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I Background

The Global Change Research Act of 1990 (Public Law 101-606) called for an assessment of national impacts that might be caused by global change. In 1997, the US Global Change Research Program (USGCRP) began taking steps to prepare a first assessment with a focus on global climate change. Four questions were posed for the First US National Assessment: 1) What are the current status and stresses, particularly for environmental resources? 2) How might climate change exacerbate or ameliorate these stresses, or introduce new stresses? 3) What actions can be identified now that might reduce damages or enhance the benefits from climate change? 4) What are the highest priority research and information needs for reducing the uncertainties about the first three questions?

Even in the initial stages the planners of National Assessment acknowledged that potential impacts from climate change as well as climate variability could vary dramatically by region of the country, as well as by basic sectors (such as forests, agriculture, fresh water quality and quantity, coastal zones, and human health). Thus the National Assessment activities included 3 basic components; assessments that would project the major impacts within a region, assessments of individual sectors at a national level; and a synthesis assessment that

* The information presented here is summarized in A. FISHER, ET AL., PREPARING FOR A CHANGING CLIMATE: THE POTENTIAL CONSEQUENCES OF CLIMATE VARIABILITY AND CHANGE-MID-ATLANTIC OVERVIEW, prepared for the USGCRP First National Assessment, sponsored by the U.S. Environmental Protection Agency, Cooperative Agreement CR 826554, The Pennsylvania State University, University Park. The OVERVIEW, plus the in-depth FOUNDATION report and more details about the assessment activities, are *available at* www.essc.psu.edu/mara.

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would build on the regional and sectoral assessments. Although work is continuing, this paper summarizes the process and findings for the initial stages of the Mid-Atlantic Regional Assessment (MARA).

II. The MARA Process and Approach

A "scoping" workshop held in September of 1997, was designed to share what was known about assessing the regional impacts from climate variability and change, and to get input from stakeholders regarding potential impacts of concern to them. Preparing for this workshop made it clear that an interdisciplinary set of expertise, applied in an integrated assessment framework would be essential. Integrated assessment avoids a piecemeal approach by including many sectors and their interactions. By accounting for multiple influences and their feedbacks, an integrated assessment yields a range of outcomes that demonstrate the uncertainties in predicting what will happen if alternative conditions prevail. However, priorities must be set so that an integrated assessment does not become unwieldy by trying to assess too much; many integrated assessment diagrams look like spaghetti. Setting priorities also ensures that the science will be in the service of society, by examining questions that matter the most.

MARA relied on a regional perspective, recognizing that issues and impacts differ by place, and that useful science would identify impacts at scales that matter to people. Large watersheds, such as the Chesapeake Bay, also have the potential for coordinated decision making because of organizations such as the Susquehanna River Basin Commission and the Interstate Commission on the Potomac River Basin. Identifying the region to assess also depends on having appropriate data. The availability of data about environmental conditions through the US Environmental Protection Agency's Mid-Atlantic Integrated Assessment (MAIA), and about expected future conditions through its Regional Vulnerability Assessment (ReVA) was another input for defining the region to be assessed. Figure 1 shows the Mid-Atlantic Region assessed; it includes all or parts of eight states (DE, MD, NC, NJ, NY, PA, VA and WV) and the District of Columbia, each of which includes watersheds for the Chesapeake and Delaware Bays, or the Albemarle and Pamlico Sounds.

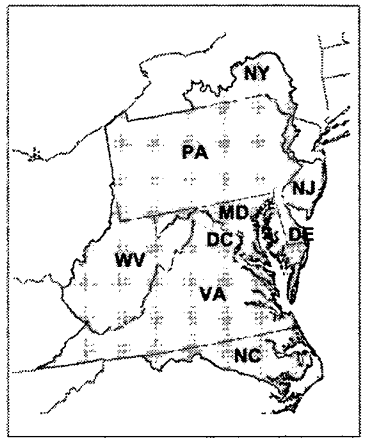

Figure 1. The Mid-Atlantic Region

Bringing together the interdisciplinary expertise for this ambitious assessment meant collaborations among several Pennsylvania State University units, with researchers at six other universities, at federal agencies, and at private organizations. A key to accomplishing the MARA objectives (i.e., answering the four questions posed in the first paragraph), has been stakeholder engagement. Stakeholders are those who might be affected by climate change or make decisions based on assessment findings. Stakeholder engagement requires initiating, nourishing, and maintaining a stakeholder network, by getting their input early and often and by providing feedback to the network about how their input makes a difference in the assessment. The MARA team had several objectives for stakeholder involvement. One was to provide input about what topics should be assessed. The 1997 scoping workshop revealed that stakeholders were concerned about the potential for negative impacts on health, coastal, and ecosystems that might result from climate variability and change. Because the National Assessment was a first attempt, the regional teams were advised to focus on a few impacts that might be most important for a particular region. The MARA team's early work revealed that coastal impacts were likely to be much larger in other regions (that were being studied by others as part of the National Assessment). The early work also showed that good health status and health care infrastructure in the mid-Atlantic region (MAR) made the literature's discussion of potential health impacts in tropical and less developed countries less relevant. Although we expected to focus on three sectors linked to climate–forests, agriculture, and fresh water–we felt that stakeholders would not find our assessment credible unless we expanded it to include coastal zones, human health, and ecosystems.

Other goals for stakeholder involvement included sharing ideas, enhancing the legitimacy of the process from the stakeholders' perspectives, raising their awareness of impacts and of the potential for actions that would reduce vulnerability or take advantage of opportunities presented by climate change, and getting their assistance in disseminating the findings. The primary mechanism for accomplishing these goals was the creation of a broad-based MARA Advisory Committee. Its 90 plus members represented citizen groups, business and industry, state and local government, federal government, and academia. The MARA Advisory Committee met 5 times during the first phase of the assessment (including a June 2001 "lessons learned" workshop). Most of the interactions, however, were by phone, mail, and e-mail. Drafts were sent to the MARA Advisory Committee members, eliciting their feedback. In some instances, members became a part of the MARA team, and are recognized as such by co-authorship on reports and journal articles. A broader set of stakeholders and experts was invited to comment on drafts of the *Overview* and *Foundations* reports; responses to their review comments are posted with the reports on the MARA web site (www.essc.psu.edu/mara).

Using the analytical infrastructure just described, the MARA team undertook four major tasks. The first was to identify and understand the region's baseline in terms of land forms, natural resources, demographics, economy and climate. Recognizing that any region will change in response to multiple drivers such as population growth, technology, and preferences about where to live, the second task was to project how the region would evolve, regardless of climate change. The third task was to project how the climate might change in the MAR. The fourth task was the most challenging, assessing the incremental impacts from the projected changes in climate. We focused on those sectors expected to be most sensitive to climate and sectors that stakeholders care about. We also accounted for the fact that people, institutions, and ecosystems respond and adapt to change, whether the feedback is positive or negative and whether the impact is a damage or a benefit, because ignoring such responses can lead to overestimates or underestimates of impacts. Other aspects of the fourth task included identifying actions that could reduce the region's vulnerability to climate and improve its resilience to climate variability, or that would enhance opportunities created by a changing climate, and identifying the highest priority data gaps and research needs.

There are many uncertainties in identifying the current baseline and in projecting the region's future, both without and with climate change. Thus, the MARA team conducted the assessment using alternative scenarios, with different assumptions about the system's physical, environmental, and socioeconomic "drivers." The assumptions used ranges so that the most sensitive aspects (of the assessment itself as well as sectors of the region) could be identified.

III. Impacts in the Mid-Atlantic Region

Temperature and precipitation are often used as the key indicators of climate. One difficulty in identifying past changes in climate is the climate's extreme variability when looking at year-to-year or decade-to-decade records. Aside from a region's typical annual cycle of weather, the records show many warm spells and cold spells, droughts and wet periods. This natural variability means that the actual measures of temperature and precipitation–which are available only for about the past 100 years–cover a period too short to detect longer-term trends. Fortunately, estimates can be derived for earlier periods from "paleoclimate" data such as tree rings and ice cores. Knowledge gained from the actual temperature and precipitation records, and derived from the paleoclimate data have been combined with knowledge about the physics behind climate mechanisms, to form general circulation models (GCMs). Each GCM uses differing assumptions because of uncertainties about climate-earth system interactions. Large computers "run" these GCMs so that their predictions of past climate can be compared with observations; most GCMs do reasonably well in simulating past climate conditions. However, the differences in their underlying assumptions make their output diverge when projecting future climate. Because there is no way to know which climate projection might be true for the future, the National Assessment recommended using the Canadian Climate Centre (CCC) model (which projects a future that is relatively warm and dry) and the Hadley model from Great Britain (which projects a future that is relatively less warm but wetter). Of the CGMs available when the National Assessment was conducted, these were the only models meeting the scientific acceptability criteria determined by the National Assessment Synthesis team. These models also represent high-end and low-end projections among the GCMs then available in the literature.

A notable feature of both the CCC and Hadley models was the expectation of continued variability in climate. The 9-year running averages allowed trends to be clearly shown, as exhibited by the heavier lines in Figure 2 for the MAR. Note that the CCC model shows more warming, but the Hadley model shows more precipitation. Additional "downscaling" model work by the MARA team suggests a future that will be somewhat warmer and perhaps a bit wetter. Results were summarized into the ranges of projections shown in Table 1. Note the indicated confidence in each projection.

Similarly, the MARA team assessed current status and projections of future ranges for selected socioeconomic factors and ecological factors. For instance, we considered two basic scenarios for agriculture. One scenario assumes that agriculture would maintain its current level of importance in the MAR. The other scenario (which we expect to be more likely) accounts for the rising opportunity cost of agricultural land and other inputs, and the expected increase in regulations on agricultural activity. The resulting scenario is that the region's agricultural sector becomes more environmentally friendly and smaller. For each scenario, we identified upper and lower bounds for how projected changes in climate might affect agricultural production, as well as the environmental impacts from agriculture.

GCM Projections

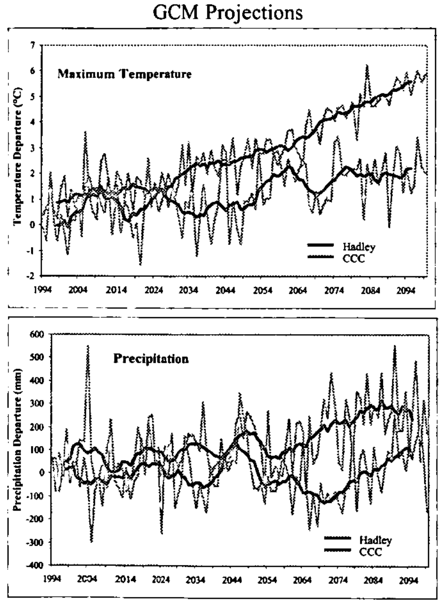

Figure 2. Hadley Center and Canadian Climate Center model differences from observed 1960-1969 base period, for maximum temperature and precipitation, nine year running averages

Projections			
	2030	2095	Confidence
CO_2	20 - 30	50 -120	Very high
Sea level (inches)	4 - 12	15 – 40	High
Temperature (°F)	1.8 – 2.7	4.9 – 9.5	High
Precipitation (%)	-1 – +8	6 – 24	Medium
Runoff (%)	-2 – +6	-4 – +27	Low

Table 1. 30-year and 100-year Ranges for Projections of Physical Factors

Figure 3 is an overall summary of MARA results. Note four features in this figure–all of which respond to stakeholder input. First, the arrows to the right represent potential regional benefits from global climate change, while those to the left represent potential damages. Their relative size portrays the relative magnitude of the impacts.[1] Second, some sectors could experience both positive and negative impacts. For example, agricultural production has a small positive arrow because the assessment projects modest increases in the region's production of soybeans, possibly corn, and tree fruits. Agricultural production also has a small negative arrow because tobacco will grow better in the MAR but even better elsewhere, putting the region's tobacco farmers at a competitive disadvantage. The tobacco example illustrates how the MARA accounted for interactions and feedback, in this case among regions. Third, and perhaps most important, the horizontal divisions emphasize the uncertainties that accompany this assessment. Although the impacts on agricultural production are among the most certain (thus in Figure 3's top category), the impacts induced by climate change on the environmental effects from agriculture are among the least

1. This portrayal is imperfect, because it shows the relative size of the change, but not the baseline. For example, the negative arrow for temperature-related heat stress shows that there will be a relatively large increase in heat-related mortality in the region's cities. But it does not show that heat-related mortality currently is responsible for only a tiny share of deaths in those cities. Consider the estimates for Philadelphia, which currently has about 146 "excess mortality" deaths per year related to hot weather conditions that might become more common under climate change. Accounting for expected changes in the city's population size and age distribution, our estimates show that this number might increase to between 282 and 682 excess deaths, depending on the GCM used. These are very large increases for this cause of death, but still very small compared to the total 23,000 deaths per year that Philadelphia experiences.

certain (thus in Figure 3's bottom category). The largest number of impacts, and most of the larger impacts, are in the least certain category. Fourth, despite our attempt to identify as many benefits as possible, the figure shows more negative impact than positive impacts, and the negative impacts tend to be larger.

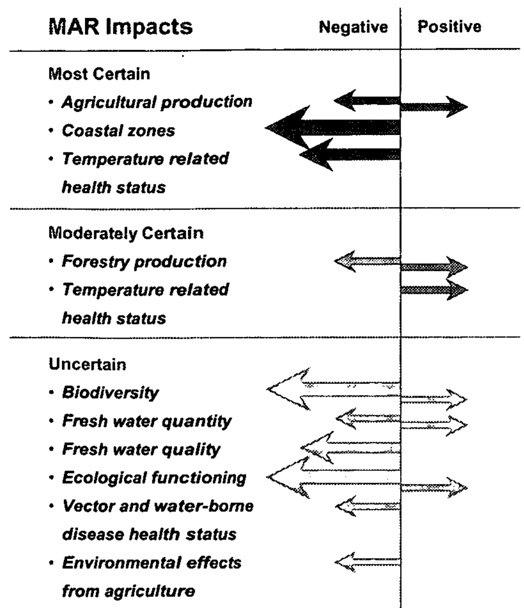

Figure 3

Some of these projections are of particular interest. Consider Figure 4. Its top portion shows the current distribution of dominant tree species in the MAR. The bottom portion shows the expected distribution under the CCC and Hadley projections of climate, respectively (because different species grow better under different regimes of temperature and precipitation). Although the distribution of dominant species differs somewhat between the CCC and Hadley scenarios, both are dramatically different from the current distribution. This suggests that despite large uncertainties in projecting climate change, the region's forest managers can expect a substantially different mix of trees for supporting wildlife habitat and recreation, or for logging. This could be a concern in locations such as central Pennsylvania, where makers of cabinets and fine furniture rely heavily on black cherry. Figure 4 suggests they will need to import their lumber under climate change conditions, or switch to alternative woods such as oak.

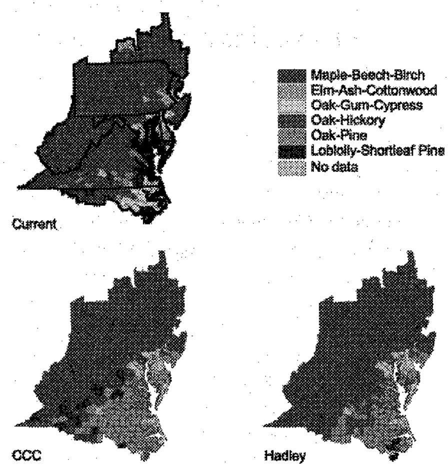

Figure 4. Dominant MAR forest types for current climate, and potential distributions for CCC and Hadley equilibrium climate scenarios, for a CO_2 doubling.

Part of the assessment of ecological impacts examined perching bird species–often called back yard birds. A 2-degree Fahrenheit increase in average temperature is likely to drive about 6 percent of the perching bird species northward from the MAR. Higher average temperatures south of the MAR would cause in-migration of new species so that the region's net decline in perching bird species would be only 3%. Examining smaller groupings yields results that are more dramatic. Warblers are a subset of perching birds. The 2-degree warming would cause about 14% of the MAR's warbler species to move northward. This would be partially offset by in-migration, so the net decline in warbler species would be only 8%. From an ecological perspective, however, there are large uncertainties about whether the species migrating into the region would fill the same niches as those no longer finding the region hospitable.

The projected changes in the region's climate would mean less habitat for cold water fish species (trout) but more habitat for warm water species (such as bass, perch, catfish). The MARA team originally thought this might be a benefit, because there are many more warm-water anglers than cold-water anglers. However, a survey showed that anglers are willing to pay modest amounts to protect current habitat–regardless, of whether they ever fish for trout.

IV. Implications

The MARA results suggest that from an overall perspective the MAR's diversified and integrated economy is likely to be resilient to climate change. However, specific sub-regions and sub-groups might bear a larger share of the negative impacts. Examples include those in the northwestern portion of the MAR who rely on black cherry lumber for making cabinets and fine furniture, and watermen who rely on already stressed commercial fisheries in the Chesapeake Bay. The results also suggest substantial concerns about potentially large risks to the region's ecosystems. Although there is much uncertainty about the projections of ecological impacts, it is certain that the regions ecosystems are already under stress because of human interventions to their habitat.

Although some readers might interpret this discussion as a gloom-and-doom story, the MARA team views the findings as providing more reasons to implement cost-effective actions that often make sense even without considering the impacts from climate change. Most of the impacts from climate change projected for MAR are similar to those that affect quality of life after poor land use and economic development planning. The potential ecological impacts from climate change are the same sorts of impacts that ecosystems currently experience because of human actions (deliberate or inadvertent). Thus, at least four types of pro-active steps are implied by the MARA findings. The first is smarter watershed management, including cost-effective coastal protection to combat raising sea-levels (with its potential for salt-water intrusion in drinking water wells and additional flooding damages as storms go farther inland), and protection of water supplies. The second step includes the use of additional incentives to help conserve water for periods and locations when drought or contamination could become more frequent or severe, and disincentives to discourage flood plain development as a hedge against sea-level rise. The third step is information dissemination to help individual decision makers account for climate change in their actions. For instance foresters would benefit from advice about what trees to plant, and how to plan for removal of timber damaged by severe storms. Although already a very adaptable group, farmers would benefit from more information about cultivars especially suited to changed climate conditions (such as warmer nights, less predictability in the last spring frost, potentially more variability in precipitation). Another information dissemination example is the success achieved by Philadelphia's weather warning system, which announces when those without air conditioning should consider using publicly available cool shelters, and includes a buddy system so that someone checks on house-bound residents during such times. A fourth action that could soon be taken is the improved monitoring of disease vectors (i.e., carriers, such as ticks and mosquitoes) that could transmit emerging diseases related to a warmer climate in the MAR.

Significant information gaps, particularly with respect to projecting extreme weather events at local levels, increase the uncertainties in the projections and make it more difficult for policy makers to choose actions that will improve the region's resiliency to climate variability and change. Thus, an action item is to improve the information available about the frequency, timing, and intensity of extreme weather, and the resulting potential impacts, particularly on agriculture, forests, fresh water, and coastal zones. Additional information gaps include the costs and benefits of alternative adaptation actions, and how local, state, and national policies will affect the region's future vulnerability.

Addressing these information gaps requires continuity in the assessment process, to maintain a team of assessment experts and a viable stakeholder network that can build and implement public/private partnerships. The assessments will be more meaningful and more useful if the teams and their stakeholder networks have the ability to evaluate a range of regional issues. This is because of the difficulty of engaging many citizens about environmental impacts that they might not observe within the near term, yet that might require investments now to ameliorate negative impacts for their children and grandchildren. The MARA results showed that many of the impacts from climate change are the same as impacts from poorly planned economic development, which people often do care about in the near term. A logical next step is to build on the MARA activities by including land use/land cover as another stressor that affects citizens' quality of life as well their ecological support system. In the Fall of 2002, an expanded assessment team, working with stakeholders, undertook this challenge in a new Consortium for Atlantic Regional Assessment.