authorbio

Tony Prato, Ph.D., is professor of ecological economics and codirector of the Center for Agricultural, Resource and Environmental Systems at the University of Missouri ...

more on author

environment: climate change

Coping with Climate Change

By Tony Prato and Dan Fagre

An ActionBioscience.org original article

articlehighlights

To stem the adverse effects of climate and landscape change, adaptive management of natural resources

- *integrates a variety of available tools*
- *provides a scientific basis for management decisions*
- *improves our understanding of how ecosystems function*

read the article learn more links get involved links

October 2006

Coping with Climate Change

By Tony Prato and Dan Fagre

What have we learned so far about how climate change is affecting our global environment? Studies show that it adversely affects human and natural systems by

Climate change is known to affect ecosystems.

- reducing biodiversity
- altering hydrological systems
- impairing biological and chemical cycles
- making it more difficult to restore degraded ecosystems

The problem is amplified by changes to the landscape.

Climate is not the only factor in the deterioration of natural systems. We are making big changes to the landscape, altering land use and land cover in major ways. These changes combined present a challenge to environmental management. Adaptive management is a scientific approach to managing the adverse impacts of climate and landscape change.

Nature and impacts of climate change

Every week it seems there is an article about global warming in the news media. It may be difficult for some to grasp the big picture of the issue, but in general, climate change has already or is expected to

Climate change is affecting weather and

- increase temperatures, particularly in the interior of continents, toward the poles and in winter
- boost precipitation in wetter areas and suppress precipitation in drier areas
- increase rain and decrease snow
- lessen peak spring runoff and cause more even year-round flows of water, thereby reducing water availability during summer irrigation and navigation seasons
- increase evaporation of water during the summer
- enhance the likelihood of lower mean lake levels, drier wetlands,

temperature.

and water shortages, particularly in mountain regions
- raise the frequency and magnitude of extreme weather events, such as hurricanes, tornadoes, and floods
- raise global sea levels causing some populated coastal areas to become inundated
- reduce the extent and duration of Arctic sea ice with adverse consequences for marine mammals
- increase permafrost melting, thereby altering soil stability and limiting modes of transportation
- increase the loss of glaciers in middle and equatorial latitudes, including premier mountain ecosystems such as Glacier National Park in Montana

It's 6°C warmer now than 100 years ago.

Global average temperature has increased by about 0.6°C over the past 100 years, with a major warming upswing in the 1970s. Warming is the result, in part, of rapid increases in emissions of greenhouse gases (GHG), particularly carbon dioxide (CO2), which is a byproduct of the combustion of fossil fuels, such as coal, oil, and natural gas, used for power generation and transportation.

When global temperatures rise and precipitation patterns change, it is expected there will be consequences on ecosystems, such as an increase in the spread of exotic species; redistribution of plants, animals, energy, water, and nutrients; alteration of natural processes and the structure and function of ecosystems.

The Arctic is warming faster than the rest of the world.

Northerly latitudes are particularly vulnerable to climate change. The Arctic Council, an intergovernmental forum for Arctic nations and indigenous people, reported that the northern ice cap is warming at twice the global rate and the Arctic region is expected to warm at two to three times the rate for the rest of the world. Arctic warming will have serious human and ecological consequences.

Nature and impacts of landscape change

Both nature and humans contribute to landscape change.

Landscape change results from natural disturbances and human activities. Natural disturbances include fire, windstorms, avalanches, landslides, tree fall, floods, and insect epidemics. Human activities causing landscape change include urban sprawl, conversion of forestland to agriculture, drainage of wetlands, and forest fragmentation from road construction and timber harvesting.

Humans have a big impact on landscapes.

Human activities often have a more significant effect on landscapes than natural disturbances because they alter the availability of energy, water, and nutrients to ecosystems; increase the spread of exotic species; accelerate natural processes of ecosystem change; and adversely affect the structure and functioning of ecosystems. Human-induced landscape change has accelerated during the past several decades because of rapid population and economic growth, particularly in countries such as China, India, and Brazil.

- Landscape change has contributed to a dramatic 1,000-fold

Most of the contiguous United States has been altered since its settlement.

increase in species extinction over the past 400 years.

- On a global basis, nearly 1.2 million km2 of forest and woodland and 5.6 million km2 of grassland and pastureland have been converted to other uses.
- During the last three centuries, 12 million km2 of cropland were lost. Between 1982 and 1997, 121,000 km2 of non-federal land were urbanized in the United States.
- More than 90 percent of the land in the lower 48 states has been logged, plowed, mined, grazed, paved, or otherwise modified from presettlement conditions.

Development in parts of the Yellowstone ecosystem has increased fourfold.

Human-induced landscape change significantly affects wildlife. For example, between 1970 and 2000, rural residential development in the Montana and Wyoming portions of the Greater Yellowstone Ecosystem increased 400 percent. Consequently, current and potential grizzly bear habitat on private lands in the ecosystem has been degraded and fragmented. Double-digit growth in residential subdivisions adjacent to the National Elk Refuge in Jackson, Wyoming, has diminished winter range for the 10,000 elk that use the refuge and displaced corridors that elk use to reach summer range in Yellowstone and Grand Teton National Parks.

Another example of significant impacts from landscape change is the Crown of the Continent Ecosystem. This ecosystem straddles the Rocky Mountains in British Columbia and Alberta, Canada, and western Montana, United States. Here are some specifics:

Most old-growth forests on unprotected lands in the Rockies are gone.

- Most old growth forests that once existed outside of protected park and wilderness areas have been harvested.
- Many rivers in the region have been altered by hydroelectric power development.
- Significant farm, ranch, and forest acreage has been converted to homes and commercial developments.
- Lakes and streams have been polluted by agricultural and urban runoff.
- Fish and wildlife habitats have been degraded.
- Active and proposed energy developments threaten protected areas.
- Large areas have been invaded by nonnative species.

The desire to preserve the outstanding wildlife (especially large carnivores) and environmental amenities from the negative effects of rapid economic growth and development in the northern Rocky Mountain region prompted creation of the Yellowstone to Yukon Conservation Initiative. The initiative involves 300 conservation organizations and covers an area larger than the states of California and Texas combined, including the Greater Yellowstone and Crown of the Continent Ecosystems.

Coping with climate and landscape change

Although climate and landscape change has positive effects on human and natural systems, it is expected to have many adverse impacts that deserve

attention. Ecosystems have an inherent capacity to resist climate and landscape change, known as ecological resilience. When this capacity is exceeded, the ecosystem can change in ways that may not be socially and ecologically acceptable.

There are ways to help ecosystems adjust to the changes.

So what can be done? Mitigation strategies can reduce ecosystem vulnerability, and adaptation strategies can increase ecological resilience to climate and landscape change. Mitigation strategies are actions to prevent, reduce, or slow climate and/or landscape change. Adaptation strategies are actions to counteract the adverse consequences of climate and landscape change. Natural resource managers can use both strategies to reduce adverse ecosystem effects of climate and landscape change.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change, which took effect in February 2005, is a prime example of a climate change mitigation strategy. The protocol commits 36 industrialized countries to curb GHG emissions, especially CO_2. Limiting increases in global temperature by 2°C would require keeping atmospheric concentrations of CO_2 below 400 parts per million (ppm). Current concentrations are about 375 ppm. Benefits of the Kyoto Protocol may be limited because it does not include some developed countries, which emit substantial GHGs, and developing countries where rapid population and economic growth is expected to dramatically increase GHG emissions.

The Kyoto Protocol is a mitigation strategy to slow climate change.

Other mitigation strategies include increasing the use of alternative energy sources and technologies (clean coal, renewable energy, ethanol, hybrid vehicles, and nuclear power). Although the United States did not sign the Kyoto Protocol, 28 states have programs to curb CO_2 emissions, and at least 166 US cities have agreed to apply the Kyoto emission reduction standards to their communities. Other initiatives, like the Apollo Alliance, bring together labor unions, environmental and business groups, and activist organizations with the mission of sharply reducing US dependence on fossil fuels. The alliance is seeking ways to do the following:

- increase the use of solar and wind energy
- power the economy with hydrogen produced from renewable energy resources
- implement green construction codes
- revitalize urban centers to reduce urban sprawl
- determine how industry can store rather than emit carbon into the atmosphere

The Apollo Alliance is working to mitigate the energy crisis.

The Apollo Alliance expects to invest $300 billion in new energy technologies and energy conservation over 10 years as a way to eliminate US dependence on foreign oil and create millions of good-paying jobs. These funds would be raised using tax incentives, public bonds, capital strategies, and other mechanisms.

Communities, too, can adapt. The Inuvialuit people of Sachs Harbor in the Canadian Arctic illustrate an example of social adaptation to climate change. They adapted by changing both the species they hunted and the timing and methods of hunting. Other adaptation strategies for climate

change include:

Communities can devise their own solutions.

- moving people out of low-lying coastal areas bound to be inundated by rising sea levels
- switching to more drought tolerant agricultural crops
- increasing use of irrigation in crop production in areas expected to become more arid
- installing snowmaking machines at ski resorts
- conserving biodiversity
- maintaining landscape connectivity to aid vegetation and wildlife migration
- reducing habitat fragmentation
- actively managing species that can adapt to climate change

Some adaptation strategies are likely to involve tradeoffs. For example, greater use of irrigation in crop production could reduce the amount of water available for other human uses and natural systems.

Several strategies are suitable for mitigating adverse effects of natural landscape change. Consider wildfire. It is a dominant natural driver of landscape change and is likely to increase with global warming. Wildfire can be mitigated by reducing fuel loads in the urban–wildland interface and extinguishing wildfires that threaten human life and property. Because wildfire has positive ecological benefits, extinguishing all wildfires is not appropriate.

As it is unacceptable to some (at least in democratic societies) to control population and economic growth--the primary drivers of landscape change--options for mitigating human-induced landscape change are limited. However, we can take these steps:

There are ways to limit human impacts.

- enact zoning regulations to limit residential and commercial development in environmentally sensitive areas, such as wildlife migration corridors, riparian areas, wetlands, river corridors, groundwater recharge areas, and critical habitat for threatened and endangered species
- purchase conservation easements to prevent development of agricultural and ranch properties
- purchase environmentally sensitive private land and manage it for conservation uses (as with, for example, lands purchased by The Nature Conservancy)
- restore degraded ecosystems (the Comprehensive Everglades Restoration Plan is an example)

When considering adaptation strategies to reduce adverse consequences of human-induced landscape change on natural resources, especially vulnerable species, we may choose to do the following:

- restrict development in buffer zones for protected areas (as is done in Biosphere Reserves)
- improve connectivity by creating wildlife corridors between

Adaptation strategies can help protect vulnerable species and their habitat.

protected areas (for example, Yellowstone to Yukon Conservation Initiative)
- move species at risk to zoological parks and more favorable habitats
- decommission roads in national forests that contain critical habitat for species adversely affected by roads, such as grizzly bear (the policy adopted by Flathead National Forest in Montana is an example)
- restrict the form of angling to catch and release only, and lower bag limits and shorten seasons for game species
- support natural migration of species to more favorable habitats

Many adaptation strategies, just like mitigation strategies, involve tradeoffs in terms of the benefits and costs to both human (economic) and natural systems. For example, restricting development in buffer zones for protected areas would reduce the amount of land available for development, but it would increase conservation of protected areas and maintain open spaces.

The adaptive management approach

Resource management faces many challenges.

The writing is on the wall: Resource managers must implement effective mitigation and adaptation strategies well in advance of expected impacts of climate and landscape change. This task is challenging for two reasons: First, most natural resource managers do not have the personnel and budget to manage their areas for potentially adverse impacts of climate and landscape change. Second, there is considerable uncertainty regarding the nature and extent of future climate and landscape change, and how natural and human systems are likely to respond to those changes, with or without mitigation and adaptation strategies.

The capacity of managers to make more informed and sound policy and management decisions related to climate and landscape change can be enhanced by (1) increasing managers' access to and understanding of the causes and consequences of climate and landscape change, and (2) providing managers with tools that allow them to identify and compare mitigation and adaptation strategies.

Adaptive management (AM) is a science- and information-based approach that is well suited for managing natural resources for climate and landscape change. It does the following:

AM is a scientific approach to managing natural resources.

- embraces the uncertainties inherent in climate and landscape change
- employs scientific methods (modeling, experiments, and hypothesis testing)
- adjusts mitigation and adaptation strategies based on new knowledge and information
- fosters ecosystem stability and institutional flexibility
- facilitates collaborative decision-making

AM has been used in a variety of natural resource management settings, including these:

AM has been employed in Canada and the United States.

- site-specific management of the state of Washington's timber, fish, and wildlife resources
- implementation of a human use management strategy for Banff National Park in Alberta, Canada
- management of ungulates and snow machine use in Yellowstone National Park
- management of the Missouri River System
- salmon recovery in the Columbia River Basin and British Columbia
- restoration of the Florida Everglades ecosystem
- improved understanding of how water releases from Glen Canyon Dam influence human and environmental values in the lower Colorado River

There are two forms of AM, passive and active. Passive AM formulates predictive models of ecosystem responses to management actions, makes management decisions based on those models, and revises the models using monitoring data. Passive AM is relatively simple and inexpensive, but it does not yield reliable information about ecosystem responses to management actions due to statistical deficiencies. Active AM overcomes these deficiencies by employing experimental data to test hypotheses about the effects of management actions, such as mitigation and adaptation strategies. However, AM is challenging to apply because it

AM may be challenging to implement.

- may not be possible to satisfy prerequisites for successful application
- is more time consuming, complex, and costly than other forms of management, such as passive AM, trial-and-error, and deferred action
- can give faulty results when relevant variables are either ignored or not held constant
- has certain application pitfalls (i.e., using linear systems models, discounting nonscientific forms of knowledge, and giving inadequate attention to policy processes that promote the development of shared understandings among diverse stakeholders)
- runs the risk of implementing management actions that fail to achieve desired outcomes

Several of these limitations can be alleviated by incorporating knowledge from multiple sources, using several systems models, implementing new forms of cooperative decision-making, and educating politicians and managers about the benefits and risks of AM.

Decision support tool

Natural resource managers are unlikely to use the AM approach to manage adverse impacts of climate and landscape change unless the approach is made understandable and accessible. This can be achieved by incorporating the approach in an Internet-based decision support tool that

integrates the following elements for specific management areas:

Managers have tools available to try AM.

- geospatial datasets such as GIS (geographic information system), GPS
  (global positioning system), and remote sensing
- models that simulate the impacts of climate and landscape change on selected indicators (e.g., using the Environmental Policy Integrated Climate model to simulate agricultural impacts, or using the FIRE-BGC model to simulate long-term changes in fuels, fire hazard, and fire behavior for different climate and landscape change scenarios)
- concepts and methods of AM
- alternative decision criteria for evaluating mitigation and adaptation strategies (e.g., minimax regret criteria, precautionary principle, safe minimum standard, and limits of acceptable change)

The decision support tool would allow managers to identify best mitigation and adaptation strategies for alternative climate and landscape change scenarios.

A pilot program to evaluate the pros and cons of the proposed AM approach to managing adverse impacts of climate and landscape change would provide valuable information. It would develop and evaluate the AM approach and decision support tool for a sample of managed ecosystems that encompasses a range of natural resource and environmental conditions, human uses and values, and availabilities of scientific information and technical expertise. Results of the pilot program could be used to identify conditions under which the approach is most likely to be feasible (that is, when expected benefits exceed expected costs).

About the authors: Tony Prato, Ph.D., is professor of ecological economics and codirector of the Center for Agricultural, Resource and Environmental Systems at the University of Missouri–Columbia. His interests include integrated modeling of human–environmental systems, assessing economic and ecological impacts of climate and landscape change, adaptive ecosystem management, and approaches for managing national parks and protected areas.
http://www.cares.missouri.edu/about/home/prato.html

Dan Fagre, Ph.D., is a research ecologist and Global Change Research Coordinator with the US Geological Survey's Northern Rocky Mountain Science Center in West Glacier, Montana. His interests include ecosystem science, impacts of climate change, mountain protected areas, landscape ecology, glaciology, and snow/ice assessment.
http://www.nrmsc.usgs.gov/staff/fagre.html

Coping with Climate Change

learnmore links

get involved references back to top

Climate change information
» Impacts of warming Arctic: http://www.acia.uaf.edu
» Intergovernmental Panel on Climate Change (IPCC): http://www.ipcc.ch
» Pew Center on Global Climate Change: http://www.pewclimate.org
» US Climate Change Science Program: http://www.climatescience.gov
» National Wildlife Federation: http://www.nwf.org

Impacts of landscape change in various regions
» Montana's Flathead County: http://cares.missouri.edu/montana/
» Greater Yellowstone Ecosystem: http://www.greateryellowstone.org/ecosystem
» Crown of the Continent Ecosystem:
http://www.nrmsc.usgs.gov/research/ecosystem.htm
http://www.nps.gov/glac/resources/bio1.htm

Technology for geographic information
» GIS: http://www.gis.com/whatisgis/index.html
» GPS: http://www.trimble.com/gps/index.shtml

Land use and land cover change
» http://www.iiasa.ac.at/Research/LUC.
» http://www.cs.utk.edu/~lucas
» http://www.scipub.net/environmental-science/land-use-cover-change.html
» http://www.grida.no/climate/ipcc_tar/wg2/132.htm

Adaptive management and decision support tools
» http://fosonline.org/resources/Publications/AdapManHTML/Adman_1.html
» http://oregonstate.edu/instruction/anth481/ectop/ecadm.html
» http://www.esg.montana.edu/esg/adaptive_mgmt_1.html

Center for Agricultural, Resource and Environmental Systems
Located at University of Missouri, CARES offers online maps or customized interactive maps from a wide range of economic, demographic, physical and cultural data. Useful for students, teachers, conservation groups, and environmental managers.
http://www.cares.missouri.edu

International Geosphere-Biosphere Program
Educators, students, and natural resources managers can learn about meetings, reports, and other news about global change.
http://www.igbp.kva.se

International Human Dimensions Program on Global Environmental Change
For professionals, this group takes a social science perspective on global change and works at the interface between science and practice.

http://www.ihdp.org

US Global Change Research Program
The site provides information about the latest research on global change.
http://www.usgcrp.gov

getinvolved links

▲learn more ▼references ▲back to top

Adopt A Wildlife Acre program
The National Wildlife Federation offers a program that allows you to symbolically adopt and protect acreage near Yellowstone National Park and throughout America.
http://www.nwf.org/yellowstone/wildlifeacre.cfm

Saving America's Farmland campaign
American Farmland Trust offers suggestions on how to manage farms and ranches to accommodate wildlife. Check out the action center to see how you can help.
http://www.farmland.org

Apollo Alliance
Find out what you can do to diminish US reliance on foreign oil and promote clean energy.
http://www.apolloalliance.org

The Wildlands Project
The project aims to set aside approximately 50 percent of the North American continent as wild land. Watch a slide show and find out how you can help.
http://www.wildlandsprojectrevealed.org

The Nature Conservancy
Discover how you can contribute to the conservancy's mission of protecting the diversity of life.
http://nature.org

Yellowstone to Yukon Conservation Initiative
Join the initiative to maintain and restore the natural heritage of the region.
http://www.y2y.net

articlereferences

▲learn more ▲get involved ▲ back to top

» Adger, W. N., and K. Brown. 1994. *Land Use and the Causes of Global Warming*. New York: John Wiley & Sons.
» Anderson, J. W. 2005. What follows Kyoto? *Resources* 157: 14–15.
» Arctic Climate Impact Assessment. 2004. Impacts of a Warming Arctic: Arctic Climate Impact Assessment. Cambridge, UK: Cambridge University Press. http://www.acia.uaf.edu (accessed Sept. 25, 2006)
» Beniston, M. 2003. Climatic change in mountain regions: A review of possible impacts. *Climatic Change* 59: 5–31.
» Berkes, F., and D. Jolly. 2002. Adapting to climate change: Social–ecological resilience in a Canadian Western Arctic community. *Conservation Ecology* 5: U514–U532.
» Chadwick, D. H. 2000. *Yellowstone to Yukon*. Washington, DC: National Geographic Society.
» Easterling, W. E. III, B. H. Hurd, and J. B. Smith. 2004. Coping with global climate change: The role of adaptation in the United States. Arlington, VA: Pew Center on Global Climate Change.
» Hall, M. H. P., and D. B. Fagre. 2003. Modeled climate-induced glacier change in Glacier National Park, 1850–2100. *BioScience* 53: 131–140.
» Holling, C. S. 1978. *Adaptive Environmental Assessment and Management*. New York: John Wiley & Sons.
» Houghton, J. T., Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell, and C. A. Johnson (eds). 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment *Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK: Cambridge University Press.

» Johnson, V. K. 2001. Trends in rural residential development in the Greater Yellowstone Ecosystem since the listing of the grizzly bear, 1975–1998. *Yellowstone Science* 9: 2–9.
» Keane, R. E., K. C. Ryan, and S. W. Running. 1996. Simulating the effects of fire on northern Rocky Mountain landscapes using the ecological process model FIRE-BGC. *Tree Physiology* 16: 319-331.
» Lee, K. N. 1993. *Compass and Gyroscope: Integrating Science and Politics for the Environment*. Washington, DC: Island Press.
» Mac, M. J., P. A. Opler, C. E. Puckett Haecker, and P. D. Doran. 1998. Status and trends of the nation's biological resources. Reston, VA: US Department of the Interior, US Geological Survey.
» McCarthy, J. J., O. F. Canziani, N. A. Leary, D. J. Dokken, and K. S. White (eds). 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Intergovernmental Panel on Climate Change. New York: Cambridge University Press.
» National Synthesis Assessment Team. 2001. Climate change impacts on the United States: The potential consequences of climatic variability and change. Report for the US Global Change Research Program. Cambridge, UK: Cambridge University Press.
» Noss, R. F. 2001. Beyond Kyoto: Forest management in a time of rapid climate change. *Conservation Biology* 15: 578–590.
» Ojima, D. S., K. A. Galvin, and B. L. Turner. 1994. The global impact of land-use change. *BioSciences* 44: 300–304.
» Peters, R. L., and T. E. Lovejoy. 1990. *Global Warming and Biological Diversity*. New Haven, CT: Yale University Press.
» Peterson, G., et al. 1997. Uncertainty, climate change, and adaptive management. *Conservation Ecology* 1: 4. http://www.consecol.org/vol1/iss2/art4/ (accessed Sept. 25, 2006)
» Prato, T. 2003. Adaptive management of large rivers with special reference to the Missouri River. *Journal of the American Water Resources Association* 39: 935–946.
» Schindler, D. W. 2001. The cumulative effects of climate warming and other human stresses on Canadian freshwaters in the new millennium. *Canadian Journal of Fisheries and Aquatic Sciences* 58: 18–29.
» Solecki, W. D. 2001. The role of global-to-local linkages in land use/land cover changes in South Florida. *Ecological Economics* 37: 339–356.
» Stewart, R. B., E. Wheaton, and D. L. Spittlehouse. 1998. Climate change: Implications for the boreal forest." Pages 86–101 in A. H. Legge and L. L. Jones (eds). Emerging Air Issues for the 21st Century: The Need for Multidisciplinary Management. Pittsburg, PA: Air and Waste Management Association.
» Turner, B. L., and W. B. Meyer. 1994. Global land-use and land-cover change: An overview. Pages 3–10 in W. B. Meyer and B. L. Turner (eds). *Changes in Land Use and Land Cover: A Global Perspective*. Cambridge, UK: Cambridge University Press.
» Vitousek, P. M. 1994. Beyond global warming: Ecology and global change. *Ecology* 75: 1861–1876.
» Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of the Earth's ecosystems. *Science* 277: 494–499.
» Walker, B., and W. Steffen. 1997. An overview of the implications of global change for natural and managed terrestrial ecosystems. *Conservation Ecology* 1: 2. http://www.consecol.org/vol1/iss2/art2/ (accessed Sept. 25, 2006)
» Walters, C. 1986. *Adaptive Management of Renewable Resources*. New York: Macmillan & Co.
» Walther, G-R., E. Post, P. Convey, A. Menzel, C. Parmesan, T. J. C. Beebee, J.-M. Fromentin, O. Hoegh-Guldberg, and F. Bairlein. 2002. Ecological responses to recent climate change. *Nature* 416: 389–395.