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John L. Crompton

To cite this article: John L. Crompton (2008) Empirical Evidence of the Contributions of Park and Conservation Lands to Environmental Sustainability: The Key to Repositioning the Parks Field, World Leisure Journal, 50:3, 154-172, DOI: [10.1080/04419057.2008.9674550](https://doi.org/10.1080/04419057.2008.9674550)

To link to this article: <https://doi.org/10.1080/04419057.2008.9674550>



Published online: 11 Mar 2011.



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Empirical Evidence of the Contributions of Park and Conservation Lands to Environmental Sustainability: The Key to Repositioning the Parks Field

JOHN L. CROMPTON
Texas A&M University

Abstract

Relatively concise executive summaries are provided for the scientific evidence supporting the parks field's contribution to five elements of environmental sustainability: protecting drinking water, controlling flooding, cleaning air, reducing energy costs, and preserving biological diversity. Given the importance of economics in government resource allocation decisions, the discussion stresses the potential economic returns from investments in parks that enhance environmental sustainability. By aligning with these five issues which are increasingly prominent on political agendas, it is suggested that parks can be repositioned from being relatively discretionary services to being a central element in the strategies used by government entities to address these issues of concern.

Keywords: *parks, repositioning, environmental sustainability, protecting drinking water, controlling flooding, cleaning air, reducing energy costs, preserving biological diversity*

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In most societies, investments in parks and other forms of publicly protected open space are viewed by elected officials as being relatively discretionary, nonessential expenditures on amenities which are nice to have if they can be afforded after the important essential

services have been funded. It has been suggested that the key to sustaining or increasing investments in parks is for them to be repositioned so they are perceived to contribute to alleviating problems which are of central concern to those responsible for allocating public

funds (Crompton, 2000). Such repositioning is likely to result in parks being perceived positively as part of the solution to a jurisdiction's problems, rather than as peripheral services that are "nice to have" but which are a drain on tax resources.

The "big idea" associated with repositioning is that funds are invested in solutions to a community's most pressing problems. The term "investing" suggests a positive, forward-looking agenda with a return on the investments. Elected officials usually have no mandate to fund programs; their mandate is to invest scarce resources wisely so they yield solutions.

The contributions that parks can provide to a community can be classified into three categories: economic prosperity, alleviating social problems and environmental sustainability. Their contributions to economic prosperity could include the role of parks in attracting tourists, attracting businesses, attracting retirees, enhancing real estate values, and stimulating sales of recreational equipment. Parks may alleviate social problems by contributing to reducing environmental stress, cultural and historical preservation, facilitating healthy lifestyles, alleviating deviant behavior among youth, raising levels of educational attainment, and alleviating unemployment distress.

The focus of this paper is the contribution of parks to the third category in that taxonomy, that of environmental sustainability. The intent is to provide a set of relatively concise executive summaries of the empirical evidence which documents the field's potential effectiveness in this domain. Positive environmental outcomes invariably result in positive economic outcomes and in the political arena it is almost always advantageous to frame an issue in economic terms when presenting a case to a legislative body.

Thus, the discussion stresses the potential economic returns from investment in parks that enhance environmental sustainability. This does not mean that parks and natural areas should be justified by their economic contributions alone. However, if no economic measure of their value is offered, then often it will be assumed by elected officials that they have no economic value. The costs of such

amenities are easy to calculate and the absence of a calculation of approximate economic benefits that offset them means there is an inherent imbalance in the information used to make decisions.

In the past decade, there has been a quantum increase in the cumulative scientific evidence that has emerged supporting the environmental contributions of parks and natural areas. The intent of this paper is to provide the field's advocates with a synthesis of these empirical findings which they can use to more effectively make their case with legislative bodies.

The term "environmental sustainability" is synonymous with "human sustainability" and "future prosperity." Without environmental integrity, human life is not sustainable and increments of environmental degradation result in decrements in future prosperity.

Environmental and ecosystem resources are sometimes referred to as "natural capital." As with other forms of capital, the value of natural capital can be depreciated. When green resources are depreciated, the services they provided are depreciated. The scientific evidence relating to five potential contributions of parks and natural areas to preserving those resources and enhancing environmental sustainability is reviewed in this paper: protecting drinking water; controlling flood; cleaning air; reducing energy costs; and preserving biological diversity.

Protecting drinking water

Water is in theory a quintessentially renewable resource. Most of the world's surface is covered in water and in many countries it falls with great regularity from the skies. Yet the carelessness and profligacy with which water resources have been used, the speed of population growth, and the increasing per capita demands for water, together mean that provision of adequate, safe supplies of drinking water is now a major source of concern and expense (Ducks Unlimited Canada, 2006). There is a clear link between the quality of water coming out of a catchment area and the extent of parkland, forests and conservation open land in that area. The relationship is widely recognized throughout the world and is

exemplified by approximately one-third (33 out of 105) of the world's largest cities obtaining a significant proportion of their drinking water directly from protected areas (Dudley & Stolton, 2003). Protecting water and protecting nature are synonymous, so protecting drinking water can provide sustainable funding for park and conservation lands.

If water flows quickly over the surface of the land, most of the pollutants the run-off carries will reach the main body of water. If the water flows more slowly or infiltrates the ground, more of the pollutants will be filtered out, either by adhering to plants and soil, or by being absorbed through plants' root systems. As water seeps through soil, the soil traps small particles and organisms suspended in it. The slowness of the flow allows suspended particles to drop from the water into the soil.

In addition to these natural filtration processes, micro-organisms in the soil break down pollutants in the water and purify it in the process (Heal, 2000). The powerful influence of park and conservation lands in protecting drinking water is exemplified by the following conclusion:

In a watershed with natural groundcover, about 50 percent of precipitation infiltrates the ground and only about 10 percent flows over the land surface as run-off. In a highly developed watershed, with its impervious surfaces and lack of vegetation, about 15 percent infiltrates and approximately 55 percent becomes surface runoff carrying sediment and pollutants to surface water bodies (Ernst, 2004a, p. 11).

Parks and conservation lands reduce the problem of sedimentation: the carrying or deposition of soil particles in water courses. Suspended soil in water supplies greatly increases the cost of making it potable. Strips of conservation land along streams are especially valuable since these riparian zones are probably the most critical of all the areas needing protection in a water catchment. Such zones can filter and immobilize sediment and other water contaminants, such as fertilizer and pesticide run-off, reducing water pollution.

There is a long tradition of park land being acquired for the primary purpose of protecting water supplies. For example, when legislation was passed by New York State in 1885 declaring the Adirondack Forest Preserve be "kept forever as wild forest lands" the primary driving force was to ensure "a regulated water supply for New York's rivers and canals" (Nash, 1973, p. 108). Thus, it has long been recognized that natural lands such as forests, parks and wetlands can help slow and filter water before it gets to rivers, reservoirs or aquifers, keeping those drinking water sources cleaner and making treatment cheaper.

A study of 27 water suppliers, found that water treatment costs for utilities using primarily surface water supplies varied depending on the amount of forest cover in the watershed. For every 10 percent increase in forest cover in the source area (up to about 60 percent forest cover), treatment and chemical costs decreased by approximately 20%. Approximately 50 to 55 percent of the variation in operating treatment costs could be explained by the percent of forest cover in the source area (Ernst, Gullick & Nixon, 2007).

Increasingly, there is a willingness to acquire land or easements protecting water courses because the cost of doing so is lower than paying for treatment plants to filter polluted water. A prime example was the decision of New York City in 1997 to invest between \$1 billion and \$1.5 billion in acquiring land and conservation easements in hydrologically sensitive areas (such as near reservoirs, wetlands and watercourses) in the Catskill Mountains from which it derives some of its water supply. Increased development and intensity of dairy farming in the area had led to deterioration in water quality. The alternative was to construct an additional filtration plant at a cost of \$6 – 8 billion, which would also have an annual operating cost of \$300-500 million. This case has widespread implications because when the costs and benefits of constructing a filtration plant or maintaining and repairing the natural filtration systems that had been purifying the city's water all along were weighed, nature won. A more detailed description of the case is given in Figure 1.

Figure 1. Protecting New York's Drinking Water

The Catskill/Delaware Watershed, the heart of New York's purification and delivery system is named after the two major rivers flowing from it. The rural landscape is famed as a scene of great beauty, with sun-struck slopes, glistening streams, and trees that explode in color each fall. Less well known is that it's also a highly efficient and valuable machine.

The cogs are 2,000 square miles of crop-filled valleys and mountains blanketed in forest, all connected by meandering streams feeding into an extensive system of nineteen reservoirs. For nearly a century, the complex natural system has been delivering water of exceptional purity to the people of New York City and several upstate counties. In recent years, it has produced as much as 1.8 billion gallons per day, serving New Yorkers with a healthy drink whose taste and clarity have been the envy of mayors throughout the United States. Indeed, in the 1930s and 1940s it was bottled and sold in other cities, such was its reputation. It was the equivalent of Evian or Perrier today. And unlike the case in most other large U.S. cities, New York's tap water has never passed through a filtration plant.

Instead, the water, born as rain and melted snow on mountaintops as far as 125 miles away from those who will ultimately drink it, is naturally cleansed as it makes its way downhill toward the reservoirs. Beneath the forest floor, soil and fine roots filter the water and hidden micro-organisms break down contaminants. In the streams, plants absorb as much as half of the surplus nutrients running into the waterway, such as nitrogen from automobile emissions and fertilizer and manure used on nearby farms. In open stretches, wetlands continue the filtering as cattails and other plants voraciously take up nutrients while trapping sediment and heavy metals. After reaching the reservoirs, the water is further cleansed as it sits and waits. Dead algae, floating branches and leaves, and remaining particles of grit slowly sink to the bottom. Some pathogens left in the water may bind to the grit and settle, too.

The mostly natural process - supplemented by small doses of chlorine and fluoride at the end of the water's journey - worked beautifully for most of the twentieth century. But then signs appeared of some mechanical failures. The trouble was relentless new development: roads, subdivisions, and second homes were popping up all over the watershed, most of which is privately owned. Failing septic systems were leaking raw sewage into streams. Farming and forestry were also taking a toll, with lawn chemicals, fertilizers, pesticides, and manure all being washed into the reservoirs at an unprecedented rate.

By 1989, these problems could no longer be ignored. The Congress that year amended the Safe Drinking Water Act, putting into motion a major review of the country's drinking water systems. New York City was faced with the potentially enormous cost of an artificial water filtration plant, estimated to cost between \$6-8 billion, plus yearly maintenance expenses amounting to \$350-\$500 million. Given that price tag, city officials engaged in vigorous lobbying and won agreement from federal regulators to try the alternative of a watershed protection program capable of guaranteeing water quality indefinitely. Rather than pay for the costly new filtration plant, the city would spend the much smaller amount of about \$1.5 billion to protect the upstate watershed, including buying tracts of land as buffers and upgrading upstate sewage treatment plants. The EPA, in turn, would grant a five-year reprieve of its order, with the possibility of renewal.

The scheme was seriously challenged as powerful developers filed suit, claiming that property values would plummet as the city imposed restrictions on new construction. Environmentalists, on the other hand, criticized the city's efforts as too weak. Nevertheless, the proposal was enacted and a major government entity invested in natural restoration,

treating it as a precious piece of infrastructure. The labor of an ecosystem which had been previously regarded as “free” was shown to have a substantial quantifiable economic value.

In 1997 the city floated an environmental bond issue using the proceeds to restore the functioning of the Catskills watershed. Restoration actions to date have been of several types. They include improving sewage treatment in the watershed by installing new systems and improving old ones. They also include buying some 100,000 acres of land in and around the watershed to prevent development and to control agricultural use. In addition, the city used some of the money to purchase conservation easements from existing land owners whose land it did not buy outright.

Some of the measures have contributed additional income to farmers. One of these involves paying farmers not to grow crops or graze cattle along the banks of streams feeding the watershed. Payments are in the range of \$100 to \$150 per acre. The intention is to prevent a significant source of pollution - runoff of fertilizers, weed-killers, and pesticides. Keeping animals out of the streams also reduces the risk of cryptosporidium. Neither filtration nor chlorination can remove the organisms that cause this disease. One of the participants in the negotiations commented that society has to arrange that farmers in the region are paid to produce environmental benefits as well as food.

New York City owns less than 8% of the land in the 2,000 square-mile watershed. An important aspect of the New York story is that by improving sewage systems in the Catskills, by initiating other measures to reduce pollution there, and by buying conservation easements, New York City has improved the Catskills community’s quality of life and injected a considerable amount of income into the region. The Catskills ecosystem has value for its beauty, as wildlife habitat and for recreation, particularly trout fishing. Restored habitat for trout and other game fish attracts fishermen. These are powerful economic engines for the area. Thus in adopting this strategy, New York City has provided some financial compensation to area residents and given them a direct financial stake in the conservation, as well as safeguarding New York City’s water supply.

Sources: Daly and Ellison (2002) and Heal (2000).

It should be noted that while the natural area’s role in protecting New York City’s drinking water supply is shown to be a financially significant contribution of these Catskill lands, it is only one of its contributions. The expenditure saved on the filtration plant is only one of a series of ecosystem values that could be included in measuring the total economic contributions of these lands.

A host of case studies documenting the key role of park and conservation lands in protecting drinking water have been published by conservation organizations in the past decade (Ducks Unlimited Canada, 2006; Harper, 2004; Dudley & Stolton, 2003; Heal, 2000; Ernst, 2004a; Stapleton, 1997; Ernst 2004b). An increasing number of cities have created dedicated funds for this purpose. For example,

Dade County, Florida, imposes a 3 percent surcharge on water bills; in Spokane, Washington, residents pay \$15 a year specifically for aquifer protection; Providence, Rhode Island, collects a 1 cent/100 gallon water usage tax specifically to fund watershed acquisitions (Heal, 2000). It has been observed that:

About 700 of the nation’s surface-water systems in the U.S. are unfiltered, with about 130 legally avoiding filtration through ownership of the source. The remainder are under pressure from the EPA to install filtration plants. Many of these could benefit economically from watershed protection. It has been calculated that within the continental forty-eight states an extension of economically

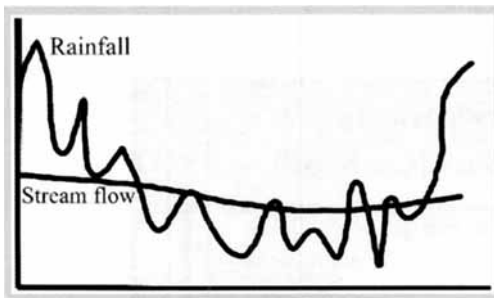
justified watershed protection could lead to protection of 10 percent of their land area (Heal, 2000, p. 57).

As long ago as 1991, the American Water Works Association pointed out that for watershed protection “the most effective way to ensure the long-term protection of water supplies is through land ownership by the water supplier and its cooperative public jurisdictions” (Ernst, 2004b, p. 11). Contemporary investment in this approach suggests that many elected officials and increasing numbers of the public recognize the superiority of this approach over paying for increased filtration and treatment plants.

Controlling flooding

When heavy rainfalls occur and flooding results, it is testimony that the efficient and effective drainage system created by nature has been abused. The abuse takes two forms: (i) the overdevelopment of watersheds; and (ii) the infilling of floodplains for development. The creation of substantial park or conservation areas in the watersheds and the preservation of the floodplains as greenways can contribute substantially to preventing the occurrence of such flooding.

Figure 2. The Role of Natural Areas on Stabilizing Rainwater Flows



Source: Heal (2000)

Rain tends to fall in short, heavy bursts which generate an uneven flow of water. Natural areas are absorbent and soak up the water as rain falls, acting like a huge sponge. These areas then release the water slowly over

time, thereby stabilizing the pattern of stream flow (Heal, 2000). This stabilization role is shown in Figure 2. Increased run-off creates higher peaks. A decrease in the elapsed time between the onset of a storm and when the peaks occur is costly to a city, since the capacity of drainage systems must be designed for peak runoff conditions which also is likely to increase downstream flooding (Nowak, Wang & Endreny, 2007).

When natural areas on watersheds are replaced by development, the natural sponge is removed and has to be replaced with a substantial built infrastructure to accommodate stormwater runoff which is both more expensive and less effective than the natural mechanisms. The traditional approach is to collect stormwater runoff by curbing and gutters which direct it to an inlet. Once at the inlet, the water flows underground inside a pipe until discharged into a channel. Without the absorption role of natural areas, the volume of water entering a channel after a storm is greatly increased while the time it takes to get there is greatly decreased. Further, concreting, piping, levees, digging new channels and other “hard” engineering solutions in one location frequently create a problem in a downstream location.

Parks and protected open space areas with coverings of trees and vegetation make two specific contributions to controlling stormwater runoff. First, their roots hold the soil in place which reduces soil erosion and, in turn, a loss of the flow-control function of the watershed. Second, they intercept and hold rainfall with their foliage, slowing the rate at which it reaches the ground and allowing some of it to evaporate.

The value of trees for stormwater management has been calculated based on avoided costs of handling stormwater runoff. Local costs are multiplied by the total volume of avoided storage to determine dollars saved by trees. Thus, for example, in the Houston area, the existing tree canopy reduces the stormwater capacity need by 2.4 billion cubic feet. The cost of creating stormwater capacity in Houston is 66 cents per cubic foot, so trees currently save the area \$1.33 billion in one-

time construction costs (American Forests, 2000).

There is really no effective substitute for the flow-control role of watersheds: "Complex and extensive engineering projects have been developed to replace the flow-control function of watersheds; however, in most cases these have proved inadequate and indeed in some cases counterproductive" (Heal, 2000, p. 48). The economic value of natural areas in this role (and in their role of purifying waters) is immense, often exceeding any value they may have as agricultural land or residential developments. However, this economic value is often unnoticed.

The second primary source of flooding is the infilling of floodplains. If these are protected in full as natural park/greenway areas, substantial cost savings are likely to accrue to a community. Floodplains are defined as the lowlands adjoining the channels of rivers, streams or other watercourses, or the shorelines of oceans, lakes, or other bodies of standing water. In his pioneering book in the 1960s, Whyte observed:

A flood plain is a great sponge. When the rains and floods come, it soaks up an enormous amount of water, returns a good part of it to the underlying water table, and then over a period of days and weeks slowly releases the rest. Building on flood plains hurts people. It is not only a question of what happens to the unfor-

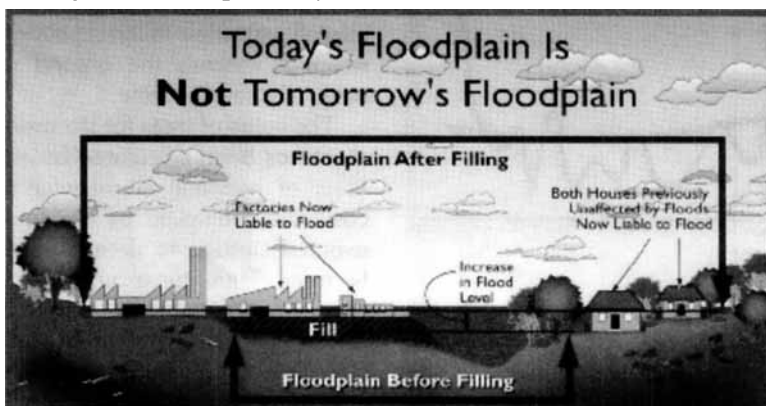
unately who live in the houses that will be inundated but to the people downstream (Whyte, 1968, p. 40).

In short, floodplains provide natural flood-water storage areas. Despite this warning, large areas of floodplains continue to be filled to facilitate development.

Figure 3 illustrates the consequence of these actions. It shows that if large areas of the floodplain are filled, then structures that were previously outside the natural floodplain will be flooded unless remedial action is taken (Association of State Flood Plain Managers, 2004). Consequently, major investments are made in structural measures such as dredging, channeling, concreting, and building dikes and levees. This is expensive; tends to deflect the flooding to downstream areas, rather than resolve it; and periodically fails in times of atypical storms, with disastrous consequences. The public pays the large bills for these infrastructure "improvements" and, thus, retrospectively provides a subsidy to developers for building where they shouldn't. Despite 75 years of large investments in federal flood control embracing these man-made "solutions" and over 30 years of the National Flood Insurance Program, the annual cost of losses from flooding has inexorably risen every year.

The harm that has been caused by the wholesale alteration of one of nature's essential ecosystems has now belatedly been recognized. Serving their natural functions,

Figure 3. The Consequences of Filling in Floodplains



Source: Association of State Floodplain Managers (2004).

floodplains are vast absorptive reservoirs of floodwaters; they are the earth's primary filter and dissolver of waterborne contaminants; their coastal marshes and riverine wetlands provide the creative essentials for countless forms of life; and left to themselves, floodplains and the life they generate offer enjoyment and recreation (Association of State Flood Plain Managers, 2004).

The U.S. Corps of Engineers historically viewed dams and levees as the solution for flooding problems but in the 1980s and 1990s, spurred by a slew of environmental regulations designed to save wetlands and endangered species, the Corps began to recognize that natural restoration was often a superior solution to flooding. For example, in the 1980s instead of damming the Charles River around Boston, the Corps purchased 8,500 acres of floodplain wetlands to prevent construction on them. The engineers calculated that letting the floodplain "store" the water would be just as effective as the proposed dam. The land cost was \$10 million, a tenth of the \$100 million the Corps estimated it would take to build the dam and levees that were originally proposed. After the Mississippi flooded in 1993, despite the Corps' tall levees and deep dredging, the federal government invested hundreds of millions of dollars to buy and demolish thousands of riverbank homes and businesses, restoring the natural floodplain and tacitly conceding that flood control was a losing proposition (Sheaffer, Mullan & Hinch, 2002).

The economic value of natural floodplains can be estimated by comparing it to the alternative cost of engineered storage space. For example, a research study conducted for the Forest Preserve District of Cook County, Illinois, found that the average cost of constructing engineered storage for floodwaters was \$13,085 per acre-foot (Sheaffer, Mullan & Hinch, 2002). This study showed that each acre of floodplain owned by the District provided an average of four acre-feet of storage. Thus, the natural value of floodplain storage in this urbanized regional setting was estimated to be \$52,340 per acre (4 acre-feet x \$13,085 per acre-foot). These values were

based on the present worth of the benefits accrued over 20 years.

Government agencies responsible for calculating benefits of floodplain management tend to primarily focus on flood-loss reduction and fail to include the benefits of managing floodplains as assets. Each acre of well-managed floodplain produces natural values, which can be expressed in monetary terms. For example, a study of the multipurpose Salt Creek Greenway applied this method of evaluating floodplain benefits to the nearly 3,500 acres of floodplain land in Cook and DuPage Counties, Illinois (Sheaffer, Mullan & Hinch (2002).

Table 1. Examples of Quantified Natural Values of Floodplain Land

| Benefit Category | (\$/acre) |
|--|------------------|
| Wastewater reclamation and reuse (nutrient recycling and irrigation to eliminate the discharge of pollutants) | 3,177 |
| Pollution abatement | |
| Nonpoint source (filtration, erosion control) | 1,165 |
| Infiltration and inflow reduction | 610 |
| Subtotal, pollution abatement | 1,775 |
| Aquifer recharge | 504 |
| Recreation | 2,721 |
| Total natural value of multipurpose greenway | 8,177 |
| Regional floodwater storage | 52,340 |
| Total natural and regional value | 60,517 |

Source: The Forest Preserve District of Cook County, Illinois, *An Evaluation of Floodwater Storage*, February 1998, and Illinois Department of Conservation, *The Salt Creek Greenway Plan*, 1993.

The sum of the natural values of floodplain land was found in this case study to be \$8,177 per acre (Table 1). In this example of wise use, flood losses were estimated to be reduced by \$630 per acre. Thus, in the Salt Creek Greenway example, the natural values associated with the wise use of the floodplain were more than 10 times the narrow, single-

purpose flood loss-reduction benefit. These results suggest that an adequate assessment of benefits should include the natural values as well as the flood loss-reduction benefits. The value of natural floodplain storage of \$52,340 per acre in the Forest Preserve District of Cook County can be applied to the Salt Creek Greenway. When this value is added to the \$8,177 calculated for natural values (filtration, aquifer recharge, recreational areas, etc.), the total value of wise use of floodplain land in the expanding metropolitan area of Cook County is \$60,517 per acre (Table 1).

The Katrina hurricane in 2005 dramatically reinforced public awareness of the limitations of man-made structures in protecting against coastal flooding when the levees protecting New Orleans failed. Natural systems such as wetlands, marshes and barrier beaches provide a level of protection against coastal storm events. The Gulf coast is rapidly losing both the barrier islands and the coastal wetlands that buffer the impact of hurricanes and flooding of the Gulf coast and southeast Louisiana. These demonstrations of the failure of expensive man-made structures presumably will consolidate support for ensuring development will be undertaken in a manner that respects natural process and the critical contributions of wetlands, greenways and protected open space.

Cleaning air

Trees, other vegetation and soils enhance air quality by removing from the atmosphere: (i) ozone and other gaseous pollutants and toxic chemicals such as nitrogen dioxide, sulphur dioxide, formaldehyde, benzene and hydrogen fluoride; (ii) particulate pollutants; and (iii) carbon dioxide.

Soils have considerable capacity to remove gases from the atmosphere and to transform them through microbial, physical and chemical processes. Vegetation can aid the process by effectively cleaning the soil in its root zones of many toxic man-made chemicals.

Vegetation removes gaseous pollution primarily through its leaves. Pollutants such as ozone, hydrogen fluoride, sulphur dioxide and nitrogen dioxide which are soluble in water are

most easily absorbed by leaf surfaces. When vegetative surfaces are wet and damp, the pollutant removal rate may increase up to ten-fold. Under damp conditions, the entire plant surface – leaves, twigs, branches, and stems – is available for uptake (Galveston-Houston Association for Smog Prevention, 1999).

In the 1980s when atmospheric chemists began measuring emissions from trees, prominence was given to the contention that trees were a creator of pollution rather than an alleviator of it. Unfortunately, this widely publicized conclusion resulted from a distortion and misuse of the data. Like all living things, trees emit certain substances as by-products of their metabolism. Some of these substances are classified as volatile organic compounds (VOCs) so called because they evaporate easily into the air and react readily with other molecules.

Ground level ozone pollution is produced by a series of complex chemical reactions primarily involving VOCs, nitrogen oxides and sunlight. The presence alone of VOCs does not lead to ozone formation. In order for ozone to form, nitrogen oxides must be present. Nitrogen oxide is a man-made pollutant produced by cars, trucks, power companies, industry, gasoline-powered lawn equipment, fireplaces, gas furnaces, gas stoves, et al. The cooling effect of vegetation which is discussed later in this paper under Reducing Energy Costs inhibits this chemical process because: (i) the rate of vaporization of VOCs increases with temperature; and (ii) the formation of ozone itself is heat dependent, that is, VOCs and nitrogen dioxide mix in sunlight at higher temperatures to form ozone. Lower temperatures mean lower ozone levels:

Is it fair then to say that trees pollute? The best and most accurate answer is no. Trees do have emissions, but "pollution" and "emission" are not synonymous terms. Embedded in the word pollution is the concept of harm – whether to health or property or ecosystems. By themselves, the chemicals emitted by plants not only do no harm but appear to play a vital role in creating healthy envi-

ronments – for plants and for people (Galveston-Houston Association for Smog Prevention, 1999, p. 8).

To calculate the value of the pollution removed by trees, economists multiply the number of tons of pollutants removed by the costs that society would have paid, in areas such as health care, if trees did not remove these pollutants. In a study of their impact on the Houston area, for example, it was found that the area's existing tree canopy removed 83 million pounds of pollutants, valued at \$208 million, annually. Specifically the tree cover removed 35.4 million pounds of ozone (valued at \$109 million), 6.55 million pounds of sulphur dioxide (valued at \$5 million), 12.2 million pounds of nitrogen dioxide (valued at \$37 million), and 1.7 million pounds of carbon monoxide (valued at \$1.7 million) (Galveston-Houston Association for Smog Prevention, 1999).

Trees and soils also help to remove particulates from the air. Increased levels of tiny particulates (10 microns or smaller in diameter) in the air as a result of combustion (cars, lawn mowers, industrial processes) have been correlated in numerous studies with increased respiratory disease, asthma, and cardiovascular and respiratory mortality (Galveston-Houston Association for Smog Prevention, 1999). Some particles can be absorbed into the tree, but most intercepted particles are retained on the plant surface. Thus, vegetation may be only a temporary retention site for some of the atmospheric particles as they may be resuspended to the atmosphere, washed off by rain, or dropped to the ground with leaf and twig fall (Scott, McPherson & Simpson, 1998).

The adverse impact of fine particle air pollution was quantified in a study of 66,000 women reported in the *New England Journal of Medicine* (Miller et al., 2007). It found that women in the worst-polluted cities had a 76 percent greater chance of dying from heart ailments than those in the least-polluted cities. Fine particles, often appearing as smoke or haze, are emitted by a variety of sources, from power plants, industrial factories, fires, as well

as automobile exhaust. Because they are so small, they can bore deep into the lungs and bloodstream, and trigger heart attacks.

Carbon dioxide is one of the "greenhouse" gases and its increased levels are thought to be the primary cause of global warming. They are attributable almost entirely to increased fossil fuel combustion and to deforestation (McPherson, Nowak & Rowntree, 1994). Trees reduce atmospheric carbon dioxide in two ways: (i) they directly sequester it as woody and folian biomass while they grow; and (ii) trees around buildings reduce heating and cooling demand, thereby reducing emissions from generating plants. This latter role of trees is discussed later in this paper in the section on reducing energy costs.

On average each person in the United States generates 2.3 tons of carbon dioxide every year, almost half of which comes from driving an automobile. An acre of trees absorbs enough carbon dioxide over a year's time to equal the amount produced by driving a car 26,000 miles (Galveston-Houston Association for Smog Prevention, 1999). In the Chicago area, the U.S. Forest Service calculated that a single tree with a trunk circumference of 30 inches removed 200 pounds of carbon dioxide, 1.1 pounds of ozone, and 2 pounds each of sulphur dioxide, particulates and nitrogen dioxide every year. The study calculated that Chicago-area trees store a total of 6.1 million tons of carbon. Large trees were found to store up to 1,000 times more carbon than small trees, and the rate of storage by large trees was approximately 90 times greater than the rate of storage by small trees (McPherson, Nowak & Rowntree, 1994)

It has been calculated that planting trees is the least expensive way to reduce atmospheric carbon dioxide. Tree planting removes one pound of carbon dioxide for about 1 cent, whereas driving more efficient cars costs about 10 cents per pound. If every American family planted just one tree, the amount of carbon dioxide in the atmosphere would be reduced by one billion pounds annually. This is almost 5% of the amount that human activity worldwide pumps into the atmosphere each year (American Forestry Association, 1992).

Utility companies that emit large amounts of carbon dioxide into the atmosphere are now investing in reforestation projects to mitigate their pollution. This approach is known as carbon sequestration. For example, American Electric Power completed the nation's first large-scale carbon sequestration through a reforestation project by acquiring 10,000 acres and reforesting 18,000 acres, and then transferring the land so it became part of the Catahoula National Wildlife Refuge in Louisiana. It was a relatively inexpensive way to offset their carbon dioxide emissions, costing less than \$10 per ton sequestered (Turner, 2006).

There are two conditions which could at least partially nullify potential air quality gains. First, the gains could be affected by pollution associated with tree maintenance activities. Various types of equipment are used to plant, maintain, and remove vegetation in cities. This equipment includes various vehicles for transport or maintenance, chain saws, back hoes, leaf blowers, chippers, and shredders. The use and combustion of fossil fuels to power this equipment leads to the emission of carbon dioxide and other chemicals such as carbon monoxide, nitrogen and sulfur oxides, and particulate matter (Nowak, 2000).

The second condition that could nullify gains is the failure to sustain a tree planting program over the long term. Nearly all the carbon sequestered by trees eventually will be converted back to carbon dioxide due to decomposition after the tree dies. Hence, the benefits of carbon sequestration will be relatively short-lived if the vegetation structure is not sustained. The goal should be to reach an equilibrium with sequestration by replacement plantings offsetting decomposition from dead trees.

A summary of the strategies that can be used by park agencies to improve air quality through the medium of trees is given in Table 2.

Beyond their role in aiding air quality, the economic value of trees in the ecological system includes alleviating flooding and reducing energy costs. The U.S. Forest Service has developed its Urban Forest Effects (UFORE) Model to enable planners and managers in local communities to measure the contribution

Table 2. Strategies to Help Improve Air Quality Through the use of Trees

- Increase the number of healthy trees (increases pollution removal)
- Sustain existing tree cover (maintains pollution removal levels)
- Minimize use of high VOC emitting trees (reduces ozone and carbon monoxide formation)
- Sustain healthy, large, low VOC emitting trees (large trees have greatest per tree effects)
- Use long-lived trees (reduces long-term pollutants emissions from planing and removal activities)
- Use low maintenance trees (reduces pollutants emissions from maintenance activities)
- Reduce fossil fuel use in maintaining vegetation (reduces pollutant emissions)
- Plant trees in energy conserving locations (reduces pollutant emissions from power plants)
- Plant trees to shade parked cars (reduces vehicular VOC emissions)
- Supply ample water to vegetation (enhances pollution removal and temperature reduction)
- Plant trees in polluted areas or heavily populated areas (maximizes tree air quality benefits)
- Avoid pollutant sensitive species (increases tree health)
- Utilize evergreen trees for particulate matter reduction (year-round removal of particles)

Source: Nowak, D.J. (2000).

of their trees (USDA Forest Service, 2007). Similarly, a conservation organization, American Forests, has built its user-friendly Urban Forest Ecosystems (UFE) Model to enable local communities to estimate the economic value attributable to their trees (American Forests, 2007).

Traffic's role in generating air pollution is well-documented. For example, as much as 50 percent of ground-level ozone pollution is a result of motor vehicle exhaust. This both triggers asthma attacks and causes asthma which is the number one reason children visit the emergency room and miss school. A study in Atlanta during the 1996 Olympic Games documented a significant drop in children's asthma attacks when single-occupancy vehicle use decreased due to the Games (Surface Transportation Policy Project, 2005).

Vehicles are now equipped with high efficiency catalytic converters which eliminate 95% of the pollution produced during normal driving. Most pollution is now emitted in the first few minutes of driving, before the catalytic converter has warmed up. This means that the most effective strategy to reduce pollution is to reduce the number of trips taken by car (Surface Transportation Policy Project, 2005).

The United States is served by a comprehensive network of roads, but a primary challenge is how to alleviate the traffic congestion clogging those roads. A part of the solution is to provide people with options to avoid it entirely, and hike and bike trails are one of those options. Those who choose not to avoid congestion, or who are unable to do so, also benefit from hike and bike trail users because the reduced number of cars on the road network means that it is less congested.

In the U.S., the President's Commission on Americans Outdoors (1987) reported there was a clamor for outdoor recreational facilities close to home. Their response was to articulate a vision of a system of recreational corridors: "fingers of green that reach out from and around and through communities all across America" (p. 142). They called for a "prairie fire of local action" (p. 73) to implement the vision. The fire has been ignited by the availability of substantial funds for this purpose in successive federal transportation acts since 1992. As a result, the most popular outdoor recreational activities in the U.S. are now those associated with urban trails – walking, jogging, biking, roller blading, et al.

Reducing energy costs

The contributions of trees to reducing energy costs occur at both the micro level of shading individual structures from solar heat and/or winter winds, and at the community level of mitigating the "urban heat island" effect. A substantial amount of empirical research on these contributions has been reported in the past decade. This effort has been led by researchers from the U.S. Forest Service, but supplemented by many others. The process by which shade trees contribute to reducing energy costs is described below:

Shade trees reduce solar heat gain by transferring the active heat-absorbing surface from an inert building envelope to living foliage. Because the heat capacity of leaves is low, most of this energy is transferred to the surrounding air. If ample soil moisture is present and environmental conditions are suitable, water in the leaves evaporates in a process known as evapotranspiration and the air is cooled (McPherson & Simpson, 1995, p. 12).

Although the main source of solar heating is usually through windows, radiant energy absorbed by walls and roofs is conducted into buildings and also significantly affects heating and cooling costs.

Planting deciduous trees on the sides of a house which shade it from the summer sun and around air-conditioners saves homeowners the cost of artificially cooling their house by an equivalent amount. Typically, two or three shade trees are sufficient to generate the potential energy savings for a house if they are carefully located. When trees are optimally located to shade a house, the data typically show annual energy cost reductions for cooling between 10% and 50% (Simpson & McPherson, 1996).

The positive impact of tree shade varies with species, direction and distance of trees relative to buildings, climate, time of the year, occupant behavior, and/or orientation of the building surface. Most potential energy savings will occur in areas with relatively long cooling seasons; large numbers of air-conditioned small buildings, such as single family homes, duplexes and mobile homes; and ample space for new tree planting.

Wind contributes to the infiltration of outside air into buildings and may account for one-third of the heat loss from a house in winter (Heisler, 1986). Thus, the planting of trees to act as a windbreak can reduce the costs of heating a home.

There are three potential negative consequences on energy costs associated with shade trees. First, surfaces heated by the sun become warmer when wind speed is low.

Thus, reduction in energy costs accruing from the effectiveness of trees as a wind break in winter may be partially offset by increases in costs resulting from less wind in the summer. Second, while trees offer shade in the summer, their presence may block solar heat from reaching a house in the winter which adversely counters some of the savings from cooling load reduction. Planting deciduous trees will reduce this negative consequence, but even their bare limbs are likely to result in some blockage. Finally, trees that overhang roofs can reduce heat loss to the cool summer sky at night. However, the aggregate impact of these negative consequences is likely to be far exceeded by the positive energy cost savings resulting from shade trees.

On average, developed areas of cities are 5°- 9°F warmer than the rural areas that surround them. This is termed "the urban heat island effect" (Figure 4). Three factors contribute to this. First, taller buildings prevent the concrete surfaces from losing heat because they act as a shield against the colder night air. Second, concrete and asphalt have a high heat capacity and thermal conductivity level. Since these surfaces retain heat, they stay hotter longer. Thus, after the sun sets, these hot surfaces continue to release their stored heat. Third, and most importantly, the lack of vegeta-

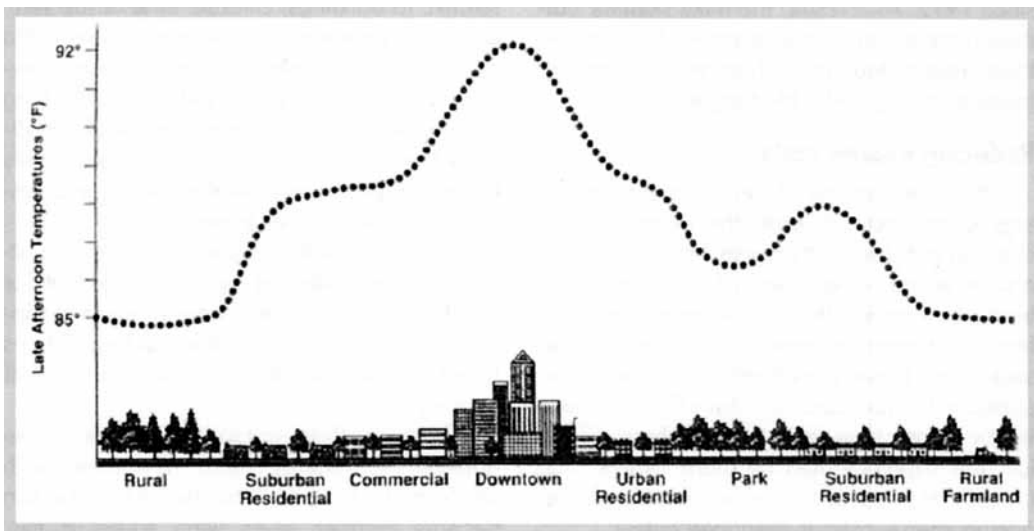
tion prevents cooling by evapotranspiration. Through their evapotranspiration process, trees act as natural "evaporative coolers" using hundreds of gallons of water a day, thus lowering the ambient temperature. A single large tree can transpire up to 100 gallons of water a day, producing a cooling effect similar to that of five average air conditioners running for 20 hours (Akbari, Davis, Dorsano, Huang & Winnett, 1992).

Increases in urban trees mean buildings in these environments require less cooling power and energy from fossil fuel powerplants (Thus, also reducing the carbon dioxide pollution and unhealthy ozone levels produced by these plants).

It has been observed that:

Rapid urbanization in the United States during the past fifty years has been associated with a steady increase in downtown temperature of about 1°F (0.8°C) per decade. The demand for electricity in U.S. cities increases about 2 percent for every degree F (3-4% per °C) rise in temperature, and approximately 3 to 8 percent of the electricity used for cooling is needed to compensate for this urban heat island effect (McPherson, Rowntree & Wager, 1995, p. 151).

Figure 4. Urban Heat Island Profile



A review of the empirical findings concluded: "Large parks or residential neighborhoods with extensive vegetation can produce air temperature reductions as great as 10°F compared to nearby areas with little vegetation" (McPerson & Simpson, 1995, p. 12).

Numerous studies have reported the magnitude of savings associated with tree cover. For example, in Houston, residents spent approximately \$714 per home on air-conditioning. The existing tree canopy in the city saved an average homeowner \$72 per year. Thus, the aggregate annual savings to the city's homeowners was approximately \$26 million per year (American Forests, 2000).

Despite the multiple economic advantages associated with trees and their aesthetic popularity with the general public, acquiring funding for large scale urban forestry improvements has been difficult for park and conservation agencies. In the past decade, however, electric utilities have emerged as viable partners to fill this financial vacuum in some communities.

From the perspective of utilities, tree-planting programs are a form of demand-side management with a tangible economic value to the utility which can be quantified based on avoided supply costs, or the decrease in supply costs to the utility due to reduced building

Table 3. Benefit Cost Analysis of the Trees for a Green LA Program

The analysis was based on 200,000 five gallon trees being trees being planted in the first two years at a unit cost of \$40 (i.e. a total budget of \$8 million). A 30 year stream of benefits was projected assuming:

- 70% of the trees planted survive after 30 years,
- 95% are planted in single family residential yards and 5% in parks and open space where trees do not shade buildings,
- 60% are planted in inland areas, where cooling loads and air conditioner saturations are greater in coastal areas, where the remaining 40% are assumed to be planted,
- and residential plantings are evenly distributed to shade the east, south, and west sides of homes.

Given these assumptions, the following monetary estimated were derived:

| Summary of Program Costs | | | |
|---------------------------------|----------------|-------------|--------------------|
| Type | Number | Avg \$/tree | Total Cost |
| Yard Trees | 190,000 | \$40 | \$7,600,000 |
| Park Trees | 10,000 | \$40 | \$400,000 |
| Total Trees | 200,000 | \$40 | \$8,000,000 |

| Summary of Program Benefits | | | |
|------------------------------------|-------------------------|------------------------|------------------------|
| Type | *PV Benefits Yard Trees | *PV Benefit Park Trees | *PV Benefits All Trees |
| Energy | \$11,160,935 | \$211,383 | \$11,372,318 |
| CO ₂ | \$984,710 | \$42,467 | \$1,027,178 |
| Air Pollutions | \$87,108,236 | \$4,584,644 | \$91,692,880 |
| Stormwater | \$8,154,515 | \$429,185 | \$8,583,700 |
| Aesthetics | \$25,936,474 | \$1,365,078 | \$27,301,551 |
| TOTAL | \$133,3444,870 | \$6,632,757 | \$139,977,627 |

| Net Present Value (Benefits-Costs): | |
|--|--|
| Yard Trees: \$125,744,870 | Benefit to Cost Ratio (Benefits Costs): 17.5 |
| Park Trees: \$ 6232,757 | Benefit to Cost Ratio (Energy Only): 1.4 |
| Total Trees: \$131,977,627 | *PV = Net Present Value |

Source: McPherson, E.G. & Simpson, J.R. (2001). *Benefit-cost analysis of LAPWD: "Trees for a green LA" shade tree program*. California: USDA Forest Service, Center for Urban Forest Research, Davis.

electrical loads. Partnering with communities offers utilities an opportunity to assert a proactive civic leadership role and to reposition themselves from being sources of pollution to being environmentally sensitive.

The first such program was initiated by the Sacramento Municipal Utility District (SMUD) in 1991:

The primary objective of this program is to plant 500,000 trees that will directly shade residential buildings and thereby reduce summer air conditioning loads. A secondary objective of the Shade Tree program is to create an urban forest that will help mitigate the urban heat island effect, or the increase in summer outdoor temperatures typically caused by urban development. Additional indirect energy benefits of the program may result from the effects of trees as wind breaks, which may reduce infiltration of unconditional outside air into homes (Monitoring & Evaluation Group, 1995, p. 1).

The SMUD's investment in the program is approximately \$2 million per year. Individual home owners who want to participate attend a training session to learn about proper planting and maintenance of the trees. They receive trees in five-gallon containers free-of-charge and are then responsible for planting and caring for the trees received. The SMUD program offers 38 different species and distributes an average of 3.5 trees per residence.

The pioneering SMUD program provided a model which other utilities subsequently adopted and by 1994 almost 70 utilities across the country had done so. Perhaps the most ambitious program was launched in 2002 by the Los Angeles Department of Water and Power. Their long-term goal was to plant one million trees throughout the city of Los Angeles during the next 10 year period. The program was launched after a benefit-cost analysis undertaken by the USDA Forest Service, Center for Urban Forest Research, estimated that the benefit to cost ratio would be 1.4 to 1 for energy savings alone, and this extended to 17.5 to 1 for all benefits. De-

tails of their analysis are reported in Table 3 (McPherson & Simpson, 2001).

Preserving biological diversity

Biological diversity refers to the number of species of plants, animals and microorganisms present in a given area, but it also describes genetic diversity within a species and ecosystem diversity (Ducks Unlimited Canada, 2006). It includes all life forms from bacteria to birds and mammals, which may number 30 million species worldwide, although only 1.4 million of these have been named. Thus, it is concerned with the movement of organisms across landscapes and the movement of genes within and among populations of organisms.

Two decades ago, the word "biodiversity" did not exist. Today it has become a household word used as a synonym for the "variety of life." This extraordinary rise to prominence stems from a realization that it is disappearing, and that unlike pollution its losses cannot be reversed. Species extinction is now occurring at an unprecedented rate, resulting in decreasing levels of diversity. There are two main reasons for this. First, the destruction and fragmentation of habitats. The first 90 percent reduction in an area of habitat lowers the species number by one-half. The final 10 percent eliminates the second half (Wilson, 1993). Second, the reductionism of modern agriculture has resulted in the use of approximately 20 species of plants to produce most of the food for society, whereas historically 7,000 plant species were used for food (Harper, 2004).

The natural diversity of living things has great value in providing food, clothing, shelter, industrial products and medicine. Consider the following illustrative examples:

- One in four medicines and pharmaceuticals has its origin in the tissues of plants, and another one in four is derived from animals and microorganisms. If half of the new drugs being developed are produced from these sources, then loss of biodiversity represents a substantial loss in life chances for future generations. The story of taxol is salutary in illus-

trating what may be lost when species are exterminated:

Taxol is a compound in the bark of the Pacific yew tree. In the Pacific Northwest area of the U.S. loggers cleared it as a "trash tree." Researchers found that taxol damaged cancer cells that were unaffected by other drugs; it can help 100,000 Americans fight breast, lung and ovarian cancer, not as a cure, but by enabling patients to live longer with less pain. Taxol may soon no longer require bark because drug companies are trying to synthesize the active ingredient (Harper, 2004, p. 103).

- Many plants, marine invertebrates, fungi, microorganisms, reptiles and amphibians have evolved chemical defenses to protect them from their natural enemies or to subdue their prey. These compounds are effective because they are biologically active, with properties that disrupt the physiology of their target organisms. Those same properties often prove useful in medicine, either as defenses against human pathogens and parasites, or to influence human physiology towards some desired objective. Ultimately, these medicinal compounds may be produced synthetically in laboratories, "but we do not yet understand the biochemistry of life well enough to design drugs for our needs from first principles – we need to rely on the accumulated experimentation and experience of millions of species that share the planet with us to recommend solutions" (Kunin & Lawton, 1997, p. 291).

- Wild relatives of crops used as society's primary food source continue to be used to maintain resistance to disease, enhance the crops' vigor, and contribute in other ways to improving crop efficiency. This applies similarly to trees which are also crops. As genetic technology progresses, practically any organism with a novel arsenal of chemical defenses or weapons could become a genetic resource of potentially great agricultural value.

- More than 218,000 of the world's 250,000 flowering plants, including 70 percent of all species of food plants, rely on

pollinators for reproduction. More than 100,000 of these pollinators are invertebrates, including bees, moths, butterflies, beetles and flies. Another 1,000 or so vertebrate species including birds, mammals, and reptiles also pollinate plants. Pollination by honey bees and other species, for example, is essential for about \$30 billion of U.S. crops in addition to pollinating natural plant species. Humans have found no technology to substitute for this natural service (Harper, 2004).

- A species of bacteria discovered in the sediments of the Potomac River is capable of breaking down chlorofluorocarbons (CFCs) in anaerobic conditions. There are many organisms in nature with unusual metabolisms and appetites that could prove to be beneficial in cleaning up some pollution problems and could be of great significance in the rapidly developing field of industrial ecology (Wilson, 1984).

- The venoms of snakes, frogs and toads have yielded a variety of nerve and muscle drugs. For example, a South American pit viper might seem of little relevance to someone living in Washington, D.C. or Chicago, yet studies of the venom of one species of these vipers led to the discovery of the angiotensin system that regulates blood pressure in human beings. Once that system was known, it became possible to devise a molecule that alters blood pressure and is the preferred prescription drug for hypertension. This compound brings the Squibb Company \$1.3 billion a year in sales and contributes to the well-being and longevity of millions of people (Wilson, 1984).

- Ecotourism is perhaps the fastest growing segment of tourism and it rests on a foundation of biodiversity.

The diversity of existing species is an irreplaceable product of an eons-long evolutionary process which provides indispensable ecological services as well as food, industrial products and medicinal benefits. Those services include recycling waste, maintaining the chemical composition of the atmosphere, and influencing the world's climate. Further, since

only a small fraction of the planet's species have been identified and an even smaller fraction studied in any depth, the potential economic value far exceeds the known value. The extinction or genetic impoverishment of species forecloses the options and associated economic benefits for future generations:

If global nuclear war does not occur, then the worst catastrophe confronting the world – and it is already well underway – is not energy depletion, economic collapse, conventional war, or even the expansion of totalitarian governments. As tragic as these catastrophes would be for us, they can be repaired within a few generations. The one process now going on that will take millions of years to correct is the loss of genetic and species diversity by the destruction of natural habitats. This is the folly our descendants are least likely to forgive us (Wilson, 1984, p. 121).

Two high profile efforts in the U.S. have been made at the federal level to arrest the loss of biological diversity. First, the Endangered Species Act was passed in 1972. It has had a positive impact in retarding the process, but has not stopped it. Second, in the late 1980s President George H.W. Bush announced a national policy of "no net loss of wetlands." This gave wetlands protection and in the few extraordinary cases where they had to be destroyed, it required that mitigation be instigated in the form of creating new wetlands to replace those that were lost.

Park agencies can contribute to the preservation of biological diversity in two ways. First, by creating park areas. The larger the area, the more likely it is to be able to sustain biological diversity. While the largest and most effective sites are likely to be located in rural areas, urban parks can also contribute on a smaller scale to preserving diversity. Urban forests are particularly valuable. For example, 20 threatened or endangered faunal species and 130 plant species are listed in Cook County, the most populated county in the Chicago Metropolitan Area (Howenstine, 1993). However, for most species isolated

park sites are too fragmented to sustain them over the long term. The fragmentation means that there are likely to be too few individuals to be self-sustaining and that inbreeding is inevitable.

The field's second contribution is the creation of conservation corridors which link park and open space areas, and facilitate the biologically effective movement of animals between them. The corridors increase the likelihood of sustainability by enabling fresh individuals to access a site. They are transitional habitats providing sufficient resources for individuals to move between sites. Poorly conceived corridors can do more harm than good because they can be a death trap for dispersing individuals, draining off healthy animals from a source area but failing to deliver them to the destination area. In urban and suburban contexts, riparian corridors often can most easily be preserved to perform this function. The challenge for park agencies is to establish the corridors in advance of development because retrofitting the landscape with corridors is both politically difficult and expensive (Soute, 1991).

Concluding comments

The market value of "unused" land is likely to be relatively low, and is likely to increase substantially when it is converted for development, agriculture, or whatever. This leads to profits to individuals involved in expediting the conversions; increased jobs and incomes to those employed in such endeavors; and increased revenues from property and sales taxes to political jurisdictions responsible for authorizing such conversions. Thus, such conversions are encouraged by all the stakeholders involved.

The flaw in this calculus is that the substantial long term economic value of parks and natural areas in preserving natural ecological systems typically is ignored because it is not expressed in market values and is difficult to measure. Nevertheless, these ecological systems are responsible for providing such fundamentally valuable services as protecting drinking water, cleaning air, preserving biological diversity, regulating climate, controlling flood-

ing and sustaining ecotourism. It is difficult to put a dollar value on, for example, "clean air." The process of calculating the value of these ecological services is complex, but when it is done by economists the values invariably exceed the values accruing from converting the land to more intensive uses. Ecological economists maintain that environmental services are capital assets that, if managed well, provide a stream of economic benefits just as any good investment does.

Most decisions about land use are made locally and are relatively small scale. Ostensibly, they are marginal, insignificant and innocuous in affecting the major role of ecological services. However, it is the aggregation of these small decisions that leads to the overall negative impact, so ecosystem service values do need to be incorporated into them. The failure to measure the economic value of these services to society accounts for their deterioration and demise.

Each day, the U.S. loses more than 4,000 acres of open space to development; that is approximately three acres per minute and the rate of conversion is accelerating every year. The benefits discussed in this paper under separate headings are all interconnected and form part of a community's "green infrastructure." Park agencies should be in the vanguard of advocating that green infrastructure is considered in concert with development, planning and infrastructure decisions (Benedict & McMahon, 2006). It has been observed that:

Converting our natural landscapes may be economically inefficient in the long term. By destroying natural capital, we are forced to find substitutes for the services they once provided. The substitutes for natural capital can be much more expensive to duplicate and operate than those provided by nature. Also, there are many goods and services only natural capital can provide. There are no substitutes that humans can create (Ducks Unlimited Canada, 2006, p.1).

Thus, the creation of parklands, conservation areas, greenways and open space has

substantial economic value. Every society has three kinds of wealth: material, social and cultural, and biological. The first two are the substance of everyday life and so are highly visible. Biological and natural wealth tend to be under-appreciated because they are not often central to our consciousness (Harper, 2004).

In a seminal paper in the U.S. parks literature, Gray and Greben (1974) lamented, "We are not identified with the major problems which confront our total American Society" which they characterized as a "deep concern and disappointment" (p. 33). Thirty years later, many would observe that a similar lamentation could be made.

This paper has sought to demonstrate that the opportunity to reposition the field so it is "identified with the major problems" is available. The issues of protecting drinking water, controlling flooding, cleaning air, reducing energy costs, and preserving biological diversity all feature with increasing prominence on the political agenda. Aligning with these issues, and demonstrating that investments in parks yield good economic returns, is likely to move parks from being relatively discretionary services to being a central element in the repertoire of strategies used by government entities to address these issues of concern.

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JOHN L. CROMPTON
Distinguished Professor
Department of Recreation,
Park and Tourism Sciences
Texas A&M University
College Station, Texas, USA
mvyandyke@ag.tamu.edu