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Property rights for plants

Roger A. Sedjo

Valuable plant genetic resources are threatened with destruction by exploitation and the elimination of habitat. How can society protect and wisely manage these materials? One solution may be to assign them property rights and to treat them as marketable resources.

All too often, the resources that civilizations take most for granted are those that require diligent attention in order to be cared for well. Plant genetic material is one of them. Also called germplasm, it is a valuable economic resource that is often in limited supply and is sometimes threatened with destruction.

It is well recognized that wild and unimproved plant genetic resources have substantial social and economic value for plant breeding programs, for the development of natural products including drugs and pharmaceuticals, and for increasingly sophisticated applications of biotechnology. Despite these acknowledged values, widespread destruction of genetic resources is occurring. Although much of the destruction is caused by excessive consumption, a more serious threat comes from land-use changes such as tropical deforestation that destroy critical habitat.

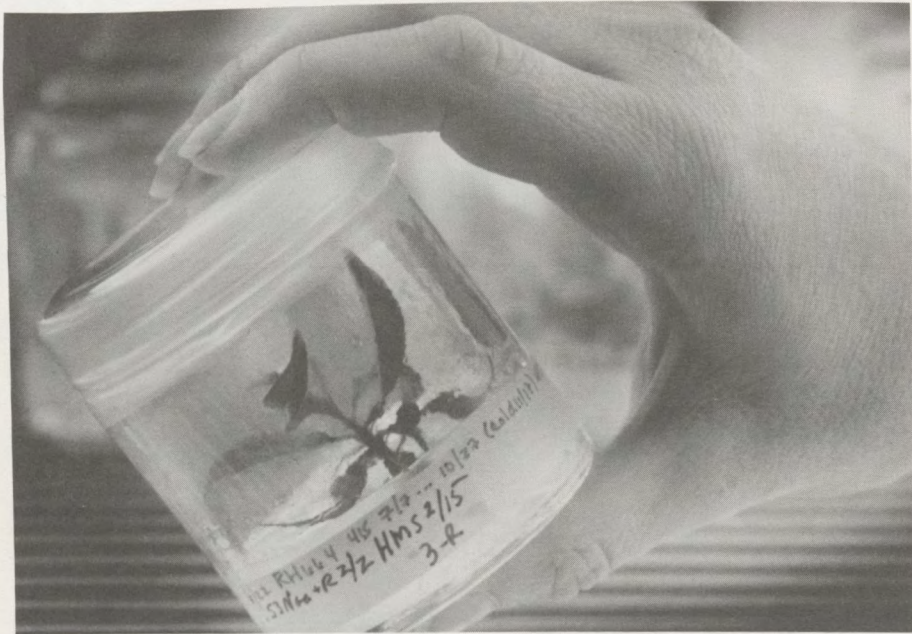
Protection against destruction is difficult to achieve under current law and management systems. Naturally occurring plant genetic resources are treated as a common property resource, owned by

no one. This absence of property rights opens up the possibility of excessive exploitation of the resource, a variation on the "tragedy of the commons." The absence of ownership denies individuals and countries the possibility of benefiting commercially from the presence of unique genetic resources within their jurisdictional boundaries. There is little incentive, other than altruism, to incur costs to safeguard the habitat of unique and endangered wild species.

Nor can this situation be easily changed by the introduction of national management and regulation. Public management usually cannot internalize to the country the benefits of genetic resources to which it has no internationally recognized property rights (although this is not the case for many common-pool resources that are under public management). Absence of property rights means, for example, that the recently discovered Mexican species of perennial maize is likely to provide Mexico with only negligible benefits, even if the desired genetic traits of the species prove to be of enormous eco-

An Anniversary

With this issue, *Resources* marks the end of its 30th year of continuous publication. See page 4 for excerpts from its first year.



K. WETTER, AGRICULTURAL RESEARCH SERVICE, USDA

Genetically engineered plants such as this disease-resistant peach shoot already are protected by property rights, unlike wild genetic resources.

conomic value worldwide. Mexico therefore has little economic incentive to preserve undisturbed any vegetation in which this and similarly valuable (but as yet unknown) plant genetic material may be hidden.

Systemic limitations

The existing management system provides property rights for improved and genetically engineered plants, as well as government protection of selected habitat. Such an approach appears to do an excellent job of generating investments for the development of technology to improve seed strains and for the distribution of technically improved genetic material to users throughout the world. However, the system is doing a poor job of protecting the wild genetic resources and the habitat in which these valuable resources reside. Furthermore, there is little in the system that addresses the question of the sharing the financial gains with the Third World.

Since property rights are not now assignable to natural species, the Third World countries in which the majority of these species reside have no means to derive financial benefits from the utilization of "their" species in commercial

applications. By contrast, since property rights in improved species are available, breeders can capture the commercial gains through improvements in resources without making payments to the countries from which the basic genetic materials derive.

Moreover, although many wild genetic resources are believed to be threatened with extinction, the existing system provides few incentives for their protection. Pharmaceutical firms and other users of genetic resources have little control over habitat maintenance in sovereign Third

There is little incentive, other than altruism, to incur costs to safeguard unique and endangered species.

World countries. These countries, for their part, lack recognized property rights to genetic resources and cannot capture the rents—that is, the financial benefits—of these resources. Thus the current system relies almost exclusively upon governments for protection of habitat in a context where governments themselves

have few direct incentives to undertake protection and where their actual performance in protection has been mixed at best.

An alternative system

Commercial pressures for land-use changes, combined with a lack of incentive for protection, create a social dilemma. If genetic resources continue to be available to all as part of our social heritage (a condition usually viewed as socially desirable), the economic incentives to protect these valuable and often fragile resources will be minimal. Yet if future government programs designed to preserve valuable habitat are no more successful than those of the past, we can expect uninterrupted destruction of habitat. Alternative systems *could* be devised that would supplement existing efforts to protect wild genetic resources. Such systems, however, might require some restrictions on availability, thus challenging the basic premise of global heritage.

One alternative system that may have merit is based on viewing genetic resources as the property of the state in which it resides. Under this system, property rights would be assigned in order to provide incentives for protection and wise management. Property rights for plant species could be expanded and extended to cover newly discovered natural species, whereas under current legal interpretations only special genetic stock, current breeder lines, and genetically engineered organisms are recognized as having ownership. Such an approach would allow the genetically rich Third World countries an opportunity to profit directly from the ownership of genetic resources. Property rights to species would also provide a direct financial incentive to protect and maintain the natural habitat in which rare and as yet unknown species may reside, since their discovery and development at some time could generate direct financial returns to the owner.

Under a system in which the concept of property rights was extended to include species not now known or utilized, newly discovered natural genetic resources

would become the property of the political state in which those resources reside. In principle, the state would be free to declare all such resources as the property of the state, or it could grant private property rights to individuals or corporations that discover the genetic resources. Having ownership of the resources, the owners—public or private—could be expected to have an interest in their long-term preservation and development.

Alternatively, the state might decide that the rights be defined in terms of the ownership of land upon which the species resides, and that such rights be treated no differently than rights to other natural resources and property in that political entity. With the state controlling the rights, it could voluntarily sell or distribute those rights in any way it deemed appropriate. A domestic corporation or governmental department could be created to manage the system, or the rights could be transferred to private interests.

Markets for genetic material

The transfer of a wild genetic resource to private interests might be accomplished by having the private interest make an initial payment and subsequently pay royalties based upon the commercial earnings of products that utilize the resource. The country where the resource resides could negotiate an exclusive agreement with a firm, or allow a number of firms to utilize the resource under a set of mutually agreed-upon conditions. Agreement might be reached as part of bilateral negotiations or as the result of a competitive bidding process. Should a particular germplasm be discovered in several countries simultaneously, the potential users would be free to negotiate the best deal possible with the country of their choice. A necessary condition for such a system is the possibility of describing a plant with sufficient specificity so that the property right could be clearly and unambiguously assigned. Only under such a condition could those rights be enforced.

Markets for genetic material could function just as markets do for other resources. A country with sole ownership of

certain germplasm, for example, might choose to behave like a monopolist in regard to a particular germplasm, demanding high prices in return for rights to utilize the resource. These conditions might be so onerous as to have no takers. Such market behavior is unlikely, however, because it runs at least two risks. First, the same natural germplasm might be discovered in another country. In this case a monopolist's bargaining power would be seriously compromised and the strategy of withholding the germplasm from development would backfire, resulting in loss of the monopoly position. Second, biotechnology may develop in such a fashion as to bypass the usefulness of the particular germplasm. Hence, by withholding the germplasm from devel-

Genetic material markets could function just as markets do for other resources.

opment the monopoly would lose its opportunity for negotiating favorable conditions.

In both cases, the longer a monopolist withholds the germplasm from the market, the greater is the possibility that events will compromise the favorable initial bargaining situation. Where several countries have the same unique germplasm resource, the possibility for collusion and the formation of a cartel exists. However, cartels have been historically unstable, and the possibilities for finding alternative germplasm resources are likely to be substantial.

It might be deemed desirable to restrict the period of property rights for natural germplasm to some limited period—say seventeen years, as it is for patents. The period could begin when the property right is assigned, presumably sometime close to the discovery of a new germplasm. However, this restriction need not compromise the incentive effects of the proposed system. The very possibility of discovering a previously unknown genetic resource with commer-

cial potential provides some incentive to preserve habitat.

In most respects the system proposed would be similar to that which currently exists for handling other resources. For example, if a country believes that it has a valuable petroleum deposit, it may choose to develop the resource itself, negotiate drilling rights with a major petroleum company, or sell some or all of the drilling rights (together with a royalty provision) to the highest bidder, who could then proceed with development. For a resource that is not commercially viable given current technology and markets, the country may choose a fourth option: set the resource aside for possible development at a more auspicious time. In principle, there is no reason why such a system of property rights could not be devised for unused genetic resources.

Advantages

The major socially desirable feature of the proposed system is that it would provide nonaltruistic incentives for the preservation of rare species and germplasm—no small matter, since the pressure on genetic resources is growing as the result of changing demands for land use. Such a system need not preclude existing governmental efforts to preserve habitat; nor should it be viewed as a substitute for existing efforts to preserve areas of wide or unique biodiversity. The two approaches are not mutually exclusive. Under the property rights system, national governments would also have economic incentives to protect regions of rich biological diversity. Thus the future value of currently unknown genetic resources could be captured. The destruction of a unique genetic resource would not only represent a global social loss, but this loss would be translated into a direct economic opportunity forgone for the country in which the resource resides.

A system that provides property rights for owners of natural plant germplasm also would provide a mechanism for the restoration of balance in the gene trade between the gene-rich Third World and the gene-poor industrial world. Just as plant-breeding countries would receive

returns to their investments in breeding, gene-rich countries would receive returns associated with their protection of germplasm from extinction and their discovery of useful previously unknown species.

A system of property rights for wild or unimproved genetic resources would not

be without significant implementation and enforcement problems. As with patents, a genetic resource must be defined in sufficient detail to distinguish it from similar but different resources. Conflicts are bound to occur. Nevertheless, the proposed system offers promise of providing an additional tool to induce social

behavior to protect the earth's valuable genetic resources—resources that are currently under heavy pressure. ■

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From early issues of *Resources* . . .

These excerpts from the first two issues of Resources suggest the continuity over thirty years in RFF's research interests—basic and applied, global and local.

From Resources no. 1, May 1959:

Malthus revalued

Good theory, like good art, simplifies, abstracts, and highlights. It is therefore, in a sense, inappropriate to ask whether Malthus believed his conditions to be complete and detailed descriptions of reality. Of course, he did not. A really good theorist is a hair-splitter only when necessary, or when engaged with a critic. The proper question is whether Malthus believed his theory and conditions to be essentially accurate. And to this, the answer is certainly that he did . . .

In Malthus' time, . . . a considerable part of "final" or virtually final output was agricultural goods . . . Thus, if a man stood on a square mile of land, or a nation on 3,000,000, the natural resources relevant for economic activity could be easily identified and measured. They were acres of cropland and pasture, board feet of standing timber, etc.

What has happened since those times to the meaning of final goods, the methods by which they are produced, and the definition of natural resources is so profound that we find the novelty difficult and seek simplification in possibly archaic analogies . . . More than 90 percent of the

increase in real gross national product in the United States since 1870 has been of non-agricultural origin . . . Finally, the natural resource building blocks have changed radically—they are atoms and molecules . . .

In significant degree, even the ultimate limits are different from Malthus'. His natural resources were conceived for a two-dimensional world nourished by acreage. Ours is a three-dimensional one, sustained by subsurface resources. His society could reach natural resources to only insignificant distances above and below his acres. We have multiplied our "reach" by many thousands. —*Harold J. Barnett*

From Resources no. 2, September 1959:

On rural reform in Venezuela

Acute poverty in rural areas and riches in cities are the ingredients for revolution. A democratic government, concerned with the welfare of its people, must undertake to help the rural poor. But agricultural colonization is only a part of the program, as is the extension of land reform. . . .

Venezuela is relatively rich—far richer than many other countries in the world. But land alone is not enough for sound agriculture, or for agricultural colonization . . . Tropical agriculture demands greater managerial skill than temperate zone agriculture. One who cannot read

and write, has no understanding of diseases and their control, and is unfamiliar in buying and selling in the market, is severely handicapped in operating a commercial farm; and there seem relatively few intermediate stages between subsistence agriculture and highly technical commercial agriculture in Venezuela.

The solution may lie in working with the ablest men, those not too old, and in training the children. Every possible help should be given to the poor rural people of Venezuela; but it may be no kindness to them, and it surely would be very expensive to the nation, to attempt to give a commercial farm to every poor family. . . .

There are ways of attacking this problem other than by agricultural settlement alone. One means might be a program of small-scale rural public works, much as the United States had in the earliest stages of the New Deal. Rural men might be given four to ten days of work monthly, at modest pay, under locally resident supervisors. One major objective would be to train them to do productive work, of kinds they do not presently know how to do. Even some formal education might be included, especially in simple arithmetic, reading of simple drawings, and the like. They could build better water supply systems, local roads and paths, local electricity supply systems, schools, and housing. . . .

Considering agricultural colonization in Venezuela, every one agrees that many mistakes have been made and much money wasted in the past. But the past is of concern only to ascertain the direction it provides for the future. —*Marion Clawson*

Social costs of chronic heart and lung disease

Maureen L. Cropper and Alan J. Krupnick

Funding requests for air pollution and disease prevention programs often far exceed the amount of money that is actually available. A recent study carried out by Resources for the Future helps decision makers clarify how and where to most efficiently make the investments.

Twenty percent of all people in the United States suffer from some form of chronic heart or circulatory disease. Eight percent suffer from either chronic bronchitis, emphysema, or asthma. In numerous ways these diseases impose costs on the persons who have them and on society. Costs include the pain and discomfort associated with chronic illness, the resources used to provide medical treatment for the disease, and time lost because of illness. The most obvious form of lost time is years lost due to premature death. However, lost time also takes the form of lost workdays and lost leisure time while a person is alive. An additional loss occurs if a person becomes less productive as a result of disease.

Society has limited resources to devote to combating chronic heart and lung disease. To help decide how to get the best value for money, those whose job it is to apportion these resources must have some idea of the monetary costs of the diseases. Suppose the government can fund a program that will discourage smoking and, as a result, cut the number of new cases of emphysema each year by 10,000. Alternatively, the same funds could be used to educate people about dietary fat which, let us suppose, would reduce by 15,000 the number of heart attacks each year. To decide which of the two investments would provide better value for money—all other things being

equal—one must determine the costs of each disease and then hold these costs against the benefits of making the investment and cutting back the number of cases that occur. In monetary terms, the benefits of each prevention program equal the number of cases of disease prevented, times the cost per case.

Researchers at Resources for the Future recently set out to measure some of the social costs of chronic heart and lung disease—specifically the medical and labor-market costs. These cost estimates are based on two national surveys—the National Medical Care Expenditure Survey and the Social Security Survey of Disabled and Non-Disabled Adults. Medical costs include the costs of medication, doctors' visits, and hospitalization. Labor-market costs include the lost earnings of people who stop working because of their disease and the reduced earnings of people who continue to work but cut back their hours or switch jobs.

The major finding in the study, not surprisingly, is that the costs of chronic illness vary greatly from one disease to another. Emphysema and ischemic heart disease (heart attack) have the largest combined medical and labor-market costs. Hypertension, on the other hand, has no labor-market effects and average annual medical expenses of only \$200 per case (in 1977 dollars). If efficiency is used as the determining factor for the allocation of funds across disease prevention programs, this information could have important implications. It should be remembered, however, that social costs such as pain and discomfort were not part of the RFF study and that these and other factors carry considerable weight in attitudes toward disease prevention and investment decisions.

Medical costs

It would seem a simple matter to compute the medical costs associated with a disease. All that one need do is to locate people with the disease and record their medical expenses over some period. In reality, it is not at all simple. Until recently, surveys providing such data on specific diseases such as emphysema, heart disease, and hypertension either were too specialized, covered too few people to be generalized to the entire U.S. population, or were unavailable.

Even where such information is at hand, there are many complications. For instance, a person may have more than one disease, making it difficult to attribute a medical expense incurred from a doctor's visit to a specific disease. Also, if people have medical insurance, they do not pay for much of their medical expenses. Thus, asking them how much they themselves have paid will not reveal the lion's share of the expenses.

Fortunately, the 1977-78 National Medical Care Expenditure Survey addressed many of these concerns. It issued a calendar diary to 14,000 households (40,320 persons) selected randomly from the U.S. population. The diary was intended as a tool to help participants accurately report their health care utilization and expenditures for approximately one year. By carefully eliciting a list of all of the diseases each person had and which of these diseases were involved in any episode of illness, the survey facilitated matching specific medical costs to specific diseases. And, by building in questions on the source of payment for each medical expense, the issue of who pays—individual families, insurance companies, or the government—could be addressed. Knowing who pays as well as how much is paid may be useful information in deciding on disease prevention investments.

The RFF study found that of the five diseases examined—hypertension, ischemic heart disease, other (nonspecific) heart disease, emphysema, and chronic bronchitis—medical expenses incurred from heart diseases dwarf those for some

of the other diseases (see table 1). For instance, expenses resulting from heart attacks (at \$1,256 per person per annum in 1977 dollars) are almost thirteen times higher than those for chronic bronchitis (at \$97), but only twice as large as those for emphysema (at \$633).

However, most people suffering from any of these five chronic diseases have very low medical expenses. Median expenses (where half the sample has higher expenses and half has lower) for heart attack, for instance, are only \$74 per year, while those for chronic bronchitis are \$23. In select cases, however, costs can be prohibitive: almost 4 percent of those who had a heart attack in 1977-78 incurred medical expenses exceeding \$10,000.

What are the costs of services being used to combat these diseases? It comes as no surprise that hospitalization, if required, is the most expensive service when compared with doctors' visits and drugs during a typical episode. It is perhaps more surprising that average hospitalization expenses exceed expenses for doctors and drugs even when the large number of people having no hospital expenses is counted.

Who pays for these expenses? In general, families pay only a small share of total expenses out of their own pockets—23 percent of medical costs for hypertension and 34 percent for chronic bronchitis, the least costly diseases. They pay only 14 percent of the costs for emphy-

sema and 10 percent for heart diseases.

For the more serious diseases, families pay an even lower share of the costs. It falls to insurance companies to pick up most of the tab for diseases such as heart attack (46 percent), reflecting the high proportion of expenses for the hospitalization component and the high degree of coverage afforded this type of expense by health insurance plans. The insurance share for emphysema is large (28 percent) for much the same reason.

A third type of funding source—the government—pays up to 44 percent of the total cost of some diseases. Medicare, available to all persons 65 and over, covers 41 percent of the costs of other (non-specific) heart diseases and between 17 percent and 35 percent of the costs of the other diseases studied. Medicaid, available only to low-income persons, funds between 7 and 17 percent of expenses for the five conditions studied.

Although a minority of total medical costs are paid directly by patients and their families, family funding is proportionately the largest source of payment for a majority of patients. This is because most patients incur a number of small expenses and families bear a larger percentage of these expenses than of large expenses such as hospitalization. This situation may reflect deductibility clauses in insurance policies, the exclusion of drugs from coverage by some policies, or other factors. But irrespective of who

pays initially, the costs of medical care are borne in the long run by society at large.

Labor-market costs

When chronic disease strikes, a person may stop working altogether or may continue working but work fewer hours or switch to a less demanding job. For each disease examined, the RFF study sought to determine how likely it is that a person with that disease would stop working. Researchers also looked at how much individual earnings were likely to drop if work was continued. To find this information, they used responses to the 1978 Social Security Survey of Disabled and Non-Disabled Adults because the survey asked respondents to identify their chronic diseases and to state whether they work and, if so, what they earn.

RFF researchers used this survey as a basis for discerning differences between the working habits of healthy people and chronically ill people. They compared the frequency with which each group worked to measure how the likelihood of working is affected by chronic diseases and, therefore, the labor-market costs of these diseases. Of the five chronic heart and five chronic lung diseases studied, only six decrease the probability of working—emphysema, heart attack, and stroke being the most important, followed by chronic bronchitis, arteriosclerosis, and other heart diseases (see table 2).

The age of onset

One important issue addressed by the study is whether the labor-market effects of a disease depend on the age when the disease first began—the age of onset. It is often argued that the effects of a disease at any age are smaller if the age of onset is earlier. According to this argument, a man is more likely to be working at age 40 if he injured his back when he was 25 rather than 35, because he has had longer to adjust to the injury.

RFF findings appeared to contradict this argument, at least for the diseases studied. Researchers found that emphysema, arteriosclerosis, and heart attack reduce the probability that a man will

Table 1. Medical Costs of Chronic Heart and Lung Diseases
(in 1977 dollars)

	Average expense	Median expense	Percentage of total expenses paid by family
Bronchitis	\$ 97	\$ 23	34%
Emphysema	633	43	14
Heart attack	1,258	116	10
Hypertension	216	54	23
Other chronic heart diseases	1,041	74	10

Source: National Medical Care Expenditure Survey.

continue to work if his disease begins between 45 and 54, but not if it begins later, between 55 and 65. They also found that having a stroke at any time after age 45 reduces the chance of working, but that the effects are greatest if the stroke occurs between ages 45 and 54.

One reason for the surprising findings may be that persons who first contract a chronic disease between 45 and 54 have had it longer than persons who get the disease after 55; the longer the duration, the more severe the disease may be. This condition is especially true for degenerative diseases. Indeed, when RFF researchers took into consideration the duration of disease, they found that contracting emphysema or arteriosclerosis between ages 45 and 54 affects the chance that someone works only if that person

has had the disease at least six years. By contrast, if a heart attack occurs between 45 and 54, the chance that a person works is lowered only for the first five years following the attack.

Among people with chronic heart and lung disease who are still able to work, how big is the drop in earnings likely to be? Using the same 1978 survey, RFF researchers found that only two diseases—emphysema and heart attack—lower earnings for people who continue to work. In the case of emphysema, the fall in earnings does not begin until a person has had the disease at least six years. Once it does fall, however, the drop is large—equal to 62 percent of earnings. Having a heart attack reduces earnings an average of 45 percent for people who continue working after an attack.

The combined effects of chronic heart and lung disease on the probability of working and on earnings if a person continues to work are substantial (table 2). Emphysema, heart attack, and stroke cause the largest annual earnings losses; however, the time pattern of losses is very different for the three diseases. Losses due to a heart attack are largest in the five years following the attack (equal to 55 percent of earnings, on average) and then decline. Losses associated with emphysema do not begin until a person has had the disease at least six years and then, up to age 55, equal 73 percent of earnings. By contrast, asthma, allergies, and hypertension appear to have no effects on earnings.

Implications for prevention

What are the implications of the RFF findings for programs to reduce the incidence of heart and lung disease (bearing in mind that only a portion of the social costs of these diseases was measured)?

First, the monetary benefits of programs to reduce the incidence of chronic disease depend on the number of cases prevented by the program as well as on the cost per case.

Second, it does not necessarily follow that a program to reduce the incidence of emphysema—for example—will yield higher benefits per dollar spent than a program to reduce hypertension, even though the former disease has far higher social costs per case.

Because the implications of the RFF findings are not straightforward, they do not suggest what decision must be made in choosing one prevention program over another. But making rational decisions about such programs can be aided by better pinpointing the medical costs and labor costs that would be saved if any one program versus another is put into place. ■

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Table 2. Earnings Losses Due to Chronic Heart and Lung Diseases
(in 1977 dollars)

	Annual earnings loss	
	Ages 45-54	Ages 55-65
Allergies	\$ 0	\$ 0
Asthma	0	0
Chronic bronchitis, onset at 25-44	3,620	5,279
Emphysema, onset at 45-54 ^a	13,391	9,676
Other chronic lung diseases	0	0
Arteriosclerosis, onset at 45-54 ^a	3,333	4,992
Heart attack, onset at 45-54	10,079	5,130
Hypertension	0	0
Other chronic heart diseases		
Onset at 45-54	4,197	0
Onset at 55-65	0	5,734
Stroke		
Onset at 45-54	8,876	8,753
Onset at 55-65	0	6,257
Annual earnings, no chronic disease	\$18,213	\$11,401

^aEffects begin once duration ≥ 6 years.

Regulatory policy, new technology, and mother nature

Leonard P. Gianessi and Cynthia A. Puffer

Newer, low-toxicity pesticides may do a good job of controlling weeds for a time, but they may also promote conditions that allow weeds to develop resistance and introduce the possibility of massive crop failures. Before all of the older compounds are withdrawn or banned for use and all of the newer ones are unquestionably embraced, it may be a good idea to consider whether the newcomers are economically sound as well as environmentally safe.

Much of the legislation introduced in the 1970s to regulate pesticides was in response to concerns over the effects of pesticide use on human health and the environment. The 1972 amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) required the U. S. Environmental Protection Agency (EPA) to reregister all of the approximately 600 active pesticide ingredients approved for use up to that time. The reregistration process requires a review of all existing data on each active ingredient and submission of additional test data needed for an evaluation of the risks and benefits it poses. In this way older pesticides are reevaluated according to current regulatory standards and testing procedures. Lately, interest in the reregistration process has sharply increased as a result of fears for public health and farmworker safety from pesticide exposure.

Due to advances in the fields of toxicology and analytical chemistry, recently developed pesticides have had to meet more rigorous testing requirements in order to be registered than those developed in the past. New compounds must now demonstrate low toxicities to humans, fish, and wildlife in order to gain approval. The pace of reregistration of older compounds, once slow, has been

accelerated by the deadlines set by the 1988 amendments to FIFRA. Within the next few years, the EPA will make decisions affecting the registration of a large number of both new and old pesticides.

One of the factors considered in the EPA's risk/benefit analyses of previously registered pesticides is the availability of substitutes for the active ingredients in question. In many cases, a compound meeting the new requirements is registered for use on the same crops and to control a similar spectrum of pests as an older chemical suspected of posing a greater risk to human health and the environment. Many advocate banning these older chemicals soon after the newer, less toxic alternatives have been made available.

Newcomers raise concerns

It turns out, however, that there is a new set of concerns arising from some of the properties of the newer pesticides. The very characteristics that make them less of a threat to the environment and public

health—namely, their low rate of application and specific mode of action—also make them vulnerable to resistance by the pests they are designed to control.

This concern applies particularly to the new classes of herbicides known as AHAS inhibitors, now gaining wide acceptance. These herbicides act by inhibiting a single enzyme (acetohydroxy acid synthase [AHAS]) necessary for the production of a few amino acids essential to the metabolism of many weeds. Many of these herbicides also have residual activ-

It may be advantageous to keep older chemicals available as insurance if the new chemistry fails.

ity, meaning that they remain active in the soil for a long time after application. Highly effective, long-term control of weeds by these herbicides exerts considerable selection pressure on the weed species' populations, allowing rarer, non-susceptible weeds to flourish and multiply. Although cases of weed resistance to many older herbicides have been noted after years of use, weed resistance to some new compounds has occurred much sooner than expected. To add to this concern, many weed scientists are worried about the potential for some weed species to develop cross-resistance to several classes of herbicides, by adopting mechanisms of metabolism or detoxification.

The potential economic consequences of increased herbicide resistance and current pesticide policy objectives were clearly demonstrated during a recent study at Resources for the Future designed to project the effects of a hypothetical ban on phenoxy herbicides on wheat. While working on the project, news of resistance to one of the newer alternatives to the phenoxy—chlorsulfuron—set off a flurry of activity within the agricultural community. The suddenness of changes in projected herbicide use and weed control strategies for wheat in many parts of the United States required drastic

Table 1. Use of Herbicides in Wheat: National Percentage of Acres Treated

	<u>1982</u>	<u>1987</u>
2,4-D	29	33
Dicamba	7	9
MCPA	6	7
Bromoxynil	3	3
Chlorsulfuron		13
Harmony		1
Metsulfuron		3

revision of the substitution assumptions of the hypothetical ban, revealing shortcomings in current pesticide policy.

2,4-D and chlorsulfuron

The recent history of the pesticides 2,4-D and chlorsulfuron clearly illustrates that substitution of one product for another may resolve one set of problems but create another set of its own. Sold under the product name of Glean, chlorsulfuron was registered for use on wheat in 1983. It was the first of the class of sulfonylurea herbicides whose mode of action is the inhibition of a single enzyme system. Chlorsulfuron has demonstrated neither mutagenic nor teratogenic properties and exhibits low toxicity to fish and wildlife. It is applied at a low rate of 0.02 pounds per acre and has residual activity in the soil for as long as three or four years. Because its residual activity can injure other crops, its use is most prevalent in continuous wheat and wheat/fallow rotations in the Great Plains. Chlorsulfuron gained wide acceptance rapidly, and began to replace 2,4-D in many areas where monoculture wheat is grown. Compared to phenoxy, it normally controls many more of the weeds in wheat.

Chlorsulfuron's "rival," the phenoxy herbicide 2,4-D, is still the most widely used herbicide in U.S. small grain production. Originally registered for use as a pesticide in 1948, 2,4-D is a systemic herbicide that is absorbed by plant foliage and stem tissue and is translocated to the actively growing parts of the plant, where it affects the plant's growth. Its mode of action is complex and not well understood, but it acts as an auxin, causing the plant to grow disoriented and too rapidly. Although 2,4-D has been widely used for forty years, it has multiple sites of action, and no significant resistance problems have occurred. It does not persist in the soil but is degraded within one to two weeks. It is generally applied at a rate of about 0.5 pounds per acre. In the 1980s, 2,4-D continues to be used on about one-third of the nation's wheat acreage.

Like many of the older pesticides, 2,4-D has been under suspicion in connection with risks its use may pose to



Weeds such as this Russian thistle have become resistant to one of the newer pesticides, chlorsulfuron.

human health. The Environmental Protection Agency has issued a registration standard for 2,4-D which mandates that workers wear protective clothing when handling it. The EPA has also proposed that use of 2,4-D be restricted in certain counties where it might pose a threat to endangered species. In addition, the agency is monitoring for groundwater contamination by 2,4-D in areas of high vulnerability to the leaching of soluble pesticides. The EPA has also identified certain data gaps while evaluating the environmental and health effects of 2,4-D, and has called for additional studies.

Considerable excitement accompanied the introduction of chlorsulfuron. In 1985, the National Association of Professional Engineers named Glean as the New

Product of the Year—the first time an agricultural product received such attention. (To put this into perspective, the winner in 1984 was the Kodak disc camera.) By 1987 chlorsulfuron was used on about 13 percent of the nation's wheat acreage.

Many analysts suggested that chlorsulfuron's introduction should be used to hasten 2,4-D's departure. They contended that chlorsulfuron was an effective replacement used in very small quantities per acre. The EPA gave serious consideration to a ban on continued use of 2,4-D, but ultimately decided against initiating a special review of the herbicide. Though no ban was imposed, the potential effects of a ban are illuminating. If 2,4-D and another phenoxy herbicide, called MCPA, had been banned for use in wheat in 1987, it is estimated that as many as 10 million additional acres per year would have received treatment with chlorsulfuron.

Meanwhile, by 1988 cases of weed resistance to chlorsulfuron had been discovered in areas where chlorsulfuron had been applied continuously for four to five years. These cases occurred in several states (Idaho, North Dakota, Kansas, Colorado, Montana, and Washington) and in three common weed species (kochia, prickly lettuce, and Russian

The marketplace will not necessarily eliminate nonperforming pesticides before irreversible damage is done.

thistle). The problem was taken very seriously by the manufacturer and the Cooperative Extension Service of the U.S. Department of Agriculture. Many wheat growers were contacted directly by the manufacturer, and major modifications were made in the label to advise users that (1) chlorsulfuron should not be used continuously on the same fields, and (2) other herbicides having a different mode of action should be used in combination or in sequence with chlorsulfuron. The

recommended alternatives included the phenoxy herbicides 2,4-D and MCPA. The use of chlorsulfuron in wheat is expected to decline, while use of 2,4-D is expected to increase.

Substitute with caution

An important lesson can be drawn from the recent experience with 2,4-D and chlorsulfuron: newer, less toxic compounds should not be automatically viewed as complete replacements for the older compounds. It is probably wiser to plan on their coordinated use. If many chemicals are banned or withdrawn from use, it may be necessary to develop and register new compounds at a much faster pace to keep ahead of resistance and other unforeseen problems. This is easier said than done, as it is becoming increasingly difficult and costly for the chemical industry to find new and better herbicides. Therefore, it may be advantageous to keep the older chemicals available as insurance if the new chemistry fails.

Concern over weed resistance, however, is only part of the issue facing those who must make decisions on how to regulate pesticides. Pesticides also need to be evaluated in terms of their long-term benefits for agriculture and the agronomic practices they promote. If the pool of available, effective pesticides is limited,

a farmer's management options may also be limited. Lately there has been much promotion of the benefits to agriculture from both crop rotation and reduced tillage. Sometimes tradeoffs must be made.

The use of chlorsulfuron, for example, is credited with certain benefits to the environment and to agricultural productivity. Its use has permitted less frequent tillage of fields, resulting in large reductions in soil erosion, water loss, and sedimentation in some areas of the Great Plains. In other areas its use has increased retention of soil moisture, thus boosting yields. However, chlorsulfuron severely limits a grower's options in rotating crops. In other words, the consequences of promoting the use of one pesticide over another can affect much more than wildlife and human health.

What role for government?

What is the appropriate role for the federal government to assume when agricultural problems arise from pesticide use? Both Israel and Great Britain have banned the further use of chlorsulfuron. However, a U.S. court ruled in 1978 that the EPA did not have the authority under FIFRA to ban pesticides on the basis of lack of effectiveness. The assumption was that the marketplace would eliminate

nonperforming pesticides. In the case of chlorsulfuron, the manufacturer took steps to limit use of the product before resistance to it became widespread. Because the manufacturer chose to act quickly and responsibly, massive crop failures may have been averted. The response of the marketplace in this case could have come too late.

These lessons suggest that pesticide rulemaking needs to encompass a broader range of objectives than the reduction of risk to the environment and human health. Concerns for efficacy, the likelihood of pest resistance, indirect environmental effects, and the promotion of sound agronomic practices ought to be taken into account. Also to be taken into account are the distributional consequences of pesticide policies—particularly command-and-control policies. Since these policies target specific active ingredients used on specific crops, the burden of the policies is felt most by those who use the restricted ingredient and especially by those whose possible pest management options are limited. Having those who use the pesticide bear the cost of the policy honors the "polluter pays" principle but does not address the issues of equity and fairness.

Flexible policy tools other than bans ought to be developed; ideas such as targeted sets of taxes on more toxic pesticides, and incentive-based mechanisms such as a marketable-permit system ought to be explored. Under such a system, for example, the amount of particular active pesticide ingredients that society would tolerate would be specified in permits; the permits could then be auctioned by government or distributed to growers. A market would thus be established in which growers could buy and sell the permits. In these ways regulators could respond more effectively to the changing conditions and problems affecting agriculture. ■

Table 2. Characteristics of the Pesticides 2,4-D and Chlorsulfuron

2,4-D	CHLORSULFURON
• Phenoxyacetic acid	• Product name: Glean
• Usage rate: .5 lb/acre	• Sulfonylurea herbicide
• Contact herbicide	• Does not injure wheat
• Controls broadleaf weeds	• Will injure non-cereals
• Soil persistence: 1-4 weeks	• Soil persistence: 3-4 years
• Can injure wheat	• Very specific mode of action
• Registered in 1948	• Registered in 1983
• Exact mechanism not understood	• Low acute, dermal and inhalation toxicity
	• Usage rate: .02 lb/acre

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U.S. farmers and Latin American debt

Elaine M. Koerner and George E. Rossmiller

Latin America is the third largest regional market for U.S. agricultural exports. Yet it continues to stagger under heavy debt burdens, millstones that severely curtail its buying power. Reduction in Latin American debt would mean economically healthier customers for U.S. farm products. But would it also unleash the tiger of competition?

For better or worse, the U.S. agricultural sector and the economies of Latin American nations are mutually dependent. The United States has the capacity to produce roughly twice what it consumes domestically. If either massive set-asides or large government inventories are to be avoided, exports must at least be maintained and ideally expanded. Latin America, with a combined population of almost 436 million, could play a critical part in finding a solution to the U.S. overproduction problem. It ranks third in the list of top U.S. regional markets, trailing Asia and Western Europe.

Though Latin America possesses the potential to become an even bigger customer for U.S. farm goods, it does not, however, possess the means. As G. Edward Schuh, dean of the Humphrey Institute of Public Affairs at the University of Minnesota, aptly phrased it during his 1989 testimony before the Joint Economic Committee of the U.S. Congress, "markets are based on income, not hungry bellies." Latin America must shed its debt burden and increase its purchasing power before it can be in a position to increase its volume of agricultural imports from the United States.

Over the past year, the Latin American debt problem appears to have worsened rather than gotten better. According to the 1989 World Bank annual report, the pace at which developing countries transferred

money back to the richer nations accelerated dramatically in 1988, hitting a record \$50.1 billion, up almost \$12 billion from 1987. (This figure is the net negative transfer, representing payments of interest and principal that are greater than new lending.)

Particular cause for concern is that the most heavily indebted nations described in the World Bank report are also currently the best Latin American customers for U.S. agricultural goods. Mexico, which has been the largest Latin American export market for U.S. agriculture every year since 1970, was at the top of the list of indebted nations. During 1988, it had negative net resource transfers of \$9.4 billion, a massive increase from its negative net transfers of \$2.9 billion in

U.S. assistance on Latin American debt can be soundly justified as enlightened self-interest.

1987. Brazil, which is number two among Latin American U.S. export markets, held the unenviable number two position for level of indebtedness.

U.S. assistance in easing the Latin American debt problem represents more than an opportunity for altruism. Such assistance can be soundly justified on grounds of enlightened self-interest through bringing tangible financial benefits to the U.S. agricultural sector. The net result of easing debt burdens would be more robust economies that would support more stable political systems and create stronger markets for U.S. exports. True, the Latin American agricultural sector would gain in strength along with

the other sectors of the economy. However, any negative effects from stronger competition from specific commodity markets would be more than offset by the overall gains.

U.S. policymakers have every reason to make a serious commitment to helping Latin America rid itself of its debt burden and move on. Those who shape policies would benefit greatly from designing an integrated rather than an isolated strategy for approaching U.S. agricultural policy and U.S. relations with Latin American debtor nations. If this strategy is to be comprehensive, it must reflect all of the forces that affect agricultural policymaking these days, not only domestic conditions but also global trade conditions and international monetary policy.

Different outcomes

Somewhat ironically, Latin American nations and U.S. farmers found themselves in the same uncomfortable set of circumstances earlier this decade. Both had taken up the option of using readily available funds to attempt to enhance their economic position, and both had become victims of suddenly tightened purse strings.

By comparison with Latin America, the U.S. agricultural sector has emerged from that extremely difficult period essentially intact. The adjustments required have been made, painful though they have been to the farmers who suffered financial stress. To help ease the adjustment, the U.S. Congress passed bailout legislation for the farm credit system. In addition, government deficit spending expanded demand for goods and services elsewhere in the economy, thereby helping to create new employment opportunities that eased the transition of some out of agriculture. In the eyes of some analysts, the U.S. agricultural sector has come out in a stronger competitive position.

Not so, however, for Latin America. No bailout legislation has been passed. The debt crisis continues. To facilitate the repayment of debts, the region has been encouraged to reduce imports and stimulate exports. To alleviate the foreign exchange shortage, there has been an in-

crease in the volume of trade among countries within the region.

Debatable gains

The volume of agricultural goods leaving U.S. borders and entering Latin America each year remains considerable despite the debt drain, but the halcyon days are over. U.S. agricultural exports to Latin America peaked in 1981 at \$6.4 billion, dropping to \$3.6 billion in 1986 before beginning to recover. During fiscal year 1988, U.S. agricultural exports to Latin America moved up to \$4.4 billion.

Some agricultural trade experts suggest that the export gains to U.S. farmers from an end to the debt crisis could total as much as \$3 billion per year. But in the view of others, the magnitude of the direct gain to the agricultural sector should not be exaggerated. They suggest that in Latin America, and especially in Argentina and Brazil, development is just as often accompanied by expanded production of meat and animal feed. Instead of importing more as they develop, such countries will probably continue to export more agricultural products, at times in competition with U.S. farm exports. While Brazil does remain a significant importer of wheat and coarse grains, of late a larger share of these imports has come not from the United States but from Argentina. Moreover, the bulk of future increased imports would more likely be nonfood items.

Argentina and Brazil clearly are competitors, producing soybeans for export in greater volume and at lower cost than anyone else. While their combined production and exports were negligible during the 1960s, their percentage of world soybean product exports had increased to 15 percent by 1979 and rose to 26 percent in 1988. In 1988, these two countries alone supplied 56 percent of world soybean meal exports and 78 percent of world soybean oil exports.

The effect on U.S. agricultural exports of alleviating regional debt problems likely would lie somewhere between a \$3 billion gain and substantial losses resulting from stiffer competition and failure to export more U.S. farm goods. Admit-



WORLD BANK

Argentina has the capacity to increase exports of field crops, such as these soybeans, apart from the debt problem.

tedly, a stronger Latin America could mean a stronger competitor in some commodity sectors. Argentina will continue to be a strong presence in international markets in wheat, corn, and soybeans. Brazil will continue to corner a significant share of the soybean market. Both countries have the resource base to continue that competition, even increase it, quite apart from the debt issue.

Overall, the threat of Latin American competition with U.S. agriculture is mitigated on two counts. First, U.S. agriculture specializes in temperate-zone commodities, while the main Latin American production zone specializes in tropical agricultural commodities. In addition, and more important, broadly based economic development and rising per-capita incomes will lead to greater demand for U.S. feedgrains as consumers increase demand for animal proteins in their diets.

Steps to be taken

Policymakers in both the United States and Latin America can begin now to take

steps to alleviate Latin American foreign debt. If efforts were undertaken by both parties to reform current domestic and trade policies, conditions would be created that would enable Latin America to better help itself to a stronger economic position. For instance, U.S. sugar producer prices (and coincidentally corn sweetener prices) are supported by a stringent and tightening sugar import quota. Liberalization of the U.S. sugar program would open the U.S. market to more imported sugar, including that from Latin America, thus increasing the region's foreign exchange earnings as a result of larger export volumes and strengthened world prices.

International trade policies in some cases have had a negative effect on market opportunities for Latin America. Agricultural exporters like Argentina and Brazil have been hurt badly by the subsidy war between the European Community (EC) and the United States. Protectionist policies have tended to reduce international market prices and reroute agricultural trade flows. This is only one of the issues

of importance in the agricultural negotiations currently taking place under the General Agreement on Tariffs and Trade. And not only Latin America is losing out under these policies. A recent study by the

The economic relationship between the United States and Latin America could become increasingly symbiotic.

International Agricultural Trade Research Consortium estimates that fully two-thirds of the cost of U.S. farm support in 1986 went to offsetting the effects of farm support by other countries. In the EC the proportion was one-third, and in Canada it was well over half. This alone is a compelling case for trade liberalization.

Latin America must do its part in policy reform. Developing countries in general, and Latin American countries in particular, use a host of policy instruments ostensibly designed to ensure cheap food at home. Examples include an overvalued currency, explicit export taxes, export licensing, and monopolistic marketing boards. These instruments often discriminate against indigenous agricultural producers, thus preventing the domestic sector from becoming a stronger competitor in the global market.

The solution to Latin American debt also must embrace more than the agricultural sector. Supporting policy reform in other domains is essential to preventing further stagnation and decline in the region. Further changes in international monetary policy, especially lending policies, could play a key part in reversing the trend toward deepening debt and in increasing financial self-sufficiency. World Bank officials say that one-third of all of its bank lending now can be described as adjustment loans, as opposed to project loans. The shift in emphasis is toward improving economic growth, investment, and related research on trade and agricultural affairs.

In the meantime, however, lending agencies continue to press for payment on

existing debt. In 1988 the International Monetary Fund cut Argentina off in the middle of a \$1.4 billion standby credit, saying it would hold back \$800 million until Argentine policies improve. In 1989, the World Bank cut Argentina off in the middle of disbursing loans worth \$550 million, which were supposed to be given in exchange for trade liberalization and tighter central bank policies. Hyperinflation has brought the country to the brink of economic collapse.

With care, competitors such as Argentina can be assisted without damaging overall U.S. agricultural trading muscle. In fact, the mutually dependent economic relationship between the United States

and Latin America could become increasingly symbiotic. Mutual benefits would be derived from healthier trade conditions that would redound to the benefit of each trading partner's agricultural sector. An investment in the future welfare and political stability of Latin America would have a positive ripple effect, not only on global agricultural trading conditions but also on global welfare and stability. ■

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Table 1. Dollar Amounts of U.S. Exports to and Imports from Latin America, and Latin American Cumulative Debt, 1975-1988
(in millions of U.S. dollars)

Fiscal year	Exports to Latin America	Imports from Latin America	Debt stocks, cumulative ^a
1975	\$2,404	\$3,818	\$ 68,938
1976	2,089	3,896	85,187
1977	2,130	5,621	130,908
1978	2,757	5,688	161,533
1979	3,371	6,707	196,355
1980	5,479	7,322	242,633
1981	6,401	6,850	296,271
1982	4,933	5,747	333,210
1983	4,858	6,061	360,312
1984	5,280	7,070	377,429
1985	4,567	7,525	388,595
1986	3,598	8,146	406,031
1987	3,765	7,576	442,481
1988	4,401	7,482	— ^b

Sources: U.S. Department of Agriculture, *Foreign Agricultural Trade of the United States*, fiscal year supplements, 1975-1988 (Washington, D.C.); World Bank, *World Debt Tables, External Debt of Developing Countries*, vol. 3, Country Tables, 1970-1979, and vol. 1, Analysis and Summary Tables, 1988-1989 (Washington, D.C., 1988-89).

^a Includes debt stocks of all Latin American countries as well as of the Caribbean countries of the Bahamas, Barbados, Dominican Republic, Haiti, Jamaica, St. Vincents, and Trinidad and Tobago.

^b Not available.

An economic model to assess fish-kill damages

Carol Adaire Jones

How much is the experience of hooking a fish worth? The Michigan Department of Natural Resources has filed suit against a 1.8 million kW hydropower plant. The department claims that the facility has substantially harmed Lake Michigan's recreational fishing resources, and is using a powerful economic model to help assess the damages.

Great Lakes recreational fisheries have staged a remarkable comeback from the devastation in the 1940s and 1950s caused by lamprey and the cumulative effects of long-term overfishing. By 1980, Great Lakes recreational fisheries were estimated to support from 27 to 55 million days of fishing per year, creating an annual net value to anglers of approximately \$0.7 to 1.4 billion. In addition, the expenditures of tourists who engaged in recreational fishing were estimated to increase economic activity by \$2.3 to 4.3 billion in communities throughout the Great Lakes states and provinces.

However, Great Lakes fisheries continue to face a wide range of environmental threats, including fish kills and toxic contamination by power plants. To fill in gaps in the regulatory authority to mitigate these injuries, environmental managers and activists in the Great Lakes region and elsewhere are beginning to seek compensation from the parties responsible for harm.

In the past, the use of liability actions to protect natural resources has been limited because property rights to the resources have not been well established. Increasingly, however, both common law and statutory principles are being asserted to define public trustees for natural resources and to establish the trustees' rights to bring legal actions for mitigation and compensation for damages to the re-

sources. But the use of liability principles to seek compensation for harm raises the thorny problem of assessing the value of that harm to natural resources.

In an important liability case, the Michigan Department of Natural Resources (DNR) is suing for damages the utilities that own the Ludington Pumped-Storage plant located on Lake Michigan. The largest hydropower facility of its kind in the country, the plant is responsible for the largest continuous fish kill in Michigan waters. In the Ludington case, the State of Michigan is pioneering the use of economic principles to measure damages, rather than relying on the ad-hoc valuation methods frequently employed. At the heart of the assessment is a model of demand for recreational fishing opportunities throughout Michigan, which pro-

In 1980, an estimated 1.1 to 3.2% of the Lake Michigan biomass of alewives was killed by the Ludington plant.

vides the basis for estimating the damages to recreational anglers as a result of fish kills from hydropower operations at Ludington.

When harm affects the functioning of existing markets, such as commercial fisheries, useful measures of damage can readily be derived from market price clues—for example, how much a pound of trout costs in the supermarket. However, Michigan allocates its Lake Michigan fisheries primarily to recreational uses. Placing a value on recreational fishing experiences is difficult, because the value is derived from the full outdoor experience, not just the opportunity to

supply the dinner table without a trip to the fish market. We have no market price clues about consumers' willingness to pay for the experience of fishing for pleasure. Therefore, when the quality of the experience is reduced by the operation of a hydropower plant, it is difficult to assess the value of the harm caused.

Losses at Ludington

Designed to serve the peak-load requirements of Michigan electric consumers, the Ludington Pumped-Storage Plant pumps water from Lake Michigan to a storage reservoir during low-demand periods and releases it back to the lake through six power-generating turbines during peak-demand hours. Millions of fish are killed every year as they are pumped in with the water and released through the pump turbines. Death occurs as a result of pressure changes, direct contact with the pump-turbine blades, and associated stress.

The largest loss occurs in the trout and salmon recreational fisheries. Due to the mobility of salmon and (to a lesser extent) trout throughout the lake, the losses at Ludington affect population levels throughout Lake Michigan waters. Because of the large losses to the recreational fishery, the state has chosen to support development of the demand model as a means of providing an economically sound basis for the damage claims in its suit. In addition to the losses to the recreational fishery, two small commercial whitefish fisheries and one small com-

Table 1. Categories of Damages from Fish Kills

Use values
Recreational fisheries
Lost angler value
(for nonreplaceable fish)
Replacement cost (for replaceable fish)
Commercial fisheries
Lost economic rents
Lost consumer value (= 0)
Non-use values
Threatened species
Lost value to citizens

mercial bloater chub fishery are affected, as are lake sturgeon, which are listed as "threatened" under the Michigan Threatened and Endangered Species Act. Three categories of fish relevant to the success of the recreational fishery are killed: forage fish (primarily alewives, which serve as food for trout and salmon), adult game fish, and juvenile game fish.

In 1980 alone, an estimated 1.1 to 3.2 percent of the Lake Michigan biomass of alewives was killed by the Ludington plant. Forage fish are considered the limiting factor in the fishery and cannot be replaced cost-effectively. Consequently, the substantial kills of forage fish reduce considerably the population of trout and salmon that can be supported in the lake, and the state must reduce its stocking of juvenile game fish (and thereby its stocking costs) commensurately. The kills of an estimated 47,000 adult trout and salmon also cannot be replaced by increased stocking, because they have consumed "their share" of the limited forage. As the state cannot compensate for the loss of forage fish or adult game fish by stocking additional fish, their loss reduces the quality of fishing opportunities available to anglers.

On the other hand, the state can compensate for the loss of 500,000 juvenile game fish (which have not consumed their share of forage) by proportionately increasing its stocking of those fish and thereby increasing its stocking costs. In calculating the change in stocking costs due to the operation of the Ludington plant, the two effects are accounted for: an increase in stocking to compensate for the kills of juveniles, and a decrease in stocking because the forage-fish kills reduce the quantity of game fish that can be supported in the lake.

Valuation of damages

Economists confront a serious challenge in placing a dollar value on changes in the quality of environmental resources, such as the harm caused by the Ludington hydropower plant. Economists estimate the value of changes in well-being due to environmental harm by measuring the minimum amount citizens are willing to



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Great Lakes fisheries have staged a remarkable comeback, but angling continues to be affected in some areas by power plant fish kills and toxic contamination.

accept in compensation for the lower quality of the resources, net of any change in costs to maintain the resources. The major focus generally has been on use values—for example, measuring the losses in consumers' value and in producers' lost economic rents from recreational or commercial fishing.

In addition, economists are recognizing that some individuals place a value on the existence of natural resources, independent of use. Measurement of lost non-use

value as a proxy for the lost non-use value.

Both use and non-use values are incorporated in the damage assessment for the Ludington plant case, though the focus is on use-values in the commercial and recreational fisheries (see table 1). Because there are national markets for commercially harvested whitefish and bloater chub, the total market supply is not noticeably affected by the power-plant kills and there has been no associated price increase. Consequently, consumers appear to have incurred no related losses. However, because use of these fisheries is limited to the one or two enterprises licensed to operate in each of the areas, it is not surprising that the commercial operations produce economic rents, estimated at 15 to 25 percent of the landed value of the fish. The lost economic rents are incorporated in the damage accounting.

The greater injury, however, is experienced by trout and salmon recreational anglers. Not only do they confront lower-quality fishing opportunities in Lake Michigan as a result of the power-plant fish kills, but those opportunities are more costly for the state to maintain.

Applying the demand model

The model of demand for recreational fishing is being employed to estimate how

The demand model assesses anglers' willingness to travel further in order to fish at a higher-quality site.

value due to fish kills, which increase the possibility of species extinction, is particularly important where the species are relatively rare. Because most of the species killed by the Ludington plant are numerous in Lake Michigan, non-use losses are probably moderate. Additional information, judged too expensive to collect by survey given the relatively small values involved, would be required to measure lost non-use value. For lack of a direct measure, replacement costs can

much recreational anglers value different quality attributes in the Great Lakes trout, salmon, and other fisheries. To estimate demand without market prices, the model relies upon Harold Hotelling's insight of forty years ago that the travel costs incurred by an individual to travel to a site function like a price for the site visit.

The demand model employs a discrete-choice version of the travel-cost method to determine each angler's choice of one (discrete) fishing site for Great Lakes trout and salmon angling from among all feasible sites in Michigan. In essence, the procedure assesses anglers' willingness to travel further (and thereby to incur greater travel costs) in order to fish at a higher-quality site. Site-quality attributes include the expected number of fish caught per hour for individual trout and salmon species, the availability of harbor slips or parking spaces, and the extent of fish contamination by toxic substances. From the estimates of anglers' tradeoffs between quality attributes and travel costs, an angler's maximum willingness to pay for improved quality or minimum willingness to accept compensation for reduced quality at fishing sites can be calculated.

The discrete-choice version of the travel-cost method represents a substantial improvement over past travel-cost techniques focusing on single-site analysis. The discrete-choice technique allows the analyst to value changes in the quality at sites, which is essential for the proposed legal and policy applications. The advantage accrues from being able to evaluate the desirability of substitute sites relative to the site chosen by an individual. For example, when one fishery is damaged, participation may decline substantially. However, if unaffected substitute sites (or species) are readily available, the loss may be relatively small. On the other hand, injuries at sites of rare quality and accessibility may impose substantial losses on recreational anglers.

In the Ludington case, after the demand model was used to estimate anglers' tradeoffs between quality and travel costs, fisheries biologists created a policy scenario characterizing what the catch rates in Lake Michigan trout and salmon

fisheries and in anadromous fish runs would be if it were not for the operation of the Ludington plant. On the basis of the estimated relationships in the model, it is possible to predict how site choices would change if the environmental improvements characterized in the scenario were to occur. The associated losses in recreational angler value from operation of the power plant can then be calculated.

Other model applications

The demand model can serve as an important tool in a variety of other possible legal actions to reduce environmental threats to fisheries and other natural resources. For example, the model can be used to capture damages when power plants change the quantity of water resources suitable for certain species.

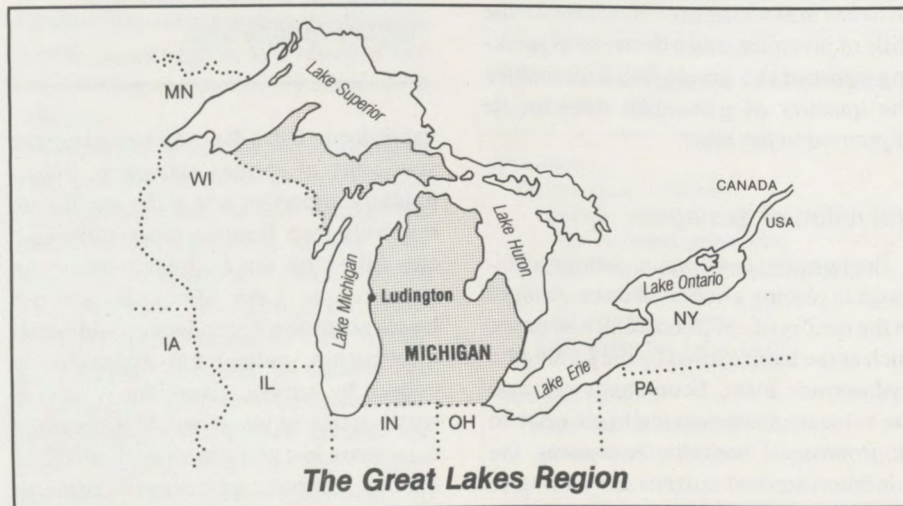
The demand model can also be used to estimate damages from toxic contamination. Restoration of a contaminated site could improve fishing quality in at least four ways that can be incorporated in the model: increasing the number of sites that can support stocking of fish; changing the relative composition of fish supported toward the higher-value game fish and thereby increasing catch rates of game fish; reducing the toxicity of the fish catch; and improving the aesthetic quality of recreational experiences.

Under the Comprehensive Environmental Response, Compensation, and Liability Act (known as "Superfund"), suits can be brought to recover the natural

resource damages that remain after cleanup of Superfund sites (as well as the pre-cleanup damages). Though the majority of Superfund litigation to date has focused on the costs of site remediation, the natural resource damage cases may become as frequent and costly as the remediation cases. Because the regulations governing the natural resource damage suits mandate the use of economic methodologies, instead of ad-hoc methods such as fish-value schedules, under Superfund the recreational fishing demand model may be an essential element for successful legal suits regarding fishery damages.

In conclusion, it is important to note that the methodology described here for valuing recreational fishing is applicable to all classes of recreation. Where the necessary data are available, the model can also be used to value harm to hunting, boating, swimming, or other forms of recreation. ■

The recreational fishing model described in this article was developed by Carol Adaire Jones, Gilbert F. White Fellow at RFF in 1988-89, in collaboration with Douglas B. Jester of the Michigan Department of Natural Resources and Theodore Graham-Tomasi of the University of Minnesota, with support from the Michigan DNR and from RFF. On leave from the University of Michigan, Jones is developing new applications for the model while at RFF as a visiting scholar during 1989-90.



Applicants sought for RFF award programs

Resources for the Future is seeking applicants for four of its award programs—the Gilbert F. White Postdoctoral Fellowship Program, the RFF Small Grants Program, the Dissertation Prize in Environmental and Resource Economics, and the NCFAP Resident Fellowship Program.

Two resident fellowships will be awarded for the 1990-91 academic year under the Gilbert F. White Postdoctoral Fellowship Program. They are intended for postdoctoral researchers who wish to devote a year to scholarly work on social science or public policy programs in areas of natural resources, energy, or the environment.

The RFF Small Grants Program provides start-up funding for new research projects or supplementary support to complete specific aspects of ongoing research related to the environment, natural resources, or energy. Grants can only be made to individuals through tax-exempt institutions.

Applications for the Gilbert White program and the Small Grants program are due by March 1, 1990. Awards will be announced in April 1990.

A third program for which RFF seeks applicants is the Dissertation Prize in Environmental and Resource Economics. The prize, first awarded in 1989, is \$10,000. All dissertations in environmental and natural resource economics (theoretical and applied) submitted for the Ph.D. or its equivalent and certified as completed between 1 January 1989 and 31 December 1989 are eligible for nomination. All manuscripts submitted for the dissertation prize must be accompanied by a formal letter of nomination from the chair of the university department in

which the dissertation was completed. Each department may nominate only one dissertation.

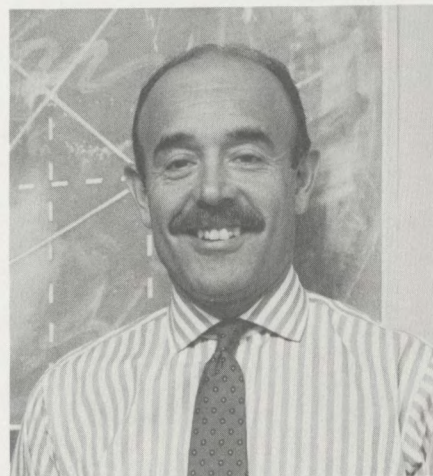
Manuscripts for the dissertation prize must be received by RFF by January 15, 1990. The award will be announced in June 1990.

For more information about any of the three award programs described above, write to the Office of the Vice President, Resources for the Future, 1616 P Street, N.W., Washington, D.C. Telephone (202) 328-5000.

A fourth award program, the NCFAP Resident Fellowship Program, is sponsored by RFF's National Center for Food and Agricultural Policy. Up to three fellowships are awarded, each for a period of six to twelve months, to young professionals who wish to pursue scholarly work on current or emerging national issues related to food and agricultural policy.

Individuals from universities, governments, and the private sector who will have completed their doctoral requirements in any discipline by the beginning of the 1990-91 academic year are eligible. Professionals who will be on sabbatical leave during the fellowship period are encouraged to submit an application.

Applications for NCFAP resident fellowships are due by April 3, 1990. Awards will be announced in May 1990; an earlier decision may be made in the case of an applicant interested in beginning a fellowship during the summer. For more information, including applications, write to Tamara A. Kloeckl, National Center for Food and Agricultural Policy, Resources for the Future, 1616 P Street, N.W., Washington, D.C. 20036. Telephone (202) 328-5117. ■



RICHARD A. BLOOM

RFF vice president Paul R. Portney

New RFF vice president

Paul R. Portney, senior fellow and director of the Center for Risk Management, has been named vice-president of Resources for the Future.

A member of the RFF research staff since 1972 and founding director of the Center for Risk Management, Portney was also director of RFF's Quality of the Environment Division. He has served as senior staff economist at the Council on Environmental Quality in the Executive Office of the President, and has been a visiting professor in the Graduate School of Public Policy at the University of California at Berkeley.

Portney received his Ph.D. in economics from Northwestern University and is the author, coauthor, and editor of many books and articles, among them the forthcoming RFF book *Public Policies for Environmental Protection*. He will continue to direct the Center for Risk Management until a successor is appointed.

Portney replaces John F. Ahearne, recently named executive director of Sigma Xi, the Scientific Research Society. ■

New university fellows

RFF recently named seven new university fellows under a program, inaugurated in 1988, that provides research support to distinguished scholars who cooperate with RFF staff members and spend time in residence at RFF.

Those who have accepted university fellowships in 1989 are:

- John M. Antle, Department of Agricultural Economics and Economics, Montana State University;
- Neil A. Doherty, The Wharton School, University of Pennsylvania;
- E. Donald Elliot, School of Law, Yale University;
- John D. Graham, Department of Health Policy and Management, School of Public Health, Harvard University;
- W. Michael Hanemann, Department of Agricultural and Resource Economics, University of California, Berkeley;
- Robert M. Stavins, John F. Kennedy School of Government, Harvard University; and
- John E. Tilton, Department of Mineral Economics, Colorado School of Mines.

The new fellows join those who were appointed in 1988: Maureen L. Cropper, Department of Economics, University of Maryland; John Mullahy, Department of Economics, Trinity College; Wallace E. Oates, Department of Economics, University of Maryland; and V. Kerry Smith, Department of Economics and Business, North Carolina State University. ■

Dissertation prize awarded

RFF has recently announced the award of its initial Dissertation Prize in Environmental and Resource Economics to Lloyd S. Dixon.

Currently on the staff of the RAND Corporation, Dixon completed his dissertation on "Models of Groundwater Extraction with an Examination of Agri-

cultural Water use in Kern County, California" in the economics department of the University of California at Berkeley, under the direction of W. Michael Hanemann.

The prize, which carries an award of \$10,000, was established in 1988. General information about the prize and the 1990 competition is contained elsewhere in this issue.

New research fellows

Dallas Burtaw and Karen L. Palmer, recent Ph.D. recipients in economics from the University of Michigan and Boston College, respectively, have joined RFF's Quality of the Environment Division as research fellows. Both are specialists in industrial organization.

New books

Markets for Federal Water: Subsidies, Property Rights, and the Bureau of Reclamation, by Richard W. Wahl

This new book clearly and authoritatively addresses significant issues of water policy in the western United States at a time when the growing scarcity of western water and the role of the Bureau of Reclamation in the allocation of that resource are becoming increasingly urgent issues.

Wahl combines his insider's knowledge of the Interior Department's dam-building, regulatory, and water-pricing decisions with an objective analysis of the efficiency of the use of federally supplied water. He suggests that rather than trying to eliminate subsidies for existing water supplies, property rights to federally supplied water ought to be clarified to facilitate market trades; that is, federally supplied water ought to enter the marketplace just as some other western water does.

An informative and useful text for both scholars and lay readers interested in western water issues, *Markets for Fed-*

eral Water will be of particular interest to water managers, engineers, and lawyers, to state government officials, and to other natural resource managers.

November 1989. 326 pp.
\$30.00 cloth. ISBN 0-915707-48-9

The Long-Term Adequacy of World Timber Supply, by Roger A. Sedjo and Kenneth S. Lyon

Is the world running out of usable timber? The authors address this question of long-standing national and international concern. Projecting modest future growth for both prices and harvest levels, the study provides theoretical and empirical justification for challenging the conventional wisdom that real timber prices will rise for the indefinite future.

The authors have developed the first economic model of the world's timber supply, and in this new study they present the model and employ it to investigate the adequacy of the long-term economic timber supply from the major timber-producing regions of the world. The study presents fifty-year projections of regional and world harvest levels, world market price, and investments in forest regeneration by region. It also considers the role of technological change in the context of world timber supply.

This book continues and extends earlier work done under the auspices of the Forest Economics and Policy Program at RFF.

December 1989. 256 pp.
\$30.00 cloth. ISBN 0-915707-46-2

Discussion papers

RFF discussion papers convey the early results of research for the purpose of comment and evaluation. They are available at modest cost to interested members of the research and policy communities. Price includes postage and handling. The following discussion papers have recently been released:

Energy and Natural Resources Division

- "Ethanol Fuel and Non-market Benefits: Is a Subsidy Justified?" by Margaret A. Walls, Alan J. Krupnick, and Michael A. Toman. (ENR89-07) \$5.00

Quality of the Environment Division

- "The Effects of Uncertainty on Policy Instruments: The Case of Electricity Supply and Environmental Regulations," by Hadi Dowlatabadi and Winston Harrington. (QE89-20) \$2.25
- "Regulating Pesticide Use: Social Costs, Policy Targeting, and Economic Incentives," by Leonard P. Gianessi, Raymond J. Kopp, and Cynthia A. Puffer. (QE89-21) \$2.25
- "A Data Appendix to Regulating Pesticide Use: Social Costs, Policy Targeting, and Economic Incentives," by

To order books, add \$3.00 postage and handling per order to the price of books and send a check made out to Resources for the Future to:

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To order discussion papers and reprints, please send a written request, accompanied by a check, to Publications and Communication at the same address.

Leonard P. Gianessi, Raymond J. Kopp, and Cynthia A. Puffer. (QE89-21-B) \$2.25

- "Longitudinal Patterns of Compliance with OSHA Health and Safety Regulations in the Manufacturing Sector," by Wayne B. Gray and Carol Adaire Jones. (QE89-22) \$2.25
- "Regression Models for Beta-distrib-

uted Outcomes," by John Mullahy. (QE89-23) \$2.25

National Center for Food and Agricultural Policy

- "Ten Truths About Supply Control," by Thomas W. Hertel. (FAP89-05) \$3.00
- "Proposition 65 and the Economics of Food Safety," by Carol S. Kramer and Eileen O. van Ravenswaay. (FAP89-06) \$3.00
- "The Political Economics of California's Proposition 65," by Tim T. Phipps, Kristen Allen, and Julie A. Caswell. (FAP89-07) \$3.00

Center for Risk Management

- "Restricting Hazardous Materials Routes on the Nations' Railroads: Some Considerations for Regulatory Analysis," by Theodore S. Glickman. (CRM89-07) Free

Books from RFF on Water Resources

Markets for Federal Water

Subsidies, Property Rights, and the Bureau of Reclamation

Richard W. Wahl

Timely, authoritative, and well-written, this new book recommends major changes in reclamation law and in the Bureau of Reclamation's policies for administering its water supply contracts. The objective of the proposed changes is to enhance the potential for market transfers of federal irrigation water in the West. The author combines his insider's view of the Department of the Interior with dispassionate analysis of the economic implications of department policies and projects. The text includes historical background, analyses of recent departmental decisions, and case studies of market possibilities.

1989 • 326 pages • index • \$30.00 cloth

Scarce Water and Institutional Change

Kenneth D. Frederick, editor, with the assistance of Diana C. Gibbons

The authors assess alternative approaches to meeting long-term water needs and resolving conflicts among competing water users in five United States regional areas. This book argues that America's water supply problems are caused largely by bad habits and poor policies—especially policies that price water far under its true value.

1986 • 219 pages • \$22.50 cloth

The Economic Value of Water

Diana C. Gibbons

This study provides a framework for understanding water values and summarizes empirical evidence about the value of water in its principal uses—for municipal, household, irrigation, industry, waste assimilation, recreation and esthetics, navigation, and hydropower. The discussions of the measurement of various values, and of the ranges of values generally associated with particular uses, are of interest to water planners, engineers, economists, and environmentalists.

1986 • 113 pages • \$9.95 paper • An RFF Study

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