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Planning for Land Use and Conservation: Assessing GIS-Based Conservation Software for Land Use Planning

Rob Baldwin, Ryan Scherzinger, Don Lipscomb, Miranda Mockrin, and Susan Stein

Abstract

Recent advances in planning and ecological software make it possible to conduct highly technical analyses to prioritize conservation investments and inform local land use planning. We review these tools, termed conservation planning tools, and assess the knowledge of a key set of potential users: the land use planning community. We grouped several conservation software tools into five themes: reserve selection, habitat connectivity, species distribution and viability modeling, threats, and climate forecasting. We found that professional planners frequently use GIS tools and are generally aware of conservation planning tools, but few planners are proficient in the use of such tools owing to lack of financial support and time for training. We propose that conservation planners and land use planners work together to strategically invest resources and maximize the conservation impact of land use planning.

Keywords: reserve selection, habitat connectivity, species modeling, climate forecasting, conservation planning, land use planning

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Introduction

The challenge to preserve healthy, functioning ecosystems and populations of plant and animal species across the planet is daunting; only 15 percent of the earth's surface is specifically managed for biodiversity conservation (Dudley and others 2010, Rodrigues and others 2004). Further, lands that are managed to protect species and their habitats are unevenly distributed across ecosystems. For example, the United States has a large and well-established system of public lands, managed for various purposes including habitat protection. However, most of these lands are concentrated in the West. In much of the United States, particularly in the East, *private* lands provide a disproportionate amount of high-quality habitat for species and ecosystem services; such resources are critical for human well-being as well as wildlife conservation.

While private land conservation efforts have grown rapidly in recent years, the total area of developed land (housing and other non-agricultural development) in the United States is still 10 times that of privately conserved lands, and land is being converted to residential and urban development at twice the rate that it is being protected (Aldrich and Wyerman 2006, NRCS 2007). Strategic management of both public and private lands combined is therefore increasingly critical to preserve biodiversity in the United States (Newburn and others 2005).

Efforts to conserve biodiversity and plan for human uses often occur on two separate tracks: conservation planning and land use planning. *Conservation planning* is a systematic effort to strategically target conservation efforts for those areas of land and water that hold the greatest promise for long-term biodiversity conservation, while *land use planning* includes work by agencies, local governments, and not-for-profit entities to allocate uses for land based on combinations of social, economic, and environmental goals.

Land use planning is often required at the local government level. Conservation planning has generally been carried out by conservation biologists through non-profit organizations, governments, and agencies; unlike land use planning, however, conservation planning is not legally required. Today, increasing effort is being exerted to link conservation biology [footnote 1] with land use planning. Part of this effort involves the development of "conservation planning software"—tools and data designed to enable strategic land use planning *and* biodiversity conservation.

Software and data that can support conservation planning take many forms, including tools developed to predict species distributions and viability, model habitat quality and connectivity, predict where and when threats will accumulate, and forecast how systems may respond to large-scale environmental changes, including climate change. Recent advances in conservation planning software make sophisticated analyses available for use by multiple organizations across a variety of spatial extents, from local to regional. These tools originated in the conservation and ecology communities, and it is unclear whether they meet the needs of land use planners or are being adopted in the land use planning community.

In 2011 a team of specialists from Clemson University, the American Planning Association (APA), and the U.S. Department of Agriculture (USDA), Forest Service conducted a review of existing conservation planning software, focused on geographic information system (GIS) platforms, to summarize and evaluate the goals, requirements, and ease of use of a number of these programs. We also worked with the American Planning Association (APA) to survey the land use planning community and assess the availability and perceived benefits of conservation planning software [footnote 2].

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[1] Conservation biology is a field of scientific study focused on the conservation of biological diversity and the effects of humans on the environment.

[2] This report is an abbreviated and edited version of an earlier unpublished report of our findings (Baldwin and others 2012).

This report reviews currently available conservation software tools and assesses the knowledge of a key set of potential users: the land use planning community. We discuss barriers to the use of conservation planning tools, and conclude with suggestions to enhance the use and adoption of conservation planning software and tools by the land use community. Appendices provide additional details, as derived from Baldwin and others (2012).

Conservation Planning Software and Other Tools

Over the past decade, GIS-based conservation planning tools have proliferated, as computing capabilities have increased and spatially explicit information about natural resources has become widely available. To review the available types of conservation planning tools, primarily GIS-based programs and datasets, we surveyed the literature for reference to established programs, searched the Internet for emerging programs, and included information on any additional software or tools of which we had previously been aware.

We grouped the conservation planning software and data we found into five themes: (1) reserve selection, (2) habitat connectivity, (3) species distribution and viability modeling, (4) threats, and (5) climate forecasting. Below we briefly describe each theme and then discuss the different features and uses of conservation planning software.

An overview of the resources reviewed for this project is presented in Table 1, organized by theme. Each program is described according to computing environment and average ease of use, data requirements, and documentation available. Most of these programs work through GIS software or the Python programming language, although a few tools are datasets or are accessed through stand-alone software. In general, programs are challenging to use, and available documentation is technical. Data requirements to use these tools are more variable, ranging from standard to highly specialized inputs. A more complete table is provided in Appendix A.

Table 1. Overview of GIS conservation planning tools reviewed for this project.

Software type	Software names	Computing environment	Relative difficulty or ease of use	Data requirements	Quality and availability of documentation
Reserve selection	Marxan, Sites, Zonation	GIS software, Zonae Cogito GIS Interface, stand-alone software	Challenging	Moderately specialized	Moderately technical
Habitat connectivity	CorridorDesigner, Circuitscape, Linkage Mapper, Unicor, FunConn, Wild Lifelines	GIS software, mostly in Python code	Challenging	Varies from standard inputs to some specialized information required	Highly technical
Species distribution modeling	Expert Opinion, Maxent, Presence	GIS software, JAVA, or standalone software	Challenging	Varies from standard inputs to highly specialized	Moderate to highly technical, except for expert opinion (not technical)
Threats	CommunityViz UrbanSim Human Footprint Future housing and impervious surface scenarios	GIS software or raster datasets	From moderately difficult to challenging	Standard inputs	Accessible
Climate	Climate forecasts, historical data, such as ClimateWizard	Raster datasets, Web interface	Moderately difficult	Standard inputs	Moderately technical

Reserve Selection Software

Reserve selection software works to strategically select areas for land conservation. Conservation biologists have developed these programs in recognition of the fact that existing networks of protected areas have often been established opportunistically (Margules and Pressey 2000). Systematic conservation planning seeks to identify the most important areas for conservation, considering both their ecological values and their levels of threat and vulnerability. An ideal system of reserves would represent the regional pool of species and ecosystems and contain enough habitats of specific types sufficient to maintain viable species populations, allow natural patterns of disturbance, and enable continued community and population processes, including shifts of species' ranges in response to climate change (Craighead and Convis 2013, Groves 2003, Noss and others 2002, Trombulak 2010). Reserve selection is closely related to other conservation planning activities including habitat connectivity and climate resilience.

Reserve selection software operates in a GIS environment, is highly technical, and can be challenging to use. This software uses algorithms to identify the most valuable areas for conservation, iteratively testing different land protection configurations to identify efficient conservation priority areas (for example, balancing the total area of land, the cost of land, and the amount of area in comparison to reserve boundary). This process also often requires consultation with regional experts and other stakeholders.

An example of output from one of these pieces of software (Marxan) is shown in Figure 1, the result of a planning process for Sitka black-tailed deer habitat in Southeast Alaska (Schoen and Dovichin 2007). For more information on reserve selection, see box, Key Resources for Reserve Selection, and Appendix B.

Key Resources for Reserve Selection

Books: Moilanen and others (2009). *Spatial conservation prioritization: Quantitative methods and computational tools*. Oxford Univ. Press.

Trombulak and Baldwin(2010). *Landscape-scale conservation planning*. Springer-Verlag.

Online Tools: MARXAN Website—http://www.uq.edu.au/marxan/.

http://www.helsinki.fi/bioscience/consplan/software/Zonation/References.html.

Selected Articles: Margules and Pressey (2000). *Systematic conservation planning*. Nature.

Noss and others (2002). *A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem*. Conservation Biology.

Pressey and others (1996). *Optimality in reserve selection algorithms: When does it matter and how much?* Biological Conservation.

For full citations, see References.

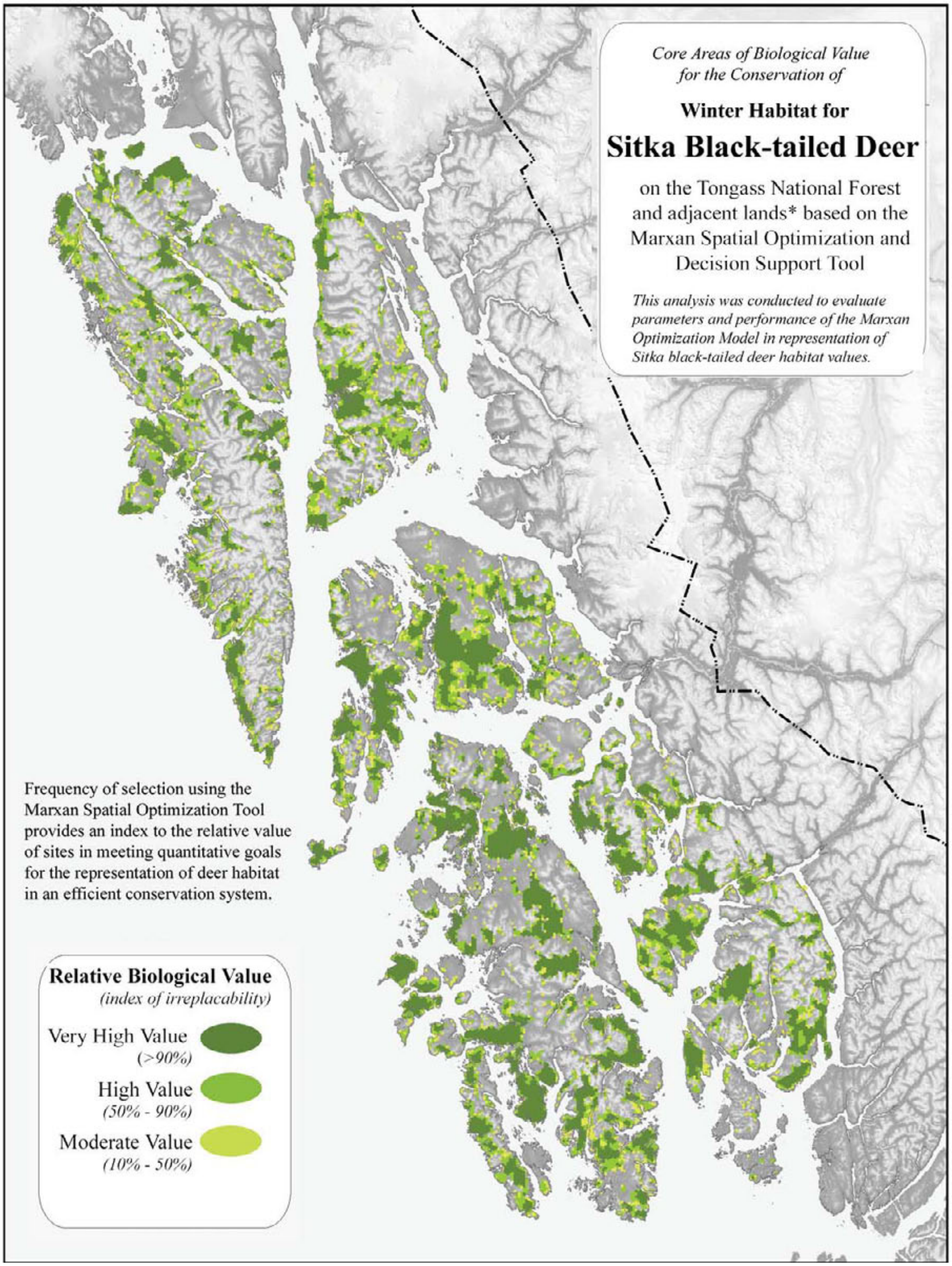

Figure 1—Reserve Selection. Core areas for Sitka black-tailed deer habitat simulated with the reserve selection software MARXAN, for Southeast Alaska. Irreplaceability scores represent the number of simulations in which a particular area was selected by the software given input parameters. Areas selected in all or a large percentage of simulations are considered higher value for achieving conservation goals. Marxan analysis and cartography by David Albert, The Nature Conservancy. Source: Schoen and Dovichin (2007).

Habitat Connectivity Software

Biodiversity and ecological processes within reserves are greatly influenced by the quality of the surrounding matrix of land and water in which the reserve sits (Noss 1983, Parks and Harcourt 2002). Habitat connectivity software within a GIS environment is used to strategically link reserves through corridors; to more generally maintain landscape connectivity or permeability for species that move more diffusely over landscapes (such as large carnivores); or to support seed transport and ecosystem processes such as natural fire regimes (Dobson and others 1999, Noss 1983). These programs use an input layer that represents landscape "resistance," or the degree that land cover and land use present resistance to movement by organisms. This concept of mapping habitat corridors is intuitively accessible, but the challenges of generating resistance layers and choosing which areas to connect on the landscape make planning for habitat connectivity a complex endeavor (Beier and Noss 1998, Beier and others 2011, McRae and others 2008).

Habitat connectivity exercises may be conducted at multiple levels, from individual species to groups of species. For example, resistance landscapes can be targeted to individual species' habitat requirements, in some cases over large areas. More commonly, researchers attempt to create generalized resistance surfaces that might work for groups of organisms; such resistance layers are often derived from maps of land cover.

Habitat connectivity also requires deciding what areas to connect. For example, planners can focus on specifically linking protected areas, or they may examine the entire landscape to enhance animal movement (Fig. 2). Among the tools available, one of the most commonly used programs is CorridorDesigner, which provides a way to map habitat-based corridors between locations, such as high-quality habitat or protected areas [footnote 3]. CorridorDesigner calculates the least-cost path between two places based on measures of habitat suitability. It calculates best connecting routes, and it identifies barriers and bottlenecks.

In contrast, the Circuitscape program models ecological connectivity across whole landscapes. Circuitscape applies electronic circuit theory to problems in landscape ecology. It models the flow of organisms and genetic material through landscapes with varying levels of resistance to that flow.

Using both approaches and maintaining the potential for multiple habitat corridors is likely to be helpful for land use planners. Given the complexity of landscapes and the needs of individual species, habitat connectivity planning is a burgeoning technical field. For more information on habitat connectivity, see box, Key Resources for Understanding Habitat Connectivity, and Appendix C.

[3] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

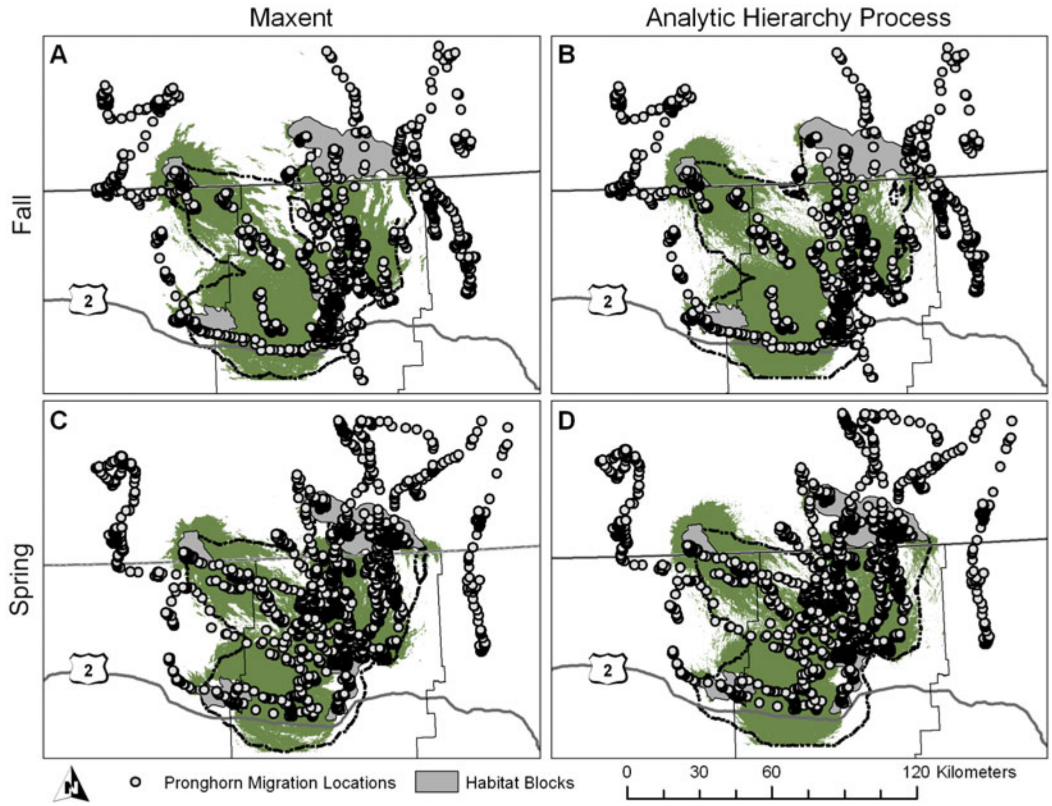

Figure 2—Habitat Connectivity. Least-cost modeling (solid line) and Circuitscape (shaded area) pronghorn migration corridors in Montana and Saskatchewan created from the 10% most traversable habitat on Maxent and Analytic Hierarchy Process resistance surfaces for fall (A) and (B), respectively, and spring (C) and (D) migration seasons. Source: Poor et al. (2012).

Key Resources for Reserve Selection

Books:

Crooks and Sanjayan (2006). *Connectivity conservation.* Cambridge Univ. Press.

Hilty and others (2006). *Corridor ecology: The science and practice of linking landscapes for biodiversity conservation.* Island Press.

Online Tools:

CorridorDesigner—http://www.corridordesign.org/.

Circuitscape—http://www.circuitscape.org/Circuitscape/Welcome.html.

Connecting landscapes: A practitioner's resource for assessing and planning for habitat connectivity—www.connectinglandscapes.org.

Conservation corridor digests—http://www.conservationcorridor.org/.

Selected Articles:

Beier and others (2011). Toward best practices for developing regional connectivity maps. Conservation Biology.

Carroll and others (2011). Use of linkage mapping and centrality analysis across habitat gradients to conserve connectivity of gray wolf populations in Western North America. Conservation Biology.

Theobald and others (2012). *Connecting natural landscapes using a landscape permeability model to prioritize conservation activities in the United States.* Conservation Letters.

For full citations, see References.

Species Distribution Models

To conduct work on reserve selection and connectivity, researchers and managers need accurate information on species distributions. Historically, species range maps were produced by experts who examined field collections and conditions under which specimens were collected (for example, habitat and elevation), and who drew potential range boundaries based on an extrapolation of those conditions.

The current way to model species distributions involves the use of known locations to develop predictive models based on mapped environmental variables. These models produce data that can be used for planning. The goal is to predict where species probably occur, based on conditions at locations where they do occur. Approaches vary in the degree of expert opinion involved, number and distribution of known species locations, information on absences, and use of environmental data (Franklin 2009).

All species distribution models are recognized as incomplete because they are likely to change not only as environments change but also as more data become available for the models to incorporate. However, even when information is limited, incomplete data on species' occurrence and environmental conditions can help build maps of species' ranges that will be useful in conservation planning.

In some cases the underlying diversity of land forms, elevation, and soils may be used as a surrogate for species distributions. Such coarse-filter mapping approaches may be particularly useful at very large spatial extents and in times of anticipated rapid environmental change. Coarse-filter approaches recognize uncertainty and make overall conservation of diversity a goal, without a focus on specific species or current assemblages (Anderson and Ferree 2010, Hunter 1991). In contrast, "bioclimatic envelope modeling" examines the relationship between climatic conditions and specific species' occurrence to estimate the conditions that are suitable to maintain viable populations of those species. These models help us understand how climate change may influence specific biotic communities, and they can be included in conservation plans, although their predictions are uncertain (Lawler and others 2009, Seo and others 2009).

Key Resources for Understanding Species Distribution Modeling

Books: Akcakaya and others (2004). *Species conservation and management: Case studies for RAMAS GIS.* Oxford Univ. Press.

Franklin (2009). *Mapping species distributions: Spatial inference and prediction.* Cambridge Univ. Press.

Online Tools: Maxent software for species habitat modeling—http://www.cs.princeton.edu/~schapire/maxent/.

American Museum of Natural History (AMNH) Species Distribution Modeling courses and background information—http://biodiversityinformatics.amnh.org/index.php?section_id=82&content_id=140.

RAMAS GIS software and background information—http://www.ramas.com/ramas.htm .

Selected Articles: Carroll and others (2003). *Use of population viability analysis and reserve selection algorithms in regional conservation plans.* Ecological Applications.

Elith and others (2011). *A statistical explanation of MaxEnt for ecologists*. Diversity and Distributions.

For full citations, see References.

Species distribution software—such as Maxent, AMNH Species Distribution Modeling, and RAMAS GIS—is often challenging to use and requires GIS software or similarly technical software. Required data and documentation are both complex and specialized, although the use of expert opinion could make this software less demanding to use. For more information on habitat connectivity, see box, Key Resources for Understanding Species Distribution Modeling, and appendices D and E.

Threats Software and Data Products

Conservation planning seeks to identify and map the distribution of activities that threaten ecosystem function and diversity; such information can help to prioritize conservation actions based on site vulnerability to threats (Abbitt and others 2000, Lawler and others 2003, Theobald 2003). While not all threats to biodiversity are human-caused, and not all human activities threaten biodiversity (Baldwin 2010), conservationists are often concerned about impacts of many human activities—including increases in housing, expansion of road infrastructure and traffic, gas and oil development, the use of some forestry and agricultural methods, and in some cases, activities to control ecological processes (for example, fire suppression or flood control) (Noss and others 2006, Rood and others 2005, van Lear and Waldrop 1989).

Among all these human impacts, land use change is often the most immediate challenge, resulting in habitat degradation, loss, and fragmentation (Harding and others 1998, Tilman and others 1994, Vitousek and others 1997). The ability to develop predictive maps of land use change and loss of naturalness in the landscape has increased rapidly over the past decade (Theobald 2010, Trombulak and others 2008) (Fig. 3). Maps that show both where threats are greatest and where ecological communities are most valuable can be used to guide conservation efforts (Baldwin and deMaynadier 2009), although not all threats are easily mapped and their effects on natural communities and ecosystems are not always well-understood. Once we have data on threats, planning tools or decision-support systems such as NatureServe Vista can help users integrate conservation with planning and stressors. Planners can create and evaluate different scenarios to determine where and how their values of interest are conserved or threatened, and develop alternatives to best achieve planning objectives (Appendix A, Table A-1) .

Among software and data products for analyzing threats, perhaps the most complex type of analysis is generating future scenarios of development—a substantial endeavor requiring specialized modeling skills, such as simulating land use change under different climate change scenarios (Bierwagen and others 2010). Some of the tools listed in Table 1 (earlier) and Appendix A are the data products from these analyses—simulations that are usually carried out over large spatial extents using standard data inputs (those datasets most likely to be available at these large scales). The completed data products are used in a GIS environment but are generally accessible and are most helpful in providing a broad-scale overview of threats. For example, the Human Footprint dataset (Appendix F) shows human influence on the environment at the global level, by combining datasets on population density and infrastructure.

Other more complex software packages allow managers to model land use change at the local level. For example, CommunityViz and UrbanSim are software packages that have been used primarily for land use planning in an urban environment; they allow users to create models and visualize human development in a GIS environment. These programs are moderately technical to use but require standard data inputs and are generally well-documented (Appendix G). For more information on threat modeling see box, Key Resources for Understanding Mapping of Threats, and appendices F and G.

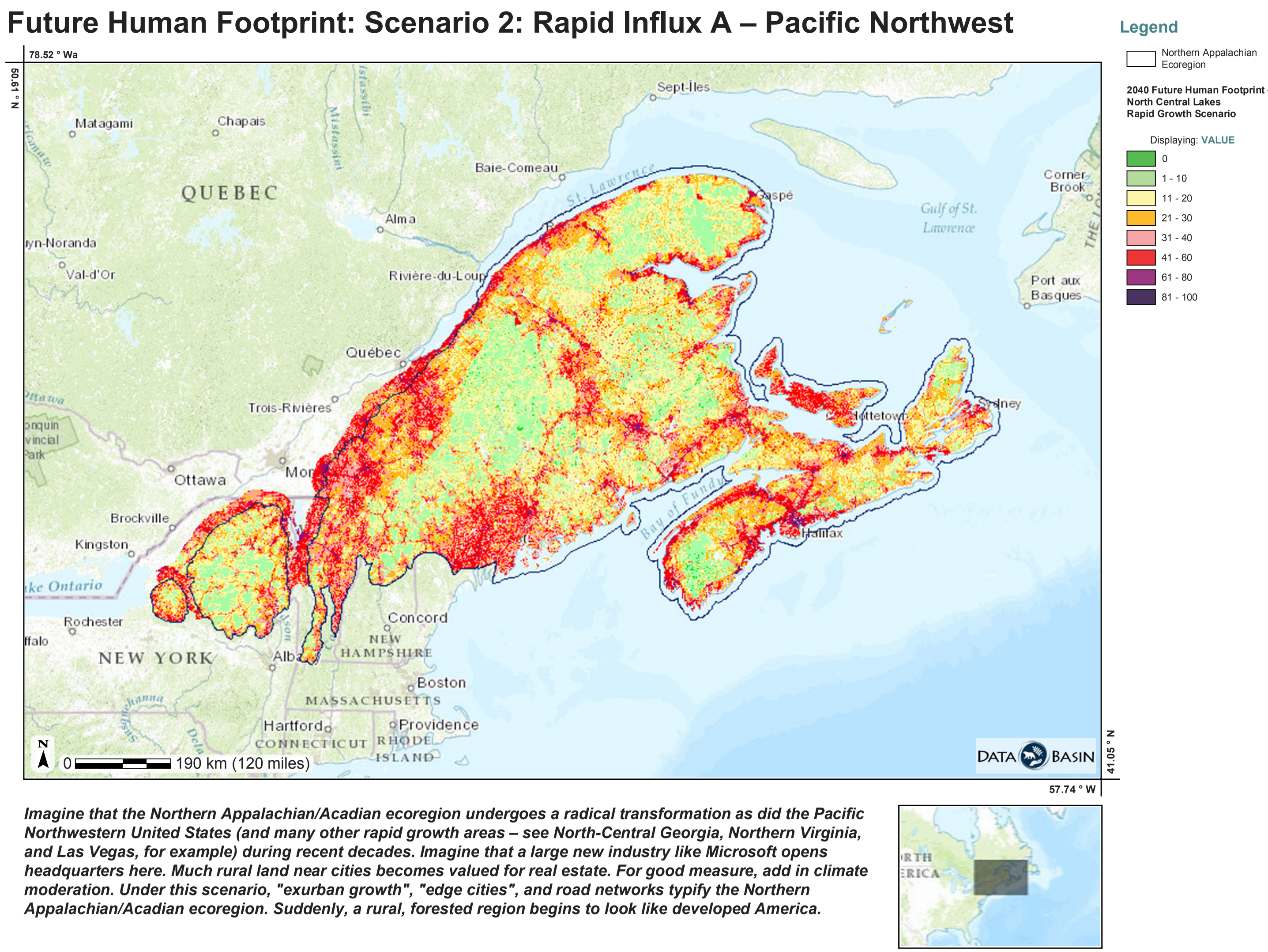

Figure 3—Threats. Degree of development pressure on areas of high naturalness under threat scenarios in the Northern Appalachian/Acadian Ecoregion. Future human footprint was generated by simulating housing growth in this relatively unpopulated region similar to that seen in the Pacific Northwest in the 1990s. Source: Baldwin, R.F. (undated), for Two Countries, One Forest Data Atlas.

Key Resources for Understanding Mapping of Threats

Books and Reports:

Stein and others (2005). *Forests on the edge: Housing development on America's private forests*. USDA Forest Service.

Turner and others (2001). *Landscape ecology in theory and practice*. Springer-Verlag.

Online Tools:

Global Human Footprint: Last of the Wild—http://sedac.ciesin.columbia.edu/data/set/wildareas-v2-human-footprint-geographic.

CommunityViz software description—http://placeways.com/communityviz/.

UrbanSim software-based simulation system—http://www.urbansim.org/Main/WebHome.

Selected Articles:

Baldwin and deMaynadier (2009). *Assessing threats to pool-breeding amphibian habitat in an urbanizing landscape*. Biological Conservation,

Sanderson and others (2002). *The human footprint and the last of the wild*. Bioscience.

Theobald (2003). *Targeting conservation action through assessment of protection and exurban threats*. Conservation Biology .

For full citations, see References.

Climate Projections

Conservation planning seeks to integrate climate change and to understand human actions in the context of rapid, current, and future climate change (Dale 1997, Thomas and others 2004, Walther and others 2002). Conservation planning that integrates climate change often focuses on the ability of species to shift their ranges given land use change and habitat fragmentation; for example, approaches described above under Habitat Connectivity Software or Species Distribution Models may typically be used.

However, when specifically focused on climate change, conservationists use projections to anticipate how climate will change in the future. These "downscaled" climate projections, or fine-grained consistent data available over large spatial extents, are generated and compiled by climatologists and then made available for natural resource managers and scientists. For example, ClimateWizard is a conservation planning tool developed by The Nature Conservancy, the University of Washington, and the University of Southern Mississippi. ClimateWizard is not a type of modeling software but rather is an Internet-based server that displays and provides access to a range of conservation-relevant climate data, based on scenarios from the International Panel on Climate Change (IPCC). Custom analyses for subregions are available.

The National Climatic Data Center is another source of climate data for planners. Understanding the way in which these data were generated requires some technical knowledge, although these models take in standard inputs. As a result, we consider these types of data to be moderately challenging to use. For more information on climate change modeling, see box, Key Resources for Climate and Conservation Planning, and Appendix G.

Key Resources for Climate and Conservation Planning

Books: Hilty and others (2012). *Climate and conservation: Landscape and seascape science, planning, and action.* Island Press.

Online Tools: Climate Wizard—http://www.climatewizard.org/ .

National Climatic Data Center—http://www.ncdc.noaa.gov/.

Regional Climate Science Centers—http://www.doi.gov/csc/index.cfm.

Selected Articles: Bierwagen and others (2010). *National housing and impervious surface scenarios for integrated climate impact assessments.* PNAS.

Girvetz and others (2009). *Applied climate-change analysis: The ClimateWizard tool*. PloS ONE.

Hannah and others (2002). *Conservation of biodiversity in a changing climate*. Conservation Biology.

For full citations, see References.

Conservation Planning Software and Other Tools: Summary

In total, our review of conservation planning software found 18 tools, which we grouped into five themes. Because each tool is different and designed for a unique purpose, these tools and data have varying characteristics and uses, answer different conservation questions, and are used at different stages of a conservation planning process. Despite the variety in tools, we found some common features among different software programs and datasets, namely that tools are often complex and require detailed knowledge of both software and the literature. Many of these tools require the use of specialized data and programming, and nearly all draw upon stakeholder/expert input.

Survey of Land Use Planners

Given the growing number of conservation software programs, we wanted to see if these programs were serving the needs of land use planners. The Forest Service partnered with the APA to assess awareness, perceptions of usefulness, proficiency with, barriers to use, and interest in training for a representative set of conservation planning tools.

To evaluate use of conservation planning tools, APA distributed an online survey to all its members (more than 40,000 planners). In total, APA received 1,872 replies, with all U.S. States and territories—including Washington DC, Puerto Rico, and the U.S. Virgin Islands—represented. Of those who responded, 82 percent worked as professional planners (65 percent public sector, 17 percent private sector). The remaining 18 percent of respondents were in academia, not-for-profit organizations, or law firms; or they were citizens engaged with planning issues. Most of the respondents represented either municipal (51 percent) or county (26 percent) entities, and most were working in rural areas or cities with fewer than 250,000 residents (Fig. 4). These employment characteristics are similar to those of the entire APA membership (APA 2012).

The survey was designed to assess familiarity with conservation planning goals and objectives, specific conservation planning tools, and constraints on planners for implementing conservation planning approaches. We specifically targeted those individuals who participated in conservation planning: if respondents did not do this type of work they were asked to forward the survey to the person in their organization who did.

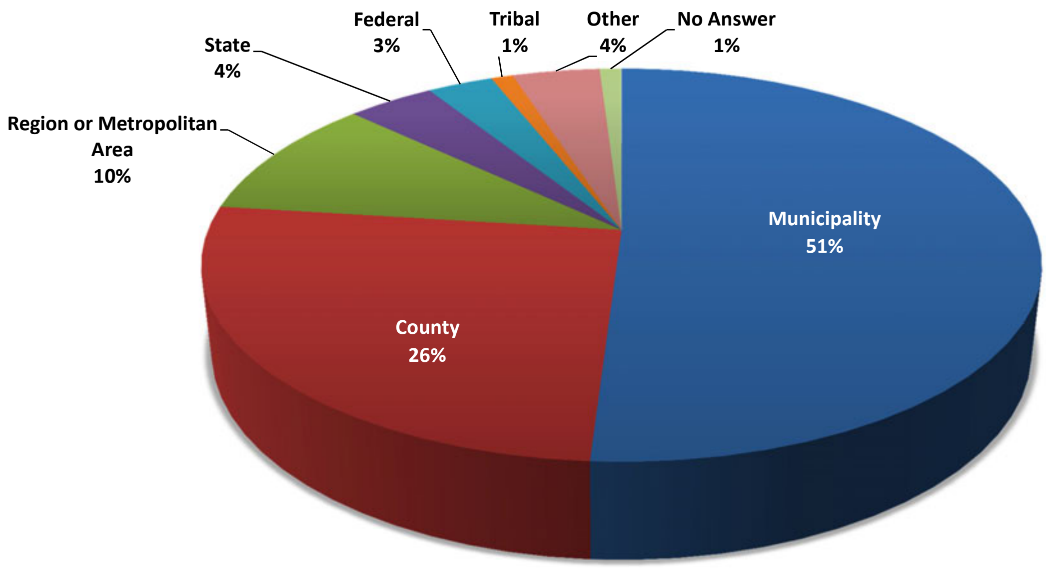

Figure 4—Demographics of APA survey respondents. These demographics are similar to the those of the entire APA membership (APA 2012).

Because the most general kind of conservation planning tool is GIS, a first question was how much the organization uses GIS for conservation planning. Most (74 percent) responded "always" or "frequently," and an additional 15 percent indicated "occasionally." Only 11 percent responded "seldom to never" or that they did not know. Regionally, the percentage of organizations that frequently or always use GIS tools for conservation planning varies over the United States but is highest in the South Atlantic and Pacific West; intermediate in the Mountain West, Northeast Central, and Mid-Atlantic; and lowest in the South Central and West North Central Regions (Fig. 5).

The institutional capacity for conservation planning may limit how individuals use these tools. Consequently, we asked planners about levels of support they receive from their organizations. Approximately half the respondents indicated that their organizations provide strong support (49 percent), are very aware of the capabilities of conservation planning tools (48 percent), and provide sufficient technical support (44 percent). However,

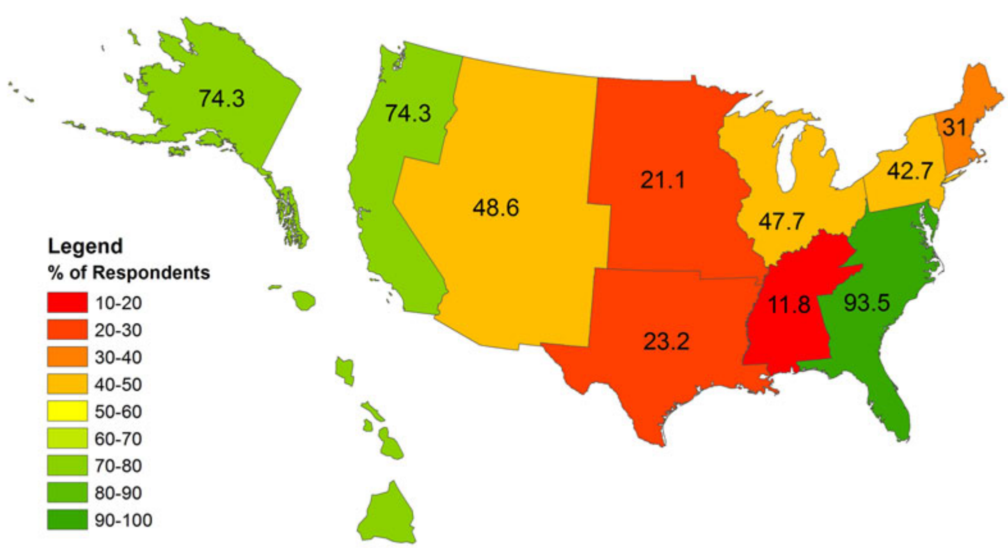

Figure 5—Regional percentage of organizations that frequently or always use GIS tools for conservation planning.

a lower rate of respondents indicated that their organization provides adequate funds for these activities; only 27 percent of respondents indicated their organizations provide or pay for training, and 18 percent indicated that their organization allocates funds to invest sufficiently in conservation planning tools.

We also wanted to better understand which conservation tools planners were most familiar with and used the most. We asked planners which specific tools they were aware of among 11 of the most common tools, which represented each theme of conservation planning software (Fig. 6). Most (65 percent) were aware of two threat/land use planning tools typically used to visualize "build out"—CommunityViz (42 percent) and UrbanSim (23 percent). There was comparatively lower recognition of the nine other conservation planning tools.

As in many technical fields there may be differences between a person's awareness of a tool, perception of the tool's usefulness, and ability to use it. To better understand the perceived utility of tools, we asked the 51 percent of respondents who claimed awareness of at least one tool how useful they found each of the tools to be. While planners expressed the highest levels of awareness for land use planning or build-out tools (CommunityViz and UrbanSim), only 16 percent found CommunityViz useful or very useful (4 and 5 on a 1 to 5 scale) and only 8 percent indicated that UrbanSim had that level of usefulness. None of the other tools fared well, either, with the greatest levels of utility achieved by Natureserve Vista (23 percent with scores of 4 and 5), RAMAS GIS (22 percent), and CorridorDesigner (19 percent).

Planners also reported relatively low levels of proficiency with tools. Only 87 planners, or 4.6 percent of total respondents, described any level of proficiency with any of the tools. The lowest levels of proficiency were claimed for UrbanSim, ClimateWizard, and CommunityViz, and greatest levels with Miradi and FunConn (Fig. 7). Examination of awareness, tool use, and proficiency together clearly indicates that most planners are not aware of or using conservation planning tools (Fig. 8). However, only 2 percent felt that the tools they *were* using were sufficient for the job, which indicates there is a role for additional tools, or combinations of tools, to help bring conservation-based planning to the land use planning community.

We then asked about barriers that might inhibit planners from using conservation planning tools. When asked what factors prevented them from using these tools in their work, 89 percent of survey respondents answered.

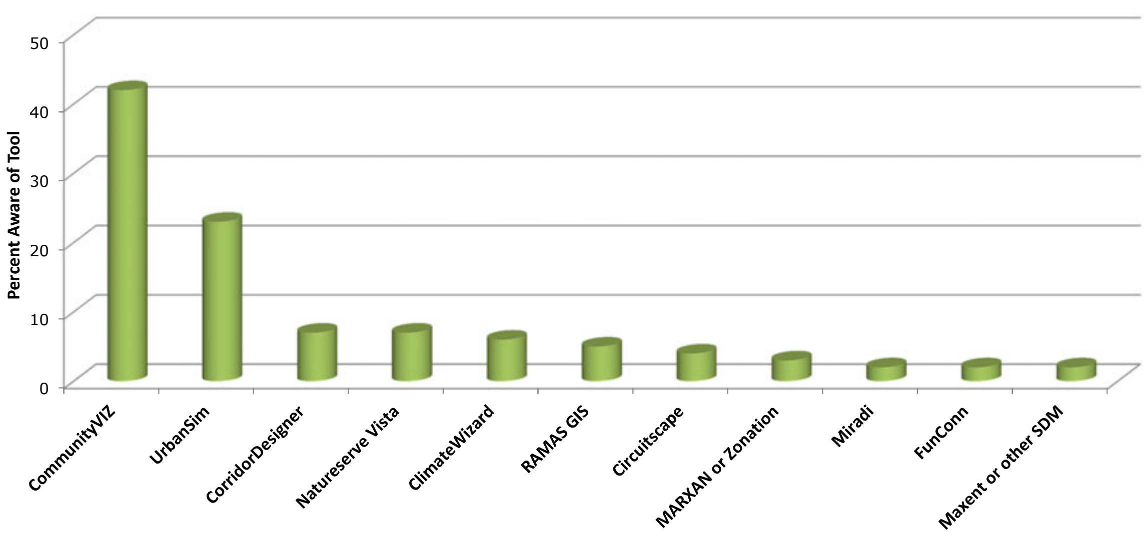

Figure 6—Awareness of planning tools. Awareness among planners of a representative set of 11 conservation planning tools. See Table 1 and appendix A for functions of tools listed here.

The top three barriers were cost of software (55 percent), time needed to learn the tool (50 percent), and cost of training (47 percent). However, planners did express interest in receiving training: the majority (51 percent) indicated very or somewhat high levels of interest, and 31 percent indicated a moderate level of interest. Regionally, levels of interest were greatest in the Northeast, South, and Interior West, with lower rates of interest in the West North Central area.

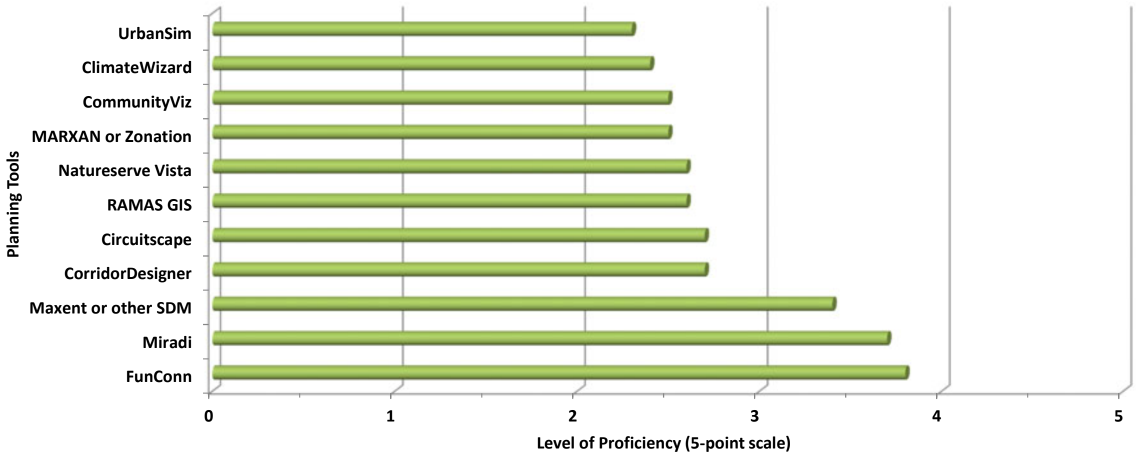

Figure 7—Level of proficiency. The mean summary (5-point scale) of levels of proficiency for conservation planning tools is displayed for the 51 percent of respondents who claimed awareness of any tool.

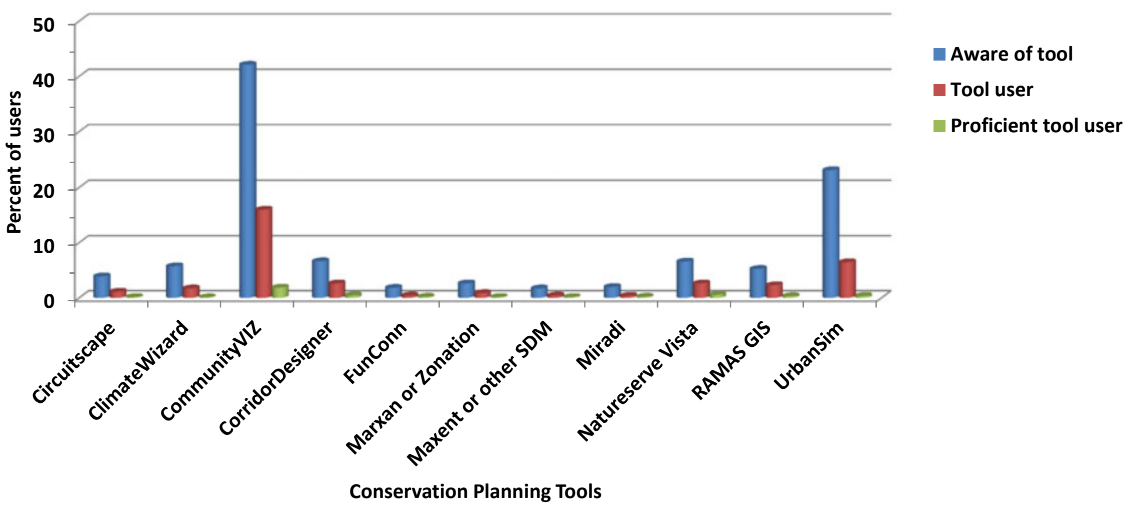

Figure 8—Awareness, use, and proficiency of conservation planning tools. Percentage awareness, user, and proficient user of different tools (total sample =1,872 planners).

Conclusions—Future Use of Conservation Planning Tools

The use of conservation planning tools for land use planning could help agencies, conservation groups, and others identify lands that face high levels of threat from human use but also hold high potential conservation value. Numerous powerful tools and extensive datasets are currently available for conservation planning, but the land use planning community has not widely adopted these tools. Insights into the lack of widespread use of such tools can be found in our review of conservation software, which shows that many of these programs are complex, technically challenging, and require a significant time investment to use. Further, our survey results combine to suggest it is unlikely that land use planners have or will have the time and resources to become expert users of these conservation planning tools.

However, additional time and training could be devoted to increasing literacy with conservation planning software among the land use planning community, and to increasing GIS capacity. Indeed, according to our survey, most land use planners are interested in training, which reveals an important opportunity for outreach and education to improve technical knowledge and application. Biologists with conservation planning expertise could then become more involved with land use planning through partnerships and collaborations. Such consultations would allow conservation biologists not only to contribute their expertise but also to inform their research by making them more aware of constraints in "real world" planning on private lands and with private-public partnerships (Miller and others 2008).

Because most of the land area of the United States is in private hands and used for multiple social, economic, and ecological goals, funding for education programs and collaborative networks to improve the use of conservation planning tools by land use planners could have a significant impact on biodiversity conservation in the United States. Where appropriate, land use planners could combine with conservation planners, land managers, and non-profit organizations to help shape not only how land is developed, but also where and how land is protected [footnote 4].

Establishing collaborations among land use planners, ecologists, biologists, conservation planning modeling experts, and public lands managers could also help expand conservation planning from academic simulations to conservation and land use action on the ground. However, conservation planning will remain complex—planning often occurs over multiple scales, with ecological processes such as climate change occurring at large geographical extents but actual management and land use planning taking place at the local level, often on private lands with multiple owners. Technological advances happen quickly as well, so that conservation planning has become a rapidly evolving field; indeed, the specific data and tools presented here will quickly become obsolete if they are not updated and revised.

A study of conservation and ecosystem-based tools in the marine environment found that the lack of consistent financial investment was another challenge for the use of many tools, leaving managers to choose between low-quality, unmaintained, but free products or commercial products with high license fees (Curtice and others 2012). For more information on this effort to compile marine-based ecosystem management and planning tools, please see the Ecosystem-Based Management Tools Network (http://www.ebmtools.org/).

These technological advances and our changing environments, as well as shifting political and economic circumstances, combine to pose substantial challenges to land use planning. Only through being iterative, integrative, and as open as possible to new techniques will we be able to incorporate conservation biodiversity issues in land use planning.

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[4] For example, tens of thousands of conservation easements have been established on private lands in the United States in recent decades.

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Appendix A—Overview of Conservation Planning Tools

Table A-1 presents a detailed overview of conservation planning tools reviewed for this project. Most are software; four are data models representing scenarios that are used in conservation planning.

Table A-1. Additional information on GIS conservation planning tools reviewed for this project

Software type	Software name	Computing environment	Programming language	Difficulty (1 = easy, 5 = lots of time investment)	Data requirements (1 = standard inputs, 5 = specialized)	Quality and availability of documentation (1 = very accessible, 5 = technical language only)	Web site for further information
Reserve selection	Marxan	Zonae Cogito	N/A	5	2	3	http://www.uq.edu.au/marxan/
	Marxan with zones	Zonae Cogito	N/A	5	3	3	http://www.uq.edu.au/marxan/
	Zonation	Stand alone	Compiled	5	5	5	http://cbig.it.helsinki.fi/
Habitat connectivity	Corridor Designer	ArcGIS 10	Python	4	2	2	http://corridordesign.org/
	Circuitscape	ArcGIS	Python	5	2	4	http://www.circuitscape.org/Circuitscape/Welcome.html
	Linkage mapper	ArcGIS	Python	5	2	5	http://code.google.com/p/linkage-mapper/
	Unicor	ArcGIS	Python	5	5	5	None found
	FunConn	ArcGIS 9.1	Python	4	2	5	http://www.nrel.colostate.edu/projects/starmap/funconn_index.htm
	Wild Lifelines	ArcGIS 10		3	1	3	http://www.twp.org/what-we-do/scientific-approach/wild-lifelines
Species distribution modeling	Expert Opinion	ArcGIS 10	N/A	5	1	1	NA
	Maxent		JAVA	3	3	4	http://www.cs.princeton.edu/~schapire/maxent/
	Presence			5	3	4	http://www.mbr-pwrc.usgs.gov/software/presence.html
	RAMAS GIS	Stand alone	Compiled	5	5	3	http://www.ramas.com/index.php?option=com_k2&view=itemlist&layout=category&task=category&id=41&Itemid=80&lang=en#gis

Table A-1. *Continued.*

Planning process integration	NatureServe Vista	ArcGIS 10	Python	2	2	2	http://www.natureserve.org/vista
	Miradi	Stand alone	Compiled	2	2	1	https://miradi.org/
Threats	Community Viz (Local Buildout)	ArcGIS 10		3		2	http://placeways.com/communityviz/
	Global Human Footprint	Raster dataset for ArcGIS, Web interface	NA	3	1	3	http://sedac.ciesin.columbia.edu/wildareas/
	Future Human Footprint scenarios	Raster dataset for ArcGIS, Web interface	NA	3	1	3	http://www.2c1forest.org/
	Future housing and impervious surface scenarios	Raster dataset for ArcGIS	NA	5	1	5	http://www.pnas.org/content/107/49/20887.full
Climate	Climate forecasts, historical data	Raster datasets, Web interface	NA	3	1	3	http://www.climatewizard.org/

Appendix B—Drilling Down Into Reserve Selection Software: Marxan and Marxan Z

What Does Marxan Do?

Marxan is a tool for selecting areas to constitute efficiently configured protected area networks (that is, reserve systems). Marxan is intended to optimize inclusion of biodiversity targets in a reserve system while minimizing cost—which at its simplest is defined by area. Boundary length, or perimeter, is minimized relative to area, which has the effect of maximizing "core" habitat relative to "edge."

Marxan Z (Marxan with zones) has the same functionality as Marxan but is able to allocate planning units to multiple zones (for example, marine protected areas of various protection levels) and to incorporate multiple costs into a systematic planning framework. Marxan Z extends the range of problems the software can solve to include the near optimal allocation of resources to multiple-zone configurations. The purpose of Marxan Z is to assign each planning unit in a defined region to a particular zone in order to meet a number of ecological, social, and economic objectives at a minimum total cost.

What Is the Marxan Work Environment?

The work environment for Marxan is the stand-alone, open-source, free GIS software Zonae Cogito, which allows users to implement Marxan in a windows environment (using a MapWindow GIS interface). By using Zonae Cogito, Marxan is made available to a wide audience including those around the world who cannot afford to purchase or do not otherwise have access to fee-based GIS software (such as ESRI ArcGIS). Zonae Cogito provides a method for incorporating input files, parameterizing models, and visualizing Marxan output, and in so doing supports a more iterative and interactive modeling and design process, essential to high-quality conservation planning.

What Are the Marxan Data Inputs and In What Form?

The inputs to Marxan and Marxan Z are text (.dat) files. There are seven fundamental input files used in Marxan Z. In addition, there are optional input files that facilitate additional functionality in Marxan Z, as shown below. Extensions and scripts are available for download to automatically create some of the input files from GIS layers in ArcMap.

Fundamental Input Files	Optional Input Files
Planning Unit	Feature Zone
Boundary Length	Boundary Cost
Planning Unit Versus Feature	Zones
Planning Unit Zone	Planning Unit Lock
Costs	Zone Cost
Zone Target or Zone Target 2	Zone Contribution or Zone Contribution 2
Input Parameter	

Generally, How Does Marxan Work?

Marxan uses the input information in computer algorithms (mathematical processes) to solve for a range of near-optimal solutions (heuristic approach). One of these algorithms is a simulated annealing process, which is described in an appendix to the documentation. The range of solutions provides output for each zone with other information in the output data files.

What Are the Marxan Outputs and In What Form?

The outputs from Marxan and Marxan Z are also in .dat (text) files. Output and input files are connected to GIS layers by the zone and planning unit identification codes or numbers. Output files are identified in the Input Parameter file and can contain various information including Summary, Sums, and Connectivity.

Appendix C—Drilling Down Into Habitat Connectivity Software: CorridorDesigner and Circuitscape

What Does CorridorDesigner Do?

CorridorDesigner provides a way to map habitat-based corridors between two places, which could be areas of high-quality habitat, existing protected areas, or other discrete locations. CorridorDesigner calculates the least-cost path between places based on measures of habitat suitability; it calculates best connecting routes and identifies barriers and bottlenecks. One feature of CorridorDesigner that makes it a comprehensive tool is that it provides ways to classify habitat suitability for a target species into population habitat, breeding habitat, or habitat patches.

CorridorDesigner has attracted a good deal of attention because of the excellent product documentation, elegance of the software design, intuitively accessible process and outputs, and ease of working within ArcGIS environment. It is fundamentally different in design and function from Circuitscape (profiled below); the two programs and others should be carefully reviewed and used in appropriate situations.

What Is the CorridorDesigner Work Environment?

The work environment is ArcGIS with the Spatial Analyst extension required. This program is written as a series of Python script tools that are used to accomplish the task in an appropriate order.

What Are the CorridorDesigner Data Inputs and In What Form?

The inputs are GIS feature layers in raster format and text files with reclassification parameters in them.

Generally, How Does CorridorDesigner Work?

The program uses raster reclassification and analysis to identify suitable habitat for focal (target) species. It then groups those areas into patches and evaluates their suitability for population, breeding, or habitat patches based on area and other species-specific parameters. It relies heavily on an "expert input" phase of parameterizing habitat suitability for focal species, and it reclassifies input layers (such as land use/land cover or elevation) on those values. The program then attempts to classify links of usable habitat among the major habitat patches, giving first priority to linking breeding habitat patches. Corridors are produced that have increasing levels of inclusiveness; the most narrow slices have the highest likelihood of supporting movement but incorporate the least variability and are most susceptible to edge effects. By calculating and evaluating possible linkages, bottlenecks and barriers can be identified.

What Are the CorridorDesigner Outputs and In What Form?

The primary product is a set of corridor slices of varying inclusiveness that are polygon shape files. These are intuitively appealing for use in conservation planning because like protected areas data, they are discrete shapes. A problem that has been discussed is that they may be seen as too definite and may not depict the spatial and temporal variability expected from gene flow in a changing world. On the other hand, they provide an excellent communications tool, and they may provide an easily understandable entry point for managers and planners new to habitat connectivity modeling. Other data products that are produced during the process are topographic index and habitat suitability factors as raster layers.

What Does Circuitscape Do?

Circuitscape models ecological connectivity across whole landscapes. Circuitscape applies electronic circuit theory to problems in landscape ecology—it models the flow of organisms and genetic material through landscapes with varying levels of resistance to that flow. Resistance is analogous to resistance to electricity; in landscapes, resistance is parameterized by values for roads, development, and natural landscapes as a function of how easily living material may pass through or by it. Circuitscape is different from other models in its approach, in that it considers all possible pathways across a landscape simultaneously. Outputs are not as simple to interpret as discrete corridor polygons, but they show different phenomena, as they are operating at larger scales. The two approaches are considered complementary.

Like CorridorDesigner, Circuitscape is being widely used. It has excellent documentation on its Website.

What Is the Circuitscape Work Environment?

Circuitscape is a stand-alone application written in Python with a graphic user interface (GUI).

What Are the Circuitscape Inputs and In What Form?

Circuitscape uses maps of habitat in ASCII grid format that can be exported from raster maps used or created in ArcGIS. One of the inputs is habitat with resistance or conductance coded into its cells. As with CorridorDesigner, this requires a step in which input layers (such as land use/land cover) are reclassified. Another input is a layer that defines regions or patches of high-quality habitat for grouping. Circuitscape will model flow between two or more nodes. The GUI prompts for additional information about options selected and whether or not the input grid contains resistance or conductance values.

Generally, How Does Circuitscape Work?

The Circuitscape program converts the input grid to a graph and runs a series of computations to determine flow paths and probability of flow along each path based on the options chosen by the user. Available RAM can influence the extent and resolution of a project that is able to be analyzed using Circuitscape.

What Are the Circuitscape Outputs and In What Form?

Outputs are a series of graphs that can be turned into ASCII grid maps for display in ArcGIS or other raster GIS program. Circuitscape outputs are more amorphous and less discrete than CorridorDesigner because they treat the entire landscape simultaneously and provide relative values for every cell, rather than attempt to define discrete areas. Circuitscape outputs provide information on areas that are important for gene flow and movements in a general sense; they also point to areas of the landscape where flow is more restricted and where connectivity may be limited and thus may be important for targeted conservation action.

Appendix D—Drilling Down Into Species Distribution Modeling Software: Maxent

What Does Maxent Do?

Maxent was developed to recognize the vastly incomplete information on species distributions. Attempts to map where and why species occur are frequently thwarted by problems that include: biased methods in which known locations of species are usually produced, difficulty in ascertaining species absence in the field, and lack of knowledge of species–environment relationships. Maxent maps are based on a "maximum entropy" approach to predict where species occur, by using a combination of (a) knowledge of where species have been observed and (b) the environmental correlates of those locations. Maxent is a general-purpose machine learning method with a simple and precise mathematical formulation. The idea of Maxent is to estimate a target probability distribution by finding the probability distribution of maximum entropy (that is, that is most spread out or closest to uniform), subject to a set of constraints that represent our incomplete information about the target distribution.

What Is the Maxent Work Environment?

Maxent is a stand-alone program written in Java, a language that is widely used. It has a graphical user interface (GUI) and can be run from a command-line interface.

What Are the Maxent Inputs and In What Form?

Maxent requires data on known locations of the species (that is, presence data), together with environmental information for the whole study area. Location data are geo-referenced—that is, they represent coordinates for observed occurrences. Absence data are not required. Environmental data are in a GIS format for the same study area and can include any available, uniformly distributed data. Climate, elevation, and land cover are potentially important environmental variables. Maxent can use both continuous and categorical data, and it can incorporate interactions between different variables. Maxent uses ASCII raster grid format.

Generally, How Does Maxent Work?

When Maxent is applied to presence-only species distribution modeling, the pixels of the study area make up the space on which the Maxent probability distribution is defined; pixels with known species occurrence records constitute the sample points; the features are climatic variables, elevation, soil category, vegetation type, or other environmental variables, and functions thereof. The program then predicts the likelihood of other populations as a continuous probability surface (grid or raster). If a threshold is defined, this technique can produce maps of suitable conditions and habitat for the species under consideration.

What Are the Maxent Outputs and In What Form?

Maxent outputs are grid or raster layers and/or tabular data in .csv (comma separated variable) files.

Appendix E—Drilling Down Into Species Population Viability Modeling Software: RAMAS GIS

What Does RAMAS GIS Do?

RAMAS GIS is highly specific software for modeling the viability of populations of species in a spatially explicit manner. Traditionally, viability of populations was assessed in a single location; RAMAS GIS uses patch characteristics and demographic information on populations to assess long-term survival in those areas. RAMAS GIS links GIS data layers with a metapopulation model for population viability analysis and extinction risk assessment. It is intended to help combine geographic data and demographic data for risk assessment. This is a terrific, powerful tool for single-species management but it requires a great deal of high-quality, specific data on populations. The program is well-documented in books and publications, and it has an informative Website and excellent instructions.

What Is the RAMAS GIS Work Environment?

RAMAS GIS is a stand-alone program that imports GIS data layers and provides tools to link metapopulation modeling with landscape data and GIS technology. It can be used in conjunction with ArcGIS. Unlike most of the other tools discussed, RAMAS GIS must be purchased.

What Are the RAMAS GIS Inputs and In What Form?

RAMAS GIS uses two kinds of data: GIS data and demographic data derived from field studies. GIS data inputs are land use and vegetation cover spatial data layers that can be coded for the ecological requirements of a species. Any map that contains information on some aspect of the habitat that is important for a designated species may be incorporated. Information is needed on dispersal distances, home range sizes, and minimum patch size. Demographic data are derived from field studies and experiments and include information on population structure, fecundity, and mortality.

Generally, How Does RAMAS GIS Work?

Once the spatial data layers for the ecological requirements of a species are imported, RAMAS GIS uses a habitat suitability map to find habitat patches. RAMAS GIS contains a separate module called RAMAS Metapop that can apply the above information to produce estimates of risk of a species for extinction and time to extinction. Demographic data are imported and used in the metapopulation model that incorporates patch structure from the GIS, to produce a risk analysis for the population. If the user has information about time change or a time series (for example habitat dynamics due to forest succession), RAMAS GIS can incorporate these data to build a time series of population-specific parameters for use in the metapopulation model.

What Are the RAMAS GIS Outputs and In What Form?

RAMAS GIS has the capacity to make a number of outputs for use in planning and research including tables, graphs and maps. Map outputs include a layer of habitat patches with high suitability for species survival that contains numerous attributes about habitat suitability, patch size, edge, survival, and growth rate.

Appendix F—Drilling Down Into Threat Modeling: The Human Footprint

What Does the Human Footprint Do?

A number of existing spatial datasets represent degree of human impact to the environment. Each of these datasets attempts to do the same thing but they differ largely in the detail of how they do it; some are quantitatively more sophisticated than others and use tools to assess, smooth, and average impacts over various scales. The Human Footprint is one of the first such approaches and is simpler than others in that the effects modeled are additive. Like the others, it is not a program but rather a raster dataset where each cell's value is a normalized index representing a cumulative human impact. The resulting "human footprint" represents the sum total of ecological footprints of human activities, not as a single number but as a continuum of human influence stretched across the land surface, revealing through its variation the major pattern of human influence on nature. The Human Footprint is a methodology that can be re-used when new input data become available. It also can be projected into the future.

What Is the Human Footprint Work Environment?

The data are displayed in a GIS working environment and result from a combination of GIS dataset layers. The Human Footprint is sometimes used in combination with other GIS datasets to derive new values of interest. Standard ArcGIS tools such as reclassification and buffer are used. Future human footprints are derived from mathematical models based on past trends and other information that might influence future conditions. Future human footprints extrapolate current values under scenarios, to make "forecasts" for future human impact.

What Are the Human Footprint Inputs and In What Form?

The first iteration of the human footprint methodology was done for the entire globe (Sanderson et al. 2002); data availability for that entire surface was a limiting factor. The Human Footprint calculated for the Northern Appalachian/Acadian Ecoregion includes four types of data used as proxies for human influence: population density, land transformation, accessibility, and electrical power infrastructure. These four types of data had nine datasets chosen to represent influence:

- Gridded population of the world,
- Global land use/land cover version 2,
- Vector map level 0 built-up centers,
- Vector map level 0 population settlements,
- Vector map level 0 roads and railways,
- Vector map level 0 roads and railways,
- Vector map level 0 coastline,
- Vector map level 0 rivers, and
- Defense meteorological satellite infrastructure program, stable lights.

Recent analyses have revealed that most of the variation in the human footprint (across subregions) is accounted for by just three variables: human population density (or housing density), roads, and land cover (Woolmer and others 2008, Theobald 2010).

Generally, How Does Human Footprint Work?

The Human Footprint is a quantitative evaluation of human influence on the land surface, based on geographic data describing human population density, land transformation, access, and electrical power infrastructure; the data are normalized to reflect the continuum of human influence across each terrestrial biome defined within biogeographic realms.

First, each of the nine datasets are categorized and assigned human influence scores, then the human influence scores for each of the nine datasets are summed to create the human influence index (HII) on the land's surface. In this scheme the human influence index scores range from 0 to a maximum of 72. Next, biomes and biogeographic realms are used to normalize this human influence. The greatest HII score in any realm is assigned 100, and the scores are normalized to the new scale 0 to 100. The lowest 10 percent of the values are selected as "Last of the Wild." Last of the Wild areas are considered areas of high naturalness and potential habitat cores for conservation action. These values are mapped as a continuous surface for the terrestrial portions of the earths' surface in raster format. A marine human footprint does exist. As with the other approaches, the human footprint can be reclassified into a landscape resistance surface to be used in connectivity modeling.

What Are the Human Footprint Outputs and In What Form?

The output is a raster (grid) map of human impact. Resolution of the map varies depending on resolution of input layers. Global grids can be 1.63 miles (1 km), and regional grids 98.4 yards (90 m). The display can be made informative through the use of symbology such that even casual viewers can readily grasp the levels of human impact and its variability, throughout (Fig. 9). While the simplicity and mathematical/conceptual features make the Human Footprint methodology a good communication tool, those features also are its drawback. More sophisticated approaches may treat impacts in a more naturalistic way, for example by smoothing a kernel of impact from roads based on traffic volume, which the Human Footprint does not do. As with all of these approaches, careful attention to the tool and its assumptions and uses is essential.

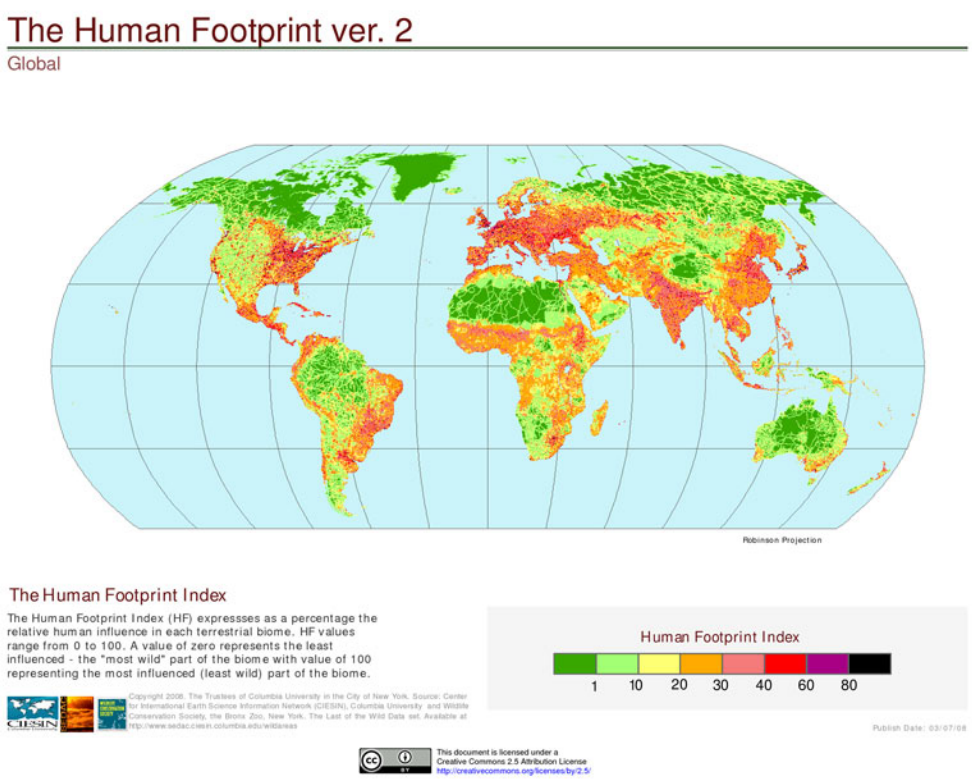

Figure 9—The Global Human Footprint. Source: Sanderson and others 2002.

Appendix G—Drilling Down Into Planning: CommunityViz

What Does CommunityViz Do?

CommunityViz is a broad-based tool designed to help planners, resource managers, local governments, and regional governments make decisions about development, land use, transportation, conservation, and other infrastructure elements in a defined area around communities. It supports planning, suitability analysis, impact assessment, and growth modeling.

What Is The CommunityViz Work Environment?

CommunityViz is an extension for ArcGIS (ESRI) and is designed to be used in participatory processes.

What Are the CommunityViz Inputs and In What Form?

Input data are in the form of GIS layers for land use and numerous infrastructure components such as roads, streams, and elevation. Input also requires interaction with the program tools to set parameters, define scenarios, and view on-screen alternative choices.

Generally, How Does CommunityViz Work?

This program uses a large number of infrastructure layers as a basis for estimating impacts of urban growth and development (or other change trend). Inputs about the layers are guided by "wizards" in a GUI to develop impact algorithms as indicators of change. Key elements of each layer are given best estimates or expert opinions to develop indicator equations. These are linked to time change, and results are displayed as tables or charts. Key indicators can be manipulated to examine different impacts visually. When all change estimates are complete, the cumulative effect can be remapped to look at impacts on different land use units and their impacts on key conservation elements as well as other resources. All can be remapped, charted, or visualized in 3D graphic presentations and reported as such.

What Are the Outputs and In What Form?

Simulation outputs are available in multiple formats:

- Numeric: ranges of values and graphs;
- Spatial: theme layers to illustrate where changes and impacts will occur;
- Visual (3D): 3D illustrations of changes and impacts; and
- Text: text files and html files reporting results.

Outputs are displayed on the computer monitor's screen and/or to files for printing or viewing.

Appendix H—Drilling Down Into Climate: ClimateWizard

What Does ClimateWizard Do?

ClimateWizard is a conservation planning tool developed by The Nature Conservancy (TNC), the University of Washington, and the University of Southern Mississippi. It is not a piece of modeling software; rather, it is a Web map server that displays and provides access to a range of conservation-relevant climate data. It integrates International Panel for Climate Change (IPCC) climate scenarios to produce maps of change, and it displays and serves climate data from the past 50 years. Custom analyses for subregions are available. ClimateWizard is well-documented on the Website and has a number of high-quality peer-reviewed publications. TNC support staff are responsive and helpful when contacted via email. When ClimateWizard was developed, the National Climatic Data Center was not as functional as it is now. Users of climate data should inspect both websites to make sure they are getting the best product for their planning needs.

What Is the ClimateWizard Work Environment?

The work environment is a Web map server. Themed maps are displayed in which choices can be made for analysis area (United States or global), time period (past 50 years, or future projections), map options (average or change values), measurement (temperature or precipitation), and future climate model (combinations of emissions scenarios and circulation models). Data can be downloaded from the site and used in ArcGIS or other GIS programs.

What Are the ClimateWizard Inputs and In What Form?

Data used on the Website are:

- United States lower 48,
- Historical data at 4-km (2.48 mi) resolution,
- Global historical data at 50-km (31.1 mi) resolution,
- United States lower 48 future model at 12-km (7.46 mi) resolution, and
- Global future model at 50-km (31.1 mi) resolution.

Generally, How Does ClimateWizard Work?

ClimateWizard provides a user-friendly Web "front end" where map displays can be made and viewed. Map displays can be downloaded as images from the Map Image section under Resources. In the viewer, values for average or change over time in temperature and precipitation can be displayed on maps at varying scales. ClimateWizard resources are provided and include case studies, documentation for data sources and models, data download, map image download, and custom analysis. Data are downloaded in ASCII format, which may be converted to ArcGIS rasters. Analysis of climate raster data can occur inside of ArcGIS.

What Are the ClimateWizard Outputs and In What Form?

Outputs include data and map image downloads. Data downloads are in ASCII format and can be used in ArcGIS. Map image downloads are made in the Web viewer and may be saved as .png files.

ClimateWizard is a good introductory tool and a notable teaching tool. Ease of display of various datasets in the map viewer allows a quick examination of patterns. Data downloads are straightforward and can readily be incorporated with other conservation planning data. The National Climatic Data Center has developed a comprehensive Website for data display and download.

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