Issue 7 July/August 1999

Acclimations

Newsletter of the U. S. National Assessment of Climate Variability and Change

An Investment in Science for the Nation's Future

By Robert Corell, National Science Foundation

Developing a sustainable future for our Nation requires investments that could be made through a variety of mechanisms and that need to be made over a range of time frames. To be effective, however, the investments need to be based on fundamental understanding. Thus, in addition to funding scientific research because the subjects being studied are intrinsically interesting, the Federal Government funds science as an investment in the Nation's future. This is particularly the case for the U. S. Global Change Research Program, which was established by Congress in 1990 to "assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change." Encompassed within this charge of assisting the Nation are several responsibilities. These include to provide assessments that are: (1) responsive to our nation's international treaty requirements (e.g., the Montreal Protocol and the Framework Convention on Climate Change); (2) responsive to the missions of individual agencies and to the Federal government as a whole as called for by Congress; and (3) responsive to the needs of the people and organizations of our Nation who are at the frontlines in having to deal with the human-induced and natural variations and changes resulting from global change. Thus, we have the responsibility to look outward, to look at the Nation as a whole, and to look inward at the rich mosaic of interactions and changes that are occurring and may occur in the future.

The National Assessment is a very key part of this effort. Not only is it looking at the Nation as a whole, but it is also looking at what is happening and projecting what will happen to the various parts of our Nation. To do this for the first time, we have had to develop a whole new approach to identifying the key issues that matter to the citizens of our country. Building bridges with stakeholders in order to accomplish this has been a new challenge, and one that we have had to pursue through new partnerships that can identify the types of information needed to support public and private investments for sustainability.

The assessment process has already taught us that there are a variety of needs for information to support understanding of and adaptation to climate variations and change. Investment in information building is needed to support technological developments and better performance and more efficient resource use. Investment in information building is needed to support wise and forward-looking infrastructure planning and development important now and for the future. And investment in information building is needed to support "learning communities" (to borrow a phrase from George Seielstad). Learning communities are made-up of groups of citizens drawn from a broad range of backgrounds (e.g. scientists, industrialists, educators, and others) participating in important two-way dialogues that help both present and future citizens learn to live and work more sustainably on the Earth.

continued on page 2

Next Issue

The next issue will provide overviews of other climate change impact assessments, including those being conducted by:

- Canada
- IPCC
- United Kingdom

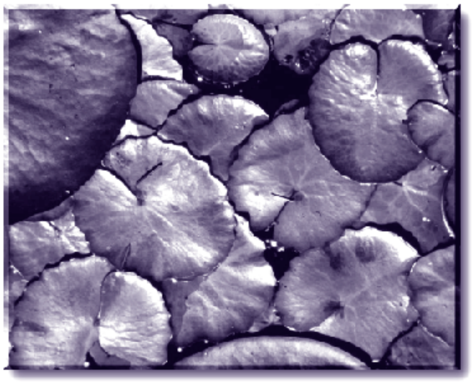
Contents

[acclimation, noun; "Adjustments to a changing environment"; Roget's Thesaurus]

Acclimations

Climate Change in Wetland Areas Part II: Carbon Cycle Implications

By Jon Kusler, Institute for Wetland Science and Public Policy



Wetlands affect the levels of atmospheric carbon in two ways: First, many wetlands, particularly boreal and tropical peatlands, are carbon reservoirs. Carbon is contained in the standing crops of trees and other vegetation and in litter, peats, organic soils and sediments which have been built up, in some instances, over thousands of years. The magnitude of storage depends upon wetland type and size, vegetation, the depth of wetland soils, ground water levels, nutrient levels, pH and other factors discussed below. These carbon reservoirs may supply large amounts of carbon to the atmosphere if water levels are lowered or land management practices result in oxidation of soils. Second, many wetlands also continue to sequester carbon from the atmosphere through photosynthesis by wetland plants; many also act as sediment traps for carbon-rich sediments from watershed sources. However, wetlands also simultaneously release carbon as carbon dioxide, dissolved carbon, and methane. Deposited sediments are, in some instances, dislodged during floods and hurricanes. The net carbon sequestering versus carbon release roles of wetlands are complex and change over time although net, gradual sequestration occurs over time for peatlands and certain other types of wetlands. Land use practices also affect sequestering.

Wetlands as Carbon Reservoirs

In carrying out photosynthesis, wetland trees and other plants convert atmospheric carbon dioxide into biomass. Carbon may be temporarily stored in wetlands as trees and plants and the living animals which feed upon them, and detritus including fallen trees and plants and the animals which feed upon them.Carbon may stored in the longer term in organic-rich soils, peats, and various forms of coal, shale, sandstone, and other sediments. It is long term storage that makes some wetlands effective as carbon reservoirs. Wetlands often provide longer term carbon storage than other ecosystems systems because decompositional processes are hindered by the saturated conditions, high acidity (bogs), and low temperatures (tundra). Many organic "flats" wetlands are underlain by deep layers of peat; permafrost wetlands may be underlain by more than a

continued on page 10

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continued from page 1

The US Global Change Research Program (USGCRP) information-building investments include observing and documenting change; understanding processes and consequences; predicting future changes; and assessing options for dealing with change. The USGCRP invests in the future through its findings that inform many of the important decisions that our Nation needs to take today and in preparation for a more sustainable tomorrow. At the same time, the USGCRP is listening to calls for information at international, national, and regional levels and specific information needs of particular stakeholder groups. The USGCRP is working to ensure that the National Assessment process will inform and help focus the research agenda and complete the two-way dialogue that occurs in a "learning community." This investment in our Nation's future--research, application of findings, and feedback--is beginning to show exciting results. There are many wonderful examples across the country of our learning together and applying research results to help real people with real challenges.

As one very specific example, the Northern Great Plains regional assessment activity is working to help many private sector businesses in the region improve efficiencies and reduce costs. This application program began by working directly with one rancher and is now working with over 250 to promote better performance and resource use in farming and ranching by providing information that allows efficiency improvements in applications of chemicals and fertilizers. This in turn results in better yields, reduced waste, reduced costs and reduced potential for polluting run-off. Information from this program is also contributing to more efficient management and harvesting of timber.

In a similar outreach to stakeholders, the Pacific Northwest regional assessment program is, among other things, working with managers of major reservoirs to provide them with better information and forecasts. For example, many of the regions' major water users were not aware that the impact of changes in the Pacific Decadal Oscillation phases and shifts could rival those of El Nino for the Pacific Northwest region. Knowledge and forecasts of such information could be important to planning both long-term water needs and meeting clean water standards.

Networks and communities of learners are being formed and developed across the National Assessment program. These efforts include information exchanges as well as dialogue and feedback that encourage all to approach current and future issues with a greater focus on long-term planning and sustainability. Again, giving just a few examples based on meetings held and contacts developed:

The Atlantic Coast-Caribbean and New England regions are working closely with teachers and educators. Many of these efforts are developing new curricula for teachers and students that encourage greater understanding of the Earth system, the role of human activities in causing change, and possibilities for a more sustainable approach.

continued on page 3

Key Issues in the Rocky Mountain/ Great Basin Regional Assessment

By Frederic Wagner, Utah State University

The Rocky Mountain / Great Basin region is the second largest of the assessment regions. Extending 15°of longitude and 17°of latitude, and covering parts of nine large western states, it is exceeded in size only by Alaska. As a result, there is a diversity of subregional climates in the region: at the northwest extreme precipitation is largely winter, frontal moisture; toward the southeast, there is a significant shift toward summer, monsoonal rain. This geographic gradient is complicated by hundreds of separate mountain ranges and basins with their own elevational gradients and local microclimates. Nevada alone has 160 mountain ranges.

We have subdivided the region into three Great Basin and five Rocky Mountain subregions, and analyzed their climate records for the past 100 years. Adjacent subregions exhibit different climate patterns, and there were no consistent patterns in any of the climate parameters across all subregions (with the exception of a tendency toward rising minimum temperatures, increased precipitation and increased streamflow in the northern portion of the region).-This spatial variability seriously complicates assessment because of the difficulty of devising reasonable scenarios for considering consequences across the region. It is unlikely that any single climatic change will occur over the entire region, and the climate models do not yet have the resolution to provide subregional detail in their predictions. We convened a September 1998 focus group meeting of climatologists and hydrologists to produce a limited set of reasonable scenarios for the region. The result was a wide range of opinions, however, with no consensus, suggesting that a wide range of possibilities needs to be considered.

Because of its aridity, water availability is a critical issue for the Rocky Mountain / Great Basin region. Some 90 percent of human water use in the region comes from surface water, three fourths of which is produced each year by melting of winter snowpacks on its mountain ranges. In February 1999, we surveyed water managers in the region about the current stresses on water resources and likely current problems associated with climate change. Later that month, we convened a focus group meeting of water managers employed at local, state and national levels, and specialists in western water law, policy and economics. A clear signal emerged that the managers' major concerns are coping with the variability in western water resources created by climate fluctuations. Their longer-term concerns focus on

the population growth in the region and the shift in demand, with primary use moving from traditional uses by agriculture to municipal and industrial needs. Climate-change effects are not very high on the attention screens of water resource managers at present compared to concerns about climate fluctuations.

However, were climate change to occur, decline in winter precipitation would reduce water resources that are already oversubscribed. The region's population growth is the most rapidly increasing of any region in the nation, and demand for water resources is likely to increase as this growth continues. Increase in winter precipitation would ease any shortage, but could exacerbate flood-control problems.

continued on page 11

continued from page 2

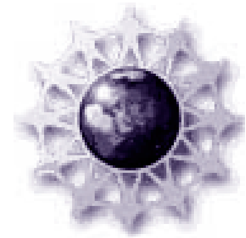
The Mid Atlantic and Gulf Coast regions are working closely with the media to provide information to a wide range of individuals.

Alaska, the Northern Great Plains and the Southwest regions are working with Native communities. These efforts are promoting a unique blend of native knowledge and scientific information toward a long-term perspective of actions and consequences.

The Metro East Coast, Southern Great Plains-Rio Grande, Pacific Islands, Appalachian and California regions are working with communities and state and local governments to use information to plan for extreme events as well as longer-term changes. Applying new technologies to current stresses can allow new perspectives and planning options to emerge to address potential future stresses.

The Southeast, Southern Great Plains / Rio Grande, Great Lakes, Rocky Mountain / Great Basin and Central Great Plains regions are focusing on working with specific resource groups composed of interested individuals and managers to promote critical information exchange and identification of research needs that will contribute to the future research agenda.- All of these efforts (and many more across the regions) require a great deal of personal interaction, a building up of trust between the various communities, application of new technologies or newly generated information, and a focus on achieving a gain for the Nation as a whole and the region or sector in particular. All of us associated with the USGCRP are excited to see how far we have come in this new endeavor in so short a time. We understand the importance of continuity, the critical importance of a more sustainable approach to our life on this Earth, and we look forward to even greater interactions and gains in the future as we continue our efforts to build and sustain learning communities.

The National Science Foundation and the National Assessment



By Thomas Spence, National Science Foundation

The National Science Foundation (NSF) was established to promote and advance scientific progress in the United States. In contrast to other agencies with specific missions, NSF is committed to ensuring that basic research needs of the Nation are met, principally by funding academic scientists in specific disciplines, and increasingly by funding multi-disciplinary efforts. Using a comprehensive peer review process, the Foundation makes over 9000 awards each year.

For the past decade, NSF has provided significant support for the U.S. Global Change Research Program (USGCRP). This program, formally established by Congress in 1990, aims to understand the complex physical and biogeochemical processes which affect and modify the Earth. NSF activities in support of the USGCRP are coordinated through an interagency process to ensure a comprehensive research program that effectively meets the needs of the Nation.

Recently the NSF and its partner agencies initiated efforts to support the Congressionally mandated National Assessment of the Consequences of Climate Variability and Change. As an initial contribution, NSF established a program to develop much-needed methodologies for assessment. This program, Methods and Models of Integrated Assessment, supports a number of fundamental studies to develop techniques which underpin assessment.

Along with other agencies, NSF has sponsored several components of the National Assessment. NSF is supporting regional assessment activities in New England, the Metropolitan East Coast, California, and, in cooperation with other agencies, Hawaii and Pacific Islands. Each of these regional projects has coupled scientific studies with impact assessments that are specifically focused on issues germane to the particular region. Each of these regional projects actively involves regional groups of stakeholders to ensure that the results of the research programs are translated into useful information for the decision-making process at the appropriate level. Additionally the efforts of these regional studies will provide information for use in the sector and national assessment activities.

- **New England (University of New Hampshire)** This regional assessment uses analyses of recent conditions and predictions of potential future scenarios to identify specific impacts on human health, forestry and water. The project has developed and fostered close contacts with a wide array of stakeholders who depend on the out comes of global change research and assessment for their decision-making. Efforts have already enlisted the participation of local governments and civic groups. The project also plans to develop a number of important data bases that will support future analyses and assessments affecting the New England area.

- **Metropolitan East Coast (Columbia University)** Large metropolitan areas pose a number of challenges for assessment. Cities such as New York and their environs may be subjected to a number of adverse conditions resulting from global change. This assessment study is focusing principally on human health, coastal inundation, water facilities, infrastructure, as well as community interaction and outreach in large and complex metropolitan areas. A variety of studies are already underway to determine the vulnerability of the regions to global change. A recent paper at the Spring AGU meeting called attention to the increased threat posed by storm surges with elevated sea-level conditions. Again, the results of the work should provide important information to guide decisions and guidelines for the development of additional research avenues.

- **California (University of California at Santa Barbara)** California, the most populous state, is exposed to a wide range of significant environmental impacts as a result of global change. This project is focusing on several potentially affected sectors including urban and water systems, coastal effects, agriculture, and ecosystems. It is building on earlier efforts that enlisted representatives of a large number of stakeholders through an extensive outreach effort. The approach will be to coordinate existing efforts of the California scientific community through modeling, scenario development, and impact assessment.

- **Hawaii and Pacific Islands (Hawaii East-West Center)** Several US agencies (NSF, DOI, NASA, NOAA) have collaborated to support this regional assessment project in the Pacific. Hawaii and the Pacific Islands are particularly vulnerable to impacts of climate change. The project will specifically address water resources, extreme events, and climate-related coastal hazards. A key component of the project is the interaction with stake holders and the development of appropriate infrastructure to enhance and support community involvement.

Although obviously sharing many issues in common, the four regional assessments cited above address very different issues and speak to quite different audiences and stakeholders. As a result, they illustrate the broad spectrum of NSF-supported regional assessment projects.

For more information:
See the NSF web site at http://www.nsf.gov.

National Assessment Annual Workshop Summary

Overview

Approximately 100 National Assessment leaders participated in the annual workshop (held in Atlanta, April 12-14, 1999), representing almost every region and sector, the Synthesis Team, and the data and scenario efforts. Major topics included:

- Scenario approaches and data needs
- Regional assessments
- Sectoral assessments
- Coverage of cross-cutting and integrative issues
- Regional and sectoral sections of the SynthesisReport
- Regional and sectoral assessment reports, including report templates, publication issues, and review processes
- Planning for next steps in the National Assessment ("Post-2000")

The following are some of the general conclusions and recommendations:

- Regions identified the need to incorporate socio-economic scenarios in their analysis and to work towards a more quantitative analysis of consequences.
- Sectors identified the needs for better recognition of opportunities, for more case studies, and for better communication between regions and sectors.
- Methodologically, there is a need to think further about how to characterize vulnerability without imparting value judgments; to describe scenarios to stakeholders in meaningful way; and to better place climate in the context of other issues.
- There is a need to build in processes to include issues emerging from the National Assessment into the USGCRP plan.
- There is a need to think further about a communication strategy for the National Assessment.
- There is a need to work towards better linkages with both national (i.e. NIGEC) and international (i.e. Canada and UK) programs and assessments.

The following summary minutes provide outcomes of some of the key breakout groups.

Scenario Breakout Groups: Monday AM

Three breakout groups were convened on Monday AM to share approaches and discuss problems concerning climate scenarios,socioeconomic scenarios, and ecological scenarios. The following provides a brief summary of the scope of each section and major recommendations.

Group	Issues Discussed	Recommendations of Further Questions
Climate Scenario	• Temperature and precipitation means and extremes. • Indices of interannual variability. • Sea level rise. • Storm tracks and synoptic patterns. • Climate diagnostics. • Intermodel comparisons. • Model validation.	• We must continue to remind the National Assessment community that GCMs are only one of three routes we have suggested for climate scenarios. • Participants agreed that the model results must be viewed as 'what-if' scenarios rather than model predictions of the future. • There is concern about which model provides the best scenarios. Given that all of themodels contain biases, it is best to view these results as a bracketing range, rather than trying to rank them. • There is interest in looking more at model diagnostics to understand why we are getting certain changes in temperature and precipitation.
Socioeconomic Scenarios	• Finer (than county-level) scale analyses. • Development and communication of socio-economic scenarios. • Use of socio-economic data sources. • Consideration of changes in non U.S. economies.	• Asmall group will be discussing changes in non-U.S. economies (Mike Hamnett, Ricardo Alvarez, Bill Solecki). • Teams are using multiple methods of developing scenarios: many are developing scenarios by sector, some are using expert judgment, and others are constructing their own scenarios. • To communicate across sectors about socioeconomic scenarios, use newsletters, a central clearinghouse, web pages. • Suggestion: use 1995 dollars for consistency.
Ecological Scenarios	• Evaluation of the current and scenario derived changes in the elements that control ecosystem dynamics. • Weighing the impact of policy vesus the impact of climate. • Role of timing of events; overlap of events affecting ecosystems and disturbance frequency.	• VEMAP results are available for theconterminous U.S. from the group and can show changes in properties such as NPP, soil organic matter, vegetation carbon, annual ET, run-off, distribution of vegetation types, etc. • Evaluation of thresholds is a useful way of communicating how current climate and GCM-derived projections of climate affect critical aspects of the ecological system (such as extreme heat waves, high rainfall days, growing degree days). • Considerations of policy and legal issues related to climate impacts need to be discussed in developing coping strategies. • Coastal areas and marine resources demand more attention in the ecosystem modeling effort.

Caucus Groups

On Monday afternoon, participants divided into four caucus groups to discuss how to better coordinate on four cross-cutting issues in the current assessment, and how to approach these issues in the future.

Group	Primary Follow Up	Recommendations for Scope/Forum
Cities and Communities	A coordinating group will be convened to distill information emerging from the regions and sectors, and to make this available more broadly. Asector assessment is encouraged on biodiversity in future phases of the assessment.	• Link the services provided by natural systems, urban systems, and climate in the analysis. Convene workshops to focus on practical measures available to increase resilience and adaptability. • Make greater use of GIS and modeling systems for land use planning. • Take advantage of the interest of professional associations, such as APA, AIA.
Biodiversity and Wildlife	The breakout group participants were able to layout the key issues that need to be addressed, the research challenges, and a set of activities that together would compose a sectoral assessment.	Address issues such as: • Factors that influence migration; • The level of carbon storage in wetlands and the related impact on conservation efforts; • The linkage between loss of biodiversity and ecosystem services; • The distribution of scientific information; and • An effective communications strategy to the public.
Tourism and Recreation	The breakout group participants explored linkages across different areas, and discussed the types of analyses that would help give a better understanding of this topic.	• There is a need for better information and measurements on transient (tourist) populations for resource management and public infrastructure. • Focus on small businesses who will be the hardest hit; larger businesses are less vulnerable in part because they are starting to diversify.
International	The breakout group participants highlighted regions and issues with important internationalconnections.	It is important to look at the responses other nations might take to climate change and the accompanying feedbacks. Countries with similar climates (and in particular with different socioeconomic status or research infrastructure) could partner; Habitat conservation plans and the establishment of corridors for species might require international cooperation.

Regional and Sectoral Reports

On Wednesday afternoon, three sessions took place (each involving all meeting participants) to discuss regional and sectoral assessment reports, review processes for these reports, future reports, and a communications strategy. The following provides information on resolution of issues and next steps.

Topic	Resolution and Next Steps
Regional and Sectoral Reports: Template	The regions agreed on an established reporting structure for consistency for their regional summary reports (see annex). They agreed that: • Each region will include, at minimum, a list of key elements; • Each region will use the format designed by Warford / Grabhorn; • Each region will choose their own color; • These reports will be written in lay language. The sectors did not come to an agreement on this issue.
Regional and Sectoral Reports: Review Process	The participants agreed on a three part review process: • *Informal reviews* of preliminary drafts internal to the assessment community; • *External review* of the draft assessment report by experts, groups, agencies, external to the assessment; and • *Concurrence review* of the final report by the sponsoring agency and key relate assessment participants, emphasizing how comments had been responded to.
Publication and Future Summary Reports	In this session, participants discussed possibilities for a wider array of communication products, including: • Drafting a second synthesis report, or a compilation of summaries of each regionaland sectoral report; • Working with journals, science magazines, and popular magazines on special issues,articles, and stories; • Seeking radio, TV and newspaper coverage; • Encouraging presentations at national meetings and conventions; • Convening a second National Forum

Post-2000 Discussion

On Wednesday afternoon, meeting participants provided input into the federal process of preparing a proposal on the National Assessment Post-2000. The following are some of the general points stated by participants:

- Consider the role of existing stakeholders networks and value of continuity (even in a "re-competition") .
- Work to cooperate with existing networks.
- Look at the NASARESAC experience in terms of partnerships, networks, and private sector involvement.
- Consider "Network of Affiliates" host / core and other partners.
- It was noted that it is difficult to talk stakeholders' language and get funding through science agencies; there is also the challenge of distillation.

continued on next page

Developing Socioeconomic Scenarios: Mid-Atlantic Case

By Jim Shortle, David Abler, and Ann Fisher, Pennsylvania State University

Climate impact assessments usually begin with climate change scenarios that describe future climate conditions given assumptions about future emissions of greenhouse gases. Climate scenarios are, however, only one type of scenario needed to assess the impacts of human induced climate change. Because of the profound effects that humans have on the environment from local to global scales, socioeconomic scenarios are essential to understanding how climate change will affect not only people, but also other assessment endpoints such as agriculture, water, coasts and forests. Developing socioeconomic scenarios for climate assessment is challenging. Here we discuss development and use of socioeconomic scenarios for the Mid-Atlantic Regional Assessment.

We have distinguished two basic types of socioeconomic scenarios: socioeconomic baseline scenarios and socioeconomic response scenarios. Impact analysis involves comparing conditions (e.g., climate, economy, and population) "with" the stimulus that induces change to conditions "without" the stimulus. For example, in defining the impacts of greenhouse gas emissions on climate, the climate baseline is the naturally evolving climate. The usually slow rate of natural climate change is of no consequence for human society in the foreseeable future (30 to 100 years), so current climate can serve as the baseline future climate.

Similarly, socioeconomic baseline scenarios describe future socioeconomic conditions as they would be without human-induced climate change, and provide the "without" condition for defining the impacts of the climate change stimulus. If socioeconomic systems were like the global climate, we would need only to project current conditions. However, this is not case – the economy and society are likely to change significantly with or without climate change. For example, mining, forestry, agriculture, and manufacturing were the largest components of the Mid-Atlantic region's economy at the turn of the century, but today they are much diminished in importance. Similarly, the economy and society of the region will undoubtedly be substantially different in the future than today in terms of their structure, producer and consumer technologies, the range of available goods and services, and public and private institutions. This in turn means that the region may be significantly different in terms of its sensitivity to climate change and its potential for response and adaptation.

Not only must we expect change, but we are also very uncertain of the socioeconomic future even without climate change. Economic and technological forecasting accuracy diminishes rapidly with forecast length. Point forecasts of socioeconomic conditions for the year 2030, to say nothing of the year 2100, would be far more likely to be wrong and misleading than to be useful. In this respect, economic modeling is well behind climate modeling – though the challenges involved in long-term economic modeling are arguably much greater than those involved in long-term climate modeling. This inability to forecast is more acute at a regional level because many socioeconomic processes and interrelationships are less stable over time and thus less predictable at a regional level than at the national level.

For example, population change cannot be predicted accurately at a regional level because the key regional determinants of population growth are regional migration inflows and outflows, which are essentially impossible to predict on a long-term basis. This tremendous uncertainty about the future without climate change means that more than one socioeconomic baseline scenario is essential for climate impact analysis.

Socioeconomic response scenarios describe the responses that society would make to climate change. Climate change, as well as expectations of climate change, will stimulate socioeconomic responses to reduce risks and exploit opportunities. These responses differ from, but have the potential to shape, final impacts. For example, there may be a variety of steps farmers can take in response to climate-induced changes in temperature, precipitation, and pests.

continued on page 8

continued from page 6

The following were identified as key elements of future program(s):

- Analysis
- Outreach / Communication
- Education
- Quiet meetings and experience and "informal" contacts
- An open process; full and open access to data and information
- K-12 education

The following were discussed as follow up:

- Keep the lines of communication open an provide additional input via Tom Wilbanks (regions), Justin Wettstein (sectors), and Paul
- Dresler (USGCRPagencies).
- Initiate a participatory planning process to develop a shared vision of a sustained USGCRPassessment program.
- Establish mechanisms for review of the current effort and continuing, self-evaluation of the evolving program.
- Address issues related to adequate support for ongoing efforts and a smooth transition to a long-term USGCRPassessment program.
- Acknowledge the significant progress made to date and recognize the valuable contributions of the USGCRPagencies, regional programs, sectoral teams, and the Synthesis Team under challenging fiscal conditions and a demanding timeline.

continued from page 7

The final impact on agricultural production will depend on these responses. Responses that are feasible given existing technology and institutions can be identified, but it is more difficult to project changes in technology and institutions. It is certain that climate change will stimulate technological and institutional change, but it is very difficult to predict just what those changes would be. Like socioeconomic forecasts of the future without climate change, forecasts of how society would respond and adapt are inherently uncertain. Multiple response scenarios are again essential to understanding impacts. However, an exhaustive list of all possible futures, or even "probable" futures, quickly becomes unmanageable. Suppose that socioeconomic futures are defined with respect to k variables and that a alternative values are considered for each variable. For instance, when a = 3, one could think in terms of a "high," a "medium," and a "low" value for each variable. The number of possible combinations of values is ak, which is large even for moderate values of a and k. For example, if a = 3 and k = 5, the number of possible combinations is 35 = 243. If k = 10, the number of possible combinations is 310 = 59,049.

Rather than point forecasts or exhaustive lists, we are attempting to construct socioeconomic scenarios that will provide concrete results for present-day public and private decision-making. This goal can be accomplished with a smaller set of scenarios selected to help identify and bound major potential threats and opportunities, and identify critical research and adaptation policy issues in the Mid-Atlantic. Increased vulnerability clearly emerges in scenarios that combine greater future baseline socioeconomic or ecosystem sensitivity with increased climate stresses on socioeconomic or ecological systems and little ecological and / or socioeconomic adaptation. This category yields upper bounds on adverse impacts and lower bounds on favorable impacts. Similarly, reduced risks clearly emerge in scenarios that combine reduced baseline socioeconomic or ecosystem vulnerability with reduced climate stresses. This category yields lower bounds on adverse impacts and upper bounds on favorable impacts. Combinations of climate and socioeconomic scenarios with offsetting effects may yield greater or smaller risks. The ranges between the upper and lower bounds could be viewed as confidence intervals.

Another crucial issue in socioeconomic scenario design is the selection of subjects (domains) and variables. The list of possible socioeconomic subjects for climate impact assessment is too large for comprehensive coverage. Our choices have been guided by our goal described above. In selecting subjects, the first step was to identify the region's sectors likely to be sensitive to climate change. We are looking at issues related to agriculture, coasts, forests, health and water. The second step was to identify and select among risks within the sectors. To illustrate, we identified four key societal interests in agriculture: food availability and cost, agricultural income and employment, rural landscape, and environmental impacts of agricultural production. Because food availability and cost are almost entirely determined by factors external to the region, such as global agricultural production and trade, we chose to focus our agricultural assessment on the latter three. We further focused our agricultural assessment by concentrating on the leading agricultural commodities in terms of land use, income and employment and water quality impacts.

Socioeconomic variables have two basic roles in climate impact assessment. One role is as an indicator of economic and social conditions that might be influenced by climate. Examples include income, unemployment, levels of economic activity in particular sectors, and indicators of health status. Climate impacts on society can be described by changes in such variables. The second role of socioeconomic variables is as indicators of socioeconomic drivers that directly or indirectly influence sensitivity and vulnerability to climate change. For example, population and income growth increase the demand for water and water quality, which has implications for the assessment of impacts of climate change on water quantity and quality.

Like the number of socioeconomic topics, the number of socioeconomic variables of potential interest is very large. Because of this and because of problems in making long-term forecasts, the best approach may be to identify variables that are particularly important and construct summary variables that aggregate over sets of interrelated variables. For example, in our assessment of agriculture, key socioeconomic categories are international markets for commodities produced in the region, markets for agricultural inputs imported to the region, regional agricultural land markets, agricultural production technologies available to producers in the region, and agricultural, land use, and environmental protection policies. Rather than constructing scenarios with specific values of each variable included within these categories, we constructed scenarios as heuristic descriptions of conditions across these categories.

Examples are presented in Table 1.

Table 1. Baseline Agricultural Scenarios for the Year 2030

Scenario	Scenario Details
Smaller, More "Environmentally Friendly" Agriculture (SEF)	• Major decline in field crop production in region • Significant decline in livestock production, perhaps smaller than decline in field crop production • Significant decrease in number of farms in region • Substantial increase in agricultural productivity due to biotechnology andprecision agriculture • Major increase in agricultural production per farm on the remaining farms • Significant decrease in agriculture's sensitivity to climate variability due tobiotechnology, precision agriculture, and improved climate forecasts • Some conversion of agricultural land to urban uses, with conversion slowed by farmland protection programs • Some reforestation of existing, economically marginal agricultural lands • Significant decrease in commercial fertilizer and pesticide usage due to biotechnology • Less runoff and leaching of agricultural nutrients and pesticides due to precision agriculture • Stricter environmental regulations facing agriculture, especially intensivelivestock operations
Status Quo (SQ)	• Agriculture as it exists today in the Mid-Atlantic Region

Calendar

NATIONAL ASSESSMENT SPONSORED MEETINGS:

Meeting of the National Assessment Synthesis Team
Washington, D.C.
July 7-9, 1999
(Contact: Melissa Taylor, e-mail: mtaylor@usgcrp.gov)

Meeting of the National Assessment Synthesis Team
Woods Hole, MA
August 10-20, 1999
(Contact: Melissa Taylor, e-mail: mtaylor@usgcrp.gov)

RELATED MEETINGS:

1999 World Conference On Natural Resource Modeling
Halifax, Nova Scotia, Canada
June 23-25, 1999
(Contact: RMA Conference Committee, e-mail: resource.conf@stmarys.ca).

2nd North American Forest Ecology Workshop
University of Maine, Orono, ME
June 27-30, 1999
(Contact: Marlene Charron, tel: 207 581-4707 or e-mail:Charron@maine.edu).

AWRA Science into Policy:
Water in the Public Realm and Wildland Hydrology
Bozeman, MT
June 30-July 2, 1999
(Contact: AWRA tel: 703-904-1225 or e-mail: awrahq@aol.com).

Seventh International Conference - Air Pollution '99
San Francisco, CA
July 27-29, 1999
(Contact: Liz Kerr, Wessex Institute of Technology,
tel: 44(0) 1703 293223e-mail: liz@wessex.ac.uk).

American Agricultural Economics Association Meeting
Nashville, TN
August 7, 1999
(Contact: http://www.aaea.org/meetings/m99/registration.html).

Food & Forestry: Global Change and Global Challenges
Reading, United Kingdom
September 20-23, 1999
(Contact: http://www.elsevier.nl:80/homepage/sag/gcte99/).

Second Annual Climate Change and Ozone Protection Conference
Washington, D.C.
Sept. 27-29, 1999
Contact: Erika Fischer, tel: 703-807-4052; http://www.earthforum.com).

Desert Technology V: Deserts in Changing Climates
Reno, NV
October 3-8, 1999
(Contact: Engineering Foundation Conferences, Three Park Avenue, 27th Floor, New York, NY, 10016-5902; tel: 212-591-7836;
e-mail: engfnd@aol.com; www.engfnd.org).

Global Environmental Change Education Workshops for Secondary and
Post-secondary Educators
Monona, WI
October 23, 1999
(Contact: http://www.seagrant.wisc.edu/advisory/GEC/workshops.htm).

AWRA's Annual Water Resources Conference
Seattle, WA
December 5-9, 1999(Contact: e-mail: awrahq@aol.com or
tel: 703-904-1225).

Synthesis Team News

The Synthesis Team held its fourth official meeting June 7-8, 1999 at the National Science Foundation to discuss progress in drafting the national summary report and its overview. The following terminology was developed for the suite of National Assessment documents that will be published in the next year:

- **Overview Document:** a summary by the Synthesis Team, consisting of about 75 pages (this will have a 4 page spread for each mega-region and sector)
- **Foundation Document:** the longer report by the Synthesis Team, consisting of over 200 pages (this has a ~15 page section for each mega-region and sector), and
- **Bedrock Documents:** the reports from the regions and sectors, as well as other outputs of the National Assessment.

The first two documents are scheduled to be published in January 2000; the Bedrock Documents from the regions and sectors will come out on a rolling basis beginning in the fall and continuing through the year 2000.

A Blue Ribbon Panel has been formed as a subcommittee of the President's Council on Science and Technology (PCAST) specifically to assist with the Synthesis Team contributions. The Panel will provide technical guidance and will oversee the process of ensuring responsiveness to reviewer comments. The first meeting of the Panel will take place June 22nd, when the members will be able to comment on a mock-up of the Overview Document.

As a next step, the Synthesis Team will have two more meetings this summer (July 7-9 in Arlington, Virginia and August 10-20 in Woods Hole, Massachusetts) where members will prepare the documents for review and publication.

continued from page 3

meter of organic rich soil; and it is not uncommon to find ten or more meters of unconsolidated organic matter in peat lands. Significant quantities of carbon from both wetland and nonwetland sources may also be trapped and stored in wetland sediments.

The long-term effectiveness of some wetlands in storing carbon is demonstrated by the extensive coal deposits throughout the world. These were formed in wetland or wetland-like conditions, in many instances hundreds of millions of years ago.

Like wetland forests, upland forests sequester carbon in standing vegetation and to a lesser extent in debris and the upper layers of the soil. However, long storage in soils is often limited due to rapid decompositional processes and re-release to the atmosphere. Rapid decomposition and re-release also occurs in some types of wetlands such as rice paddies.

The total amount of carbon in wetland standing vegetation, debris, peats and other soils is large, and it has been estimated that wetlands hold 35% of the total terrestrial carbon. Drainage of peatlands, tundra, and other wetlands acting as carbon reservoirs results in oxidation of the organic matter, releasing it to the atmosphere as CO2, methane, and other greenhouse gases. Conversely, enhancement, restoration or creation of certain wetlands may provide important additional carbon sinks.

Wetlands as Active Carbon Sinks (Sequestration)

Photosynthesis by wetland plants converts atmospheric CO2 into biomass. Wetlands are, therefore, net carbon sinks if the rate of plant production exceeds the rate of decomposition for fallen trees, litter, and wetland soils (e.g., peats) and net export through release of gases or water transport of dissolved carbon or sediments. Wetlands often store more carbon than other ecosystems despite their low productivity due to low decompostion rates. In addition, wetlands may act also as net carbon sinks if they trap carbon-rich sediment from upland sources and such accumulation exceeds losses. Many riverine, estuarine, coastal and estuarine wetlands trap large quantities of sediment from natural and anthropogenic watershed sources.

Rates of photosynthesis in wetlands, of course, vary. Some wetlands (e.g., coastal flats, playas) have little vegetation with resulting limited production of plant biomass; some (e.g., salt marshes, tropical forests) have much vegetation and high rates of production. Trees and other vegetation grow quickly in tropical and temperate wetlands with ample sunlight, nutrients, water and warm temperatures. In contrast, the growth of trees and other vegetation is slow for high latitude wetlands (e.g., peatlands) with less sun, nutrients, and water and colder temperatures.

Rates of decomposition also vary and fluctuate over time, depending upon a variety of interrelated factors such as temperature, water levels, hydroperiod, flow of water and nutrients. In addition, removal of carbon by physical processes may occur quickly in some wetlands and very slowly in others. For example, litter, peat and carbon rich sediments may be quickly removed from some coastal wetlands by frequent coastal storms; riverine flood flows may scour some riverine wetlands. In contrast, organic mater in bogs may remain undisturbed for hundreds or thousands of years (e.g. bogs) in others.

Research on peat lands indicates that photosynthesis and decompositional processes are complex and fluctuate in a specific setting, depending upon ground water levels, temperature, substrate availability, nutrient levels, methanogene population and other factors. Research suggests that, overall, peatlands are net carbon sinks. However, releases of carbon dioxide and methane may exceed photosynthesis in some circumstances. In addition, peat lands may convert carbon dioxide to methane-a more active atmospheric gas. It has been suggested that wetlands are a source of 15% to 20% of atmospheric methane.

Processes vary at different levels with a peat deposit. The lower levels of peat (catotelm) produce larger amounts of methane while the upper levels (acrotelm) produce carbon dioxide and at least partially oxidize methane released from the lower levels. The output of methane is determined by the production of methane by methanogenic bacteria and its removal by methanotrophic bacteria. Studies suggest that if the water levels are lowered in the upper levels due to drainage, decreased precipitation, or increased evaporation and transpiration, carbon dioxide and methane production may exceed sequestration. However, this may not continue once the upper levels of peat are oxidized to the level of the new water table.

Impact of Climate Change on Wetland Carbon Sequestering

Climate change will likely affect the ability of wetlands to sequester carbon, but the results will vary and are difficult to predict. Increased CO2 in the atmosphere will result in increased plant growth in most if not all wetlands, and the potential for increased carbon sequestration will increase under certain circumstances. Increased rainfall may also result in increased sediment deposition in some wetlands. Other the other hand, increased temperatures may result in decreased ground and surface water levels for many wetlands due to increased evapotranspiration where precipitation decreases, remains steady, or only slightly increases. Decreased ground and surface water levels and increased temperatures may result in increased decomposition. The carbon storage and sequestering role of peatlands could also be reduced by the melting of permafrost. Certainly, responses will be complex. Eville Gorham wrote in 1991 that, "given the diversity of possible responses by boreal and subartic peatlands to climatic warming, it is impossible at present to predict their future contributions to the global carbon cycle" - and others have recently endorsed Gorham's conclusion.

Management Strategies for Protecting and/or Enhancing Carbon Reserves and Wetland Carbon Sequestering Capabilities

A variety of strategies are available to protect and or enhance carbon reserves and wetland carbon sequestering. Some would be compatible with broader biodiversity protection goals and other goals to protect wetland functions;

continued on page 11

continued from page 10

others would not. Some strategies include:

- Protect natural wetlands systems.
- Conduct regional inventories and prepare management plans for wetlands of greatest importance as carbon reserves and for carbon sequestering.
- Control fires.
- Protect low flows and residual water.
- Install water control structures.
- Plant trees, other vegetation.
- Restore, enhance, and create wetlands.

Conclusions and Recommendations

There is broad agreement that certain types of wetlands contain large historic, reservoirs of carbon in above ground biomass, litter, peats, soils and sediments. There is also agreement that land management practices such as drainage may release at least a portion of the carbon. However, accurate estimates are not available for total carbon reserves in wetlands the U.S. or other countries. And, the impacts of various land management practices such as forestry upon such reservoirs are also only partially known.

Similarly, there is broad agreement that wetland plants continue to convert atmospheric carbon into biomass and carbon-rich sediments continue to be deposited in wetlands. Net carbon sequestration occurs as long as rates of conversion exceed decomposition and external transport of materials from wetlands. However, it is difficult to evaluate the net carbon sequestering role of wetlands because decomposition of organic matter, methanogenisis and sediment fluxes are extremely complex and there are gaps in scientific knowledge.

What is needed to better evaluate generically and in specific settings the roles of wetlands as carbon reservoirs and for carbon sequestering and to guide protection, enhancement, restoration or creation efforts. Acombination of literature surveys, scientific consensus-building measures (workshops), field measures and laboratory studies are needed. Some priority topics for such evaluation efforts include: evaluating wetlands as carbon reservoirs; estimating sequestration rates in wetlands; and enhancing, restoring and creating wetlands.

For more information, contact:
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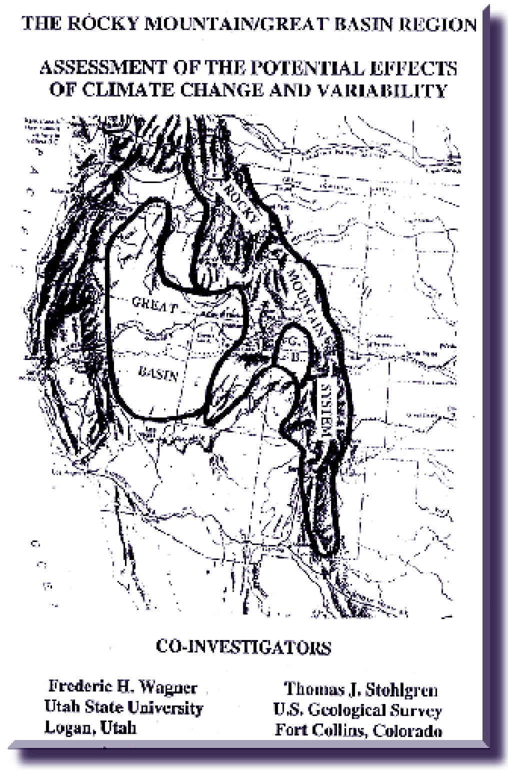
continued from page 3



With agriculture using 75-80 percent of water allocations in the West, it is looked upon as a buffer to absorb rising municipal and industrial needs.

Rising temperatures could shorten snowpack seasons by delaying the autumnal change from rainfall to snow, and advancing spring snowmelt. The result could be a change in seasonal run-off schedules that might or might not coincide with power, municipal and agricultural withdrawals; the changes might also alter the availability of water for aquatic ecosystems and recreational use, especially through protracted summer run-off seasons. A shortened snowpack season could also place at risk many ski businesses that must have a minimum number of skiing days to operate profitably

Because western ecosystems are substantially water limited, the regional assessment will closely examine the potential effects of both precipitation increase and decrease. A particular concern will be the effects on fire frequencies. Dry years in the mountains make the montane forests more fire prone, but the shrub steppe less so. Wet years in the shrub steppe enhance growth of herbaceous understories, increase ground fuels, and increase fires that convert native, perennial vegetation to monotypes of exotic annuals. Other ecological effects to be analyzed are changes in plant community composition, vulnerability to invasion by non-native plant species, and effects on threatened and endangered species, especially stream and wetland organisms.

One sector that is closely adjusted to current climate patterns is the livestock industry, which pays fees to graze its animals on the 75-80 percent of the region that is public land. Ranchers typically operate from privately owned home ranches where they may or may not have significant acreage of irrigated forage crops, move animals to national forest ranges in the mountains in summer, and to low-elevation U.S. Bureau of Land Management lands in winter. Depending on the native rangelands available to an operator and the productivity of the natural vegetation, it may be necessary to provide seasonal, supplemental forage, either produced on the home ranch or purchased on the open market.

Thus, by depending on forage produced by the natural vegetation, and on supplements for which prices vary according to weather conditions, the industry is closely attuned to the vagaries of weather. Because it operates on a thin profit margin, the livestock industry would be significantly affected by climate change. Decline in precipitation would eliminate profitability for many ranchers. Increases in precipitation and temperatures could enhance forage production and grazing-season lengths on natural vegetation. Both would reduce costs and increase profitability.

The next stage in the regional assessment is to hold additional focus group meetings with those sectors most likely to be affected by climate change: tourism (with special attention to the skiing industry), cultivated agriculture, livestock industry and natural ecosystems.

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