Land of Opportunity

The American Response To Climate Change

The Adirondack Model: Using Climate Change Solutions to Restore a Rural American Economy

Working Memorandum

Natural Resources & The Role of Adirondack Lands and Forests in Carbon Mitigation

Sector Team Leads

Colin Beier, *SUNY-ESF, Adirondack Ecological Center*
Dan Spada, *Adirondack Park Agency*

Sector Team

Susan Arnold, *The Wild Center*
Tom Berry, *The Nature Conservancy*
Dirk Bryant, *The Nature Conservancy*
Ray Curran, *Adirondack Sustainable Communities*
John Davis, *Adirondack Council*
Mike DiNunzio, *Association for the Protection of the Adirondacks*
David Gibson, *Association for the Protection of the Adirondacks*
Michale Glennon, *Wildlife Conservation Society*
Wendy Hall, *Adirondack Wildlife.org*
Dan Kelting, *Adirondack Watershed Institute*
Craig Milewski, *Paul Smith's College*
Dan Plumley, *Association for the Protection of the Adirondacks*
Curt Stager, *Paul Smith's College*

Table of Contents:

Adirondack Background

The Adirondack region is unique in many ways. The Adirondack Park was formed in the late 19th Century primarily to protect the forests, mountains, lakes, wetlands, and rivers that provided the water resources that fed much of New York's canal system, which was a key component of the State's economic engine at that time. Over the past five generations, the Park has provided a dependable, clean, and abundant flow of water that helps sustain its natural and human communities and still underpins the economic vitality of the region.

Creation of the Park has done much more than protect water resources. For example, the six-million acre Adirondack Park is a biological treasure trove, and is one of the world's last remaining bastions of the vast temperate deciduous forest that once covered much of Europe, parts of Asia, and most of Eastern North America. Over 90 percent of this type of forest has been lost to fragmentation and development worldwide. The Park is also recognized as a world model of conservation that integrates public wildland protection and private land stewardship in a lived-in landscape where about 140,000 people make their home in more than 100 individual communities and host about 10 million visitors each year.

In an effort to balance the need for environmental protection with the needs of human communities in the Adirondacks, the Park was placed under the regional planning and zoning authority of the New York State Adirondack Park Agency more than a generation ago. Recently, the Park was included in a federally funded study of the environmental, social, cultural, and economic threats and opportunities facing the 26-million-acre Great Northern Forest that runs from Lake Ontario across Northern New York, Vermont, and New Hampshire to the coast of Maine. That study focused upon ways to enhance the quality of life for local residents through the promotion of economic stability for the people and communities of the area by maintaining large forest areas, encouraging the production of a sustainable yield of forest products, and by protecting recreational, wildlife, scenic, and wildland resources.

At the dawn of the Twenty-first Century, the natural and human communities of the Adirondack region are once again threatened, not by unsustainable resource extraction as in the past, but by the pervasive impacts of acid deposition, mercury contamination, and accelerated global climate change. With its relatively small population, the Adirondack Park has a limited potential to achieve globally significant reductions in greenhouse gas emissions. But dollar savings related to energy conservation, efficiency, and production from local, renewable sources could be significant for struggling households, businesses, institutions and local governments in the Park. The Energy $mart Park Initiative estimates that annual *per capita* residential and commercial energy costs are at approximately $2,000 and rising very rapidly, putting the total annual energy bill for the Park at about $260 million. Saving 20 percent of the energy used in the Park would save about $52 million per year - over half a billion dollars in 10 years – dollars that can stay in the Park and help build economic strength, encourage energy independence and enhance the quality of life for human communities.

The Adirondack Park is an ideal place for exploring ways to make climate action planning a practical reality for rural communities. The transition to a clean, green, energy future will benefit the Park's human communities as well as the natural communities. It will unearth new job creation potential, new business opportunities, training, certification, skill-building, and educational needs which will, in particular, provide opportunities for young people to remain in the area. It will lay the groundwork for local governments to take a leadership role in developing more independent and lower carbon local economies. It will include defining the value to the Park of "greening" the tourism industry and outlining the steps required to become a Green tourism destination. This "greening" process will likely emphasize the health and economic benefits of producing and buying local food.

The region is already experiencing impacts from changes in the global system of climate patterns. Adirondack residents, visitors, businesses, and government representatives are increasingly seeking ways to lessen their own impact, reduce costs, and anticipate future needs in this uncertain context. It is through local choices, made as communities and individuals, about energy supply and use, transportation, solid waste and land use that Adirondack towns and villages can lead in addressing these challenges. *(Adapted from Energy $mart Park Initiative, November 2007 work plan draft)*

I. Executive Summary

This workshop will summarize current knowledge and raise key questions about climate change in the Adirondack Park, with an emphasis on forests and their associated resources, including timber, water, biodiversity, recreation and scenery. We are concerned with how Adirondack ecosystems and human communities will respond to climate change and how forest management and land use practices may provide opportunities for climate mitigation through carbon sequestration. Preliminary data on the carbon services provided by Adirondack forests will be presented for comparison with a regional greenhouse gas emissions inventory. Our workshop goal is to frame management strategies that will enhance both the resilience and mitigation capacity of the Adirondack Park in the face of climate change, without sacrificing the numerous other values and benefits of forest ecosystems for local Adirondack communities.

II. Key Concepts

Climate change is a global phenomenon, highly variable at regional and local scales.
The strongest directional climatic changes are being observed in the Arctic. At lower latitudes, the trends and impacts are highly variable, and may be more related to the increasing frequency and severity of weather conditions, such as droughts or storms. A difficult aspect of climate change is that past understanding of climatic variability tells us little about what to expect in the future. This uncertainty should be kept in mind when interpreting global climate projections and their impacts, which serve as valuable tools, but not as certain predictions of the future.

Ecosystems will respond to climate change in new and often unpredictable ways.
Natural communities are not static things, they are ‘moving targets’, and because of their complexity it is very difficult to predict their responses to a changing climate. Modern ecosystems represent a legacy of past changes in climate, geology, interactions among species, and most recently, human influence in the biosphere. Gradual and predictable responses to climate change have been observed, but we find that because of their complexity, ecosystems often experience abrupt and severe changes. While forest ecosystems tend to change slowly in response to climate, rapid changes can occur when climatic shifts are either linked with, or directly cause, increases in localized disturbances such as fire, drought, insect outbreaks and diseases. In other cases, climate change may alleviate certain stressors in forest ecosystems, such as drought, if projected increases in precipitation occur as expected.

Diverse communities with natural disturbance regimes are more resilient to change. Resilience is the capacity of a system to absorb change, reorganize under new conditions, and retain its essential characteristics, such as structure, function, and variability. As climate change shifts the baseline conditions upon which species are adapted, the physiological tolerances of certain species may be exceeded, possibly driving some to local extinction. Ecosystems with a natural assemblage of species tend to exhibit functional redundancy, meaning that localized extinctions may have relatively little impact on ecological functions. By contrast, where ecosystems have been modified to reduce diversity by increasing the abundance of a few species, or to stabilize predictable flows of resources (such as crops or timber), resilience to change is lower, and loss of species can have much stronger cascading negative effects on ecological functions. Ecosystem vulnerability may be exacerbated by other simultaneous stressors and large-scale drivers of change, such as acid deposition and land use.

Impacts of climate change will require the adaptation of species, including humans.
Although efforts to mitigate catastrophic changes are by no means futile, our environment will undoubtedly experience some degree of climate-induced change in the future. In this changing landscape, the resilience and adaptability of human and natural communities will be tested. As certain species may no longer thrive, certain economic sectors may struggle; meanwhile, there will be new opportunities for species and industries. Overall, we find that diversity and flexibility is key for coping with change, whether we are concerned with ecosystems or employment.

Land use / forestry practices provide opportunities for climate change mitigation.
Carbon sequestration in forest vegetation and soils is currently recognized as the most promising short-term approach for stabilizing atmospheric concentrations of the greenhouse gas carbon dioxide (CO_2). Through 'carbon forestry', scientists and managers are examining ways to store atmospheric CO_2 through both conservation of forests and production of durable forest products. In addition, restoration of forested wetlands and soil conservation are recognized as important steps for maximizing CO_2 storage potential in forested landscapes. Of course, with a changing climate, ecological functions that govern carbon budgets are likely to change, requiring careful observation and study to ensure the best management practices are in place.

Mitigation efforts should be balanced with other environmental benefits for society.
Climate change is perhaps the single greatest challenge to society in the coming century, yet we must avoid addressing the climate crisis in ways that generate new environmental and social problems. For example, forestry practices can potentially maximize long-term carbon sequestration, but potentially at the cost of other ecological services, including the regulation of local climate by forest vegetation. Instead of maximizing a single benefit, we should seek to optimize a range of goods and services from ecosystems (including carbon sequestration) in order sustain a diversity of forest resources, values and future management options.

III. Current Knowledge

A. IMPACTS of CLIMATE CHANGE in the ADIRONDACK PARK

Recent climatic changes in the Adirondacks are mixed and geographically variable. Unlike observations in boreal and arctic regions, instrumental records in the Adirondack region do not suggest sharp increases in average temperatures throughout the year, especially in winter months. Instead, Adirondack weather records during the 20^{th} century indicate both warming and cooling trends in average monthly temperatures. Snowfall and snow depth overall is declining, but highly variable from year to year. The strongest overall weather trends – warming and wetting – have been apparent in the months of August and September (Fig. 1). Keeping in mind that the 'window' of analysis has a strong effect on the trends observed, century-long trends in the Adirondacks and those of the last three decades often differ dramatically. For example, average September temperatures have changed little overall during the 20^{th} century, but have increased steeply in the last three decades (Fig. 1). Overall, these observations are complicated further by a high degree of local variation in these trends. Stager and others (2008) have provided an initial analysis of these trends; a more detailed and spatially-explicit analysis of regional climatic changes is forthcoming (Beier and others, *in prep*).

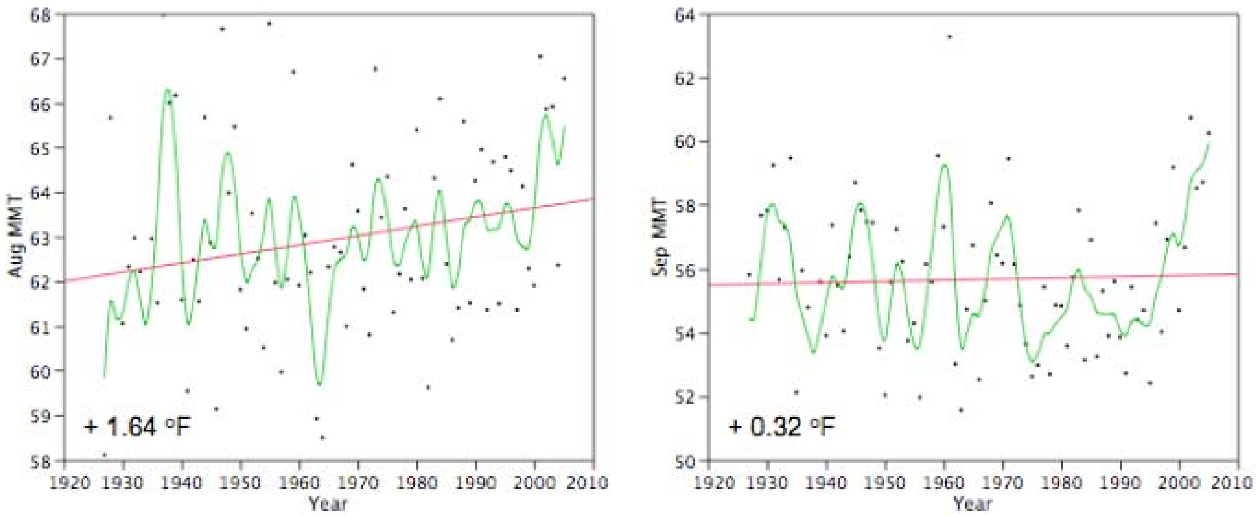

Figure 1. Trends in mean monthly temperatures (MMT °F) for August and September, based on aggregated data for 8 weather stations in the Adirondack region (Stager and others 2008).

Future Adirondack climate is projected to support oak-hickory and oak-pine forests. Modeling studies suggest that the Adirondack region's climate in 2100 will be similar to that associated with contemporary oak-pine and oak-hickory forests further south (Prasad & Iverson 1999). Despite the popular interpretations of these models, they do *not* predict that northern hardwoods like sugar maple and birch will be eradicated from the Adirondacks this century. In the near term, it is likely that northern red oak will likely expand its range in the region. These changes will probably occur gradually, but other factors influencing forest health – such as sugar maple decline resulting from acid deposition – may accelerate compositional shifts.

Continued decline of sugar maple will have significant ecological and economic impacts. The combined impacts of acid rain and climate change will continue to threaten the viability of sugar maple in the Adirondacks. Sugar maple accumulates calcium (Ca) in its foliage, and supports the storage and cycling of this biologically critical nutrient which is becoming depleted in Adirondack forest soils affected by acid rain. A wide range of organisms, especially breeding birds, salamanders, and snails, require significant Ca inputs for growth and reproduction. Therefore, decline of sugar maple may have cascading effects on biodiversity and productivity of communities throughout the Adirondack Park. In terms of the economic value of maple sugaring and the scenic amenities of fall foliage, the decline of sugar maple may be partially (but not completely) offset by increases in red maple. Such substitutability between red (soft) maple and sugar (hard) maple is certainly not true for timber values; although lost sawtimber value of sugar maple may, however, be offset by an increasing availability of oak sawtimber.

Additional discussion questions:

1. Is there a difference in vulnerability to climate change among Forest Preserve and private Adirondack lands?
2. How might other large-scale anthropogenic stressors, such as acid rain, influence the vulnerability of Adirondack ecosystems to climate change?

3. How might climate change influence the vulnerability of Adirondack ecosystems to other large-scale stressors, such as acid rain and invasive species?
4. What will these potential environmental changes mean for local communities?

B. ADAPTATION to CHANGE in the ADIRONDACK PARK

Ongoing adaptation of Adirondack species to climatic changes have become evident. Scientists and local residents have observed changes in phenology – the rhythm and timing of species behaviors and ecological processes – in the last several decades in the Adirondacks. This includes earlier blooming of spring flowers, earlier arrival of migratory song birds, and northward shifts in the range distributions of breeding birds, including many southern species moving into the Adirondacks. Such changes in timing can be the first indicators of climatic shifts, but they also have implications for the productivity, health, and diversity of forest communities. For example, cycles of thawing and freezing in late winter and early spring can damage plant tissues and interrupt normal cycles of hibernation and torpor for a variety of forest species.

Northward shifts in breeding bird distributions indicate bird communities are adapting. Comparison of New York State Breeding Bird Atlas data between two census periods (1980-85 and 2000-2005) indicates that numerous bird species have experienced northward range shifts, including many southern species moving into the Adirondacks. Landscape-scale shifts in bird distributions are probably attributable to climatic changes, but may also be related to land cover changes resulting from abandonment of agricultural land (Zuckerberg 2008). As southern species move into the Adirondacks, resident species will face increased competition.

Local economies dependent on natural features will need to adapt to climate changes. Climate change will present both challenges and opportunities for local economies. For example, if climate projections for the northeastern U.S. are accurate, and the Adirondacks become one of the few locales in the region with consistent winter snow, winter tourism and recreation may grow dramatically. Local decision-makers will have to find the balance between capturing this growth opportunity while sustaining the wilderness character of the Park and adapting to both changing recreational uses and changing winter weather. Local governments may struggle with heavy snow years as municipal budgets have adjusted to reflect the decreasing snowfall observed over the last two decades. Decline of sugar maple may leave the Adirondacks with a decimated sugaring industry. Changes in precipitation may alter hydropower potential, affecting many Adirondack communities dependent on cheap electricity; meanwhile, the downstream impacts of changes in water provision from the greater Adirondack watershed could have implications (ecological and economic) from the St. Lawrence to the Hudson rivers.

Additional discussion questions:
1. Does the protection of forest land support more adaptive and resilient natural communities in response to climate change?
2. How will local economies and cultures respond to changing weather conditions?
3. Does the existence of the Forest Preserve promote or constrain the ability of local communities to be adaptive in coping with changing climate and environment?

C. MITIGATION FUNCTIONS of the ADIRONDACK PARK

Adirondack Park Forest Preserve lands provide significant carbon storage services.

Much of the Forest Preserve consists of maturing and old-growth forests that are either approaching, or have reached, a steady state carbon flux in which new growth (sequestration) is more or less balanced by mortality (respiration and decomposition). However, these old-growth forest soils tend to store immense amounts of organic carbon, especially in areas dominated by conifers (which produce recalcitrant litter that decomposes very slowly) and cooler sites, such as north-facing slopes and higher-elevation forests (where soil temperatures constrain respiration rates). Intact forest watersheds transport large fluxes of dissolved organic carbon in groundwater into aquatic systems where it serves as a key input for lake and stream food webs, and remains within the forest ecosystem's carbon cycle. For these reasons, the Adirondack Forest Preserve primarily serves a carbon storage function, which itself will be sensitive to climatic changes and other anthropogenic stressors such as acid rain and forest diseases/pests.

Table 1 provides a rough (but conservative) estimate of the above- and below-ground carbon storage in the Adirondack Park. Based on these data and other sources, on a per-acre basis the Adirondack Park is among the 5 largest carbon sinks in the continental United States.

Managed forest lands in the Park provide significant carbon sequestration services.
Forest management promotes young and vigorous regeneration that sequesters significant amounts of carbon in biomass and, to a growing degree as a forest matures, in forest soils. Forests managed on sustained yield rotations can maximize carbon sequestration and, through production of durable goods, support the long-term storage of this carbon. Net sequestration rates are determined by many factors including stand composition, site productivity, soil fertility and depth, disturbance regime, and

Table 1. Carbon storage in forest biomass and soils, and the estimated proportion attributed to the Adirondack Park, based on percentage of each county within the Blue Line. Biomass units are in millions of metric (dry) tons (MMT). Carbon equivalent (CE) units are presented in teragrams (Tg). One Tg = one MMT. Estimated soil carbon is derived from the NCASI-USDA COLE site.

				Adirondack Park		
County	Aboveground Biomass (MMT)	Estimated Soil C (Tg CE)	% County in ADK Park	Above-ground Storage (Tg CE)	Below-ground Storage (Tg CE)	Total Storage (Tg CE)
Hamilton	18.49	38.89	100.0%	9.24	38.89	48.13
Essex	35.29	38.70	99.9%	17.63	38.66	56.29
Warren	17.09	17.53	93.9%	8.03	16.46	24.49
Franklin	25.84	32.81	67.9%	8.77	22.27	31.04
Herkimer	22.41	25.85	60.0%	6.72	15.50	22.22
Fulton	11.10	8.85	59.6%	3.31	5.28	8.59
Clinton	16.09	16.13	45.7%	3.68	7.37	11.05
Saratoga	21.45	44.88	34.5%	3.70	15.50	19.2
St. Lawrence	45.99	14.05	27.6%	6.34	3.87	10.21
Lewis	24.86	23.62	20.0%	2.48	4.72	7.2
Washington	18.54	9.85	18.8%	1.75	1.86	3.61
Oneida	20.62	17.27	2.1%	0.21	0.36	0.57
			TOTALS	**71.86**	**170.74**	**242.6**

silvicultural practices. Because harvesting practices can result in massive CO_2 fluxes from affected soils, managers seeking to maximize sequestration can (1) emphasize yarding practices that minimally disturb soils, and (2) implement partial retention silvicultural systems in order to mitigate the increases in soil temperatures associated with canopy removal that, in turn, increases soil respiration (and CO_2 release).

Table 2 provides a county-level estimate of changes in Adirondack Park forest biomass, or growing stock, based on 1993 and 2004 USDA FIA data and related products. Changes in growing stock were used to estimate changes in aboveground carbon content, which provides a rough approximation of net carbon fluxes from forest lands. A positive flux number suggests net CO_2 sequestration, while a negative flux number suggests net CO_2 emission, or loss by other means, including removals. In the Adirondacks, net carbon loss can probably be attributed to timber harvest. Harvested products can reflect the spectrum from long-term storage (e.g., durable goods like sawtimber) to near-term emissions (e.g., chips for generating power). Overall, these are highly aggregated estimates that should be interpreted with considerable caution. Suitable data were not available to estimate changes in soil carbon.

Strategies to increase Adirondack Park climate mitigation are 'working on the margin'. Land use changes that convert agricultural or otherwise developed uses into forested land yield the greatest net benefits in terms of carbon sequestration and storage. Because over 95% of lands in the Adirondack Park are forested, any regional management regime focused on climate mitigation functions of the Park will yield only marginal returns to scale, in terms of additional carbon sequestered and stored. For this reason, carbon sequestration will probably be, at best, a secondary objective for private landowners in the Park, and should not necessarily be emphasized at the expense of other important forest goods and services. For example, more lands could be transferred to the Forest Preserve in order to increase the Park's natural

Table 2. County-level estimates of changes (Δ) in forest biomass and C storage (ΔC Biomass), weighted by county representation to provide a rough measure of net carbon fluxes for the Adirondack Park (ΔTg CE yr^{-1}). A positive sign suggests net C sequestration, while a negative sign suggests net C loss. Units are million metric tons (MMT) of dry biomass and teragrams of CO^2 equivalent (Tg CE).

County	Net Growth (MMT)	Mortality (MMT)	Removals (MMT)	Δ Biomass (MMT)	Δ C Biomass (Tg CE)	County Weighting	ADK Park ΔTg CE yr^{-1}
Hamilton	0.71	0.24	0.49	-0.01	-0.01	1.000	-0.01
Essex	1.04	0.28	0.34	0.42	0.23	0.999	0.23
Warren	0.72	0.15	0.52	0.05	0.03	0.939	0.03
Franklin	0.80	0.34	0.75	-0.29	-0.16	0.679	-0.11
Herkimer	0.38	0.12	0.34	-0.08	-0.04	0.600	-0.02
Fulton	0.38	0.05	0.09	0.24	0.13	0.596	0.08
Clinton	0.54	0.20	0.14	0.21	0.11	0.457	0.05
St. Lawrence	1.93	0.10	0.66	1.17	0.64	0.345	0.22
Saratoga	0.92	0.48	0.28	0.16	0.09	0.276	0.02
Lewis	1.14	0.21	0.34	0.60	0.33	0.200	0.07
Washington	0.53	0.08	0.09	0.36	0.20	0.188	0.04
Oneida	0.94	0.09	0.16	0.69	0.38	0.021	0.01
TOTALS	**10.03**	**2.34**	**4.2**	**3.52**	**1.93**		**0.60**

carbon storage capacity, but this would reduce the capacity to actively (and repeatedly) sequester carbon from the atmosphere for long-term storage in durable wood products. Instead of major changes in management and land use policy, current practices can be adjusted to maximize the long-term climate mitigation functions of managed forests in the Adirondack Park.

- Timber production should emphasize yields of durable goods that represent a stable, long-term mechanism for carbon storage.
- Certified professional foresters should be engaged for each logging job; currently roughly half of small harvesting jobs in the Park are 'loggers choice' without systematic guidelines.
- Silvicultural prescriptions should emphasize selection or partial retention systems that produce sustainable yields, and strike a balance between maximizing growth rates of regenerating trees and mitigating post-harvest CO_2 fluxes from affected soils.
- Best management practices should include measures that minimize the disturbance of forest and wetland soils with high carbon storage potential.

Additional discussion questions:

1. In addition those listed above, what forest management practices are well-suited for carbon sequestration and storage in the Adirondack Park?
2. What immediate opportunities and challenges exist for implementing these 'carbon forestry' practices?
3. How might biomass and bioenergy change land use and forest management in the Adirondack Park?
4. What unintended impacts of 'carbon forestry' strategies might influence the provision of other forest ecosystem services?
5. What are the regulatory and policy-related factors that would constrain such climate mitigation efforts in the Adirondack Park?

IV. Future Directions

Our goal for this workshop is to build consensus on the objectives, strategies and policies needed to sustain the natural and human communities of the Adirondack Park. The end product will be a set of policy, management, and scientific goals and recommendations that can be endorsed by all members of the working group. To this end, we have identified three primary themes where actions can be taken in the near term, ranging from scientific research to active management, to community outreach and education. We provide a few discussion topics for each theme but these are not meant to be exhaustive. Subgroups for each theme will meet independently to provide suggestions for next steps and long-term goals, and will reconvene with the entire working group to identify conflicts and build consensus on compromises.

WORKSHOP THEMES

Protecting the 'protected' areas

Effective conservation during a period of rapid environmental change requires understanding how 'protected' ecosystems might respond to multiple stressors. Impacts of climate change, acid rain and invasive species may threaten even the most strictly protected wilderness landscapes like the Adirondack Forest Preserve. Topics for this subgroup may include the immediate steps needed to (1) observe and understand the responses of the ecosystems in the Forest Preserve to climatic and other environmental changes; (2) adaptively manage the Forest Preserve for multiple values under a changing climate; (3)

conserve rare and threatened species and habitats that are likely to suffer under a changing climate; and (4) exchange knowledge on climate change and conservation with other parks and protected areas.

Carbon forestry in the Adirondacks

Working forests in the Adirondack Park provide valuable carbon sequestration services, and these climate mitigation functions can be enhanced through a variety of management practices. At present, however, carbon will probably remain a secondary objective (and revenue source) for forest managers and landowners. Topics for this subgroup may include (1) how local conditions will shape the implementation of certain practices; (2) the opportunities and obstacles for production of durable wood products for long-term carbon storage; and (3) the role of forest certification programs in creating market-based incentives for carbon sequestration and storage. This theme will also produce specific recommendations for forest management strategies that support a balance among diverse forest uses and values, in addition to timber and carbon.

Building resilient rural economies

In general, rural economies tend to become strongly dependent on a single economic sector, whether it is resource-extractive (e.g., timber, mining, fisheries) or amenity-based (e.g., tourism and recreation). Due to this lack of diversity in economic activities, rural economies tend to be vulnerable to larger-scale social and environmental changes. By contrast, resilient economies are adaptive and flexible with a broader representation of economic sectors, from manufacturing to ecotourism. This resilience affords greater sustainability in the face of climate change. The challenge for Adirondack economies is to capture the diverse benefits of their environment in sustainable and innovative ways. Topics may include (1) community-based forestry strategies that generate wood products and renewable energy; (2) value-added ecotourism and recreation that encourages lodging and outfitting in rural communities; and (3) policy initiatives that compensate rural communities for the ecosystem services provided through land conservation.

Reference & Literature Cited

Prasad AM and LR Iverson. 1999 (- ongoing). A Climate Change Atlas for 80 Forest Tree Species of the Eastern United States. [online] http://www.fs.fed.us/ne/delaware/atlas/index.html, Northeastern Research Station, USDA Forest Service, Delaware, Ohio.

Stager JC, McNulty SA, Beier CM and J Chiarenzelli. 2008. Historical patterns and effects of changes in Adirondack climates since the early 20th century. *Adirondack Journal of Environmental Studies* (in press).

Zuckerberg B. 2008. Long-term responses of breeding birds to climate change and reforestation in New York State. Ph.D. dissertation, State University of New York, College of Environmental Science and Forestry, Syracuse, NY.