CLIMATE CHANGE, AGRICULTURE, & WATER RESOURCES IN THE MID-ATLANTIC

6/23/2010

Proceedings from a Regional Science Workshop

The following document summarizes presentations given at a workshop sponsored by the Mid-Atlantic Water Program to build a common understanding amongst scientists working in agricultural production, water resources, and climate science; identify needs in decision-making; and begin a process to build partnerships and tools to address decision-making needs.

Climate Change, Agriculture, & Water Resources in the Mid-Atlantic

PROCEEDINGS FROM A REGIONAL SCIENCE WORKSHOP

Table of Contents

Table of Contents

This material is based upon work supported in part by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Agreement No. 2008-51130-19500. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

INTRODUCTION

On June 23, 2010, the Mid-Atlantic Water Program hosted a science workshop to discuss how climate change will affect agricultural production and water resources in the Mid-Atlantic, and the decision-making tools needed to address production, environmental management, and policy needs. The invitation-only workshop included participation from climate, agricultural, and natural resource scientists from across Maryland, Delaware, Pennsylvania, and Virginia. The goals of the meeting were to:

1. Introduce and build a common understanding amongst scientists working in agricultural production, water resources, and climate science;
2. Identify needs in decision-making and facilitate a discussion of what information gaps require greater research and what tools need developing; and
3. Develop partnerships and ideas to build into proposals for further funding of tool development and research.

The following document summarizes presentations and discussions from the workshop.

APPLYING CLIMATE SCIENCE

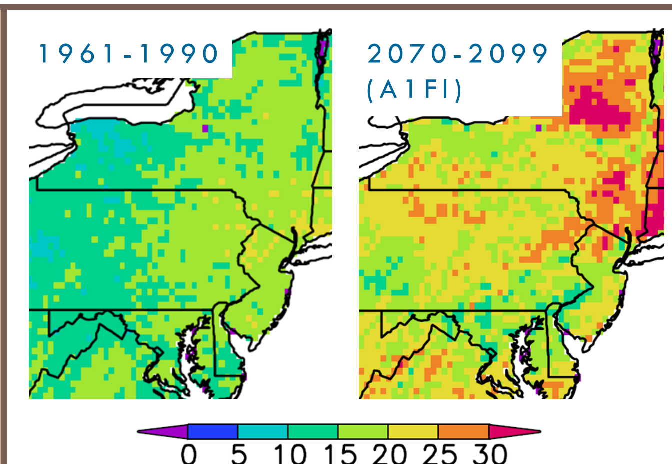
To estimate future changes that might be expected in our climate, scientists must first make some assumptions about what the future might look like, especially the amount of heat-trapping emissions that will be in the atmosphere. Scientists make estimates of future emissions by creating scenarios of what population growth, energy use, economic development, and technology use could look like in the future (see Box 1, "Possible Emissions for the Future").

These emissions are the basis for global climate models (GCMs). GCMs can then be used to further simulate changes in climate, hydrology, and other variables of interest. On average, these models pick up on many of the main large-scale climate and temporal features very well. However, they are currently less capable of simulating individual events (e.g. storms, hurricanes, nor'easters, etc.). GCM resolution is also too coarse for many regional decision-making applications, which require an understanding of how extreme events and other climactic trends will affect local areas, like a small watershed, a city, or even a neighborhood. For these two reasons, downscaling techniques must be applied to address concerns at a more local scale (see Box 2, "About Downscaling").

Policy-makers grappling with emissions reductions must also recognize that it takes decades for CO_2 to influence the climate and take into account that the amount of CO_2 already in the atmosphere will lead to warming in the coming decades. And continued CO_2 emissions in the early part of the century will affect climate in the middle and later parts of the

This figure shows model estimates of short-term drought frequency (# of droughts over a 30-yr period), based on the historic climate (1961-1990) and a projected future climate (2070-2099). Under the A1FI emissions scenario, in which the atmospheric CO_2 concentration is approximately triple the pre-industrial average, drought frequency is expected to double in many areas, primarily as a response of higher temperatures increasing evapotranspiration rates.

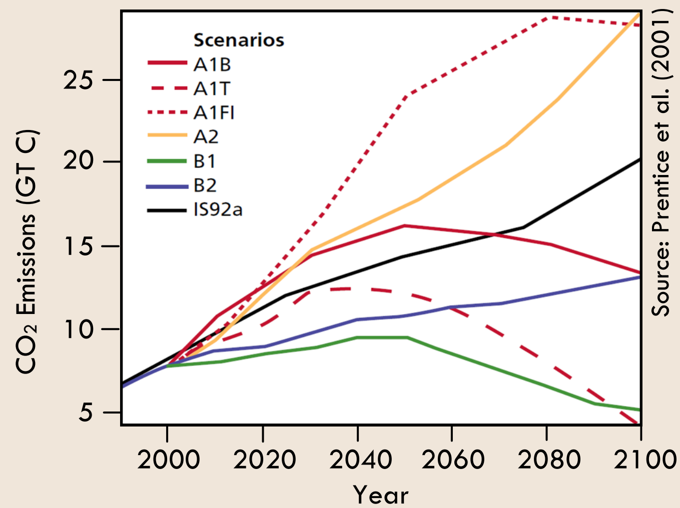
Source: Hayhoe et al. (2007)



century. As the nation develops strategies to address emissions controls, policy-makers must take into account the inertia of the CO_2 already in the atmosphere and the challenges this, and future emissions, pose on meeting goals.

BOX 1: POSSIBLE EMISSIONS FOR THE FUTURE

As reported in the IPCC's Special Report on Emissions Scenarios, CO_2 concentrations at the end of the century range from approximately double to triple pre-industrial levels. Each scenario represents an image of how the future can unfold, depending on varying levels of global development, greenhouse gas emissions, and driving factors. The following descriptions (taken verbatim from the report) explain the assumptions used for each scenario.



A1 Future world of very rapid economic growth, global population that peaks in the mid-21st century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family has three groups that describe alternative directions of technological change in the energy system: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2 A very heterogeneous world where the underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than other storylines.

B1 A convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

B2 A world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, and with intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is oriented toward environmental protection and social equity, it focuses on local and regional levels.

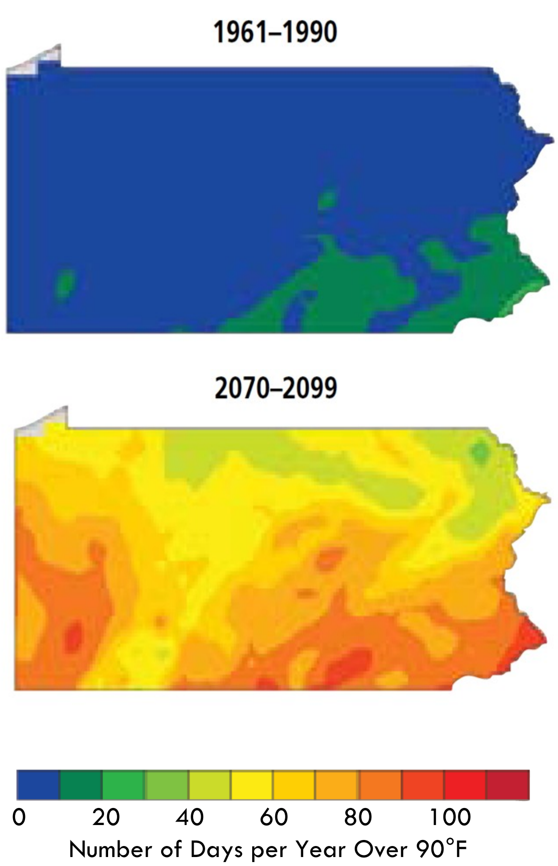
BOX 2: ABOUT DOWNSCALING

Downscaling is the process of making coarse-resolution global climate model output relevant at the local scales of interest. There are two approaches to downscaling, which can be combined.

Statistical downscaling uses relationships based on current observations to link large-scale atmospheric and oceanic features to phenomena of interest. Essentially this process is based on past correlations between various climate variables, with the assumption that these correlations will not change in the future (Fig. A).

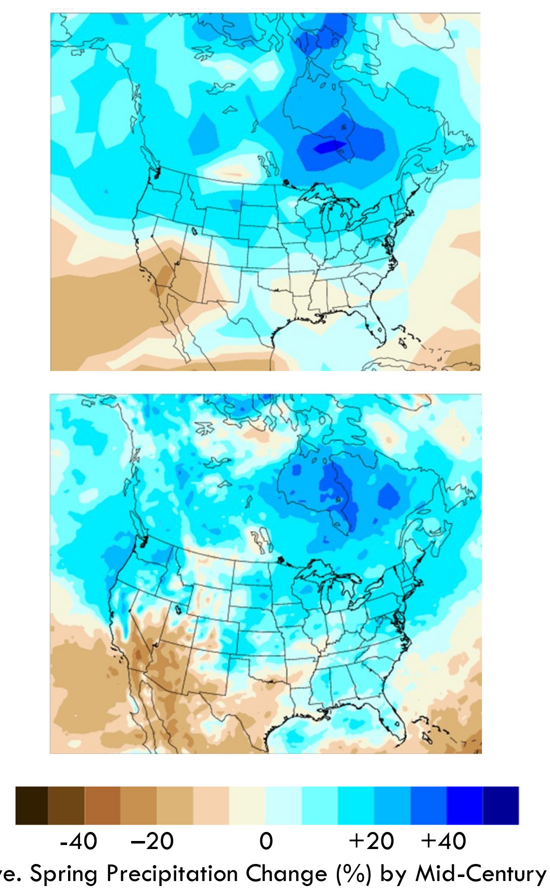
Dynamical downscaling nests a high-resolution regional climate model (RCM) into a GCM (Fig. B).

Fig. A shows the number of extremely hot days (>90°F) per year in Pennsylvania for the recent past (top). These observations provide a basis for the statistical downscaling techniques used to forecast the number of extremely hot days per year in PA for the end of this century, under the A1FI scenario (bottom).



Source:
Union of Concerned Scientists

Fig. B illustrates how nesting a regional climate model within a global model helps to refine the output for a given area. Both panels show the spring precipitation change (%) by mid-century (A2) - the top panel used only the GCM, while the bottom panel nested the RCM in the GCM.



Source: North American Regional Climate Change Assessment Program

Projections for The Mid-Atlantic

When Najjar et al. (2010) applied the A2 scenario to seven different climate models, the outputs for average surface air temperature and precipitation changes over the Chesapeake Bay Watershed show that, at the end of 21st century:

- Temperature changes are positive for all models, with an average increase of about 5°C (9.0°F)
- There was little agreement over precipitation changes. More models predicted a wetter climate, but some predicted a drier one. Globally, dry regions get drier, and wet regions get wetter. However, the Mid-Atlantic is in a transition zone, so the change in precipitation is modest and the direction is uncertain. Winter and Spring precipitation will likely increase.
- An increase in the intensity of rain events is very consistent across models. Intensity will increase due to an increase in water vapor levels that accompanies warming.

PROJECTED CHANGE	LIKELIHOOD
Warming	Extremely likely
Higher sea levels	Extremely likely
Higher winter & spring precipitation	Very likely
Higher annual precipitation	Likely
Higher winter & spring streamflow	Likely
Greater hydrological extremes	Likely
Greater annual streamflow	As likely as not
Sources: Boesch (2008), Christensen et al. (2007), Hayhoe et al. (2007), Najjar et al. (2009), Najjar (2010), Shortle et al. (2009)	

Implications for the Chesapeake Bay

As presented in the report from the Chesapeake Bay Program Science and Technical Advisory Committee (Pyke et al. 2008), nutrient and sediment loading to the Chesapeake Bay could respond in a non-linear manner.

Based on the spatial correlation between precipitation and nitrogen loading in the Northeast U.S., a 15% increase in rainfall may yield a 65% increase in nitrogen loads. Currently, there is no mechanistic understanding of this correlation. More research is needed in this area, as some scientists argue that nitrogen loads could decrease with warming.

The non-linear relationship between streamflow and sediment load indicates that an increase of streamflow by 30% will result in a 130% increase in sediment loads. As streamflow increases with higher precipitation, more erosion will occur with higher concentrations of sediment.

The great sensitivity of the Bay to climate change and variability leads to the unavoidable conclusion that restoration efforts must account for the effects of climate change in order to succeed.

"... RESTORATION EFFORTS MUST ACCOUNT FOR CLIMATE CHANGE TO SUCCEED ..."

PROJECTED IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

Global Forces & Price Determination

Globally, climate change could benefit countries in mid-latitudes, as production could decrease in tropical regions and areas of greater latitude.

For moderate climate change, on the order of 2-3°C (3.6-5.4°F), greater productivity and longer growing seasons could decrease prices. Climate change on the order of a 5-6°C (9.0-10.8°F) increase will be too warm to be beneficial to grain and oilseed crops.

Prices received in the Mid-Atlantic for grains, oilseeds, and most livestock products, are determined by global markets. Production in this region is not significant enough to affect world market prices. The Mid-Atlantic, however, significantly influences national markets for dairy, and some fruits and vegetables. Hay and seasonal fruits and vegetables are internal to the region and their markets are determined entirely by our production and consumption.

Crop Production

With increases in carbon dioxide, potential CO_2 fertilization (or enrichment) effects on crop yields will vary depending on the type of crop. C_3 crops may increase by 10-25%. C_3 crops represent most crops worldwide, including wheat, rice, soybeans, many types of hay, fruits, vegetables, potatoes, cotton, peanuts, sugar beet. C_4 crops may increase by 0-10%. C_4 crops include corn, sorghum, and sugarcane. For the Mid-Atlantic, we can expect greater percentage increases in soy yields than corn.

Animal Production

Warming may lead to heat stress in livestock kept outdoors, at least some of the time. Beef cattle are more tolerant of heat stress than dairy cows. Dairy cows benefit from cool conditions. One study shows that milk production could decrease by 10-25% with a 5-6°C (9.0-10.8°F) increase in average summer temperatures.

For indoor animal production, such as poultry, eggs, and hogs, higher temperatures will require more investment in cooling (ventilation, insulation, fans, etc.). Currently, most indoor animal production in the U.S. occurs in states to the south of the Mid-Atlantic. Warming could lead to a shift in production in the Mid-Atlantic region, assuming energy prices stay relatively low.

Fruits & Vegetable Production

Fruits and vegetables are much more climate-sensitive than other crops. Quality is critical in determining price and whether the product can be sold. Cool-season crops may be especially sensitive to summer heat stress. More frequent droughts would damage fruits and vegetables most vulnerable to quality defects caused by fluctuations in water availability. A longer growing season, however, does open up early- and late-season opportunities, when prices are higher. Warming may also open up opportunities for more profitable fruits and vegetables. For examples, wine grape production currently uses many native American varieties. With higher temperatures, producers may be able to shift to higher-valued European varieties.

A 15% INCREASE IN RAINFALL MAY YIELD A 65% INCREASE IN NITROGEN LOADS

Weeds

CO_2 fertilization may also promote weed growth. Most of the world's worst weeds are C_4 plants, although many weeds affecting the Mid-Atlantic are C_3 plants. Warming could also promote northward expansions of warm-season weeds, such as kudzu. Crop-weed interactions are complex, and it is hard to say whether climate change will favor crops over weeds or vice versa.

Pests

As with warm-season weeds, plant-parasitic nematodes and insects could move northward with warming. Warming may also increase populations of marginally overwintering insects like the corn flea beetle. Insects may develop more quickly in a warmer climate, and those that produce several broods in a season could complete more life cycles per year. Since natural predators, such as birds or predatory insects, may also benefit from warming, the trends for pest populations are unclear.

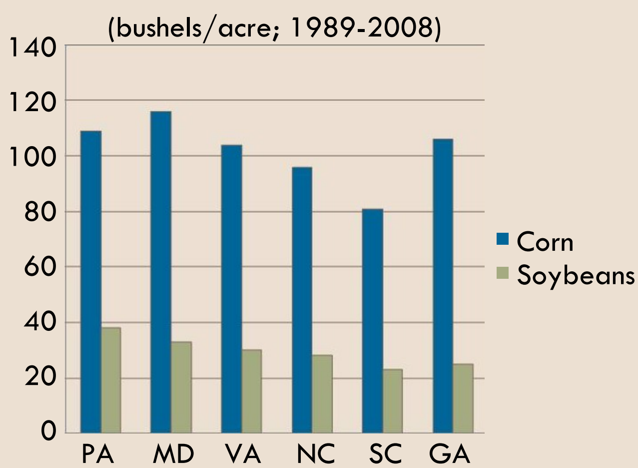
SOUTHERN STATES ANALOGUE

USING THE SOUTH AS A GAUGE FOR FUTURE PRODUCTION IN THE MID-ATLANTIC

To better understand how crop production will look in the Mid-Atlantic, we could look to the south to see how agriculture will respond. However, this "Southern States Analogue" is not a perfect fit, since many other important variables, such as differences in soil, are not accounted for.

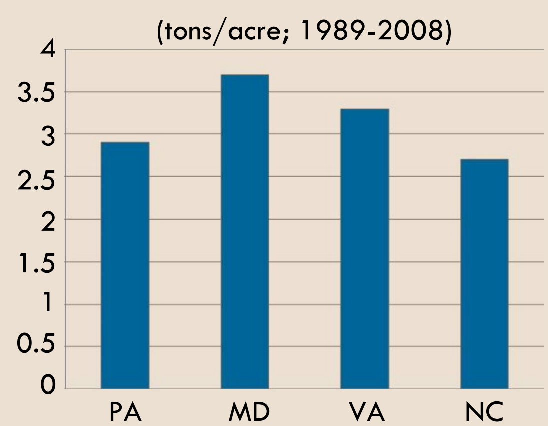
PRODUCTION YIELDS BY STATE

FIELD CROPS



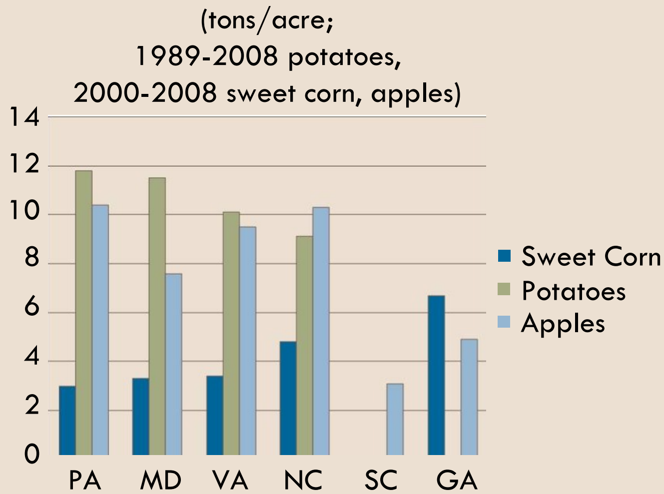
The figure above indicates no consistent pattern for feed corn yields when moving southward from Pennsylvania to Georgia. For soy, yields do decrease when moving south.

ALFALFA



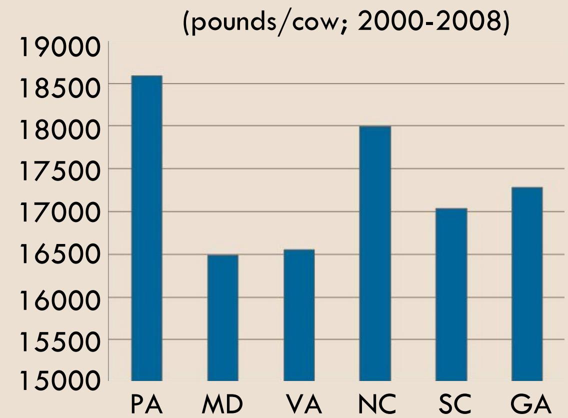
The figure above demonstrates that, like feed corn, alfalfa shows no consistent trend in yields from Pennsylvania to North Carolina.

FOOD CROPS



The figure above shows yield trends for sweet corn, potatoes, and apples from Pennsylvania to Georgia. Since sweet corn benefits from warm weather, yields are highest in GA and decrease when moving northward. Potatoes and apples, on the other hand, thrive in cooler weather, so yields tend to decrease when moving south.

MILK YIELDS



The figure above indicates that there is no clear trend for milk yields when moving southward from Pennsylvania to Georgia.

Source: David Abler, Pennsylvania State University

CURRENT STATUS OF MID-ATLANTIC AGRICULTURE

Poultry

Poultry production, especially broilers, is a significant contributor to the region's agricultural economy, particularly in supplying feed mills and processing plants. In 2007, more than one billion broilers were sold for a value of $2.6 billion. Mid-Atlantic states produce about 12% of the US total, with each state ranking between 8th and 15th in national production. In comparison, each of the top three states – Georgia, Alabama, and Arkansas – produce more than the region's total. Broiler production tends to be highly concentrated in three major areas: the Shenandoah Valley, Delmarva, and Lancaster/ Berks/Lebanon counties in Pennsylvania.

There is little local room for growth of this industry. Profitability of the whole industry depends increasingly on export demand. The Mid-Atlantic is a relatively marginal production region, with higher labor and feed transport costs than others. The majority of poultry feed is produced outside the region, bringing concern about feed price risk. Sporadic incidents of low-pathogenic disease in the region cause concerns about possible impacts of climatic change on regional disease outbreaks.

Dairy

A total of $2.5 billion in dairy products were sold in the region during 2007. Dairy is widely distributed across the watershed, but is overwhelmingly concentrated in Pennsylvania, which has over 75% of total dairy cows and dairy product sales. Lancaster

County alone has 15% of the region's dairy cows, and more than 1 in 5 dairy cows are either in Lancaster or Franklin counties in SE Pennsylvania. Challenges to this industry arise from environmental policies, low milk prices, and low unit margins. As milk production per cow increases in the US, the number of cows falls. And with all milk prices in 2009 nearly 1/3 lower than the previous year, Mid-Atlantic dairy farms are either 1) going out of business, or 2) getting much larger. With the recent implementation of a regional regulatory effort to reduce pollution though a bay-wide Total Maximum Daily Load (TMDL), the dairy community worries about how they will be affected.

Beef

In 2007, the region's 55,000 cattle farms generated $1.4 billion in sales of cattle and calves (including all cull cows, calves, stockers and feeders). Virginia has the most farms and sales, but Pennsylvania has comparable numbers. These two states produce over 80% of total sales in the region.

However, the distribution of beef cows is spread widely across the majority of Mid-Atlantic counties. Pennsylvania, Maryland, and Delaware have at least 1 beef cow on a farm in nearly all counties, although there is no large concentration. The cattle industry is neither concentrated nor efficient in this region. Farm profits are often low or negative. Principal challenges to this industry come from 1) urbanization and increased land prices, and 2) environmental policy impacts such as livestock exclusion from streams.

Corn

In 2007, there were 8.8 million acres of total Mid-Atlantic harvested cropland. Between grain and silage, 31% of that total was corn. Pennsylvania dominates in corn acres at 52% of the total, while Maryland and Virginia harvest about 20% of the total acres each. The most intense production occurs in the Lancaster area of Pennsylvania and the Delmarva Peninsula. The coastal plain produces the most corn, but significant acreages are grown in the Shenandoah Valley and throughout most counties in PA. Corn yield in the Mid-Atlantic is, on average, about 75% of the average yield in Iowa, due to the region's lower yielding soils and frequent droughts.

Soybeans

Soybeans comprise 17% of the region's 8.8 million harvested cropland acres. Most production occurs in the same counties as corn grain, and is even a bit more concentrated on the coastal plain. Virginia, Pennsylvania, and Maryland each produce a little under 1/3 of the region's total.

IN THE MID-ATLANTIC, SOY YIELDS WILL LIKELY INCREASE MORE THAN CORN

Hay

Hay is everywhere except the Coastal Plain, making it the inverse of corn grain in some ways. Production occurs at some level across 83,000 farms, encompassing 44% of all harvested cropland in the Mid-Atlantic in 2007. Most counties produced more than 4000 acres of hay of some kind. Hay provides the feed for most beef operations as well as dairy operations. In Virginia and Maryland, production is strung along the Ridge-and-Valley region running up the Shenandoah Valley into southern Pennsylvania. Pennsylvania production occurs across the state. Pennsylvania has 45% of the hay acres and Virginia has 33%.

Barley

Barley is a relatively small acreage crop in the Mid-Atlantic, comprising only 1% of harvested cropland. However, it is a winter annual (affected by winter climate rather than summer). With the Osage ethanol plant now in operation in Hopewell, VA, a much larger market has opened for barley. To satisfy the plant's operating needs, thousands more acres of production will be needed. Only 125,000 acres were produced in 2007, led by Pennsylvania and Maryland.

Vegetables

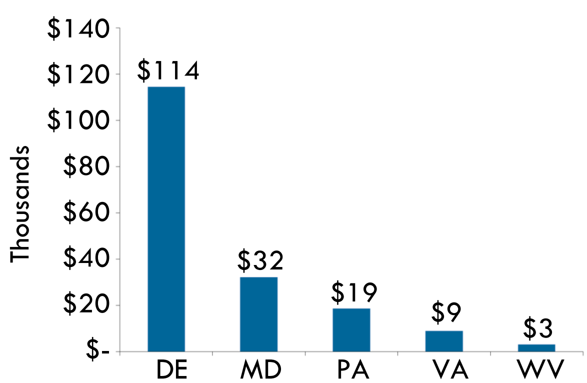
Sales of all vegetables totaled $353 million in 2007, led by Pennsylvania with over 1/3 of the total. Vegetables for sale are produced in fairly isolated pockets around the Mid-Atlantic. Most of these vegetable products are produced for fresh consumption and feed local or DC metropolis markets. These crops are highly sensitive to climatic conditions. Overall, about 50% of vegetables are produced with irrigation.

BOX 2: STATISTICS ON MID-ATLANTIC FARMS

In the Mid-Atlantic, Delaware dominates per-farm sales. When lumping all types of farms together, the average sales and government payments for Delaware farms was over $400,000 per farm. West Virginia farms received $25,175 per farm, the lowest in average sales and government payments across the Mid-Atlantic. When adjusting for production type, poultry farms (or those whose sales are comprised of over 50% poultry products) received the most in sales and government income across the region – bypassing the average of all farms, in some cases, by several fold. Dairy is also a significant source of sales and government payments in all states except Delaware, where irrigation capacity has allowed much greater production of fruits and vegetables.

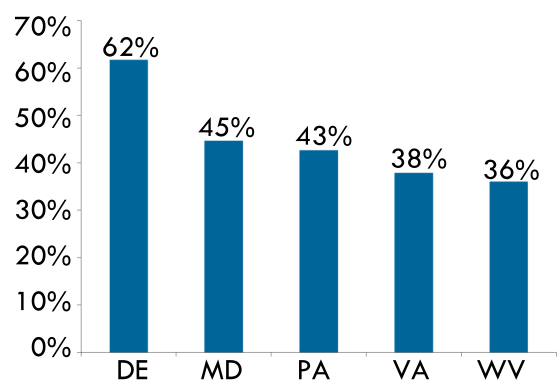
Average Net Cash Farm Income (NCFI)

The NCFI of Delaware farms is quite high, suggesting that many of its farms are full-time and profitable. On average, farms in the other Mid-Atlantic states do not generate enough NCFI to completely support a farm family, and barely support expenses of the farm itself.



Proportion of Farms with Net Gains

More than 60% of DE farms reported net gains, while less than half reported net gains in the other states.



Source: 2007 Census of Agriculture

INCORPORATING RISK INTO ADAPTATION STRATEGIES

When developing climate adaptation strategies, most utilize a paradigm of predicting, then acting. For instance, one typically chooses a global climate model, downscales it to the region of interest, and then applies it towards local needs.

Another means of developing adaptation strategies is to assess the risk to the area of interest and then act. This methodology essentially works backwards from the resource management question of interest by setting a *target*, applying potential *scenarios*, and assessing impacts to the broader *system* relating to the area of interest.

TARGET TYPES	EXAMPLES
Management Target	Production level/yield; Load allocation; Abundance; Reliability; Comfort; Discharge limits; etc.
Ecological Threshold	Temperature limitations
Physical Limits	Material strength

Assess Risk, Then Act:

Targets represent the desired *state* of the resource. Without a preferred state, there can be no impact. Since climatic conditions can directly or indirectly affect the state of the target, setting the right target is critical to achieving significant impacts.

Relevant climate change scenarios have the potential to alter the state of the target. Depending on the management concern, scenarios can include temperature, precipitation, evapotranspiration, runoff, sea level, etc.

In assessing the effects of the climate change scenarios on the state of the targets, it is important to consider impacts to the broader agricultural, environmental, and engineered systems that pertain to the target, such as related buildings, transportation systems, infrastructure, fields/orchards, animal operations, runoff controls, wetlands, watersheds, etc. Climate change is an input to measure the impact on the target's state. For instance, orchards may be sensitive to meteorological events. So how will changes in precipitation, growing days, or pollination conditions affect the yield, quality, and timing of production?

> “WHEN APPLYING A *PLAUSIBLE* CONDITION, UNCERTAINTY NO LONGER MATTERS...”

Applying Risk Assessments to the Chesapeake Bay

The level of uncertainty may delay decision-making, in hopes that more information will be available in the coming years. But we are unlikely to reduce critical uncertainties in the near future. By applying a plausible condition, uncertainty no longer matters. Specific projections are less important, as decision-makers must manage for a broad range of uncertainty.

By the end of the century, the bulk of the climate variation will be based on our present-day decisions and actions. In the Chesapeake Bay watershed (CBWS), decision-makers utilize the CBWS model to help determine management targets. This suite of models relies on environmental dynamics and individual management practices to formulate outputs. Yet, there has been little to no evaluation on how climate change affects the overall Bay system or the individual management practices.

One study (Imhoff 2007) on the Monocacy watershed demonstrated that a plausible increase in greenhouse gas emissions could result in an 11% increase in nitrogen-loading. Further assessment showed that three specific practices, which consist of only 18% of the watershed's land-use, could cause nearly 47% of the increase in total nitrogen loads. These practices include high-till nutrient management with manure application, low-till nutrient management, and bare construction. Such conclusions demonstrate that land management practices could respond differently to climate change. Historic relationships may not be adequate to set restoration priorities, so understanding climate sensitivities is critical.

BOX 3: ECONOMIC ASSESSMENTS FOR PENNSYLVANIA FARMERS (CASE STUDY)

To better understand impacts of climate change on agricultural production in Pennsylvania and the economic implications from market drivers, a team of Penn State scientists developed a dynamic computable general equilibrium (CGE) model of the Pennsylvania and national economies. The model projects the economies for Pennsylvania and the U.S., both with and without climate change. The CGE traces the path of the economy on an annual basis to 2050 and covers the entire economy, divided into 32 sectors.

Pennsylvania Dynamic CGE Model Output

PRODUCT	CLIMATE CHANGE IMPACT ON PA PRODUCTION	CLIMATE CHANGE IMPACT ON U.S. PRODUCTION	NET IMPACT OF CLIMATE CHANGE ON PA, RELATIVE TO U.S.
Grains & Oilseeds	Increased production	Increased production	Little change in revenue
Fruits & Vegetables	Increased production	Increased production	Increased revenue
Beef, Dairy, Poultry, Eggs, & Hogs	Decreased production	Production decrease greater across the nation than in PA	Increased revenue due to competitive advantage

Researchers did not run scenarios for bioenergy crops, however there is interest in doing so.

Climate variability is currently a critical driver for economic and policy-decisions, as demonstrated at a recent conference with insurance companies and FEMA. While the CGE model does account for increasing temperature and precipitation, it cannot capture climate variability. CGE models excel in showing changes in the economy and production due to changes in average temperature and precipitation.

Source: David Abler, Pennsylvania State University

CHESAPEAKE BAY TMDL

The Chesapeake Bay TMDL has been established by the EPA Chesapeake Bay Program. Using the CBWS model, the EPA has been developing load allocations for nitrogen, phosphorus and sediment, from both point and non point sources. Statewide Watershed Implementation Plans have been accepted for all headwater states. And by the end of 2011, local-level Watershed Implementation Plans for counties and watershed segment sectors will be devised, based on basin-specific source-sector load allocations determined by the EPA's CBWS Model.

Climate change is not currently considered in the model that is determining allocations. While we lack quantitative information on both the sensitivity of the TMDL and the individual Watershed Implementation Plans to plausible changes, we have reason to believe that these considerations may make a substantial difference and that including climate change in the CBWS Model will be critical to achieving load allocations. The Chesapeake Bay is vulnerable to changing climatic conditions, and the TMDL, itself, will change depending on which climatic conditions we utilize as inputs.

Without a systematic consideration of climate change in the development of the TMDL, and the associated regulatory programs, efforts to protect and restore the Bay could be at risk. Parties have made legal challenges to TMDLs in other parts of the United States, in part, on the basis of a failure to consider climate change impacts. To avoid such matters, the EPA should incorporate climate scenarios into the CBWS Model in the near future and then reassess the scenarios and risks on a 5-year cycle.

The lack of consideration for climate change is inconsistent with goals of the US EPA's leadership and high-level policy positions, such as those described in the US EPA Office of Water Climate Change Strategy and articulated by the White House Council on Environmental Quality. As a national leader, the Bay Program should take the lead in understanding the implications of climate change for its most critical resource management decisions and ensure that restoration actions will be effective over the conditions they are likely to experience during their performance lifetimes.

DECISION-SUPPORT TOOLS MUST BE SITE-SPECIFIC TO ENSURE FARMER IMPLEMENTATION

DEVELOPING DECISION-SUPPORT SYSTEMS FOR MID-ATLANTIC PRODUCERS & STAKEHOLDERS

DIFFERENT TOOLS FOR DIFFERENT DECISIONS

Scientists who have developed decision-making models provided case study presentations that demonstrated the need for a variety of tools that cover everything from the daily decision-making needs of producers to the long-term forecasting of regional crop viability and investment impacts.

With a multitude of decisions needed on a farm every day, producers require different tools for different decisions. The Southeast Climate Consortium (SECC), a NOAA-funded Regional Integrated Science and Assessment Center consisting of scientists from nine universities across the Southeast, has developed a suite of tools for producers. These tools help with specific pre-season, in-season, and daily decision-making needs for a variety of sectors, from blueberries to cattle. In their experience, decision-support systems require site-specificity in order for farmers to use the tools.

Like the tools developed by the SECC, scientists at Cornell developed Adapt-N, a tool for the nutrient management needs of corn-growers in the northeast. This interactive tool allows farmers to provide their specific location, crops, and management practices and receive recommendations on nitrogen application.

Given the climate forecasts and current regulatory dynamics related to the Chesapeake Bay, decision-makers in industry and policy are equally in need of decision-support tools. Presentations from the Joint Global Change Research Institute and the University of Maryland's Earth System Science Interdisciplinary Center, demonstrated how models and forecasting systems can address the decision-making needs of agricultural industries and policy-makers.

Each tool varies in scope, but all required a great deal of funding to develop. Participants of this workshop were eager to address these needs.

Needs & Next Steps

Producer Needs

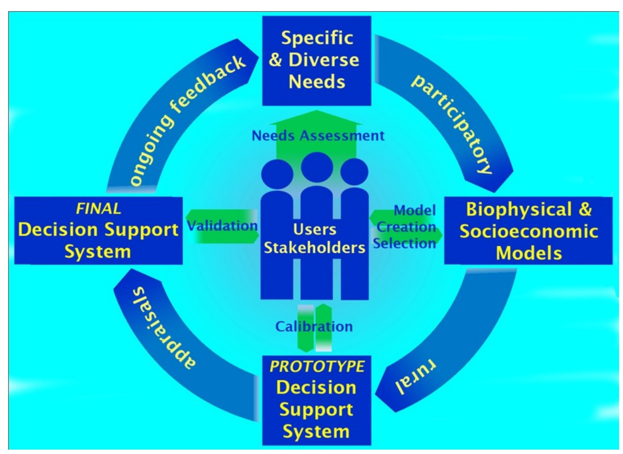
Helping producers is a critical and unmet need in the region. Along with actual producers, this audience also includes the people and organizations that work with producers, such as agencies, insurance companies, extension agents, consultants, technical service providers, NGOs, traders, etc. Addressing these varied target audiences requires scaling tools and information to their individual needs.

Since little has been done to address any of these audiences, a first step in building support would be to reach out to the information sources as a bridge to working with producers. Given the current state and profitability of agriculture, getting producers to implement climate-sensitive practices will be limited to win-win opportunities. Experience from other efforts indicate that the information should be varied in scale depending on the need.

Box 4: The Southeast Climate Consortium Experience (Case Study)

Sources of uncertainty exist at every level – ocean models, atmospheric models, crop models, production practices, human-decision making. But developing Decision-Support Systems (DSSs) in conjunction with knowledgeable organizations and end-users reduces this uncertainty.

- **What we need to understand:**
  - What farmers can do theoretically?
  - What farmers can do practically?
  - What farmers are willing to do and change?
- **How to assess needs, define values/belief systems, test prototype systems:**
  - Surveys and interviews
  - Focus groups
  - Workshops
- **Problems with Decision-Support Systems:**
  - Non-adoption
  - Short-term use
  - Deterministic nature
  - Exaggerated expectations
  - Lack of user-friendliness



The above decision-making process, by Cabrera, Breuer, and Hildebrand, has been implemented by the SECC to develop several different tools for various crop needs. Their experience demonstrates that farmers require site-specificity to participate.

Source: Norman Breuer, University of Miami

Policy & Management Needs

Currently, the greatest management need in the Mid-Atlantic is to revise the Chesapeake Bay Watershed Modeling Suite so that it includes climate change factors. The current TMDL process allows for revisions in 2011 and 2017. The best mechanism to make recommendations would be to go through the Bay Program's Scientific and Technical Advisory Committee.

Other areas of interest include:

- County-level planning to support local food demands
- Tracking trade-offs or synergies across BMPs implemented for various reasons (e.g. nutrient reduction, habitat restoration, climate mitigation)
- Legislative opportunities to promote climate change activities

Research Needs

Several areas were identified that require additional research within a climate framework:

- Insect/Pest Management
- BMP sensitivity/effectiveness
- Energy opportunities and crops
- Nutrient and sediment movement
- Farm/sector resilience, viability, and investment
- Crop production, including:
    - Changes in types
    - Seasonal needs (building predictability for near-term, not decades)
- Water resource needs
    - Water availability and infrastructural needs
    - Seasonal and interdecadal changes

Next steps

To proceed with the momentum that was built at this workshop, the Mid-Atlantic Water Program will continue to reach out to agencies and producer organizations to:

- Build awareness of the need for decision-support tools,
- Garner support from partner organizations,
- Facilitate sector-specific discussions to include producers and representative organizations,
- Promote the larger research questions that have not been addressed for this region,
- Facilitate the growth of a network of interdisciplinary scientists interested in developing decision-support tools for producers, industry representatives, and policy-makers, and
- Identify funding opportunities.

APPENDIX 1— WORKSHOP AGENDA

8:30 am **Welcome and Opening Remarks**

8:45 am **Setting the Stage**

Climate projections for assessing hydrological and agricultural impacts in the Mid-Atlantic Region — Raymond Najjar, Penn State University

Impacts of Climate Change on Agricultural Production in the Region and Around the World — David Abler, Penn State University

Assessing Risk and Planning for Impacts — Chris Pyke, US Green Building Council

10:00 am **Break**

10:15 am **Discussion – Sector-specific Concerns and Decision-making Needs**

Corn, Soybeans, and Vegetable Crops — Dave Hansen, University of Delaware

Cattle, Dairy, and Poultry Operations — Jim Pease, Virginia Tech

- What is/are the key climatological factor/s affecting production success?
- What are the key economic (local and global) factors affecting production success?
- What environmental concerns need to be addressed? Specifically relating to water resources (e.g. ground and surface water consumption and pollution), energy production for the grid (e.g. biofuels stock production) and for farm needs (e.g. anaerobic digesters), and greenhouse gas reduction on the farm and in the wider industry.

11:15 am **Climate Scientists Panel: Applying Models to Our Concerns**

Harold van Es, Cornell University

Allison Thomson, Joint Global Change Research Institute

Norman Breuer, University of Miami and University of Florida

Bala Prasad, Earth Systems Science Interdisciplinary Center

12:35 pm **Lunch**

1:45 pm **Brainstorming Session/Discussion – Responding to Climate Change**

- What audience(s) need to be addressed?
- What types of tools, programs, models and risk assessments need to be developed?
- What are the priorities?
- What do we need to ensure development and implementation?
- Are we addressing all the timescales (e.g. near-term adaptation strategies, long-term decision-making systems)?
- What are the research gaps?

3:15 pm **Next Steps and Closing Remarks**

3:30 pm **Adjourn**

APPENDIX 2 — REFERENCES

Boesch, D.F., (editor) 2008. Global Warming and the Free State: Comprehensive Assessment of Climate Change Impacts in Maryland. Report of the Scientific and Technical Working Group of the Maryland Commission on Climate Change. University of Maryland Center for Environmental Science, Cambridge, Maryland.

Christensen, J.H., et al. 2007. Regional climate projections. In: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Avery, M. Tignor, H.L. Miller (Editors), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 847-940.

Hayhoe, K., et al. 2007. Past and future changes in climate and hydrological indicators in the US Northeast. Climate Dynamics 28, 381-407.

Imhoff, J.C, et al.. 2007. Using the Climate Assessment Tool (CAT) in U.S. EPA BASINS integrated modeling system to assess watershed vulnerability to climate change. Water Science and Technology 56(8), 49-56.

Najjar, R.G., L. Patterson, and S. Graham. 2009. Climate simulations of major estuarine watersheds in the Mid-Atlantic region of the United States. Climatic Change 95, 139-168.

Najjar, R.G., 2010. Analysis of climate simulations for use in the "Climate-Ready Adaptation Plan for the Delaware Estuary", Final report to the Partnership for the Delaware Estuary, 21 pp.

Najjar, R.G., et al. 2010. Potential climate-change impacts on the Chesapeake Bay. Estuarine, Coastal and Shelf Science 86, 1-20.

Nakićenović, N., and R. Swart. 2000. Special Report on Emissions Scenarios. A Special Report of Working Group III of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, U.K. and New York, NY, 599 pp.

Prentice, et al. 2001. Chapter 3. The Carbon Cycle and Atmospheric Carbon Dioxide. In: J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Da, K. Maskell, C.A. Johnson (Editors), Climate Change 2001: The Scientific Basis. Cambridge University Press, New York, NY, pp. 183-237.

Pyke, C.R., et al.. 2008. Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations. A Report from the Chesapeake Bay Program Science and Technical Advisory Committee (STAC), Annapolis, MD. 59 pp.

Shortle, J., et al. 2009. Pennsylvania Climate Impact Assessment, Report to the Pennsylvania Department of Environmental Protection, Environment and Natural Resources Institute, The Pennsylvania State University, 350 pp.

United States. Dept. of Agriculture. National Agricultural Statistics Service. 2007 Census of Agriculture. Washington: GPO, 2009. Print.