultural, forestry, and conservation organizations as well as others within the value chain to partner with us in engaging their members in this important conversation. To learn more about how your group can support and participate in our adaptation dialogue, go to [www.25x25.org/adaptation](http://www.25x25.org/adaptation).

Changes in climate and other market demands will present real challenges for our nation’s agriculture and forestry system, necessitating adaptation at a number of different levels and timescales. In determining our future path, we would be wise to heed the words of Benjamin Franklin, “An ounce of prevention is worth a pound of cure.” As this report demonstrates, there are numerous pathways available to not only meet these challenges, but do so in a way that strengthens production systems, improves profits, and reduces environmental impacts. With your help, we can continue building upon the great progress already being made by farmers, foresters, and ranchers.

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**We Want to Hear from You!**

What did we miss? What are the right priorities? What changes are you seeing in your area and how are you or others adapting? To provide feedback on this report, or for more information on the 25x’25 Adaptation Initiative, go to [http://www.25x25.org/adaptation](http://www.25x25.org/adaptation). There, you will find a link beneath the description of this report where you can share your thoughts with the Adaptation Work Group.
Agriculture and Forestry in a Changing Climate: Adaptation Recommendations

Introduction

Many farmers, foresters, and ranchers throughout the United States are adjusting their operations to reduce the risks associated with increasingly variable and unpredictable weather. In addition to erratic weather, producers are facing unprecedented economic, social, and environmental pressures which require that they balance for multiple outcomes. These challenges include feeding, clothing, housing, and fueling a rapidly growing world, making decisions in increasingly volatile local and global markets, and managing to continually renew and protect soil, water, and air resources.

These pressures are accompanied by high levels of uncertainty which compel land managers to re-evaluate past decisions, seek new information and strategies, and take adaptive actions. Of course, adaptive management is not new to agriculture or forestry producers. Wet and dry seasons come and go. And from the time the very first seeds were planted in the ground, producers have been making adjustments to meet the many challenges of an unpredictable Mother Nature. The history of United States agriculture is a tale of adaptation and remarkable progress in the face of these challenges. Since 1950, producers have more than doubled their production, becoming sources of innovation in genetics, robotics, soil conservation, alternative systems of agriculture and forestry, and applying a wide variety of technologies which have helped to make our nation a breadbasket to the world while providing good livelihoods for their families.

Yet, despite these advances, recent years have demonstrated just how vulnerable our production system remains to changing weather conditions. The year 2011 was one of the most expensive years for weather-related disasters in United States history, with a record-breaking twelve disasters that exceeded one billion dollars in damages. The National Oceanic and Atmospheric Administration (NOAA) placed the combined price tag of just these events at $52 billion\(^1\) and they helped contribute to a record payout of $10.8 billion in indemnities from crop insurance companies, exceeding the $8.6 billion record set in 2008.\(^2\)

The losses of 2011 could now pale in comparison to those of 2012, when one of the nation’s greatest droughts and heat waves led the U.S. Department of Agriculture to designate thirty-one states as disaster areas. For

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\(^1\)Often referred to as “producers” throughout this document.
foresters, the unusually dry conditions and low snowpack translated into “megafires” that put us on pace towards the third worst fire season on record. The Corn Belt was similarly hard hit as farmers watched a record projected harvest turn into the lowest yield since 1995. In response, food prices have risen for consumers and the crop insurance payment record, set only a year ago, could be double that of 2011. As of March 2013, the tabulation has reached $15.7 billion. And, faced with higher feed costs and other stresses, livestock producers have trimmed their herds to the lowest numbers since 1952.

As many scientists look ahead, these once occasional or rare events are expected to grow more common and more intense in many parts of the country, throwing into question whether “business as usual” will suffice for the future of agriculture and forestry. The 25x25 Adaptation Work Group began their work by using internationally respected sources to identify some of the ongoing changes that are occurring in weather patterns and their impacts on agriculture and forestry systems. The results of this research, published in a February 2012 background brief entitled, “Agriculture and Forestry in a Changing Climate: The Road Ahead,” confirm many of the experiences described by producers in this document, such as higher temperatures; changing precipitation patterns; new threats from weeds, pests, and diseases; increased humidity; and stronger storms. These changes, however, have not been uniform. Instead, each region has experienced and will continue to experience, its own set of challenges. And, while no one can state definitively what the future will bring, one thing is certain: our future climate is unlikely to look like that of the past century.

But our nation is not solely at the mercy of these trends. Rather, there are many options available to address this uncertainty and mitigate risks while strengthening productivity, cutting input costs, and improving the quality of the land — even in the context of disasters like those experienced in 2011 and 2012. This paper explores many of these options through a series of recommendations for producers, researchers, policymakers, and supporting groups. Together, they span the whole of the United States agricultural system, from plants to animals and from fields and forests to the halls of Congress.

The 25x25 Adaptation Work Group believes that with forethought, leadership, and the right priorities, our nation’s agriculture and forestry systems can not only meet the challenges of the future, but thrive in the midst of them. This paper is intended to begin the conversations needed to make this shared vision a reality.
John Vrieze owns and operates a farm in northwestern Wisconsin, just east of the Twin Cities. His family’s roots in the area extend deep as they have farmed the same plot for more than one hundred years. Since returning home in 1972, John has seen some significant shifts in weather and climate. Milder winters, up an average of 4°F from 1950 in his county, have lengthened the growing season for corn. “My father’s generation would have planted 80- to 85-day corn hybrids and we’re now using 100-day hybrids,” John says. The result has been higher yields.

However, not all the changes have been positive. The longer growing season and warmer weather have introduced new weeds and insects that now survive winter in greater numbers. “We are getting bugs up here that used to be a problem just for Missouri and farther south,” John says. While this initially led him to use stronger insecticides, a shift to genetically modified crops has helped to reduce the need for chemicals. Nonetheless, he finds that there is a need sometimes to spray the fields twice a year in order to account for the longer growing season.

Heavy rainfalls have been a concern as well. Though annual rainfall has increased only by four to seven inches around his farm, the average number of days per decade with two inches or greater rainfall has doubled since 1950, from seven to just over fourteen. John adds, “We generally build a dairy for hundred-year storm events. We’ve had six of those somewhere in the state in the past five years.”

Perhaps the greatest problem facing his farm has been an increase in summer heat, nighttime temperatures, and humidity. This change has been especially hard on his cows which, under heat stress, produce less milk and fewer calves. At first, John added several fans to the barn to cool the cows. Then he started adding even more fans and misters. Now he is using soakers to help control temperature.

“When we first built our large dairy in 1997, we didn’t even think about keeping the cows cool as there was no reason to spend the extra capital for a couple of days of heat stress during the summer,” John says. “If I were building a new barn today, climate control features would be first on my priority list. This of course adds not just to the cost of putting up a new facility; it adds to the operating costs since they require more energy and water use.”

John has also experimented with diversifying his farm. In addition to growing commodity crops and raising cattle, he uses a methane digester to convert cow manure to heat to warm a greenhouse where they produce vegetables and fish year-round.

John’s experiences illustrate how adaptation to changes in climate pose new obstacles, but also new opportunities. In summing up his efforts, he says, “When I grab the harp, so to speak, I want my grandchildren to know that I tried to do something to address all of these problems.”
Since 2002, Jim Gray has managed a forest for a family owner near Fort Bragg, in the North Carolina Sandhills. The area typically receives abundant rainfall but grapples with drought due to its coarse, porous soils. His goals for the property are profitability and restoration of longleaf pines within a regime that guarantees a dependable cash flow and ongoing conservation improvements.

The decision to restore longleaf pines is no accident. In addition to its legendary ability to withstand fire, the tree is especially resilient to harsh weather, even hurricane force winds. This has been particularly important given the unusual, extreme weather Jim has seen over the past few decades, such as a tornado in January 1995, a hurricane in September 1996, and an early season ice storm in December of 2002.

While North Carolina’s long-term records don’t reflect a significant change in temperatures and precipitation outside of the historic records, the swings from year to year have been erratic and the higher highs and higher lows in temperature, as well as the longer growing season, have introduced new weeds and more insects. Prescribed fire can be especially effective in managing these problems, but the results can also be disastrous if not conducted at just the right time. To schedule prescribed fires and other activities like harvesting, Jim and his crew rely on the latest technology — a RAWS weather station about two miles away from their site. This station provides them with the up-to-the-minute weather data, including wind, temperature, and relative humidity, needed to make management adjustments, such as shifting to nighttime burning or using spot burns rather than line fires. Jim’s devotion, advocacy, and expertise with fire have not gone unnoticed. In 2011, he received an award from the North Carolina Prescribed Fire Council as well as Consulting Forester of the Year award from the state Association of Consulting Foresters.

Jim uses every tool available in managing his lands. When endangered species protection threatened the management of the property, he proactively enrolled it into the Safe Harbor program to ensure that his clients were not penalized for the habitat improvements they made for red-cockaded woodpeckers. Those protective efforts paid off when a proposed power line right-of-way was slated to cut-across the property. The documentation of endangered species helped dissuade the utility from using their initial route, which would have adversely impacted the birds and taken productive land out of use.

Jim has a realistic eye toward climate variability. “Work with the weather you’re given but use the best science, art, and technology with an eye to what’s coming,” Jim says. As with most successful foresters, he uses his years of experience to make gradual changes along the way. When asked about the changes he has seen over the course of his career, he replies simply, “Adapt or retire. Those are the options as I see it.”
Adaptation Recommendations

Adaptation represents a powerful tool in addressing many of the uncertainties facing producers and supporting groups. Adaptation strategies come in many different forms, but typically fall into three major categories: actions to increase resistance to changes in climate in order to maintain existing practices; actions to improve resilience by investing in steps that preempt disasters and restore systems in the wake of them; and actions to transform operations. Examples include planting drought-resistant hybrids to resist the impacts of decreased precipitation; extending rotations of corn and soybeans to include wheat and cover crops to build resilience to extreme weather; and diversifying production systems to incorporate ecosystem services that would transform the landscape and protect producer incomes in the face of significant changes in climate.

The recommendations of the 25x’25 Alliance Adaptation Work Group are designed to reflect all of these possible types of actions. While there are many different ways to group adaptation measures, we have placed our recommendations into five distinct, yet overlapping categories:

- Research
- Production systems and practices
- Risk management
- Decision-making tools
- Communications, outreach, and education

In identifying adaptation strategies for producers, policymakers, researchers, and other service providers and supply chain partners, the Adaptation Work Group was guided by four critical criteria. The first was profitability. For an adaptation step to be viable for an individual producer or an industry as a whole, it must maintain or improve the bottom line.

Our second criterion was productivity. The world’s population is expected to grow from seven billion today to over nine billion by 2050. When combined with rising standards of living in many developing countries, agriculture will be under greater pressure than ever in the coming years to do more with less in meeting food, feed, fiber, and fuel demands. However, these two objectives should not be met at any cost because our future profitability and productivity are inextricably linked with our stewardship of the land. Our proposed actions are intended to maintain, if not enhance, environmental outcomes.

Finally, the Adaptation Work Group believes in self-determination. Our recommendations offer options for producers and supporting groups to consider, not a series of actions we believe should be imposed on land.

Figure 1 – This chart of Kansas wheat production by the Kansas Department of Agriculture illustrates both the progress experienced in production since 1950 as well as the greater volatility in yields over the past few decades.
managers and their service providers. We understand that each producer and region will have their own unique challenges and opportunities for adaptation, and we believe in the ability of farmers, foresters, and ranchers to determine ultimately what is best for their land and their operations.

Many people may not realize that adaptation is occurring right now. When producers put their crops into the ground earlier in the season to take advantage of earlier springs and narrowing planting windows, they are adapting. When foresters plant a more resilient tree species or seedling variety in response to an emerging pest, they are adapting. Even a dairy operator installing a methane digester to produce energy represents a form of adaptation. The purpose of this paper is to identify, support, and speed up a process that many producers have already begun on their farms, forests, and ranches.

Research

From pest-resistant hybrids to powerful data systems enabling precise targeting of irrigation and other inputs, a firm foundation of public and private research lies beneath the incredible success of American agriculture. In the future, this research base, whether it be in new technologies or best practices, must be expanded and refined to provide producers with the tools and information they need to succeed. The following are priority research recommendations to aid producers in adaptation.

1. Support governmental, academic, and private research designed to create more accurate climate forecasting and scenarios at the spatial and time scales needed to inform producer decisions. Producers make decisions on a wide range of time scales. For instance, a producer may want to know what conditions will be like tomorrow for spraying, next season for planting, or even ten to fifty years from now for purchasing land, installing drainage tile, and planting trees. Climate forecasts\textsuperscript{ii} and scenarios\textsuperscript{iii} can serve as powerful allies in helping producers to answer these types of questions. Many producers already use climate forecasts and scenarios, but there a number of steps that can be taken to make them even more relevant for agriculture and forestry, particularly forecasts ranging beyond two weeks. Key areas of focus should include:

a) The relationship between ocean temperatures and local climates – The quality of current climate forecasts is dependent on the quality of forecasts of the Tropical Pacific Ocean (El Niño/La Niña) cycle, the North Atlantic Oscillation, and the degree to which local climates are sensitive to these and other

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{AgroClimate.png}
\caption{AgroClimate, a service of the Southeast Climate Consortium in partnership with NOAA, provides producers with a number of helpful decision tools, including climate outlooks. Within these outlooks are the potential impacts on individual crops. This information helps farmers to make strategic decisions based on weather conditions anticipated months in advance.}
\end{figure}

\textsuperscript{ii} Climate forecasts are generally from a period of two weeks through two years into the future.

\textsuperscript{iii} Climate scenarios are climate model simulations beyond two years into the future.
large-scale phenomena. Better understanding of these relationships will help improve the accuracy of climate models.

b) **The impact of soil moisture on local climate** – In the top layers of soil, soil moisture acts on shorter time scales to influence day-to-day weather. At deeper levels, it affects slower processes at regional scales and serves as a source of water that deep-rooting plants bring to the atmosphere during droughts. The effects of soil moisture on climate are not yet fully understood nor incorporated into models.

c) **The ability of regional climate models to simulate precipitation** – Regional climate models differ greatly in their ability to represent accurately both the amount and timing of precipitation.

d) **Changes in the probability of extreme weather events** – Changes in climate are altering the frequency of extreme weather events, but further research is needed to quantify and integrate these changes into decision tools. This information will not only inform producer decisions, it will inform supporting groups such as policymakers and crop insurance companies.

e) **The measurement of additional variables to the existing national weather monitoring network** – The quality of climate research can only be as strong as the data that it utilizes. Humidity, wind, soil organic matter, soil moisture, solar radiation, temperature, and other metrics all help describe climate yet are not collected on enough monitoring sites throughout the United States to adequately inform research.

f) **A real-time “nationwide network of networks” to pool weather data collected across the nation** – In the future, weather data will need to be aggregated and shared in a “nationwide network of networks” that will bring together measurements being taken by various federal, state, and local agencies and the private sector into an easily accessible, searchable, real-time archive. This will speed and strengthen future research.\[^iv\]

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\[^iv\] This process is already under way, with the “network of networks” concept being reviewed by several federal agencies. Efforts to consolidate a variety of measurements are being taken by the federal government, which is producing archives now available under the Meteorological Assimilation Data Ingest System (MADIS).
2. Engage in public and private research to determine the impact of anticipated changes on crops and animals. Though many agencies, universities, and corporations are examining the impact of climactic changes on plants and animals, more research is needed in order to know exactly how these changes will affect agriculture and forestry. The 25x’25 Adaptation Work Group’s priorities in this area include the need to:

   a) **Match production plant and animal species, and genetic variation within species, to expected new moisture and temperature regimes** – Changes in weather and climate will alter the most adapted production species in some areas. Both producers and researchers will need to regularly evaluate the species that are appropriate for various areas.

   b) **Quantify the effect of increasing carbon dioxide on the nutritional quality of plants** – While higher carbon dioxide conditions are expected to increase yields for some plants, it may decrease their nutritional quality. This is especially important for pests and livestock.

   c) **Evaluate responses to higher nighttime temperatures in both plants and animals** – Discussions of climate change often focus on higher daytime temperatures, but nighttime temperatures can be almost as damaging for plants and animals since it may limit their ability to recover from heat stress.

   d) **Research short- and long-term changes in water availability and timing** – With better information on water availability and timing, producers reliant on irrigation and rainfall can adjust their management to account for shifts.

   e) **Examine the effect of higher temperatures on seasonal water use patterns and their influence on yields for different crop areas** – Atmospheric water demand is driven by the temperature of the atmosphere. Higher temperatures will increase the rate of crop water use; however, knowledge is lacking to quantify how the combined effect of increased water use rates, coupled with higher temperatures will affect yields.

   f) **Study weeds and pests to determine the traits that enable them to thrive or fail under changing conditions** – Many weeds and pests have proven especially adept at adjusting to new environments. Understanding the reasons will help us to combat them, find ways to improve upon cultivated crops, and protect animals.

   g) **Quantify weed dynamics as part of cropping systems** – Weeds have shown a positive response to increasing carbon dioxide, and changes in temperature and soil moisture may provide an advantage for competitive weeds in farming systems. Understanding the dynamics of weeds may help reduce the cost of weed management.

   h) **Measure the “chilling requirements” of crop varieties** – For some crops, particularly fruit and nut trees, extended periods of cooler temperatures are essential for production. The yields of these plants are being threatened by warmer winters. Quantifying their “chilling requirements” will help producers assess their suitability for planting in their area. Research should also be conducted into the chilling requirements of nursery plants and seedlings prior to lifting for out-planting.
i) **Examine the impacts of changing moisture and temperature regimes on nutrient cycling** – Soil nutrient cycling is dependent upon temperature and moisture regimes in the soil. Increasing temperatures and more variable soil supply may adversely affect the ability of the soil to supply nutrients to meet crop demands.

j) **Manage soil and crops to increase water-use efficiency** – With rainfall expected to become less frequent and intensify in some regions of the country, there will be greater need to manage the land to use water more efficiently. Systems to improve water infiltration and reduce evaporation should be explored. In addition, steps should be taken to improve soil organic matter since it enhances the ability of the soil to retain water. Integrated nutrient and tillage management, which involves a mix of fertilizers and organic amendments, is one option for increasing organic matter.11

k) **Quantify carbon sequestration resulting from various management practices** – Carbon sequestration has a number of positive impacts on soil, such as improving drainage and its ability to hold water and store nutrients.12 Furthermore, carbon sequestration removes carbon dioxide from the atmosphere, providing a service that could eventually have market value. Quantifying the carbon sequestration benefits of various practices will help producers and policymakers understand the best techniques for enhancing soil quality while delivering a vital ecosystem service that builds resilience to drought.

l) **Evaluate and document beneficial soil services, such as changes in soil quality, productivity, erosion, and water and air quality** – Although much is known about soil, a lot remains to be studied. The various services that can be provided by soil, such as sequestration and improved water and air quality, should be cataloged with research focused on maximizing this potential.

m) **Study the role of micro-organisms in soil carbon and nitrogen stabilization** – Both soil micro-organisms and nitrogen stabilization are important to improving soil quality and require additional study. Soil micro-organisms can enhance soil carbon and nitrogen storage, aggregation, and nutrient cycling and can be affected by soil management. Understanding interactions between soil micro-organisms and climate are key to adapting cropping systems to drought and climate variability.

n) **Evaluate the influence of increased humidity on plant water use rates** – Rising humidity affects atmospheric demand for water vapor and will potentially decrease the rate of crop water use; however, the interaction of humidity with more variable soil water supplies caused by changes in precipitation is not understood.

o) **Quantify the impact of prolonged drought on the survival of perennial crops as well as management practices required to ensure survival** – With droughts expected to become more frequent and more intense in some parts of the country, we will need to know the exact impacts of these events, particularly on perennials, to have a better sense of the risk they pose and potential solutions.
p) **Examine how changes in temperature might impact commodity storage practices** – Changes in temperature, particularly in winter, can create new risks to stored feed, such as mold, which can lead to aflatoxins. Research should be conducted to determine best storage practices and new measures to protect producers from storage related problems.

q) **Study the extent and effects of the “desynchronization” of pollinators with plants** – Warmer winters in some areas of the country have caused plants to lose synchrony with pollinator species. The extent and impacts of this must be catalogued and thoroughly studied.

r) **Collect phenological data throughout the country** – Seasonal events such as the timing of flowering, breeding, and migration (phenology) often serve as cues for cultural practices like planting and harvesting and provide information on how the natural world is responding to changes. This information should be gathered from across the nation. The [USA National Phenology Network](https://www.phenology.gov), part of the United States Geological Survey, provides the infrastructure for reporting and recording plant and animal phenology.

3. **Examine the economic, political, and social barriers to adaptation facing producers.** Adapting will require not just an understanding of the impacts of a changing climate on agriculture, but also an understanding of the various barriers facing producers and other stakeholders as they adapt. In some cases these barriers might be economic. In other cases, they could be the result of social constraints or conflicting government policies. Our knowledge of these barriers can be strengthened if we:

a) **Expand the collection and evaluation of data on current practices, the adoption of new practices, and their outcomes** – Successful adaptation will require knowledge of the practices that are currently being employed, as well as the level of access to science, climate and weather data, and technologies. Data should also be collected on how practices on farms, forests, and ranches are changing in response to climate and their respective outcomes. This information will offer policymakers an understanding of our present system, the potentials that exist, and where best to allocate finite resources.

b) **Determine the limitations of resistance and resilience strategies** – Though efforts to resist changes and build resilience will be effective in many areas, some producers may find it necessary to transform their operations. This process can be aided if we improve our understanding of producer beliefs, values, knowledge, experiences, economic goals, their social relationships, and other factors.
associated with decision-making in order to strengthen education strategies and formulation of policies that incentivize effective adaptation.

c) **Research how local, state, and national social, economic, cultural, and political institutions can help support adaptation measures** – Adaptation will require changes throughout the entire value chain, not just at the producer level. The organizational structures and value chains in forestry and agribusiness (crop, technical, and legal advisors, bankers, extension, cooperatives, etc.) can be barriers or enablers that increase producer capacity to adapt. Research should be conducted to determine how these groups can serve as allies for producers in adaptation.

d) **Study the role and impact of producer organizations as trusted sources of information to encourage collective action to change policies and influence markets** – Producer organizations already serve a valuable role in disseminating information to producers. As such, they represent powerful vehicles for communicating science, technologies, and adaptation strategies.

4. **Expand private research into new bioengineered species more resilient to anticipated changes while preserving heritage varieties.** Biotechnology has already proven an effective tool in building the resilience of the American agriculture system. Biotech cotton, or Bt cotton, provides a powerful illustration. Bt cotton has been genetically modified to produce a toxin that is lethal to some of cotton’s traditional predators. The result has not only been higher cotton yields, but also a radical reduction in pesticide application by farmers and even an increase in natural predators to cotton pests. Despite these past successes, current varieties may not be as effective in the face of climate pressures such as drought, salinization, high temperatures, and new pests and pathogens. Biotechnology can be strengthened if we:

a) **Increase private research by agricultural technology and life science companies into new varieties of plants and animals capable of enduring projected stressors** – New biotechnology species could be key to maintaining operations in certain areas while expanding planting in others. This research is well underway with new drought resistant corn varieties hitting markets across the United States over just the past few years.

b) **Expedite the federal process for approving new bioengineered species** – While the 25x25 Adaptation Work Group is supportive of exercising due diligence in testing all new bioengineered species, the approval process can be especially lengthy. Policymakers should examine opportunities to expedite it without compromising consumer or ecosystem safety.

c) **Develop new best practices for using bioengineered species** – Like many tools, overuse and improper use of biotechnology plants can diminish their effectiveness over time by encouraging the development of resistance within the very pests they are designed to combat. Private companies could partner with service providers and trade organizations to develop and publicize best practices to ensure that new crops remain effective.
d) **Preserve heritage plant and animal varieties** – In some cases, preparing for the future will mean exploring the past. Though we will need new varieties and species of crops and animals, we will also want to invest in the preservation and maintenance of “heritage” plant and animals whose genetic diversity could be useful in addressing specific changes in conditions, particularly pests and pathogens.

5. Develop new crop management tools, such as pesticides and herbicides, for anticipated changes. As with biotechnology, today’s herbicides and pesticides may not be up to the challenges of tomorrow. The effectiveness of certain classes of crop protection products under simulated higher carbon dioxide (See Figure 6 on page 32) levels provides a warning on the potential limits of our current crop management tools. Avoiding such outcomes will require a new generation of pesticides and herbicides. In addition, effort must be made to:

a) ** Expedite the process of federal approval for new crop management tools** – Similar to biotechnology, policymakers should examine opportunities to speed approval processes without compromising consumer or ecosystem safety.

b) **Study and publicize best practices for the application of crop management tools** – Suppliers and trade associations could engage producers and supporting groups in the best practices for pesticides and herbicides while protecting the products from overuse that might contribute to resistance.

c) **Examine how beneficial insects and pathogens might be utilized for pest management** – Crop management tools should not be understood solely as a technological endeavor. Research must be conducted into how beneficial insects and even pathogens might be used for pest management. These ideas are being incorporated into “integrated pest management” strategies.
Geothermal Hog Barn

Research has already begun in many different sectors on new facilities to meet changing conditions. University of Minnesota Agriculture engineer Dr. Larry Jacobson has experimented with using geothermal to heat and cool a 900-sow facility in western Minnesota. Though it has more expensive upfront costs than other heating and cooling options, the system can help to reduce heat stress on livestock by providing temperature control and removing moisture. This is especially useful on high dew point nights when evaporative cooling is less effective. The experiment had the added benefits of reducing energy use and feed consumption, as well as methane and nitrous oxide emissions.

6. Design and manufacture new equipment and facilities to meet the changing needs of producers. Research and development should not be limited to the laboratory and fields; it will also be required on the factory floor. New equipment and facilities can improve efficiencies and enable transformation within agriculture and forestry. Areas where additional research is needed include:

a) More versatile equipment to help producers diversify their operations and address narrowing planting and harvest windows – New products from manufacturers are already helping producers to accomplish more in less time. They are also cutting input costs through technologies like precision agriculture.

b) More efficient forestry harvesting equipment – Thinning has been recommended for reducing the threat of pests and fire, yet it is often prohibitively expensive. New equipment could help to reduce these costs.

c) New facility designs for animal agriculture – New animal agriculture facilities should have improved energy efficiency, biosecurity measures, and in-barn climate control features. Facilities could also be designed for on-site composting and integrating energy production through technologies like anaerobic digesters.

d) More efficient water management systems – Water resources are expected to become more scarce in many areas of the country, particularly the Southwest. More efficient water management systems will help to expand the availability of water and prevent the depletion of aquifers.
Ray Gaesser – Iowa Grain Farmer

Ray Gaesser has been growing corn and soybeans in a no-till system in Adams County, Iowa, since the early 1980s. He has been experimenting recently with cover crops in an effort to control problems with erosion. “During the last several years we’ve seen an increase in rains that exceed three inches per hour or dump six to eight inches per day on our fields,” Ray says. “This has caused erosion in our no-till system where we haven’t had it before.”

A recent study from the Rocky Mountain Climate Organization and the Natural Resources Defense Council, entitled “Doubled Trouble, More Midwestern Extreme Storms,” supports Ray’s observations. According to the report, the Midwest saw a 52 percent increase in rain events of three inches or more during the 2000s as compared to a 1961 to 1990 baseline.13 Over the same period in Iowa, there has been a 33 percent uptick in such rains. A U.S. Geological Survey gauging station in Ray’s neighboring county shows a similar climb in two-inch rainfalls, going from just nine storms in the 1960s to twenty-one in the 2000s.

These increases can lead to a number of issues in the field, including erosion, loss of nutrients, prevention of timely weed control, surface crusting, narrowing planting and harvest windows, and compaction. The extent of these impacts depends on what season the rain is occurring. The most notable trend has been a rise in spring rainfall. This comes at a time when the soil, even in a no-till system, is most susceptible to erosion.

To combat these heavy rains, particularly those in spring, the Gaessers are using a fall-seeded annual cereal rye or ryegrass. Ray and his son Chris first started experimenting with rye as a cover crop through the field trials of the Iowa Soybean Association’s On Farm Network™ several years ago and have seen no negative impact to yields. In 2011, they seeded several hundred acres of their more highly erodible land to rye and were so impressed with the results that they seeded one-thousand acres of cover crop in 2012.

“This past spring we received a four-inch rain in one hour and ten minutes. While our steeper no-till fields saw significant erosion, we observed almost no erosion in our no-till plus cover crop fields,” says Ray. “We seem to be in a cycle of extreme weather and rain events. We recognize a need to adapt our management and conservation practices.
Production Systems and Practices

The history of agriculture and forestry is one of constant change and continuous improvement. This process of adaptive management will need to continue for producers to maintain viable operations in response to a changing climate. The following are recommendations for strengthening production systems, conservation, ecosystem services, and infrastructure.

1. **Implement conservation practices designed to maintain the productive capacity of land.** The future productivity of the land is directly linked to the conservation practices that we engage in today. The following conservation practices for building and preserving the soil have been identified by the Adaptation Work Group for consideration by producers:

   a) **Increase the soil’s water-holding capacity by improving soil organic matter content** – With heavier rainfall events creating problems for many producers, the implementation of practices to increase soil organic matter will help to prevent erosion and loss of valuable nutrients. It will also make crops more resilient to drought by retaining additional water.

   b) **Engage in conservation tillage practices to improve soil quality** – For many farmers, conservation tillage has become a standard practice for dealing with erosion, runoff, soil compaction, and declining organic matter. In addition to reducing input costs, conservation tillage can protect soils from heavier rainfalls and/or prolonged drought.

   c) **Plant cover crops to provide additional soil protection** – Like conservation tillage, cover crops are becoming a popular tool for increasing soil organic matter and preventing erosion and runoff, especially during winter and early spring. An example of this technique and its advantages can be found on page 14.

   d) **Explore the use of conservation buffers to reduce runoff and enhance ecosystem services** – In addition to preventing runoff, conservation buffers filter water, create habitat, offer shade for livestock, reduce water temperature, increase dissolved oxygen, and prevent algal blooms in waterways. Research even suggests that buffers, such as those composed of miscanthus or switchgrass, can protect against chemical drift.16

   e) **Utilize wetlands and new field drainage practices** – Heavy rainfalls and changes in the timing of precipitation may require new drainage networks. A number of options exist to meet this need,
including buffer strips that scavenge nutrients and wetlands for additional filtration. Controlled drainage techniques, such as using a flashboard riser to allow water in a drainage outlet to be raised or lowered, can improve production and maximize nutrient use.

f) **Diversify and lengthen cropping systems that enhance soil structure** – Longer crop rotations can help break up pest and weed cycles, thereby reducing input costs and enhancing the soil’s productive capacity.

g) **Consider biochar to improve soil health** – Biochar is a charcoal byproduct created by burning biomass slowly at low heat. Though additional field research will be needed, biochar has been demonstrated to have a number of benefits as a soil amendment, including improving nutrients, tilth, and water management. In addition, it is a means of sequestering carbon into the soil.¹⁷

h) **Engage in irrigation practices that improve water-use efficiency** – In many regions that already rely on irrigation, the climate is expected to become drier and create new demand for water-saving irrigation practices. In addition to conducting regular maintenance and audits on existing systems, many producers are recycling water, changing to drip systems, and using precision irrigation to target specific areas of their fields with the exact amount of water needed.

2. **Adopt new production practices designed to address climate-related challenges.** Practices that we have relied upon in the past may not be suitable for future weather conditions. Though many different adaptation practices are being tested on farms, fields, and forests across the country, the Adaptation Work Group identified the following for special consideration:

a) **Diversify agriculture and forestry operations to increase revenue and reduce risks** – Defined as the re-allocation of an operation’s productive resources (such as land, capital, farm equipment, and labor) into new activities, diversification is a fundamental means of reducing risk. It can encompass a wide variety of actions, as demonstrated by the story of Wisconsin farmer, John Vrieze, on page 3. For example, producers can diversify their operation by generating energy or managing multiple tree species to decrease threats from pests and diseases. To assist in diversification, we recommend:

- **Public policy support to enable the creation of and access to new markets** – One of the greatest challenges to diversification is the lack of markets for particular products. For instance, switchgrass is especially effective for conservation buffers; however, unless there are local markets for switchgrass, like biofuels or co-firing electricity, there are few incentives for planting it. The same can be said for forest thinnings. Policymakers can help address the “chicken and egg” problems related to the absence of products for markets and/or the absence of markets for products by creating incentives for new industries that will eventually become self-sustaining.
Review and remove economic and regulatory impediments for energy production – Rural America is uniquely rich in renewable energy potential; however, many producers interested in generating their own power face economic, technological, and regulatory barriers at a variety of levels. These should be identified by policymakers and addressed in consultation with a wide range of stakeholders, including utilities and regulatory bodies. This step could also help to address other issues, such as manure management in the case of methane digesters.

b) Manage forests to reduce risks posed by pests and fires
   – Drought and warmer winters enable pests to thrive and greatly increase fire risk. The year 2012 demonstrated how devastating this threat can be, with a record number of acres burned in so-called “mega-fires” throughout the West. Nonetheless, there are a number of steps that land managers can take to make forests more resilient to fire, such as:

   • Implementing fuels reduction activities
   • Introducing prescribed fire regimes
   • Managing for more resistant species and increasing forest diversity
   • Placing increased focus on silvicultural practices that increase tree vigor and growth
   • Intensifying stand-level monitoring of pests and invasives
   • Improving remote sensing and aerial monitoring
   • Enhancing existing tools such as the Forest Inventory and Analysis (FIA)

c) Manage forests for stronger storms – In addition to new pests and fires, foresters are being challenged by stronger storms. To meet these challenges, foresters can:

   • Mitigate storm surges through restoration and incentives to protect undeveloped coastal lands
   • Investigate planting higher densities
   • Use higher residual densities after thinning to protect crop trees
   • Plant and thin in accordance to topography and wind direction
   • Reconsider the size, extent, and management of riparian zones to account for greater flood frequency
   • Restore riparian areas to improve water infiltration, slow overland flow, and regulate the landscape’s water retention
   • Establish contingency plans to adjust timber and biomass procurement and harvest systems in case of severe forest damage
d) *Increase herd disease surveillance in livestock* – Higher temperatures and humidity increase the threat of pests and pathogens for livestock. Addressing this challenge will require heightened herd surveillance. Facilities with new biosecurity measures and decision tools to easily identify pests and pathogens can be invaluable in addressing this problem.

e) *Utilize best management practices to reduce heat stress on livestock* – Climate modeling points to an increase in heat waves in parts of the country. Problems with heat stress can be addressed through:
   - Altering rations from forage to other feed
   - Increasing available shade
   - Developing and using new facilities with greater climate control
   - Making additional fresh, clean water available
   - Improving watering systems to avoid water loss and increase water conservation and reuse

f) *Explore the impact and flexibility of subsurface water management systems* – Farmers in some regions of the Midwest have installed “pattern tile” subsurface drainage systems to reduce the waterlogging of soils that has resulted from increased precipitation. Data and research are needed to better understand performance of such systems under precipitation extremes, including potential negative consequences during drought.

3. Develop new private and public sector programs and markets for creating additional value for ecosystem services. Ecosystem services are environmental benefits, like clean air and water, which are produced by the land and enhanced by land managers. Ecosystem services are enjoyed by society as a whole and relied upon by industries and communities. Because everyone benefits from ecosystem services, mechanisms should be established that reward their production. The delivery of ecosystem services can be encouraged through both public conservation incentive programs and private markets. To achieve and enhance these efforts, we recommend:

a) *Evaluate a wide range of models for incentivizing ecosystem services* – A variety of ecosystem service incentive programs are currently being tested across the nation. These include reverse auctions, water quality and nutrient trading, and guarantees of reduced liability insurance or protection from further regulation (safe harbor). Other models have used market access as an incentive. This approach is being implemented by companies like Wal-Mart and Patagonia that use a zero to one-hundred metric system based on a long list of land management practices to guide their purchase of sustainable cotton.

b) *Provide adequate testing for evaluating pilot incentive programs* – Pilot ecosystem service incentive programs should have standardized and robust testing incorporated from their inception. This information will provide a baseline for assessing future progress and enable researchers to attribute successes properly for replication in other parts of the country.

c) *Remove state and federal barriers to experimenting with new incentive models* – In some cases, federal and state authorities should allow for special treatment of pilot program areas, such as
exemptions from additional regulation, as a means of encouraging additional participation over the course of testing periods.

d) **Modify and leverage existing federal programs for adaptation and the production of ecosystem services** – Even with private incentive programs for ecosystem services, the federal government will have an important role to play in supporting the adoption of conservation practices. Government programs should be examined and encouraged to include incentives for managing lands in ways that provide the greatest good per public dollar and offer multiple ecosystem services. Government programs should also be studied for how they might be modified to supplement public and private efforts.

4. **Create new and upgrade existing infrastructure to meet climate challenges.** Both public and private infrastructure will need to be altered in order to account for changes in climate. The Adaptation Work Group identified these specific areas where changes in infrastructure will be desired:

a) **Design and implement new siting for animal agriculture** – New facilities should be designed to address surface water and airshed management as well as extreme weather events.

b) **Offer information and support for upgrading existing structures** – Though new structures will be needed, consideration should also be given to how existing structures can be modified to meet changing conditions. This could entail weatherization and the addition of new structural features. Assistance should be provided in assessing risk to current structures as well as identifying potential solutions and effective low-cost means of funding them. For instance, upgrades that reduce electricity use could be funded through long-term, low-interest loans that would be paid back over time through related savings.

c) **Evaluate additional public investment in the development and maintenance of water infrastructure such as locks and dams, reservoirs, and other flood control structures based on climate models** – Large-scale water infrastructure such as dams, reservoirs, and flood control structures are expensive and require regular upkeep, but can serve as a bulwark against flooding and drought. Analysis should be conducted to determine how best to use these to mitigate climate impacts based on long-term projections. Nonetheless, given the expense and public challenges to these efforts, such projects should not be a substitute for other water management strategies, such as restoring and protecting wetlands and riparian buffers as noted earlier in this section.
Steve Irsik – Kansas Rancher

Steve Irsik has been managing his family’s farm in Southwest Kansas since 1973, but he can trace his connection to the area all the way back to the times of Wyatt Earp and Doc Holliday. In fact, his grandmother got to know the two men when she moved to Dodge City by stagecoach in 1880. This gives Steve a long historical perspective when he thinks about how the area has changed.

“In southwest Kansas, our climate is like the Texas pan handle was ten years ago. We’ve moved south in my mind,” Steve says. “The winters are milder and the rain has become more erratic. We used to get a lot of storms with at least two inches of rain. Now they are a rare event.”

Prolonged droughts have affected his operation. In addition to raising anywhere from 1,500 to 2,500 beef cattle, Steve grows irrigated corn, wheat, alfalfa, and sorghum. The lack of substantial rains has reduced the quality of grazing land for his beef cattle, which has made him more reliant on expensive feedstocks. It has also led to problems with weeds that have proven more resilient to dry conditions than the native grasses.

“Certain weeds are here now that weren’t here forty years ago. Others are much worse than they used to be and they’re getting a hell of a lot harder to kill,” Steve notes. “In response, we’re rotating herbicides to avoid resistance and selectively grazing our cattle.”

In coping with these changes, Steve has also found developing new varieties of beef cows helpful. “We have been working hard on the genetics of our animals over the last twenty-five years to build ones that use less resources,” he states. “We are now using less grain to produce a better product at a younger age. This means less demand for land and water and less carbon dioxide and methane emissions.”

These gains notwithstanding, Steve has been forced to liquidate a portion of their cattle to keep their operation whole. In fact, the U.S. Department of Agriculture reported that the number of cattle bound for feedlots in Kansas in September 2012 was down 25 percent from the previous year.18 This decline has had a ripple effect on the rural economy as packing plants have had to close their doors.

The drought has posed similar problem for Steve’s crops. With fewer two-inch rains, less water is soaking into the subsoil. Because of this, he has stepped up efforts to retain the water on his land. “We’ve been doing no till for the past twenty years and maintain a lot of surface residue to absorb big rains, prevent runoff, and protect the living micro-organisms,” Steve explains.

Like many in the area, he has tapped into the Ogallala Aquifer, an underground reservoir spanning from South Dakota to Texas, to assure steady yields. But Steve has genuine concerns about this as a viable strategy moving forward. “We’re pumping the Ogallala out faster than it is recharging,” he says. “Essentially, we’re mining it. As we move into a drier future, there will be higher demand for irrigation. But if we continue this way, it will not be there.”

When asked about climate and adaptation, Steve states simply, “We tend not to think long-term. But we need to try to peer over the horizon and figure out where we are going to be in the country in terms of our natural resources. We need to ask ourselves what we should be doing today to prepare for the next decade and beyond.”
Risk Management

The 25x’25 Adaptation Work Group recommends using risk management to address climate challenges at both the producer and policymaker levels. Risk management is the systematic management of uncertainty to minimize potential losses. Producers are no strangers to this. After all, it comprises many of the decisions they make on a daily basis. However, this approach should be broadened to include the short- and long-term risks associated with climate changes. Doing so will lead to more resilient agricultural and forest systems.

1. Maintain a robust federal crop insurance program. Crop insurance is now the primary safety net for many farmers and, like many tools, it will need to be adjusted in light of changes in climate. In May 2010, the U.S. Department of Agriculture’s Risk Management Agency released an assessment of the impacts of climate change on the nation’s crop insurance system. The study found that because production yields varied so greatly from one global climate model to another, conclusions were difficult to reach. Nonetheless, there are steps that can be taken to prepare crop insurance for the future:

   a) Study the potential expansion of federal insurance programs to cover additional practices – Expansion of federal insurance programs should be explored for methods of production such as livestock, forage crops, specialty crops, organic agriculture, and other emerging products.

   b) Alter crop insurance rates, loss adjustment standards, underwriting standards, and other program materials to account for new production regions and practices – Changes in climate may result in changes in production practices. For instance, areas that have not relied heavily on water-saving practices in the past may switch to irrigation. Because of its reliance on historical yields, crop insurance may not necessarily accommodate such changes. New technologies may help producers of perennial crops who have difficulty getting access to crop insurance because of a shortage of historical yield data due to measurement difficulties.

   c) Conduct additional studies on the impact of climate change on crop insurance – As climate modeling continues to improve, new studies should determine how crop insurance will be affected by climate change. Subsequent studies should integrate the role of extreme events into scenarios to enhance their accuracy.

   d) Examine how federal crop insurance programs could help facilitate adaptation – Because compensation for losses is the economic driver to participate in federal programs and purchase crop insurance, insurance programs for the agricultural sector should seek to balance the need to support producer revenue with maintaining a resilient production system. In some cases, federal crop insurance rules may need to be updated to account for certain adaptation practices. For example, producers can lose their eligibility to harvest a crop for livestock or biomass if they allow a cover crop to grow past a certain date. Such obstacles should be identified and addressed to harmonize the system with effective adaptation options.

2. Ensure that there are adequate disaster relief programs available to producers for natural disasters. Even with proper risk management, not all disasters can be averted. If projections are correct, weather-
related disasters are expected to become more frequent throughout the century. When they occur, there should be proper supports in place to make producers whole. To strengthen these supports, we can:

a) **Maintain disaster relief programs supporting a wide range of producer needs** – As the federal government explores budget cuts, disaster programs are increasingly coming under threat. Yet the number of weather-related disasters has climbed in recent years and is expected to continue climbing in the years to come, making these programs more valuable than ever.

b) **Develop local, state, and federal disaster response plans** – Cities, states, and the federal government should consider agriculture and forestry in the creation of disaster relief plans. In the case of forestry, this would mean creating protocols for events such as hurricanes and tornadoes to triage areas quickly and enable harvesting. Individuals and agencies at the local level should be designated to facilitate the development of these plans.

c) **Designate “rapid response teams” to gather data on the societal responses and agricultural impacts of extreme weather events** – State agriculture and natural resource extension services should create rapid response teams to assess the actions of individual communities after disasters. Information on how agriculture and forestry respond to extreme weather events, as well as the effectiveness of those responses, can be used to shape the actions of other communities experiencing similar events.

d) **Examine how disaster relief programs might be coupled with adaptation measures** – As with crop insurance, there are situations when relief programs might serve as an obstacle for adaptation. In areas where previously rare disasters become more commonplace, the possibility of coupling relief programs with assistance for transforming operations may represent a more cost-effective public investment.

3. **Provide multiple avenues for funding adaptation measures.** Adaptation can be capital-intensive. For instance, in areas where rainfall is declining, irrigation may be needed. Though this practice can improve the predictability of harvests, transitioning to it can be prohibitively expensive. There are many examples like this where multiple avenues should be explored to help farmers, foresters, and ranchers adapt, including:

a) **Encourage private banks to offer low-interest loans and establish revolving loan funds** – The private sector can contribute to funding adaptation measures as well. In cases where adopting a given practice or technology is expected to improve or stabilize prices, banks can take advantage of the reduced risk by offering low-interest and revolving loans.

b) **Provide producers low-interest payment systems from retailers and manufacturers** – Like banks, retailers and manufacturers can offer low-interest payment systems to allow producers to pay back purchases over time using the benefits gained from higher yields and efficiencies.

c) **Explore funding that rewards watershed- and landscape-level responses to changing conditions** – Incentivize whole farm and watershed-wide production systems and practices that incorporate performance-based environmental management as an adaptive response to the increased volatility of climate, markets, and social conditions.
Al Herndon – Florida Strawberry Farmer

About ten-thousand acres of strawberries are grown every winter in Florida, making the state the second largest strawberry producer in the country behind California. Al Herndon has been in the strawberry business in Citrus County, Florida, for over sixteen years and, like all other strawberry growers in the state, has the annual challenge of controlling diseases during the cropping season. Growers in Florida must protect their crop with numerous pesticide applications to produce fresh fruit of marketable quality that does not spoil shortly after harvest. Fungicides are by far the most frequently used pesticide because they are applied on a tight preventive schedule for months during the production season to protect plants and fruit mainly from anthracnose and Botrytis fruit rot.

Environment and diseases are closely related, and climate variability greatly affects the place, timing, and severity of disease. The southeastern United States is strongly influenced by El Niño and the Southern Oscillation (ENSO). In an El Niño year, the region typically experiences a winter and spring that are colder and wetter than normal, while La Niña brings drier and warmer conditions. This difference in climate conditions during the strawberry season translates into different disease risks and related opportunities to reduce the number and alter the timing of fungicide applications.

In 2009, researchers at the University of Florida implemented a system to help growers in Florida track disease risks and apply fungicides only when conditions are favorable for disease development — the AgroClimate Strawberry Advisory System (SAS). At that time, Al Herndon became a consultant and started experimenting with the system to guide the application of fungicides in one of his client’s farms. At the beginning, he was skeptical of the system, arguing that it was impractical and probably would not work. He tested the system on only nine rows of strawberries and sprayed the rest of the field with the traditional schedule, which normally requires over twenty fungicide applications during the season. In the first year of tests, the area of the field where the system was used required only twelve to fourteen applications, and early yields were higher than the rest of the field. The annual yields were similar in both areas. In the second year, Al dedicated one acre to the system with similar results. As the years went by, he kept increasing the area under SAS and gaining confidence in the system.

Al recently retired and, although he is not growing strawberries anymore, he continues to help other growers implement the system. He firmly believes that accounting for climate variability and using the AgroClimate Strawberry Advisory System can help growers reduce the number of applications by as much as 50 percent. This greatly reduces the cost of production without impacting the yields or quality of the fruit.

Al Herndon took advantage of new decision tools for strawberries developed by the University of Florida to reduce his pesticide use and input costs.
Planning and Decision Support Tools

For the purposes of this report, tools are defined as devices, methods, or rules that assist producers in making decisions. Our nation’s producers already have various decision tools created by private companies, universities, and government agencies at their disposal for a wide range of purposes such as detecting invasive species, determining when to spray, and weighing diversification options. As the past becomes a less reliable predictor of the future, decision tools will be all the more important.

1. Develop new tools to take advantage of how producers will use and access information in the future.

Both new and old tools will need to be adapted for how farmers will access information in the future. An excellent example of this is Thermal Aid, a smartphone application developed by the University of Missouri (shown at right) to help producers determine which animals are at risk for heat stress. Another example is the Strawberry Advisory System on AgroClimate featured on page 23, which sends text messages to subscribed producers to notify them when conditions are ideal for chemical application. These types of intuitive and immediately accessible tools represent the next generation of agriculture and forestry decision tools. The process of developing these is well underway at many universities and corporations and should be both continued and encouraged.

2. Provide regular updates to decision tools dependent upon climate data.

Many tools used by agriculture and forestry rely on historical climate data in order to be relevant. For instance, resource management recommendations have been developed by federal agencies, institutions, and universities over the last

Thermal Aid Smart Phone App

Thermal Aid provides an excellent example of how old tools can be adapted for the ways in which producers will access and use information in the future. Developed by the University of Missouri, this phone application combines live weather data from a given location with cattle respiration rates that are added by the producer using the software’s built-in timer. With this tool, farmers can easily assess early signs of heat stress and target specific animals and areas for additional cooling.

Figure 2 – In January of 2012, the U.S. Department of Agriculture released its first update of its Plant Hardiness Zone Map in two decades, placing many areas throughout the country into new climate zones.
eight decades based on temperature and precipitation regimes that occur within certain probabilities like a “twenty-five-year event.” Unfortunately, changes in climate are altering these probabilities. Another example is the U.S. Department of Agriculture’s Plant Hardiness Zone Map, which helps individuals determine what to plant in their region. In January of 2012, the department released its first update to the map in over two decades, placing many parts of the country into different climate zones. Such tools should be revised more frequently in order to keep pace with changes in climate. Fortunately, new technology makes the process of updating this information much easier.

3. Incorporate climate change information and data into existing tools.

Most existing decision-making tools are not geared towards climate change or adaptation, but rather inform producers about more specific outcomes based on risks that occur within their production systems. These specifics may be part of an adaptation strategy, but are not communicated as such. Linking climate information to these tools will provide producers with a better understanding of the changes they will be addressing in the future.

4. Integrate tools to provide a more comprehensive picture for decision-making.

Most decision-making tools evaluate stressors like pests, diseases, and invasive species independently from one another. Since these problems do not occur in isolation in the production system, integrating different tools can present a more realistic assessment of risks and simplify decision-making. For example, pest and disease outbreaks are expected to become more frequent and new pests may emerge. Penn State’s PestWatch is a valuable tool for evaluating pest outbreaks and will inform on the necessity and timing of pesticide application, but it is not currently linked to climate change information.

5. Engage in local- and watershed-level planning with all relevant stakeholders.

In places where water resources are stressed and becoming scarce, local and regional water planning will become increasingly important. This planning should incorporate climate change models and be conducted in conjunction with multiple stakeholders, including agriculture, so that each party has an opportunity to shape the community’s responses and expectations prior to a point of crisis. Watershed-level planning will likely require agreements between multiple states. Similar plans should also be developed for future flooding.

The National Drought Mitigation Center at the University of Nebraska-Lincoln helps groups develop and implement measures to reduce vulnerability to drought. Their website also catalogues state drought plans.
David Marvin – Vermont Maple Syrup Farmer

Maple syrup is big business in Vermont. The state meets about 40 percent of the United States maple syrup demand and the product has a $200 million footprint in Vermont’s economy.20 However, producers say it has gotten harder in recent years for the industry to thrive.

“We have made syrup three times in February over the past ten years. That’s something we have never done before,” David Marvin says. “The seasons are beginning and ending much earlier.”

David would know. He has been commercially producing organic maple syrup on a 300-acre and 15,000-tap farm near Johnson, Vermont, for over forty years. This area used to be the heart of the maple syrup production region, but milder winters over the past few decades are threatening to move the business northward. Over the past fifty years, average winter temperatures in Vermont have risen around 4.5°F.21 While this may be welcome news for some, maple syrup farmers rely on a cycle of freezing temperatures at night and thawing during the day for syrup production in winter and early spring. When enough days pass without freezing temperatures, the sap flow stops. In other words, warmer winters mean less cycles and less syrup.

The work of University of Vermont researchers confirms much of what David has seen in the past few decades. Dr. Timothy Perkins of the Proctor Maple Research Center has found that the syrup season in New England is arriving eight days sooner and ending eleven days earlier than forty years ago. This marks a loss of three days of production — a trend expected to continue into the future.22

Fortunately, the changes have yet to translate into losses in overall production. This is largely due to advancements in technology. Though vacuum tubing systems have been used for years, the refinement of the equipment and technique over the past decade has enabled producers like David to boil more syrup even with a shorter season. “These new systems can make a flow on even on a poor flowing tree,” says David.

Another problem facing maple syrup farmers has been damage to forests from stronger and unusual storms. “We’ve had four major weather events over a little more than a decade,” says David. “We had an ice storm in 1998, Hurricane Floyd in 2000, a tornado in 2010, and Hurricane Irene in 2012, which took two months to clean up.” While these types of events are hard for any producer to cope with, they are especially difficult for maple farmers since it takes forty to fifty years for a new tree to yield syrup. David is quick to point out that, unlike other crops, “When we lose our resource, it’s gone for a lifetime.”

David’s experience demonstrates some of the potential limits to adaptation strategies designed to increase resilience and resistance. “I won’t see the demise of the maple industry in our area, but my kids and grandkids might and we are certainly thinking about that,” he explains. “I know of a supplier in Southern Vermont that is moving to Northern Maine, where the temperatures are better. But we’re not that mobile. My adaptation strategy — if we couldn’t continue to do what we are doing, we would need to do something different. We would be out of the maple business.”
Communications, Outreach, and Education

The best technologies, groundbreaking studies, and decision tools in the world will matter little if we cannot effectively get information into the hands of producers. Recognizing this, the Adaptation Work Group has developed recommendations to strengthen outreach to farmers, foresters, and ranchers.

1. Engage in producer-to-producer dialogues to connect producers in areas experiencing changing conditions with those already accustomed to addressing similar challenges.

Many of the producers featured within this document mention that they are now seeing pests that have traditionally been associated with other areas of the country. Under most scenarios, climate zones are expected to continue shifting, leaving many producers facing challenges like new pests and diseases that they are unaccustomed to dealing with in their area. However, our nation has a wide range of climate conditions for which producers have already developed and refined best management practices over centuries. Because of this, producers from around the country may serve as trusted and valuable resources for other producers. Commodity groups, farm and forest organizations, and state agriculture agencies can play an important role in connecting producers from various parts of the country, whether in-person or through online forums.

2. Encourage ongoing dialogue between scientists, policymakers, and agricultural organizations.

Scientists, policymakers, and agricultural organizations all stand to benefit from regular exchanges of ideas. For scientists, such dialogue is an opportunity to spotlight their work and develop a better understanding of producers’ concerns and how research might benefit them. For agricultural associations and policymakers, regular conversations with scientists will provide a chance to share their perspectives and offer more information for their members and constituents on challenges and solutions that may not be widely recognized. The Southeast Climate Consortium’s Tri-State Working Group provides an example of how such groups can interact to enable mutual learning.23

3. Involve producers and trade associations in research decisions and implementation.

Too often, research is conducted away from the individuals it is designed to benefit. Multi-directional exchanges and learning among scientists, producers, and trade associations is necessary for science to be
transformed into applications and technologies that producers and their supporting industries find useful. Research on new practices and strategies must be integrated within the landscape at field and forest plots to capitalize on the expertise of scientists as well as producers. Moreover, grower groups can play an important role in identifying the types of studies needed by their members. This will ensure that the research is relevant and has an even larger platform for distributing results.

4. Address the challenges of reaching landowners.

Reaching landowners is becoming more difficult due to increases in absent ownership of land. But there are a number of steps for addressing this issue. For instance, educational materials and information can be provided through professional farm managers and consultants. Websites and electronic newsletters offer additional avenues for sharing information with landowners.

5. Conduct cross-disciplinary efforts in researching and communicating adaptation measures.

Through cross-disciplinary work the whole can be made greater than the sum of its parts. For instance, the Tri-State Working Group, supported by the Southeast Climate Consortium, includes a diverse array of researchers, such as climatologists, agronomists, crop modelers, plant pathologists, anthropologists, sociologists, and communications specialists. Each of these specialists contributes uniquely to answering complex cross-disciplinary climate-agriculture questions. Such efforts can be a powerful vehicle for engaging in and disseminating actionable research.

6. Provide additional support for existing outreach networks such as agricultural extension, government agencies, and universities.

There is already a network of various organizations in place throughout the nation that can serve as effective communicators for adaptation strategies. Extension, state agencies, and universities all have considerable experience in communicating with the agricultural and forestry sector. In addition to holding workshops for landowners and making resources readily available, these groups can conduct “train-the-trainer” events for agricultural and forestry advisers and others who producers turn to for advice in decision-making. These organizations need support to continue their operations and conduct adaptation education programs that will produce effective results.
A Path Forward

Though the recommendations included in this document are the result of a year of work with various stakeholders from agriculture, forestry, and supporting groups, they mark the beginning rather than the end of a conversation. This report is intended as a living document, to be revised and expanded upon as new information from a wide range of sources is brought to light. As such, we not only welcome, we encourage your feedback on the types of adaptation measures needed to enable our nation’s producers to succeed in the context of a changing climate.

Over the course of 2013 and 2014, 25x’25 Alliance staff members and volunteers will be offering presentations, workshops, webinars, and other forums to discuss the ideas found within this report and to gather feedback on what we got right, what we missed, and what is needed for individual crops and communities to adapt. In doing so, we invite agricultural, forestry, and conservation organizations as well as others within the value chain to partner with us in engaging their members in this important conversation. To learn more about how your group can support and participate in our adaptation dialogue, go to www.25x25.org/adaptation.

Changes in climate and other market demands will present real challenges for our nation’s agriculture and forestry system, necessitating adaptation at a number of different levels and timescales. In determining our future path, we would be wise to heed the words of Benjamin Franklin, “An ounce of prevention is worth a pound of cure.” As this report demonstrates, there are numerous pathways available to not only meet these challenges, but do so in a way that strengthens production systems, improves profits, and reduces environmental impacts. With your help, we can continue building upon the great progress already being made by farmers, foresters, and ranchers.

We Want to Hear from You!

What did we miss? What are the right priorities? What changes are you seeing in your area and how are you or others adapting? To provide feedback on this report, or for more information on the 25x’25 Adaptation Initiative, go to http://www.25x25.org/adaptation. There, you will find a link beneath the description of this report where you can share your thoughts with the Adaptation Work Group.
Appendix: Impact of Changing Weather and Climate on Agriculture and Forestry

In developing their adaptation recommendations, the 25x’25 Adaptation Work Group examined how anticipated changes in climate might impact our nation’s agriculture and forestry systems. The results of this research, published in a February 2012 background brief, entitled “Agriculture and Forestry in a Changing Climate: The Road Ahead,” confirm many of the experiences described by producers featured in this report.

Relying on internationally respected sources such as the National Academy of Sciences and the U.S. Global Change Research Program, the Adaptation Work Group highlighted the following climate trends as particularly important for agriculture and forestry:

- Higher temperatures
- Greater risk of flood and drought
- Increased carbon dioxide levels

This section offers a summary of the impacts of these three factors. A more in-depth examination of these and other changes can be found in the Adaptation Work Group’s background brief.

Temperature

Average temperatures within the United States have risen more than 2°F over the past fifty years (See Figure 1). This change has contributed to spring arriving nearly two weeks earlier throughout much of the United States over the last two decades, expanding the growing season for some crops. By 2100, researchers believe our nation’s average temperatures will rise by as much as 4 to 11°F.

While higher temperatures can improve production for plants and animals, beyond a certain threshold crops fail and livestock succumb to heat stress. Higher temperatures can also be a boon for pests, pathogens, and weeds that will be able to thrive in higher elevations and latitudes. Ozone poses yet another concern. Ozone is toxic to most plants and its levels tend to increase with higher temperatures. According to a 2009 study, global yield losses due to ozone are already between 7 percent and 12

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Footnote: High above the earth in the stratosphere, ozone serves as an important shield against harmful ultra-violet rays from the sun. But at the ground level (troposphere), ozone is a harmful pollutant formed by a reaction between sunlight and hydrocarbons with nitrogen oxides largely from industrial emissions and motor vehicle exhaust.
percent for wheat, 6 percent and 16 percent for soybean, 3 percent and 4 percent for rice, and 3 percent and 5 percent for maize.\textsuperscript{25}

The timing of higher temperatures is important. Higher nighttime temperatures limit the ability of animals to recover from daytime heat and increase plant respiration rates, thereby altering the amount of carbon that can be captured during the day. Though the trend of warmer winters may come as welcome news for the average American, it could mean higher insect survival rates and an increase in the generations of pests during the growing season. Milder winters can also cause fruits and nut trees to fail to meet their “chilling requirements” or bloom ahead of schedule, rendering them vulnerable to late frosts. This was the case for Michigan fruit farmers in 2012; most of their crops were wiped out after an unusually warm winter caused tart cherry trees to bloom ahead of schedule in March. A frost a few weeks later caused production to drop from 157.5 million pounds in 2011 to a forecasted 5.5 million pounds in 2012.\textsuperscript{26}

Though it is possible that production could initially benefit from higher temperatures, plants and animals will experience greater risk of failure from heat and other heat-related stressors as the century continues.

**Precipitation**

Over the past fifty years, rainfall in the United States has increased about 5 percent.\textsuperscript{27} While the average may not be significant, changes in precipitation have varied from region to region, with the Northeast becoming wetter and the Southwest becoming drier. As scientists look out over the century, they anticipate that these trends will continue.

Droughts, when combined with rising temperatures that increase evaporation, are expected to become more frequent and intensify. This will increase the risk of forest fires and place additional stress on water systems. Nowhere will this be more apparent than in the Southwest, where the drying of the last several decades is projected to continue under almost every climate scenario.

![Projected Change in North American Precipitation by 2080-2099 under a higher carbon dioxide concentration scenario.](image-url)
For agriculture and forestry, the distribution of precipitation throughout the year can be just as important as annual totals. A trend that many producers have seen is, simply put, when it rains it pours. Very heavy precipitation events, defined as the heaviest 1 percent of all events, have increased by 20 percent nationwide (Figure 3). This change has been most notable in the Midwest (31 percent) and Northeast (67 percent), which have experienced unprecedented flooding in recent years.98 According to the U.S. Global Change Research Program, by the end of the century, precipitation events that are now 1-in-20 year occurrences are projected to occur every four to fifteen years, creating new challenges for water management, erosion control, and insurance, and narrowing the windows for planting and harvest.99

**Carbon Dioxide**

The concentration of carbon dioxide in the atmosphere has climbed from around 290 parts per million (ppm) in 1880, to over 380 ppm today98 and is expected to rise to as high as 850 ppm by 2100.

At first glance, increased carbon dioxide might be beneficial to agriculture and forestry because plants use carbon dioxide as a valuable source of food. However, higher levels of carbon dioxide won’t just benefit production crops; some weeds are poised to thrive under elevated carbon dioxide conditions as well, potentially requiring the use of additional herbicides. This point is illustrated in Figure 4, which compares two fields, both treated with same amount of the popular herbicide RoundUp™. Under the simulated higher carbon dioxide conditions, RoundUp is much less effective.

![Figure 6 - The left photo shows weeds in a plot grown at our current carbon dioxide concentration of about 380 parts per million (ppm). The right photo shows a plot in which the levels have been raised to about 680 ppm. Both plots were treated with same amount of RoundUp™ herbicide.](image-url)
Furthermore, quantity should not be mistaken for quality. Plants may produce more biomass under higher carbon dioxide levels provided that they are not limited by other factors, but the nutritional quality of those plants can decline. This may cause livestock and pests to consume more food in order to achieve the same level of nutrition.

Like temperature, higher carbon dioxide conditions will pose new benefits and challenges.

**Implications**

So what will all of these changes mean to agriculture and forestry? Researchers have come to a wide range of different conclusions on their exact impact. For instance, in studying the effects of climate on corn crops, David Lobell, Wolfram Schlenker, and Justin Costa-Roberts found that for the past three decades changes in climate have reduced corn yields worldwide, relative to a stable climate, by 5.5 percent.

The most comprehensive synthesis of existing research was released in February of 2013 by the U.S. Department of Agriculture. This report, entitled “Climate Change and Agriculture in the United States: Effects and Adaptation,” expands upon many of the agency’s previous conclusions, such as the impacts cited throughout this section, and details their implications for animal agriculture and a variety of crops. The report unequivocally concludes that climate change will adversely impact U.S. agriculture, stating that “increases in temperature coupled with more variable precipitation will reduce productivity of crops, and these effects will outweigh the benefits of increasing carbon dioxide.”

While no one can state exactly what the climate will be like in the future for each region of the United States, the majority of the scientific research points to real challenges for our nation’s agriculture and forestry sectors as shifts in weather patterns continue and intensify over the course of the century. For this reason, adaptation has increasingly become a subject of interest for producers, supporting groups, and policymakers.
Additional Resources

Agriculture and Forestry in a Changing Climate: The Road Ahead
Website:  [http://www.25x25.org/storage/25x25/documents/Adaptation/agriculture_and_forestry_in_a_changing_climate_-_the_road_ahead.pdf](http://www.25x25.org/storage/25x25/documents/Adaptation/agriculture_and_forestry_in_a_changing_climate_-_the_road_ahead.pdf)

A background brief by the 25x25 Alliance Adaptation Work Group that uses internationally respected, peer-reviewed sources to present some of the current and anticipated shifts in climate and weather patterns that agriculture and forestry will need to address in order to maintain and enhance future productivity and the delivery of ecosystem services.

USDA Climate Change Program Office
Website:  [http://www.usda.gov/oce/climate_change/index.htm](http://www.usda.gov/oce/climate_change/index.htm)

The Climate Change Program Office serves as the focal point for the U.S. Department of Agriculture (USDA) on climate change issues and is responsible for coordinating activities with other federal agencies, interacting with the legislative branch on climate change issues affecting agriculture and forestry, and representing USDA on United States delegations to international climate change discussions. The site contains links to USDA climate change programs and websites. Major USDA climate change resources available on the site include:

1. Synthesis and Assessment 4.3: The Effects of Climate Change on Agriculture
3. USDA Climate Change Science Plan
5. Climate Change and Agriculture in the United States: Effects and Adaptation
6. Effects of Climate Variability and Change on Forest Ecosystems: A Comprehensive Science Synthesis for the U.S. Forest Sector

The Global Change Research Program is in the process of developing a new National Climate Assessment. A draft of the paper was released for public comment in January 2013. In addition to updates on the general science, it includes a chapter specifically dedicated to agriculture and climate change.

USDA Economic Research Service: Climate Change Briefing Room

The Economic Research Service (ERS) climate change program focuses on the economic implications of climate change for United States agriculture. This briefing room describes the ERS climate change research program and provides information related to climate change and agriculture. Numerous ERS reports, web links, and other resources related to a wide range of climate change issues are also available on this site.
Agricultural Adaptation to a Changing Climate: Economic and Environmental Implications Vary by U.S. Region
Website: http://www.ers.usda.gov/media/848748/err136.pdf

This USDA study explores potential impacts of climate change on agriculture. It finds that while impacts are highly sensitive to uncertain climate projections, farmers have considerable flexibility in adapting to changes in local weather, resource conditions, and price signals by adjusting crops, rotations, and production practices. Such adaptation, using existing crop production technologies, can partially mitigate the impacts of climate change on national agricultural markets. Adaptive redistribution of production, however, may have significant implications for regional land use and environmental quality.

U.S. Global Change Research Program
Website: http://www.globalchange.gov/

The U.S. Global Change Research Program coordinates and integrates federal research on changes in the global environment and their implications for society. This site contains links to climate change resources located throughout the thirteen departments and agencies that support climate change science programs. The full set of Synthesis and Assessment Reports that made up the last United States climate change assessment are available on this site.

Nicholas Institute for Environmental Policy Solutions
Website: http://nicholasinstitute.duke.edu/

The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to help decision makers in the government, private sector, and nonprofit community address critical environmental challenges. Drawing upon Duke’s expertise in the areas of economics, science, law, engineering, and finance, researchers have conducted multiple studies on how forests, agriculture, and land use change can mitigate and adapt to climate change at a global and national scale. These and numerous other reports, white papers, and other products assessing the economic implications of various policy approaches to a wide range of climate change issues of interest to agriculture and forestry can be found on their website.

Forestry and Agriculture Greenhouse Gas Modeling Forum
Website: http://foragforum.iti.org/index.cfm

The Forestry and Agricultural Greenhouse Gas Modeling Forum is sponsored every two years by the USDA, U.S. Environmental Protection Agency, and Agriculture and Agri-Food Canada. The forum brings together leading members of the climate change modeling and policy communities to discuss the current status of modeling capabilities, likely advances in modeling capabilities over the next two years, and the information needs that policymakers view as high priorities. To date there have been six meetings of the forum. Organizing themes vary to reflect current interest. Reoccurring areas of focus include key modeling and policy
design priorities, climate change adaptation and food security, greenhouse gas mitigation, bioenergy, deforestation, and Reducing Emissions from Deforestation and Forest Degradation (REDD). The forum website is maintained by the Research Triangle Institute and contains agendas, presentations, and participant lists.

**AgroClimate**

Website:  [http://agroclimate.org/](http://agroclimate.org/)

AgroClimate is an interactive website with climate, agriculture, and forestry information that allows users to assess resource management options with respect to their probable outcomes under forecast climate conditions. AgroClimate uses crop simulation models along with historic and forecast climate data to compare changes in probable outcomes under different climate conditions.

**Pine Integrated Network: Education, Mitigation, and Adaptation Project**

Website:  [http://www.pinemap.org/](http://www.pinemap.org/)

The Pine Integrated Network: Education, Mitigation, and Adaptation Project (PINEMAP) is one of three Coordinated Agriculture Projects awarded in 2011 by the USDA National Institute of Food and Agriculture. PINEMAP focuses on the twenty million acres of planted pine forests managed by private landowners in the Atlantic and Gulf coastal states from Virginia to Texas, plus Arkansas and Oklahoma. These forests provide critical economic and ecological services. Southeastern forests contain one-third of the forest carbon in the contiguous United States and form the backbone of an industry that supplies 16 percent of global industrial wood, as well as 5.5 percent of the jobs and 7.5 percent of the industrial economic activity of the region. PINEMAP integrates research, extension, and education to enable southern pine landowners to manage forests to increase carbon sequestration; increase efficiency of nitrogen and other fertilizer inputs; and adapt forest management approaches to increase forest resilience and sustainability under variable climates.

**USA National Phenology Network**

Website:  [http://usanpn.org](http://usanpn.org)

The USA National Phenology Network brings together citizen scientists, government agencies, non-profit groups, educators and students of all ages to monitor the impacts of climate change on plants and animals in the United States. The network harnesses the power of people and the Internet to collect and share information, providing researchers with far more data than they could collect alone.

**The National Drought Mitigation Center**

Website:  [http://drought.unl.edu/](http://drought.unl.edu/)

The National Drought Mitigation Center at the University of Nebraska-Lincoln helps groups develop and implement measures to reduce vulnerability to drought. Their website also catalogues state drought plans.

**Report to the President on Agriculture Preparedness and the Agriculture Research Enterprise**
Website:  http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_agriculture_20121207.pdf

A report to the White House by the President’s Council of Advisors on Science and Technology examining the preparedness of American agriculture and its research system for climate change. Among the report’s conclusions is that present agricultural research efforts are inadequate and that $700 million a year must be invested into the field in order to ensure our nation continued role as a world leader in agriculture.

**Producer Story Credits**

Jim Gray story and photo on page 4 was prepared by Mark Megalos, Extension Associate Professor, North Carolina State University College of Natural Resources, PI in a PINEMAP USDA/NIFA project in partnership with Jim Gray, forest consultant and manager of the 3,500 acre forest in Hoke County, NC. For more information, contact: namegaloncsu.edu or wendylin@ufl.edu.

Ray Gaesser story on page 14 prepared by Heath Ellison and Roger Wolf at the Iowa Soybean Association.

Al Herndon story on page 23 prepared by Clyde Fraisse and Natália Peres at the University of Florida.

Other producer stories prepared by Tim Fink at the 25x25 Alliance.

**Charts, Graphs, Diagrams**


_Figure 3 –_ United States Global Change Research Program, “Global Climate Change Impacts in the United States,” 2009, pg. 27.

_Figure 4 –_ United States Global Change Research Program, op. cit, pg. 31.

_Figure 5 –_ United States Global Change Research Program, op. cit, pg. 32.

_Figure 6 –_ United States Global Change Research Program, op. cit, pg. 75.
Endnotes


9. Photo taken and text prepared by Mark Megalos, Extension Associate Professor, North Carolina State University College of Natural Resources, PI in a PINEMAP USDA/NIFA project in partnership with Jim Gray, forest consultant and manager of the 3,500 acre forest in Hoke County, NC. For more information, contact: mamegal@ncsu.edu or wendylin@ufl.edu.


Prepared by Heath Ellison and Roger Wolf at the Iowa Soybean Association.


Prepared by Clyde Fraisse and Natália Peres at the University of Florida.


28 United States Global Change Research Program, op. cit., pg. 32.

29 United States Global Change Research Program, op. cit., pg. 32.

30 United States Global Change Research Program, op. cit., pg. 17.
