

Cornell University College of Agriculture and Life Sciences

The Environmental Sciences

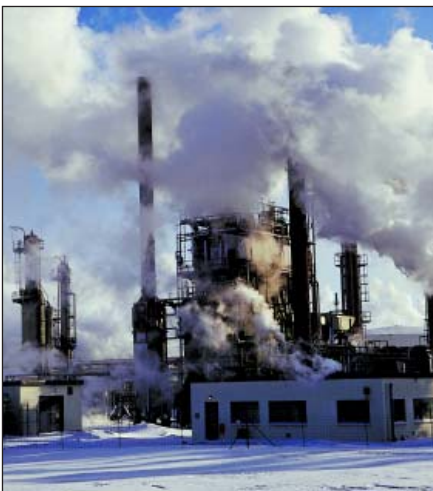
IMPACTS 2007



SUMMARY

Developing solutions to economic, environmental, and social issues for a sustainable world requires the collaboration and input of many minds across diverse disciplines. With its unusual scholarly breadth and outreach capacity, the College of Agriculture and Life Sciences (CALs) of Cornell University is extraordinarily well positioned to be a leading global force for creating and delivering the best scientific knowledge and practical solutions in the fields of environmental science and sustainability.

The impact of CALs work in the environmental sciences is enhanced by world-class programs in plant biology, natural resources, environmental engineering, pest management, genomics, computational and information sciences, and other areas. In addition, experts in business, economics, and sociology help create market-based solutions to environmental problems, whether for New York or for the developing world, that are socially, economically, and environmentally sustainable. These efforts are backed by CALs' strong tradition of international engagement and collaborative problem-solving. And in every county in New York, Cornell Cooperative Extension's trained professionals identify needs and deliver solutions for a wide array of local and statewide environmental stakeholders.



THE ISSUES

The environmental sciences comprise one of four areas of academic priority for CALs. More than 270 faculty members in 14 departments are working to understand and address the mounting challenges to our environmental well-being. CALs faculty, staff, and students work regionally, nationally, and internationally to introduce sustainable farming methods, improve soil and water, protect biodiversity, improve technologies for alternative energy, foster sustainable trade, and bring awareness of the challenges wrought by global climate change. The following highlights represent only a small sample of our research and outreach in these areas.



IMPACTS

Sustainable energy

Cornell is a national leader in the effort to develop more efficient production technologies for ethanol and other environmentally friendly biofuels and the lead university for the 14-state Northeast Regional Sun Grant Initiative.

Perennial grasses such as switchgrass are predicted to be more environmentally sustainable than corn as a source for ethanol fuels. Technologies developed over the course of 20 years of research in CALS are being used to make cellulosic plant biomass from species such as switchgrass more susceptible to enzymatic conversion aimed at extracting sugars for fermentation to ethanol and producing other valuable chemicals. Using the facilities of Cornell's Nanobiotechnology Center, CALS scientists are exploring the use of advanced imaging systems as a way to study how cellulose-degrading enzymes move across the cellulose fiber to liberate glucose. Studies aimed at characterizing plant enzymes that might also be used to degrade cellulose for conversion to fermentable sugars recently yielded the breakthrough discovery of a new class of cellulases with the potential to enable more efficient production of ethanol. Other projects are focused on the fermentation of plant sugars to ethanol and hydrogen. (*Walker, Biological and Environmental Engineering [BEE]; Rose, Plant Biology*)



A CALS biogeochemist has recently described an economical and efficient way to produce fuel while offsetting global warming: pull carbon dioxide out of the atmosphere by charring, or partially burning, trees, grasses, or crops without the use of oxygen. This process, called biochar sequestration, doubles the carbon concentration in the residue, which can be returned to the soil as a carbon sink. The exhaust gases produced by this low-temperature smoldering process have the potential to be converted into enough energy to offset about 10 percent of annual U.S. fossil-fuel emissions. (*Lehmann, Crop and Soil Sciences [CSS]*)



CALS researchers are also examining the technical feasibility of using fuel-cell technology to convert biogas derived from the anaerobic digestion of dairy manure into electricity and heat on the dairy farm. The potential success of fuel technology could increase farm profitability by well over 20 percent and reduce waste impacts on the environment by over 25 percent. Also under study is a method for removing hydrogen sulfide, the most difficult contaminant in manure-derived biogas, through the use of compost produced on the farm. Another proposal is to connect greenhouses with dairies, which can produce enough surplus energy to heat and run a greenhouse. (*Scott, BEE*)

Climate change

Cornell marine scientists are documenting and analyzing such global warming-induced effects as dramatically increased incidence of coral disease in the Caribbean and large, rapid ecosystem shifts along the northwestern continental shelfwaters of the Atlantic Ocean. A Cornell-led group has been charged with studying the distribution, causes, and impacts of coral disease in all the world's oceans as part of a \$29 million grant from the Global Environmental Facility / World Bank Coral Reef Targeted Research Program. The bottom-up regime changes in the Atlantic have been attributed to a combination of the influx of fresh water from polar ice melting and climate-driven shifts in Arctic wind patterns that have redirected ocean currents. (*Harvell, Ecology and Evolutionary Biology [EEB]; Greene, Earth and Atmospheric Sciences [EAS]*)

Ecologists and evolutionary biologists are assessing the extent and effects of climate-induced disruptions of important interactions between species. For example, CALS scientists working with the Union of Concerned Scientists have documented an advance in spring bloom dates for lilacs, grapes, and apples, while integrated pest management specialists have found that they must begin



monitoring certain crop insects several weeks earlier than they used to, and tree swallows throughout North America have shifted their laydates in response to the earlier arrival of spring. (*Winkler, EEB; Wolfe, Horticulture*)

The Cornell Computational Agriculture Project is compiling daily weather data from hundreds of sources and using high-performance computing to turn it into practical advice for farmers. Soon, a farmer will be able to enter information about the farm on a Web page and receive advice such as how much nitrogen fertilizer to apply to a corn crop or an analysis of the effect on profits of adding that fertilizer, tailored to the farm's location within five kilometers or less. The database will eventually be used to refine other applications such as weed control, turfgrass management, and mosquito control and include feedback on the social costs of using nitrogen fertilizer, showing its effect on water quality and climate change. (*van Es, CSS; DeGaetano and Wilks, EAS*)



The atmospheric concentration of methane, a greenhouse gas, has doubled over the past two centuries. This is a cause for concern since, molecule for molecule, methane absorbs and re-emits 20 times more heat than carbon dioxide. Acidic peatland ecosystems dominated by Spaghnum mosses are responsible for an important percentage of the methane reaching Earth's atmosphere, but the microbial processes that lead to this output are not well understood. Researchers at Cornell are applying molecular biological, microscopic, and chemical techniques to the characterization of these microbial populations in an effort to enable prediction of the effects of potential global environmental changes on their activities. These studies have yielded several novel microorganisms that have improved our understanding of the natural world and have potential biotechnological uses. (*Yavitt, Natural Resources, and Zinder, Microbiology*)

Environmental pollution

A CALS professor has shown that atmospheric deposition of nitrogen, much of it from vehicle exhaust, is a significant and underestimated source of nitrogen pollution in Northeast coastal rivers and bays. His studies have demonstrated that the flux of nitrogen pollution from the major watersheds in the Northeast to coastal rivers and bays, including the Chesapeake, is very sensitive to climate and is likely to grow worse as climate change worsens and the flow of fresh water down rivers increases. His efforts to effect changes in public policy include high-level government briefings and Congressional testimony and service on a federal advisory committee to determine the causes and potential solutions of the dead zone in the Gulf of Mexico. He is also president of the Coastal and Estuarine Research Federation, the largest professional society in the world concerned with coastal issues. (*Howarth, EEB*)



How will agriculture be affected by the increased levels of carbon dioxide, reactive nitrogen, and ozone that are expected to accumulate in the atmosphere during the next century? The effects of air pollution on cabbage, sweet corn, and snap beans are under study as a means of predicting these effects. By identifying resistant cultivars and the mechanisms that crop species use for defense against pollution compounds, these studies aim to provide information to help plant breeders develop varieties that will yield well under future conditions of greater pollution. (*Sparks, EEB and Björkman, Horticulture*)

Analyses of various plant materials for their capacity to take up heavy metal pollutants from water have led to the finding that locally produced bark, properly sized, is highly efficient for this purpose. This technology has now been commercialized and will be used at a site in upstate New York to remediate chromium pollution. Tests have also indicated that it very effectively removes cobalt from an industrial waste stream in Ohio where this approach is expected to be used soon. Variations of this approach are being developed to remove hydrogen sulfide from landfill gases and to remove cobalt from an industrial site



in the Midwest. This enterprise is expected to create new markets for agricultural waste products and lead to the development of a new industry in New York state to provide environmentally friendly methods for decontaminating water and removing toxic and corrosive hydrogen sulfide from biogas. This technology will permit more efficient use of biogas from farm manure digesters or landfills for bioenergy production. (Harman, *Horticultural Sciences*)



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The remediation of groundwater contamination is the focus of genomic sequencing work in anaerobic bacteria of the genus *Dehalococcoides*, novel microbes that can convert the solvents perchloroethylene (PCE) and trichloroethylene (TCE) to nontoxic ethylene. (The first organism shown to do this, *Dehalococcoides ethenogenes* strain 195, was discovered and described by these researchers in 1997.) The sequencing information will be used to develop next-generation molecular tools to assess bioremediation of PCE and TCE-contaminated sites and provide bioinformatic platforms for gene array and proteomic studies of reductive dehalogenation, the process by which these anaerobes remove chlorine from these and other highly chlorinated organic compounds that are among the most pervasive groundwater pollutants in the developed world. (Zinder, *Microbiology, with Gossett, Civil and Environmental Engineering*)

Sustainable ecosystems and biodiversity

CALS research and extension programs on the applied biology and integrated management of the eight major diseases of grapes in the Northeast have helped producers of native grape varieties reduce their fungicide spray programs by approximately three applications per year over the past 10 to 15 years. In addition to its environmental benefits, this increased efficiency results in an annual savings of approximately \$1.8 million across 20,000 acres in New York alone. In higher-value wine grapes, disease control has been estimated to cost nearly \$500 per acre per year, while, per acre, the loss of four tons of grapes to a ubiquitous disease such as powdery mildew costs approximately \$6,000. A mere 5 percent annual reduction in fruit lost to disease provides an annual savings of approximately \$1.1 million in farmgate value and up to \$11 million in retail wine value. (Wilcox, *Plant Pathology*)



The field of chemical ecology – the study of the strikingly complex array of chemical means that insects use for defense and for attracting mates, for example – was created at Cornell, and groundbreaking discoveries made in this area and in research on insect pheromone communication have yielded many environmentally sound approaches to insect control. (Eisner, *Entomology, with Meinwald, Chemistry and Chemical Biology; Roelofs, Entomology*)

The Bioacoustics Research Program at the Laboratory of Ornithology develops digital recording equipment, computer software, and algorithms that are used by scientists around the world to study animal communication and to monitor the health of wild populations. Scientists at Cornell use this technology to study various species of birds, elephants, and whales. One project involves working with the U.S. Army to implement acoustic monitoring systems at several bases, including Fort Drum, New York, to evaluate the distribution and abundance of endangered songbirds. The whale studies are aided by use of the U.S. Navy's Integrated Undersea Surveillance System. (Clark, *Lab of Ornithology; Vehrencamp, Neurobiology and Behavior*)

Cornell research and outreach in integrated pest management are helping both conventional and organic growers in New York choose the most effective, least-toxic products for weed control. Careful tests of pesticide effectiveness with a wide variety of crops, weed spectrums, and growing conditions have shown that farmers with a basic knowledge of weed life cycles can cut their herbicide applications by one-third to one-half by eliminating pre-emergence herbicide applications in favor of total post-emergence weed control programs. (Hahn, *CSS*)



Research headed by a professor of forest ecology recently provided the most conclusive evidence to date linking the decline of sugar maples in the Northeast to the effects of acid rain. Acid deposition depletes soil calcium, and this study showed that the addition of calcium, in an amount equal to measured depletion, resulted in a marked recovery of sugar maples in an acidified watershed in New Hampshire. (*Fahey, Natural Resources*)

The Cornell University Biological Field Station has compiled 50 years of continuous data on all levels of nutrients, including top predator fish, in the food web of New York's Oneida Lake. This program is recognized internationally for its contributions to the understanding of large lake ecosystems and freshwater fisheries dynamics. This research has improved understanding of the response of lakes to large global events such as climate change and invasive species, the economic benefits of managed ecosystems, and the role research plays in good stewardship of our natural resources. (*Mills, Natural Resources*)



Invasive species

Cornell serves as the Northeast regional hub for the National Plant Diagnostic Network, which was established by a provision in the Food and Agriculture Defense Initiative of 2002 to protect the agricultural system from the spread of invasive plant pests and pathogens. Nationally, the network has trained over 3,400 Cooperative Extension educators, crop consultants, and others as "first detectors" who can quickly recognize problems that warrant further investigation. Their role is vital, as experts have only about two weeks to detect, diagnose, and respond to an outbreak in order to keep its impact low. (*Hudler and Snover-Clift, Plant Pathology*)



The introduction of *Bacillus thuringiensis* (Bt) into crop species through biological engineering has been an effective and environmentally valuable strategy for reducing pesticide use to combat many insect pests, but these efforts are now being thwarted by the development of Bt resistance in a number of insect species. One of these is the diamondback moth, which occurs wherever crucifers are grown and has been estimated to cost growers \$1 billion annually. CALS entomologists and plant breeders studying this phenomenon have found that broccoli plants bred to express two different Bt genes are more resistant to the diamondback moth than plants expressing only one of the Bt genes, and that these plants are more suitable for use in developing countries where farms lack the acreage to employ additional management strategies. (*Earle, Plant Breeding and Genetics; Shelton, Entomology*)

The dynamics of DNA sequence divergence are being examined in two strains of European corn borers, introduced pests that have had significant economic impacts in North America. The strains differ in their pheromone communication systems and also in the number of generations they produce per year. After constructing a genetic linkage map that includes the major genes important for pheromone and life-cycle differences, this laboratory is now characterizing patterns of variation across the genome. These patterns provide baseline data that may help to predict the ability of future variants that confer Bt resistance to spread. (*Harrison, EEB*)

In partnership with the U.S. Department of Agriculture and the New York State Department of Agriculture and Markets, Cornell scientists have succeeded for 60 years in preventing the spread of the golden nematode, an invasive pest of potatoes, tomatoes, and eggplant. Since its discovery, Cornell has developed and released 20 potato varieties that very effectively limit the invasive pest's ability to reproduce. Each season that a resistant variety is grown, the golden nematode population in that field shrinks by 90 to 95 percent—without the use of pesticides—and the nematode has remained confined in the United States to nine New York counties as a result. But the battle to develop resistant plants—a process that typically takes 13 years—continues against a newly detected race of golden nematode. At risk is an estimated \$0.5 billion to \$4.8 billion in losses to production and marketing of nursery, turf, and vegetable crops. (*Perry, Plant Pathology*)



Despite the magnitude of the threat from invasive species, victories are possible. Purple loosestrife, a beautiful but overwhelming weed that had become a fixture in ditches and wetlands from coast to coast, has been brought under control in the last decade. In cooperation with the U.S. Fish and Wildlife Service and many other federal and state land management agencies, Cornell began releasing four species of loosestrife-loving beetles in 1992 that have been busily reducing loosestrife abundance in over 35 states. As a result, pesticide use has been significantly reduced, and native plants and animals are returning to formerly uninhabitable areas. Since the beetles die off as they eliminate their sole food source, the researchers are assured that one problem won't be replaced by another. (*Blossey, Natural Resources*)



Sustainable international economic growth

CALS is collaborating with NASA, the World Bank, and a nongovernmental organization in Brazil to assess the environmental impacts of reduced-impact logging in the Amazon region. Their assessments of damage to the forest and forest soil, gaseous losses, stream discharge, and the export of carbon and nutrients through wood extraction have found that reduced-impact logging inflicted minimal damage on an area basis. Their activities have helped commercial forest owners receive certification as sustainable forest managers. Certification requires that owners constantly improve their practices and monitor their impact; it aids in increasing income margins and opening new markets for certified timber and timber products. (*Lehmann, CSS; Riha, EAS*)



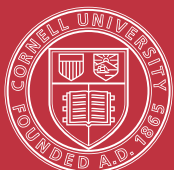
The African Food Security and Natural Resource Management Program brings together faculty from five CALS departments in research on "poverty traps" in Kenya and Madagascar. Their aim is to advance interdisciplinary research, training, and outreach integrating the biology of the area with the economics of farmer behavior as influenced by market and nonmarket institutions and the broader policy environment. (*Barrett, Applied Economics and Management; Pell, Animal Science and the Cornell International Institute for Food, Agriculture, and Development*)

CALS entomologists are participating in a major effort to eradicate dengue fever, a complex and disabling disease that infects millions of people in the developing world and whose incidence is growing. The project is being funded with a \$19.7 million grant awarded by the National Institutes of Health with funds provided by the Bill and Melinda Gates Foundation. Cornell's effort is focused on rendering the dengue vector, *Aedes aegypti*, incapable of carrying the disease, an approach that would greatly reduce pesticide use as well as the disease's physical and economic toll. (*Harrington, Entomology*)

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