Chapter 1 – Strategic Conservation Matters

In July 2016, a Japanese company manufactured the last VCR, and there are probably a few holdouts who are grieving. Humans, for the most part, don't like change. Why, we wonder, does someone always have to go and muck up a perfectly familiar and predictable device, replacing it with some new form of technology that is going to cause confusion and may take a while to learn how to operate successfully? Eventually, we figure out how our newest smart phones work and realize we love their capabilities and have a hard time imagining living without them. But for many it's an unnerving and grumpy process put off for as long as possible. Inertia in the face of new technologies is an ancient human trait. Imagine the early human who first realized that tossing food into a fire was a good thing. You can bet the rest of the group had their doubts.

Now consider the implications of our resistance to change and new technologies in the context of environmental conservation. Environmental problems such as air and water pollution or endangered species protection have been referred to as "wicked problems." They tend to be extremely complex, involving natural sciences, social sciences, and engineering, and the money needed to solve these problems is far from trivial—in the United States alone, an estimated $10 billion are spent annually. Globally the annual expenditures are approximately $30 billion). Since environmental issues broadly effect the public, the major sources of funding have traditionally relied on public money collected from taxpayers, and the idea of raising and spending tax money is politically sensitive. In general, the more politically charged a problem is, the greater the anxiety associated with a new approach or technology possibly failing. Organizations such as the U.S. Department of Agriculture (USDA) and National Park Service, which provide

grants to environmental conservation organizations, face intense political scrutiny of decisions that are fraught with uncertainty even when using a known technology.

In fact, most of the government agencies and non-governmental environmental organizations that allocate funds for conservation still rely on outdated and severely flawed methods of selecting projects. Research has shown that these approaches are as inferior and outdated as the VCR but are still used every day.

A key problem is that methods of selection commonly used in conservation efforts do not properly take the cost of the projects into account. Advances in applied mathematics and economics, such as linear programming, have led to development of sophisticated systems that can analyze the costs and benefits of a suite of proposed projects and identify the set of selections that provides the total maximum conservation benefit for the lowest cost, and numerous studies have demonstrated that these algorithms could enable governmental and nonprofit agencies to provide the same or better outcomes as older methods while spending less money. Simply defined, strategic conservation is a planning process that considers multiple criteria when selecting a suite of projects to fund or initiate within a limited budget rather than relying solely on one criterion, such as environmental benefit.

Why have these organizations so far failed to adopt these much-improved high-powered tools and technologies? They have good intentions and follow emerging science in identifying new environmental threats and providing potential natural resource management solutions such as removing invasive plants. Certainly, their leaders are not lazy and care about the environment. As lifelong environmentalists who have worked closely with them, we know they are compassionate people who devote their personal and professional lives to addressing the wicked challenges facing the environment and work each day to accomplish great things. But they are not immune from inertia, risk aversion, and political pressure.

Inertia, risk-aversion, political pressure, a lack of public pressure, and limited budgets and staff resources all contribute to conservation organizations being “stuck.” There’s no question that the mundane

human tendency to avoid change plays a part. It is easier for individuals and organizations to continue to do what they already know how to do, even when it does not provide the best outcome and does not efficiently use taxpayer money. Skill sets also play a part. Most conservation professionals are not trained in economics or mathematics; they are natural or physical scientists. In fact, many of them likely shunned economics courses because of a mistaken view that economics promotes business interests over environmental concerns so they have not followed the development of economics and mathematical programming relative to conservation and have not imagined how these tools could enhance their work. Furthermore, computer programming and algorithms can seem complicated; it is easier to use a conservation selection mechanism you thoroughly understand and more difficult to explain a programming method to stakeholders who value a transparent, simple process.

The dirty little secret among those who fund such projects is that failing to adopt new scientifically proven techniques for allocating their funds is wasting literally billions of dollars and severely restricting what they are accomplishing with those funds. The question we address in this book is how to overcome those barriers. We highlight how conservation efforts have made mistakes and missed important opportunities, measure the magnitude of those errors, and provide, in essence, a Quick Start Guide to superior technologies based on the science of strategic conservation.

A nudge is needed

We have long considered why conservation professionals have not actively sought cost-effective selection techniques to try and have called for greater collaboration between academics and conservationists (Prendergast et al., 1999; Armsworth et al., 2004; Allen et al., 2011; Messer and Allen, 2010; Banzhaf, 2010; Duke et al., 2013). Some writers had noted that initially there was a lack of awareness of the methods among conservationists (Ferraro and Pattanayak, 2006) and perhaps some misunderstandings about potential challenges associated with implementing them because they were perceived as too "prescriptive"

(Prendergast et al., 1999). We and our colleagues have worked in the decade since to allay those concerns and demonstrate the value of adopting programming methods.

A lack of public pressure plays a major role. Environmental crises such as contamination of the water supply in Flint, Michigan, with lead and increasing poaching of elephants in Africa attract media attention that stirs people living far from the affected area to demand action. People want to see these problems solved and understand that they won't be solved without spending money. However, many do not think about where the money comes from (taxes they and others pay) or pay close attention to the processes by which their money is spent. So when a conservation program fails to meet its objectives, taxpayers rarely ask why the conservation organization failed to make the best possible use of their money. There is no public push for conservation agencies to upgrade their selection methods. Many conservationists know that their current selection methods are inadequate and want to do better, but they report having little incentive or ability to make needed changes. Thus, public pressure—from the members of the public who care most about conservation—will be required to make effective conservation a higher priority.

Learn a bit from baseball history

As documented in the book *Moneyball: The Art of Winning an Unfair Game* and the subsequent movie starring Brad Pitt, the Oakland Athletics professional baseball team and general manager Billy Beane used new applied mathematics and statistical analytics (referred to as sabermetrics) and an evidence-based approach to assemble a winning team in late 1990s and early 2000s despite having a significantly smaller budget than other successful teams. They found that the collective wisdom of baseball insiders who relied on statistics such as runs batted in (RBIs), batting averages, and number of stolen bases to evaluate players did not produce winning teams. So instead, the Athletics' management used statistical analyses to identify factors that did affect a team's ability to win, such as players' on-base percentages and slugging

percentages, and sought players who excelled in those areas and could be acquired at a lower cost. The approach was unconventional and was initially dismissed. But after they repeatedly made the playoffs despite a payroll about one-third the size of the New York Yankees' $125 million payroll, the approach spread widely, first in baseball and eventually in numerous sports as teams hired sabermetric experts.

We believe a similar transformation is needed in conservation. Agencies and organizations that fund and initiate environmental projects can make better use of the public and private funds they administer and significantly improve their "batting averages" in terms of how well they protect and remediate the environment with their efforts by hiring people who specialize in strategic conservation tools and principles.

The next generation of environmental problems

Current conservation efforts are often less about saving large, irreplaceable landscapes or even protecting endangered species. Instead, large sums are being spent to reduce carbon emissions, improve water quality through better nutrient management, conserve open space and farm land, and protect green infrastructures such as headwaters that provide drinking water and flood protection. In the vast majority of cases, the projects under consideration for funding are not unique; many, if not all, of them can deliver the desired benefit to some degree. Some projects provide a greater benefit than others, but the cost of acquiring them also varies. These types of projects are the next generation of conservation, and they are uniquely suited to strategic conservation approaches.

Our Backgrounds in Conservation

It may seem a bit odd to include a description of our backgrounds as part of the first chapter. However, we felt that by telling our stories, as lifelong environmentalists who had dedicated our professional careers to

solve these wicked problems, that we could help provide some insights into the challenges that conservation efforts in general facing. We can also explain where these principles and tools for strategic conservation have come from and what problems they were designed to address.

We have worked on conservation issues within non-governmental agencies, governmental agencies, and within academia. We love spending time outside and are passionate about environmental protection. However, we have to admit that we are also nerds. We grew up marveling at state-of-the art computers such as the Commodore 64 and our summer camps included not only hiking and camping, but computer programming. While many of our geeky contemporaries took their love of computers and programming into creating the businesses of Silicon Valley, we sought to combine our passions of computers with our love for the outdoors. So while we saw millions of people stand in line for the next iPhone so they can more quickly play Candy Crush, we stood their amazed as the science of strategic conservation continually evolved and the rush from the environmental community for these new tools and technologies was more like a whisper.

To help you understand how we came about wanting to write this book and develop tools to help conservation, let us briefly provide you with some of our background.

Background of Kent Messer

In 1992, Kent Messer attended the United Nations Earth Summit in Rio de Janeiro, Brazil, as a student reporter. That global summit was attended by leaders of more than 150 countries and several thousand nongovernmental organizations (NGOs) and laid the ground work for the Climate Change Convention and the Kyoto Protocol. The issues negotiated were (and are) complex scientifically and politically. As a sophomore in college, Kent had previously experienced environmental conservation mostly as slogans on t-shirts and posters. It became clear to him at the summit that conservation work would require teams of

experts in various disciplines, including science, behavior, sociology, and economics; no one person could bring all of the expertise needed even for relatively small-scale problems.

Kent was earning his bachelor's degree at Grinnell College in Iowa in the anthropology department, studying human behavior in general and the nexus of agricultural and environmental concerns in particular. To understand how farmers made decisions about moving to sustainable practices, he supplemented his anthropology courses with time spent time riding tractors and combines during the fall harvest and sitting around dinner tables talking with farm families about the risks and financial challenges they faced. He also spent a summer in the Talamanca Mountains on the Caribbean side of Costa Rica, where poor farmers were actively clearing the rainforest to plant rice and beans in the hope of securing a better future for their families. Once again, the behaviors observed were more complex than he expected. Some farmers in Iowa, for example, were early adopters of no-till agriculture to prevent soil erosion and integrated pest management while others stuck with traditional methods and at times over-applied fertilizers, thus polluting streams and aquifers. In Costa Rica, some poor farmers retained the rainforests on their property despite the financial sacrifice it meant for their livelihoods. These experiences convinced Kent that the only way to have a positive influence on the environment was to understand what drives both positive and negative behaviors by governments, organizations, and individuals.

Fresh out of college and armed with a better understanding of human behavior, Kent responded to a three-line newspaper advertisement for the job of executive director of Bluff Lake Nature Center, a newly established environmental education program in Denver, Colorado. The fledgling organization's four-person board of directors had secured nine months' salary and hoped to find someone crazy enough to take the job. At 23, Kent embraced the challenge and began developing environmental education programs for low-income residents of a handful of inner-city communities who had lived next to Bluff Lake for generations and never visited it because it was sequestered behind barbed wire fences as part of the Denver International Airport's "crash zone."

Given its outdoor location, its young (and cheap) staff, and its reliance on volunteers, Bluff Lake Nature Center could deliver high-quality educational programs to school children for a low cost. Kent quickly learned, however, that governmental and philanthropic funders were not very concerned about cost-effectiveness. As he struggled to write grants to fund Bluff Lake's educational programs, he noticed that the funding agencies, such as Denver's renown Scientific and Cultural Facilities District, which spends over $50 million per year of taxpayer funds, seemed not to care that the Bluff Lake's educational programs delivered a similar quality educational experience at much lower cost than the large and fancy Denver Museum of Nature and Science that was down the street. Instead of receiving extra points by grant reviewers for Bluff Lake's cost effectiveness, the museum's proposals, prepared by a large team of professional staff members committed to grant writing and fundraising, were frequently funded at high levels and Bluff Lake would get a trickle of the remaining funds.

Kent's story is not one of sour grapes over failed grant proposals. In fact, as executive director, he raised sufficient funds for his own salary and for salaries for two additional staff members and put the organization on a solid financial path; Bluff Lake Nature Center and its environmental education programs are thriving 25 years after its founding. Instead, it highlights the fact that reviews of grant proposals rarely consider the cost of the successful outcomes of the applicants. Thus, if the Denver Museum of Nature and Science submitted a well-polished grant proposal that delivered an exceptional educational program to 1000 students for $45,000 that was considered superior to a solid grant proposal that delivered a very high quality education program to 1,000 students for $15,000. Sure, the educational programs at the Denver Museum of Nature and Science were likely better. But the differences weren't that great and certainly not worth three times more money per kid. Thus, if the goal was truly to educate kids about the environment, why weren't the funders more concerned about getting a good "bang for their buck" when it came to limited funding?

Kent also became aware that this problem was not limited to a handful of foundations focused on education; it was widespread. Another example is the Great Outdoors Colorado Trust, which has spent

approximately $1 billion of funds raised through the Colorado Lottery on environmental and recreational projects in Colorado since it was created in 1992. Again, another large environmental funding agency was dedicated to doing great things but not formally incorporating methods that ensured that these important projects be achieved in a cost-effective manner.

Thus, these experiences influenced Kent's thinking as he went to graduate school, first to receive a master's degree in resource policy and behavior in the School for Natural Resources and Environment at the University of Michigan and then to receive a Ph.D. in agricultural and resource economics in the Dyson School of Applied Economics and Management at Cornell University. At Cornell, Kent was fascinated by the idea that mathematics and economics could be used to help conservation become more cost-effective. Members of the faculty, such as Jon Conrad, were developing the theoretical underpinnings for optimization approaches that could help land conservation managers get more "bang for their buck" from the limited funds available for conservation.

Kent's experience with conservation and fundraising efforts at Bluff Lake in Colorado had given him an intuitive understanding that many funding decisions in the world of conservation were flawed and went against the effort to protect the environment rather than supported it. Therefore, Kent wanted to learn these techniques and see whether they could be made into user-friendly software applications that would allow conservation professionals to quickly compare all possible combinations of potential conservation projects and make the best possible choice. In particular, he wanted to build tools that facilitated the expertise of conservation professionals and their tremendous understandings of the local landscape and ecology. Therefore, he considered it best if the tools would complement—instead of substitute—for the conservation group's traditional project evaluation criteria. With these tools, the conservation agency could select the set of projects that guaranteed the maximum possible conservation benefit given their limited budget.

Kent also wanted to develop these decision support tools to integrate with geographic information systems (GIS) and be flexible to accommodate a variety of constraints, not just budget constraints. For example, the tools should be able to accommodate acreage goals or recognize that the staff capacity to acquire land in a given time period is limited. Thus, he was interested in developing tools that conservation organizations and agencies could use when they faced situations in which they had a much larger pool of potential projects than they could afford to acquire.

Kent's Ph.D. dissertation research on cost-effective conservation was published in the peer-reviewed *Journal of Environmental Management*. As a professor and eventually the Unidel Howard Cosgrove Chair for the Environment in the Department of Applied Economics and Statistics at the University of Delaware, Kent has subsequently published more than 60 related academic and popular articles on topics that include forest preservation, protection of water quality from poorly maintained dirt roads, agricultural land preservation, and the U.S. military's efforts to meet its obligations under the Endangered Species Act while actively using its bases for training to ensure military readiness. His efforts to advance the use of sophisticated new technologies for selecting projects to fund or pursue have been extended in recent years to personally addressing his economist and conservation colleagues whenever the opportunity arises, including speaking at the *LTA National Land Trust Rally* and the *National Conservation Training Center*.

In 2014, Kent was selected to be the co-director of USDA's national Center for Behavioral and Experimental Agri-Environmental Research (CBEAR). As a recognized USDA Center for Excellence, CBEAR collaborates with USDA to implement innovative ideas that can improve the effectiveness of the governments' conservation program and to carefully measure the true outcomes of those efforts.

Background of William Allen

Ironically, Will was the one who thought he wanted to become an economist when he was in high school and selected economics as his likely major when filling out college applications. He grew up in the Washington D.C. metropolitan area where there was constant talk of economics in the context of balancing the government's budget and stimulating economic growth while also feeding the military-industrial complex of the 1980s. It seemed like every family Will knew had at least one member working at the Pentagon or as a bureaucrat involved in federal policy or finance. Will found that politics seemed to get in the way of a logical, rational approach to spending within means and balancing budgets, and he was determined to help change that!

In high school, Will was enamored with the idea of economics as a means of imposing efficiency on government and formulating cost-effective policy solutions. But his notion of efficiency was largely abstract and general, associated only with monetary and fiscal policies. He loved nature and treasured his experiences with conserved landscapes such as the Arizona desert and the California coast but never thought about linking economics and nature in a tangible professional sense.

While at Stanford during his freshman year, Will started exploring the environmental movement. That fall, 1989, the Berlin Wall fell and suddenly policies and financial investments designed to counter the Eastern bloc could be redeployed for good of a different kind. Will started thinking about using economics for protection of the environment—save the planet and save some cash at the same time! This newfound interest in the environment led to coursework in environmental engineering, statistics, and a class on oceans in the geology department.

Between his sophomore and junior years, Will interned in Washington, D.C., at Economists Incorporated, a well-respected consulting firm co-founded by Stanford faculty member Bruce M. Owen. It seemed like a perfect opportunity to merge his interests in economics and the environment. But, as is often the case with internships and early career experiences, he mostly learned what he didn't want to do. His

exposure to economics was limited to anti-trust issues in the U.S. steel industry and deregulation of Puerto Rico's phone service (the Ma Bell break up came late to the island), which matched the expertise of the firm's principals but did not align with his interests despite the highlight of his internship—a spirited, summer-long debate with a staff economist about federal fuel efficiency for automobiles, known as the Corporate Average Fuel Economy (CAFE) Standards. Now what?

At the time, there was no "environmental" major at Stanford. The Department of Economics had no apparent environmental focus. He was not interested in the biological angle—it seemed too detached from environmental policy (perhaps ironic given Dr. Paul Ehrlich's (1968) work on the population growth and links between economics and human development policy). Perhaps counter-intuitively, Will chose urban studies as a major. It provided an opportunity to "specialize" in environmental planning and design (other specializations included architecture and community organizing), allowing him to assemble a curriculum that integrated environmental and land use planning into the policy realities of built environments. This was his introduction to city and regional planning as a profession.

During his junior year, Will enrolled in Stanford's Washington, D.C., residency program where he took courses in economic regulation and federal environmental policy and had a full-time internship at the World Wildlife Fund working on an initiative called the National Commission on the Environment. This was an incredible experience with opportunities to interact with three former Environmental Protection Agency (EPA) administrators, Alice Rivlin (who has been, among other things, director of the Office of Management and Budget and vice-chair of the Federal Reserve), and many others. He attended a retreat at the Frank Lloyd Wright Wingspread House near Racine, Wisconsin, which made the professors who taught Stanford's "Utopia and Reality in Modern Urban Planning" class jealous.

Will thought the National Commission on the Environment's recommendations were first rate; many were way ahead of their time in using "nudge" tactics, Pigouvian taxes, and other tools to support policies that could reduce "externalities" that plagued many well-intentioned environmental regulations at

the time. Ultimately, though, adoption of these rational, cost-effective environmental policies came down to politics. Ironically, the election of Bill Clinton to the White House actually dampened prospects of adopting many of the policies outlined in the report. Many of the leading commission members had served under Republican administrations, so they were in a much better position to influence policy had George H. W. Bush been re-elected. So for the most part, implementation of the recommendations mostly languished during the Clinton years.

Coming back to Stanford for his senior year, Will had to finish his urban studies degree and decide what to do next. The primary project in the required three-quarter applied earth science class involved the development of a general plan for the City of Pacifica, California (on the coast near San Francisco airport). Will learned all about land use planning—what to do and mostly what not to do when developing land in environmentally challenging areas. Pacifica was (and is) notorious for losing structures due to landslides and coastal bluffs eroding into the ocean. The professors, Irwin Remson and George Mader, took students on great field trips throughout northern California, showing creeping earthquake faults that were tearing up streets and sidewalks and stopping for lunch on the former foundation of a house that slid into the Pacific Ocean.

Noticing Will's interest in environmental planning and sustainable development, Professor Mader suggested that Will should apply to city and regional planning schools. After some research and ruling out management consulting and investment banking, which seemed to be the only on-campus jobs offered by recruiters in the early 1990s, Will applied to graduate programs at University of Virginia and University of North Carolina (UNC) Chapel Hill. His application essays? How can the planning profession best support sustainable development and environmental protection efficiently and cost-effectively using a mix of regulations and incentives?

Will ultimately chose UNC, and his faculty advisor, David Brower, recommended a class in GIS. Will had an affinity for maps—his father had worked at the National Geographic Society—but had always

thought of maps as art and still had nightmares about coloring slope maps and using dot-matrix printers for suitability maps in his class on applied earth science at Stanford. As it turned out, taking the GIS class was a revelation for Will. Computer cartography allowed him to make maps using unlimited layers of information without hand-drawing anything! He had learned about suitability-analysis mapping, pioneered by Ian McHarg in his book *Design with Nature*, but GIS was many steps beyond gray-scale transparency sheets. These emerging GIS and remote-sensing technologies were producing sophisticated map information that could be used to identify land that was the most sensitive environmentally and to identify areas where development would be most suitable or would at least have the smallest environmental impact. That class and an additional hands-on GIS class taught in the Department of City and Regional Planning became the foundation for Will's first employment during graduate school.

In 1993, Will had lunch with Patrick F. Noonan, founder and president of The Conservation Fund (the Fund) and former president of the Nature Conservancy. Pat was an acquaintance of his father. Pat was the one person Will's father knew who had a degree in both city and regional planning and business administration. Pat founded the Fund in 1985 with a unique dual charter with the Internal Revenue Service to focus on both environmental protection and economic development. During lunch, Pat described how the Fund worked with public agency partners to acquire and protect high-priority land for conservation while being cost-effective and efficient, thus saving millions of dollars because the land would be acquired at discounted prices. Will mentioned his GIS studies and interest in assisting agencies in identifying the most important parcels for conservation, allowing them to better achieve their missions. He felt that the planning profession needed to do a better job taking advantage of these new tools to cost-effectively protect important conservation lands. Pat said something to the effect of "Oh, so you are learning GIS? We need somebody to do GIS. Go meet with our office in Chapel Hill and see if they have a project for you to work on." An office in Chapel Hill!

Will met with the Fund's Chapel Hill staff, which then consisted of Dick Ludington, Mikki Sager, and Page Crutcher. Ludington bought the conservation lands, Sager worked in land-rich cash-poor communities

to build local constituencies that supported land conservation as an economic development tool through nature-based tourism, and Crutcher designed the conservation projects in the communities using her expertise in landscape architecture. They were interested in GIS, specifically to map important resources in eastern North Carolina to support more on-the-ground conservation and promote nature-based tourism opportunities in economically disadvantaged areas. Mikki obtained a grant to support a summer internship for Will that extended through the summer and into his second year of graduate school. The work became both Will's master's thesis and the Albemarle-Pamlico Bioregional Greenway Plan prepared by the Fund.

Will went to work full time for the Fund after graduation. He continued to work on GIS and planning services in eastern North Carolina but also expanded his portfolio to other parts of the country, including supporting establishment of the Midewin National Tallgrass Prairie near Joliet, Illinois. He learned about a project underway in the Fund's south Florida office called the Loxahatchee River Greenway. At the invitation of Fund colleagues Beth Dowdle and former fellow UNC-Chapel Hill graduate student Matt Sexton, Will flew to Palm Beach County, Florida, to learn about this cutting-edge project involving both acquiring land for conservation and strategic conservation planning.

The John D. and Catherine T. MacArthur Foundation had significant land holdings in northern Palm Beach and southern Martin Counties within the Loxahatchee River watershed, which is part of the Everglades ecosystem and a source of drinking water and, at the time, was Florida's only Wild and Scenic River. Due to urban sprawl and agricultural development, increased fragmentation of the watershed was likely without a strategic conservation plan for restoration and preservation of the Loxahatchee River. The key to the strategy was to identify the suitability of the MacArthur Foundation holdings for development and conservation. Particularly suitable conservation land that prevented habitat fragmentation and protected fresh water supplies could be sold to the South Florida Water Management District, and land more suitable for development could be sold to generate revenue that would support the mission work of the foundation.

The Fund, with the support of the MacArthur Foundation, convened more than a dozen resource agencies and nonprofits involved in various resource management issues related to the Loxahatchee River. Through GIS-based modeling, the group identified important core natural areas that best supported watershed protection and areas best suited as greenway corridor connections for recreational trails and habitat connectivity (Diamond and Noonan, 1996)[1]. The planning process was completed in the mid-1990s and by 2004, most of the core areas and potential greenway linkages had been acquired and protected. The GIS methodology developed for the project served as a foundation for future collaborative work with nonprofit Thousand Friends of Florida and University of Florida's GeoPlan Center to create the Florida Ecological Greenways Network.

Will decided this was the model that the fund should use for its strategic conservation planning services. The key obstacle to scaling this model across the country was an inability to share GIS data and tools with local stakeholder groups interested in planning and implementation of conservation solutions. Virtually all of the professional GIS analyses at the time were done on UNIX hardware, and the software available for personal computers had limited capabilities. Will saw two potential approaches to tackling the problem. The first involved development of a GIS for a strategic conservation planning course that was co-developed with University of Florida's GeoPlan Center. Starting in 1998, Will and Dr. Paul Zwick taught the class at the National Conservation Training Center in Shepherdstown, West Virginia. The second strategy involved partnering with Frank Conkling, the MacArthur Foundation GIS staffer who developed the GIS modeling for the Loxahatchee project.

Will collaborated with Conkling to develop customized GIS applications that provided decision-support capabilities for land use planners and other resource managers. The Loxahatchee River work had been completed using Esri's ArcInfo™ software platform, and at the time, Esri provided a set of developer tools called MapObjects that allowed for development of free-standing, lightweight GIS applications that

[1] Diamond, H.L. and P.F. Noonan. 1996. *Land Use in America*. Washington, DC. Island Press.

provided mapping functionality on personal computers without an ArcInfo license. The first pilot GIS application was developed for the Midewin National Tallgrass Prairie and was called Midewin Prairie Explorer. A key feature of the tool was the ability to explore land use planning and conservation scenarios and to assemble packages of data and text that could be submitted to the USDA Forest Service as comments for their land and resource management plan process.

The next project it was used for was in the Catoctin Mountains in Maryland. Maryland's Department of Natural Resources (MD DNR) had identified the mountainous areas of Frederick County as a top conservation priority in western Maryland. Catoctin Mountain Park was a National Park Service property that was famous as the home of the presidential retreat known as Camp David. The Fund worked collaboratively with MD DNR and the Catoctin Land Trust to develop the Catoctin Mountain Explorer application. Both groups used the tool to identify potential conservation acquisition opportunities.

Serendipitous convergence on the Catoctin Mountain Project

At Cornell, a graduate student was in search of a dissertation topic. Kent was working on applying optimization methods to conservation projects as part of his doctoral dissertation in applied economics. His research sought to apply cost-effective conservation techniques to an ongoing land acquisition initiative in the Catoctin Mountains in central Maryland. In 2001, Maryland established the "GreenPrint" program with a budget of $35 million. Administered by MD DNR, the program established a source of land conservation funding to protect the state's most important ecological land. In particular, the state sought to protect a network of large contiguous blocks of resource land, "hubs," linked by "corridors" that would form a "green infrastructure" network. Estimates were that approximately three-quarters of the desired network lacked formal protection and was subject to development. MD DNR selected the Catoctin Mountain Region as an area of special attention because of its ecological, historical, and political importance. The mountains are situated in central Maryland and are an extension of the Blue Ridge geological feature of the Appalachians.

A significant portion was already protected by a variety of local, state, and federal agencies, and Kent's Ph.D. study had focused on the northern section of the mountain range, which was primarily in Frederick County.

The results of Kent's study were profound. As shown in Messer (2006), Kent found that GreenPrint could achieve a significantly greater aggregate conservation value if it used the cost-effective conservation technique of binary linear programming (BLP) (see chapter 8 for details) rather than its traditional benefit-targeting (BT) approach, which simply ranked the projects from highest to lowest in terms of conservation value and then purchased as many as possible until the budget was exhausted. For three budget scenarios—$1 million, $2.5 million, and $5 million—being considered by GreenPrint, use of BLP would have achieved aggregate conservation values that were 4.9, 3.6, and 2.0 times greater, respectively, than would be achieved by BT (Table 1.1). Additionally, use of BLP achieved higher scores for each of the biophysical attributes the GreenPrint program had identified as important. For example, with a $2.5 million budget, BLP preserved 1.6 times as many acres of green infrastructure and the aggregate ecological score was 4.2 times higher.

Another way of measuring the benefits of the approach was to evaluate savings that cost-effective conservation could deliver. One way to calculate the savings was to determine how much money would be required for BT to achieve BLP's aggregate conservation value. For the three budgets used in the study, BT would have required an additional $3.1 million, $3.7 million, and $3.9 million respectively. With a $2.5 million budget, for example, BLP achieved an aggregate conservation value of 283.5; the cost for BT to obtain that value was $6.177 million (147% higher). In other words, BLP could have achieved the same level of conservation benefit as BT while spending $0.9 to $3.5 million less. Those are large numbers, and the research also showed that the greatest efficiencies were achieved in the low-budget scenarios. This was particularly important since conservation efforts frequently do not have enough financial resources to fund all of the valuable projects available.

Given these results in the first case study, Kent and Will immediately understood that the results were not unique to forest protection in Maryland. They could be readily replicated in a variety of settings, including watershed protection, endangered species conservation, and farmland preservation. In all of those instances, BLP techniques could secure substantial benefits that would otherwise be lost. Kent and Will soon collaborated with colleagues on additional projects that demonstrated the value of cost effective conservation in projects involving agricultural preservation and green infrastructure in Kent County, Delaware and Baltimore County, Maryland. This book was borne from the revelations of the Catoctin study and refined over more than a decade of working together to apply strategic conservation throughout the United States. The results of these studies and knowledge we have gained through these collaborations form the core of this book. We focus on identifying cost-effective project selection methods that target specific lands, carefully incorporate both benefits and costs, and seek to maximize conservation outcomes that are important to the public.