The Next Frontier: Projecting the Effectiveness of Broad-scale Forest Conservation Strategies

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Abstract

Conservation and land management organizations such as The Nature Conservancy are developing conservation strategies to distribute protection efforts over larger areas and a broader range of ownership and management techniques. These 'distributed conservation strategies,' such as working forest conservation easements, are based on the premise that blending resource extraction, such sustainable timber harvest, and conservation should yield greater socio-economic benefits without significantly compromising the conservation of biodiversity or the sustainable provisioning of ecosystem services. However, it is unknown how well these strategies will compare to traditional conservation preserves or if they will be robust to climate change and resource demand over the coming centuries. Due to scarce financial resources and the relative difficulty of negotiating easement acquisitions, it is important for forest conservation and management organizations to know which strategies most effectively meet conservation goals. Meanwhile, the long duration required to evaluate most monitoring questions leads to a lag in knowledge transfer and delayed adaptive management. In this chapter, we discuss the challenges and time constraints to measuring conservation effectiveness and illustrate a scenario-building approach that we are applying to understand the conservation effectiveness of working forest conservation strategies in two large conservation acquisitions in the Great Lakes region of the United States. We show how this approach can be used to evaluate potential outcomes for biodiversity and

the provision of ecosystem services resulting from varying conservation strategies and discuss implications of this approach for the future of forest conservation.

Introduction

In the face of a rapidly changing world that includes globalization, climate change, trends in population growth, and the accompanying increase in resource and energy demands, innovative forest conservation strategies could play an important role in how land is allocated and used. However, the typical size, costs, lack of historical examples, and local or regional implications make development and implementation of innovative management and conservation options particularly challenging. Additionally, the effectiveness for broad-scale forest conservation actions depends largely on their social legitimacy. That is, persons that may be affected by or are responsible for implementing these actions must be allowed to have a voice in the decision-making process (Daniels and Walker 2001). Moreover, the public at large—stakeholders, community groups, indigenous peoples, and local experts—are becoming more connected to conservation decision-making for several reasons, including the cross-boundary requirements of many conservation targets and strategies, ease of communication through information technology advances, and heightened interest. Thus, the trend toward participatory conservation decision-making has contributed toward investment in sustainable forest management options that balance the interests and needs of multiple stakeholders.

After setting the context of historical and traditional conservation thought in the United States, we will discuss scenario-building and modeling approaches designed to evaluate the effectiveness of emerging conservation strategies.

A brief history of conservation

Forest conservation has a rich global history, with ideologies and practices simultaneously evolving in different geographical and cultural contexts. While important for understanding and applying conservation today, detailed recounting of this history is beyond the scope and purpose of this chapter. To situate our work within a historical context, we focus on the roots of forest conservation in the United States, where two prevailing ideologies concerning nature have informed forest conservation—the preservationist and conservationist perspectives.

The preservationist perspective grew out of the broader romantic-transcendentalist cultural movement of the 19th century, in which nature was viewed as an intrinsically valuable and inspirational part of divine creation. Importantly, this perspective placed humans outside of 'nature,' meaning that utilization and intervention in nature by humans was unnatural and destructive. Formative works that articulated and shaped the preservationist perspective include the writings of Ralph Waldo Emerson (*Nature*, 1863) and Henry David Thoreau (*Walden*, 1854). Naturalist and founder of the Sierra Club, John Muir also played a pivotal role in the preservation movement through his writings and advocacy, especially for the protection of the Yosemite Valley. Preservationist philosophy provided the basis for Muir's argument for preservation of natural areas irrespective of economic valuations.

Contemporary to the development of the preservationist perspective and in many ways a response to its ideology, the conservationist perspective viewed nature as useful for the provisioning of resources and materials for human consumption and to fuel economic growth. As a result, early conservation was largely aimed at the sustained harvest of particular species. This anthropocentric view was popularized largely by Gifford Pinchot, the first chief of the United States Forest Service (USFS), and the ideology of efficient and multiple uses of public lands, such as timber harvest, recreation, and hunting, remains a mandate of both the USFS and the Bureau of Land Management (BLM) today. Though President Theodore Roosevelt, a friend of Pinchot, was credited with nationalizing the conservation effort, Roosevelt was deeply concerned with species protection and allied more with the preservationist perspective promoted by John Muir (Figure 1).

Fig. 1. President Theodore Roosevelt and John Muir on Glacier Point in Yosemite Valley, California in 1903. Photo courtesy of the Library of Congress.

The early dialogue between preservationists and conservationists inspired extensive research and discussion among both scientists and land managers. A synthesis of the preservation and conservation perspectives emerged in the mid-twentieth century. This "Ecological Land Ethic" was put forth most clearly in Aldo Leopold's *A Sand County Almanac* (1949), which describes nature as a system of interdependent components, some useful for human use and some not, all of which are required for proper functioning of the system. This ‘systems view’ reflects the sophisticated understanding of both evolutionary and ecological processes that result in the functioning of ecosystems and their provisioning of goods and services. Importantly, from this perspective, humans are considered a component of the ecosystem whose influence, both positive and negative, must be understood and acknowledged in land management and conservation decision-making.

Traditional conservation approaches

Just as the theoretical foundations of conservation have evolved, so have the goals of conservation and the strategies utilized to accomplish these goals. Conservation approaches have consistently been expanding in scale both spatially and ecologically. Advances in scientific methodology have expanded the scale at which humans are able to perceive and understand the environment, revealing that species and ecosystems require resources beyond a single preserve.

Early naturalists first observed ecological degradation on a relatively fine scale, noting the decline of individual species or natural areas, and linked this degradation with human presence and activity. As a result, ecological studies and conservation management were conducted on a local scale, with the establishment of nature reserves aimed at excluding human activity. Also, conservation efforts often focused on the protection of individual species, as embodied by the Endangered Species Act of 1973. This approach was supported by the static equilibrium view of ecosystems, where human activities were viewed as unnatural and destructive. However, single species approaches to conservation largely divorce the species from its ecological context.

Advancing ecological understanding and technology prompted conservation planning and approaches to expand to broader landscape scales. Ecological research revealed that ecosystems were, in fact, dynamic, open systems that change over time in response to natural and anthropogenic disturbances. In parallel, ecological research and technology (computing power, remote sensing, and GIS) expanded the spatial scale at which ecosystems and processes could be investigated and understood. The sub-discipline of landscape ecology developed (Troll 1950; Turner et al 2001). As a result, ecologists and conservation practitioners were able to understand the broad-scale dynamics of ecosystems and recognized that successful conservation efforts would need to be larger in scope and broader in scale to ensure the persistence of these important dynamics (Boutin et al 2002).

Changing conservation

The broadening of conservation efforts in both scope and scale has forced conservation practitioners and land managers to address the important issue of defining the proper scale and boundaries of conservation units. Historically, political boundaries were the default boundaries of conservation units. These boundaries mostly followed a "defensible perimeter" without consideration of non-human issues unless they were of strategic importance with regard to resources or protection (e.g. rivers or cliffs). However, Lopez-Hoffman et al. (2009) note that many species of animals regularly migrate across international borders; the same is likely the case for county and state borders. One tool that conservationists use to plan across political boundaries and define conservation units are thematic maps focused on the biotic and abiotic properties that are "the basic units of nature on the face of the earth" (Tansley 1935).

A commonly used type of thematic map is an ecoregion map, which shows the Earth’s surface subdivided into identifiable areas based on macroscale patterns of ecosystems—that is, areas within which there are associations of interacting biotic and abiotic features. These ecoregions delimit large areas within which local ecosystems recur more or less throughout the ecoregion in a predictable fashion on similar sites. In other words, there is relative homogeneity in the properties of an area (Omernick et al 1997). While a number of scientists have mapped ecologically relevant characteristics, such as life zones (Holdridge 1967; Merriam 1898) and biotic provinces (Dasmann 1974), ecoregions are necessarily interdisciplinary due to the relationships between abiotic and biotic properties including geology, soils, climate, and nutrient cycling (Loveland et al 2004). Bailey's ecoregions distinguish areas that share common climatic and vegetation characteristics (Bailey 1998, 2005). Ecoregion maps are useful in land management and conservation in a number of ways. For example, The Nature Conservancy combines ecoregion maps with information about the distribution of species, communities, and ecosystem functions and processes to assess the biodiversity and conservation importance of areas within an ecoregion, providing a working blueprint for long term management and conservation.

Even with improved technologies and methods, scientists and land managers have found several challenges to developing conservation strategies at ecoregional scales. For example, most landscapes are divided into small parcels each with different owners. In this situation, gaining the support of enough landowners to implement broad-scale conservation strategies may be difficult. Alternatively, in landscapes with relatively few landowners, changes in land ownership may affect cooperative efforts over a large proportion of the project area. Also, voluntary landscape planning and management efforts are often difficult to fund and maintain and can be temporary as a result.

Despite these challenges, there are a growing number of compelling reasons to continue with ecoregional assessments. First, conservation opportunities are arising at unprecedented spatial scales, such as large corporate timber divestments (e.g. International Paper in the eastern and central United States). Second, while investments may be viewed as opportunities, there is great potential for accelerated landscape fragmentation if divested lands are not purchased as a whole or placed under a conservation easement that significantly limits subdivision. In addition, the successful conservation of species with large home ranges, such as many carnivore species, and species that require large, continuous forested areas also depends on ecoregional or landscape-scale strategies. Finally, climate change science suggests a need to conserve larger areas and connectivity to enable adaptation and ecosystem resilience (Millenium Ecosystem Assessment 2005b).

Not only has the scale of conservation efforts increased spatially to incorporate larger areas, conservation efforts are also expanding in scope. Ecosystem services are increasingly recognized as an important basis and catalyst for conservation. Ecosystem services are the conditions and processes through which natural ecosystems, and the species that comprise them, sustain and fulfill human life (Daily 1997). More simply, they are the benefits that people obtain from nature, which range from aesthetic pleasure and recreation to pollination of crops and water and nutrient cycling (Diaz et al 2005). ‘Provisioning’ ecosystem services include resource extraction, such as harvest of timber or non-timber forest products. Recently, there has been an interest in forest areas that can supply woody biomass for energy production.

Additionally, conservation decision-making is engaging a broader range of stakeholders. Where government agencies had previously taken the lead on land management and protection, conservation organizations are more active in participating in and leading conservation efforts today, partnering with local, regional, and federal governments as well as land owners and land users to achieve conservation goals. Today, participatory and community based conservation are more common, where stakeholders, community groups, indigenous peoples, and local experts are significantly involved in conservation planning and decision-making. In fact, many conservation practitioners are looking to traditional or local ecological knowledge to inform plans and strategies (Agrawal et al 1999). Public participation may not be appropriate to all conservation decision-making. Instead, many conservation practitioners collaborate with local experts to ensure locally and socially relevant decisions (Gustafson et al 2006).

New directions in conservation

Conservation strategies are evolving in response to this expansion in scale and scope toward what we term 'distributed conservation.' This approach spreads the economic and human resources available for conservation more thinly and across larger areas, as opposed to concentrated conservation efforts that focus on providing higher levels of protection to a smaller area. A concentrated conservation approach might purchase forest land to protect species of interest in a 'reserve', setting land aside from any extractive or working lands management. This may be optimal for some conservation targets, such as species relying exclusively on core habitat or species that are extremely sensitive to anthropogenic disturbance. However, strict preservation of relatively small areas is not effective for other targets, including wide-ranging species, landscape matrix species, species dependent on large-scale disturbances, and other non-species specific conservation targets such as community-level targets and ecosystem services. On the other hand, a distributed conservation approach could protect forest land by investing in specific land resource rights. For example, the international market for forest carbon credits invests in the carbon resource of a forest while allowing continued sustainable uses (Millennium Ecosystem Assessment 2005b; O'Connor 2008). Conservation easements also offer distributed conservation, a way to protect biodiversity, especially from fragmentation, by taking land out of development while still allowing sustainable uses (e.g. resource management or harvest, some recreation). However, easements may also be seen as a compromise, and the implications of forest management restrictions on landowners must be taken into account.

Many of the assumptions that underlie distributed conservation strategies, such as working forest conservation easements (WFCEs), are untested and are not without risks, including ecological, social, public relations, and economic risks. It is unclear if blending resource extraction (e.g. provisional ecosystem services) with conservation will yield a net conservation gain, that these broader, distributed strategies will more efficiently spread resources, or that today's conservation strategies will be robust to climate change impacts over the coming centuries.

Ideally, all conservation actions are monitored over time, and insights provided by monitoring are integrated into the management regime. This adaptive management allows the conservation strategy to remain flexible and effective in the face of new information, disturbances, and unanticipated dynamics (Gregory et al 2006; Moore et al 2008). Both on-the-ground and remote sensing methods are an integral part of management and monitoring at the landscape scale and are often coupled to provide an understanding of conservation over the long term. However, a more comprehensive understanding of conservation effectiveness often requires monitoring efforts that span decades, likely exceeding the duration of current trends in forest divestiture or funding opportunities as well as the timeframe for effective mitigation of external disturbances such as climate change. Therefore, there is a clear need to incorporate methods that inform current conservation opportunities by providing insight into the potential future outcomes of conservation strategies for both biodiversity and ecosystem services.

Scenario-building and landscape modeling: an integrated approach

Scenario-building approaches offer environmental planning and monitoring a glimpse into the potential future outcomes of decision-making and external change. A scenario is an account of a plausible future (Peterson et al 2003a). Scenarios have been used at least since WWII as a way of strategizing responses to opponents' actions. In the 1960's and 70's, scenario approaches were adopted as a business planning tool, particularly by the oil industry facing a rapidly changing global market (Mahmoud et al 2009). In the context of this paper, a scenario represents, describes, and accounts for the conditions that lead to one or more alternative futures (Figure 2). Rather than relying on predictions, which are quite uncertain under complex changing conditions, scenarios "enable a creative, flexible approach to preparing for an uncertain future," and recognize that several potential futures are feasible from any particular point in time (Mahmoud et al 2009). Among the most well-known applications, the Millennium Ecosystem Assessment used scenario analysis to understand the consequences of global ecosystem change for human well-being (Millenium Ecosystem Assessment 2005a; Carpenter et al 2006; Cork et al 2006).

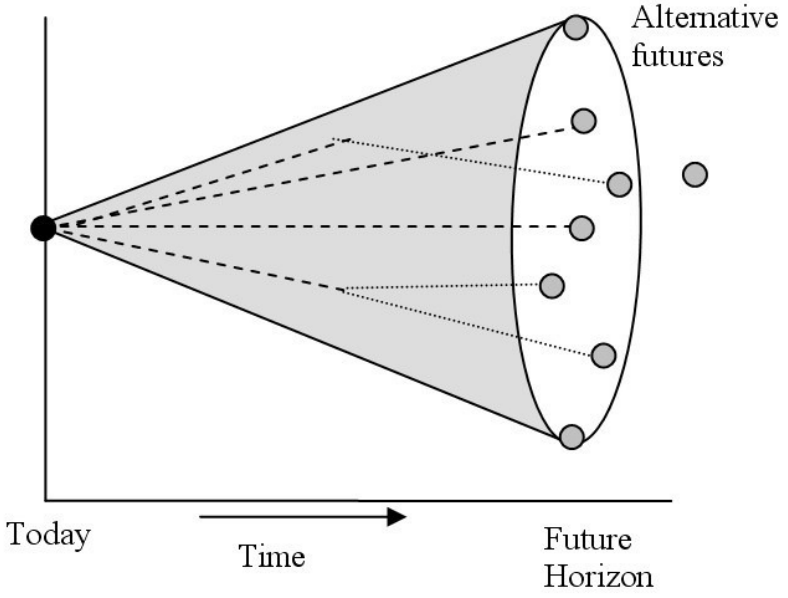

Fig. 2. Conceptual diagram of the use of scenario analysis to generate alternative futures (Mahmoud et al 2009, adapted from Timpe and Scheepers 2003).

In regional environmental applications, scenario analysis is often integrated with landscape modeling to create spatially-explicit alternative landscape futures resulting from land management, policy, climate change, and resource or energy demand alternatives (Baker et al 2004; Gustafson et al 1996; Nassauer et al 2007; Peterson et al 2003a; Provencher et al 2007; Sala et al 2000; Santelmann et al 2006; Santelmann et al 2004; Schumaker et al 2004; Sturtevant et al 2007; Tilman et al 2001; White et al 1997; Wilhere et al 2007; Zollner et al 2008). More specifically, a *landscape* scenario refers to the different possible conditions and accounts that underlie landscape change (Nassauer and Corry 2004), where the alternative futures are *spatially explicit* representations of plausible landcover patterns (often generated by using landscape modeling). Thus in this context, scenario-building is the *process* by which a team that includes stakeholders and/or experts defines the sets of conditions that will be used to generate future landscapes, and then simulates possible future land cover patterns based on those conditions. This synthesis can provide conservation practitioners and land managers with insight into the possible future landscape resulting from each scenario, enabling them to evaluate and compare the effectiveness of different strategies at achieving specific goals.

Scenario approaches vary broadly, and Mahmoud et al (2009) provide a comprehensive review of the types and applications of scenario approaches. Generally, we talk about two types of scenarios: e*xploratory* scenarios describe the future according to known process of change and extrapolations from the past. They can project forward using past trends (as with climate change), or anticipate upcoming change that significantly varies from the past (e.g. new demands for woody biomass for energy production). As an example, Metzger et al. (2006) considered vulnerabilities of ecosystem services across regions in Europe under various land use change scenarios. Their assessment showed, for example, that southern Europe may be particularly vulnerable to land use change. On the other hand, when alternative scenarios are developed to depict a desired or feared outcome and are utilized to develop strategies to achieve or avoid that outcome, respectively, they are referred to as *normative or anticipatory* scenarios (Mahmoud et al 2009; Nassauer and Corry 2004). For example, normative scenarios were applied in an iterative, interdisciplinary process for visioning alternative agricultural futures in watersheds of the Upper Mississippi River valley. This team looked at water quality, biodiversity, farm economics, and aesthetics under three leading constituency goals: a) maximizing agricultural commodity production, b) improving water quality and reducing downstream flooding, and c) enhancing biodiversity within agricultural landscapes (Nassauer et al 2007; Santelmann et al 2004).

In either case (exploratory or anticipatory), scenarios can be developed through a collaborative process among various stakeholders (Hulse et al 2004; Peterson et al 2003a; Theobald et al 2005). In the case of forest landscape scenarios, the input of stakeholders, such as landowners, foresters, and ecologists, can be used to set up the conditions of various strategies and to understand the alternative futures and contrasting trends that might result from those strategies. Stakeholder participation can continue beyond scenario development to inform the iterative evaluation and implementation stages. For example, three alternative scenarios of varied ecosystem service use through 2025 were developed for a northern Wisconsin (USA) lake region. These scenarios sparked a discussion of alternative futures and helped local people consider how the region might develop (Peterson et al 2003b). The collaborative learning process (Daniels et al 2001; Gustafson et al 2006) builds trust among diverse groups, lends social legitimacy to the outcomes of the process, and takes advantage of the place-based knowledge provided by these stakeholders. Put together, this approach recognizes that no amount of quantitative data or modeling alone can predict the dynamic behavior of complex natural systems (Figure 3). Yet, teams working in specific places or systems can build scenarios informed by years of practical knowledge along with empirical and simulated data. Scenario planning offers a framework for developing more resilient conservation policies when faced with uncontrollable, irreducible uncertainty (Peterson et al 2003a).

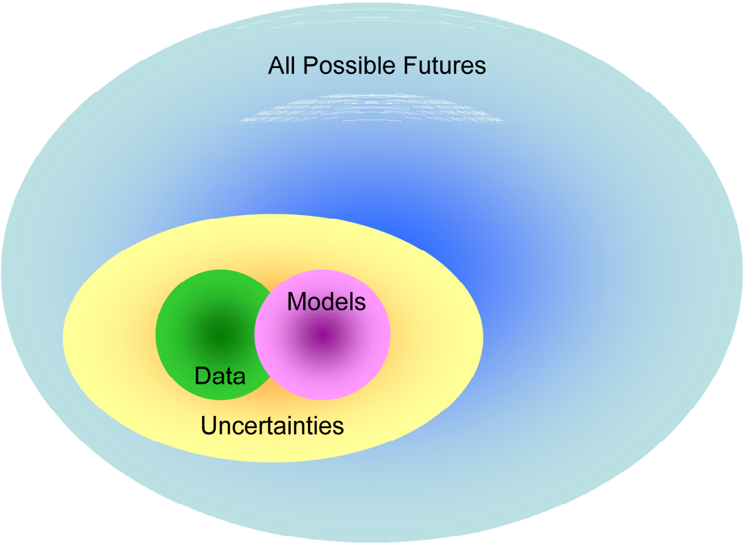

Fig. 3. The full set of possible futures (blue ellipse) is only partially represented in available data (green circle) and models (magenta circle). Together, the data and the models allow us to project the uncertainties, or knowable unknowns (yellow ellipse). But there remain many unknown futures that may exist beyond our estimation of uncertainties (blue ellipse). The probability of any model projection depends on the full set of possible futures, most of which are unknown (Carpenter et al 2006, based on the ideas of L. A. Smith 2002).

Concerns about scenario approaches tend to center on the validity of the experts' knowledge and the selection of experts and stakeholders to include in the process. Scientists at a recent landscape ecology workshop (US-IALE 2009) commented that if scenarios are built as stories without empirical data, the public will “think we don’t know what we are doing.” A related concern is that scenarios are not probabilistic, as they can include unlikely events or events to which a probability cannot be assigned. Indeed, sometimes scenarios with highly unlikely but very impactful events can be quite informative. For example, at the time of the oil embargo (1973-74), scenario planning previously undertaken by Shell Oil helped the company to respond quickly to maintain stability in an unpredictable market (Mahmoud et al 2009). Still, while scenarios can address many of the uncertainties in a system, they cannot necessarily be quantified (e.g. Figure 3). Thus, a stigma or misunderstanding about how scenarios are formed, their purpose, and their credibility may still persist.

The other key component to building integrative landscape scenarios is the selection of appropriate ecological modeling software. In a review and classification of ecological models, Scheller and Mladenoff (2007b) provide a valuable classification based on three criteria. The first criterion is whether the model includes or excludes spatial interactions, referring to whether or not the model represents the movement of energy, matter, or information across the landscape (Reiners et al 2001). The second criterion asks whether or not the software uses static or dynamic ecological communities. A particular model may keep an ecological community intact over time (static models), or the communities may shift to include or exclude new members (dynamic models). For example, Vegetation Dynamics Development Tool (VDDT) (ESSA Technologies Ltd. 2009), an open-source state and transition model, has static successional classes that are user defined communities. The amount of each successional class on the landscape can change, but the species composition will not. The third criterion is whether the model includes ecosystem processes. Modeling software that simulates ecosystem processes follows changes in net growth, biomass accrual, and decomposition. An example of such modeling software is LANDIS-II (Scheller et al 2007a). But, with the addition of spatial interactions, dynamic communities and tracking of ecosystem processes comes increased complexity and inputs.

The process of selecting modeling software can help to refine research objectives, define the audience, and set realistic goals (Sturtevant et al 2007). For example, if the objective of the modeling exercise is to inform stakeholders of the potential outcomes of management scenarios, then the ability to explain the outputs and process in a meaningful way is important. This suggests working in a less complex modeling environment. Alternatively, if the audience for the modeling exercise is more academic in nature and the questions involve factors such as ecosystem processes, then selection of a more robust software package is warranted, if possible.

Like any approach to understanding complex systems, ecological modeling efforts present complexities and challenges. For example, obtaining reliable, correctly scaled inputs can be difficult and sometimes impossible. Ecological systems are driven by processes that are the foundation of ecological modeling software. For example, VDDT requires that probabilities be entered for each disturbance (transition) per time period (e.g., if the mean fire return interval is 100 years, then the annual yearly probability is 0.01). Often this information is lacking or is from a particular study site that may or may not be representative of the landscape under consideration. Sometimes it is necessary to make assumptions about particular disturbances or management actions. In a landscape modeling exercise, Provencher *et al.* (2007) were uncertain about the effectiveness of particular invasive treatments. In this situation, modelers are required to make assumptions based on best information or model multiple scenarios (e.g. treatments are 25%, 75% and 100% effective).

Template Project: Wild Rivers Legacy Forest and Two-Hearted River Watershed

We are applying scenario analysis coupled with landscape modeling to evaluate and compare the effectiveness of both concentrated and distributed conservation strategies. These strategies include: 1) no conservation action, 2) persistence of current management strategies in the study areas, 3) all land in the study areas managed as a protected reserve aimed at biodiversity conservation, 4) all land in the study areas managed under a WFCE. An example of a distributed conservation strategy, WFCE's are based on the premise that sustained timber harvest and recreation activities should yield greater socio-economic benefits (ecosystem services) without significantly compromising biodiversity conservation (ecological targets). The possible future landscapes and potential outcomes for biodiversity and the provision of ecosystem services are evaluated for each alternative conservation strategy in the presence of external drivers of landscape change, including various climate change projections, development pressures, and demand for woody biomass in the Great Lakes region of the United States.

We focus on two study areas (Figure 4): 1) the Wild Rivers Legacy Forest (WRLF) area in northern Wisconsin encompasses 26,300 ha and contains both state-owned and managed forests as well as lands that are owned and managed by Timber Investment Management Organizations (TIMOs) with state-held WFCEs; 2) the Two Hearted River (THR) Watershed in Michigan's Upper Peninsula encompasses 46,538 ha and contains a mix of working forest easement and TNC-owned land that will be managed under Forest Stewardship Council certification (Forest Stewardship Council 2009). These two areas are similar in forest and landscape composition (riparian systems and hemlock-hardwood forest types predominate) and are typical of the adjacent Great Lakes and Superior Mixed Forest ecoregions. These two sites are regionally important for conservation due to the variety of conservation targets addressed and large-scale effort to abate the threat of subdivision as large landowners divest. Other examples of similar WFCEs occur in Maine with the Pingree Forest Easement implemented in 1999 by the New England Forestry Foundation (NEFF 2009) and in Minnesota with the Koochiching WFCE implemented in 2007 (TNC 2007). These sites exemplify the innovative landscape-scale forest conservation strategies at work today, with many organizations and stakeholders at work on the landscape.

The scenario-building process we use (Figure 5) is distilled into five general, iterative stages: 1) information gathering and scenario development, 2) target selection, 3) determining model parameters, 4) spatially-explicit landscape modeling, and 5) synthesis of spatial narratives. Each stage is informed by our core team, consisting of conservation professionals and landscape ecologists, as well as local experts and stakeholders via four interactive in-person and web-based workshops (orange boxes, Figure 5). We have divided these partners into two groups: an Expert Group that has site- or subject-specific expertise and participates in Workshops 1, 3, 4; and a Steering Group with regional expertise to ensure alignment with TNC goals and to consider our project within the broader forest management and monitoring context, whose role is focused on Workshops 2-4.

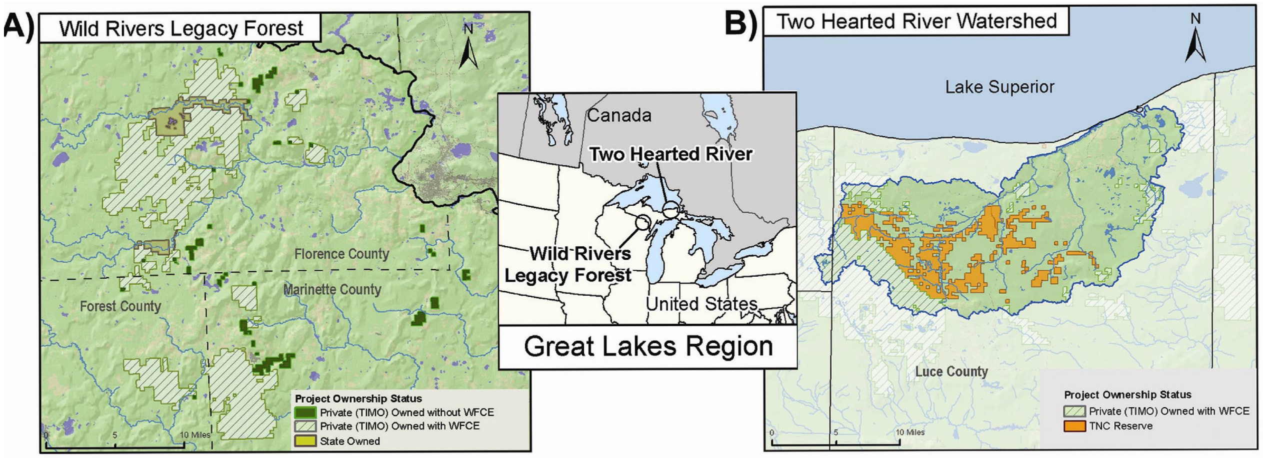

Fig. 4. Maps showing the Wild Rivers Legacy Forest in Northern Wisconsin (A) and the Two Hearted River Watershed in Michigan's Upper Peninsula (B). Maps courtesy of John Wagner, The Nature Conservancy in Wisconsin.

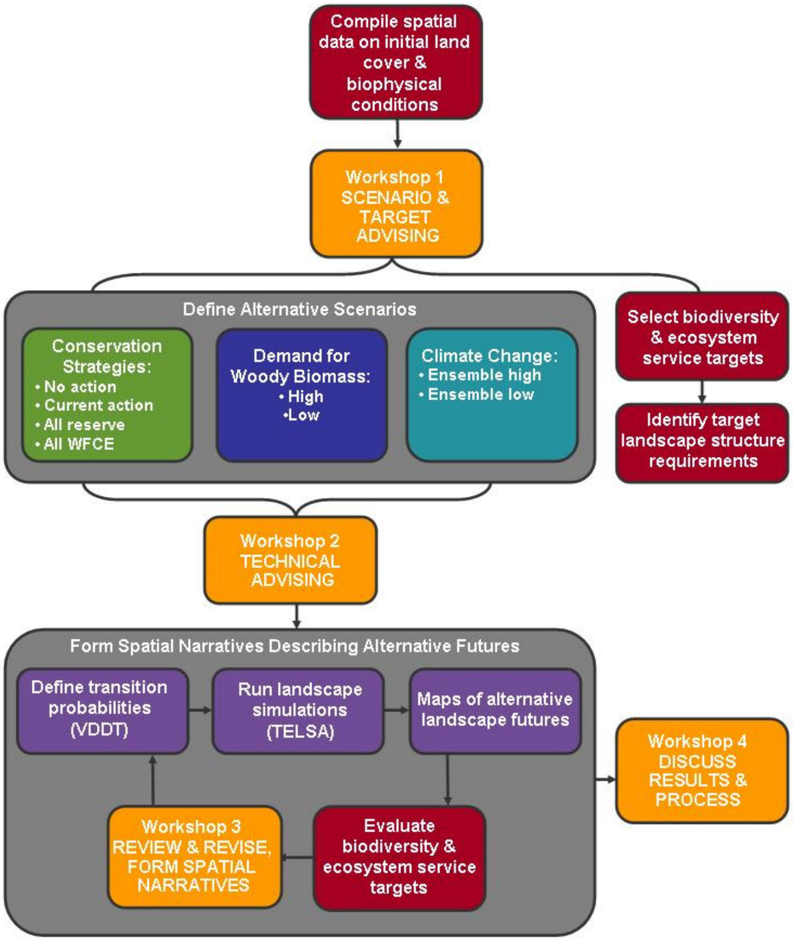

Fig. 5. Flow chart of the scenario-building process, infused with local and regional expert knowledge during four workshops (orange boxes).

Information gathering and scenario development

The first stage focuses on developing the scenarios or different possible conditions that may drive landscape change in our study areas. These are exploratory, rather than normative, scenarios. Scenario development requires an understanding of the initial state of each study area as well as the dynamic biotic and abiotic processes affecting these areas. First, initial maps of the two study areas are constructed by using land cover data and setting biophysical conditions. Initial landscape structure (composition and configuration) of the study areas is quantified by using spatial landscape metrics and indices. These initial landscape maps and indices provide the baseline from which alternative future landscapes diverge during the modeling process.

Once the baseline status of the study areas is established, the next step is to define the scenarios for which we will model possible future landcover. Each scenario is composed of a set of conditions that influence landscape change. Here, each scenario is a combination of a conservation strategy, a level of demand for woody biomass for energy production, and a climate change projection (Figure 5). The Expert Group provides crucial input for defining these scenarios in Workshop 1, including details about the alternative conservation strategies and demand for woody biomass that might be applied in each of our study areas.

Climate change projections are also a key component of each scenario. Rather than developing a new suite of climate change projections, a time-consuming and resource-intensive process, this project utilizes existing climate change projections. Specifically, we use climate change projections and rates for Great Lakes terrestrial ecosystems projected with Climate Wizard software developed by TNC, the University of Washington, and the University of Southern Mississippi (TNC 2009) and informed further by work of the Wisconsin Initiative on Climate Change Impacts (WICCI) Forestry Working Group (pers. comm., Sep 2009). We then migrate selected climate output variables (e.g. change in temperature, precipitation rates) at defined time steps into model definition as described next.

Target selection

Input from the Expert Group is also integral to selection of ecological and ecosystem service targets for each study area, the other component of Workshop 1 (Figure 5). Because the possible conservation outcomes for both biodiversity and ecosystem service targets are evaluated based on maps of possible land cover for each alternative future, all targets must have specific landscape structure or forest composition requirements. For example, ecological targets for THR include species such as Weigand's sedge and *Potamogeton confervoides* (algae-like pondweed) as well as communities such as Great Lakes Beachgrass Dune, Bog Birch-Leatherleaf Poor Fen, Jack Pine - Red Pine Barrens, Great Lakes White Pine - Hemlock Forest (TNC 2000), and fishless lakes. For each of those targets, we draw from known occurrences, existing studies, and expert knowledge about habitat and landscape structure requirements, especially in terms of spatial pattern and forest composition. We also relate the targets to indicators of forest health that TNC maintains. Then current and projected future habitat under different scenarios can be mapped, based on measured landscape and forest health indices.

Ecosystem service targets for this area fall primarily in the provisioning (e.g. forest products – timber, game, jobs) and cultural services (e.g. recreation, bird-watching) categories (Diaz et al 2005). In particular, we focus on demand for woody biofuels for energy production. As with ecological targets, landscape structure and forest composition requirements will be determined for each of the selected ecosystem services, and measured landscape cover in each of the different scenarios will be used to estimate their ability to provide the selected ecosystem services.

Determining model parameters

The next step is to determine the model parameters for each study area with the input of both the Expert and Steering Groups in Workshop 2. Model parameters, including ecological pathways of disturbance and succession, and how these pathways will be influenced by projected climate variables and demand for woody biomass, must be defined and incorporated into the model interface. Though these parameters are grounded in the principles of forest and landscape ecology, expert input and local knowledge about the dynamics of our study areas refine the landscape modeling process.

Spatially-explicit landscape modeling

We are using spatially explicit forest models to simulate landscape configurations for different conservation management strategies and climatic impacts (Mladenoff et al 1999). Our primary modeling tool is the VDDT/TELSA suite developed by ESSA technologies, which has been grouped with models that include spatial interactions among static communities, but exclude ecosystem processes (Scheller et al 2007b). The Vegetation Dynamics Development Tool (VDDT) has been used extensively by the LANDFIRE program and other projects with TNC involvement. This free and relatively user-friendly tool provides a state and transition landscape modeling framework for examining the role of various disturbance agents and management actions in vegetation change. We are using VDDT to build transition diagrams with succession, management, and disturbance pathways and transition probabilities. These transition diagrams are further informed by data on climate change and woody biomass demand gathered in Workshop 1 as well as by expert input in Workshop 2 (Figure 5). Once the diagrams are built for particular ecological systems and management strategies, the model is run to obtain expected proportions of the landscape that will be in specific successional classes (states).

To generate spatially-explicit landscape maps, the state and transition models developed with VDDT are linked to the Tool for Exploratory Landscape Scenario Analyses (TELSA). TELSA projects multiple states for multiple ecological systems across the landscape to produce spatial data. TELSA is polygon-based, requiring that specific geographic areas be assigned to an ecological system and an age class. VDDT is the foundation for the spatial modeling in TELSA, and thus its non-spatial models serve as major inputs to guide the spatial modeling.

For each conservation alternative, management regimes are assigned by area and parameters, based on input from the Steering Group. Then, the TELSA main model is used to simulate land cover changes at 25, 50, 100 and 200-year time steps under each of the four conservation strategies, and with various degrees of climate change and demand for woody biomass. The results from the TELSA modeling yield simulated landscape maps for each time step under each combination of conservation strategy, climate change, and demand for woody biomass, for a total of 24-32 initial simulations (more with additional iterations). Using the TELSA spatial analysis tool, we can evaluate some of the landscape requirements determined for each selected target and ecosystem service. For additional metric analysis, raster output maps from these modeling runs can be used as input layers in FRAGSTATS. Map and graphic output from TELSA and FRAGSTATS allow us to compare and communicate potential outcomes between conservation strategies and to look at resulting landscape indices among strategies with climate change impacts.

Synthesis of spatial narratives

Participants at Workshop 3 review and consider the series of landscape simulation outputs. Using their combined knowledge of the systems, they identify which scenarios are plausible, and build narratives, or storylines, around those alternative landscapes to describe human-ecological dynamics behind the visible landscape change. Input from this workshop also guides us in modifying the model and running additional iterations to produce more plausible simulations.

Finally, these scenarios are disseminated to TNC's forest conservation leaders in Workshop 4, a conference-style workshop at a central location within the upper Great Lakes region, to review lessons learned about various protection strategies. We invite an open discussion of the spatially-explicit narratives that emerged from the study, evaluating maps and graphics that convey how the two landscapes might look and function in the future. As a group, we reflect on implications of these scenarios considering, for example, whether TNC made the right decisions with these conservation strategies.

Conclusions and implications: pushing the frontier

Given the context of global change, innovative forest conservation strategies will be critical to future ecosystem health and diversity as well as the quality of life as provided by ecosystem services. However, the success of these strategies depends on their ability to address very challenging issues: making decisions with incomplete information, working across multiple political boundaries, limited resources and varied vulnerabilities and needs of conservation targets. While there will never be a perfect 'toolset' to address all of these issues for each stakeholder, we suggest that by creative use of new and existing approaches we can advance conservation.

Here, we have presented scenario-building as a flexible tool for informing and optimizing broad-scale forest conservation efforts. This integration of scenario analysis and landscape modeling enables scientists and conservation practitioners to understand the potential outcomes of the complex and simultaneous interactions of the diverse milieu of processes that influence landscape change over time, including ecological processes, climate change, and interactions of humans and the environment. We have demonstrated how the scenario-building approach can be used with local expert and stakeholder teams to explore and model and understand these complex dynamics in forested ecosystems in North America, and we expect that this approach can be tailored to provide insight into other conservation settings and drivers of landscape change. For example, this scenario-building approach (Figure 5) could provide insight into the possible futures of grasslands given various climate change and grazing pressures, or it could be used to understand the possible response of salt marshes to rising sea levels and development pressures.

Scenario-building complements both monitoring and adaptive management of ongoing conservation efforts. Areas revealed as vulnerable under a particular conservation strategy may warrant more intensive monitoring. And, by suggesting how different parts of the landscape could plausibly respond under various scenarios, adaptive management can be considered to redirect landscape change. Target ecosystems that respond poorly under changing climate scenarios might be candidates for a modified conservation strategy. Additionally, while the scenario-building process suggests plausible landscape outcomes, we expect that it will also lead to enhanced shared conservation management. Involving local experts and managers in defining the models and visioning futures will likely lead to more realistic outcomes (as opposed to black box models) and increased cooperation in conservation strategies (Gustafson et al 2006).

Scenario-building also facilitates conservation planning. By comparing the potential outcomes of different conservation strategies in an area of interest, conservation practitioners can make informed decisions about how to best utilize scarce financial resources and reduce the risks associated with the implementation of innovative strategies. In other words, this approach can be used to determine when and where concentrated versus distributed conservation may be most effective. These outcomes can inform the processes of negotiating easement acquisitions, arranging conservation strategies on the landscape, and maximizing return on conservation investments.

If successful, scenario planning projects should result in decisions that respond better to a changing environment and socioeconomic conditions. Only through long-term monitoring and landscape-scale experiments can this metric truly be assessed. However, it is clear from our past experiences, and from literature (see Mahmoud et al. 2009), that scenario-building promotes discussion and a more thorough consideration of potential complications and benefits of innovative broad-scale conservation strategies. In addition, we have learned that often the best way to communicate is by considering how various strategies may affect local ecosystems. The perspectives gained from scenario-building are often provocative, leading to engaging discussions and a better understanding of the system(s) of interest. It is clear that only through cooperation and constructive communication can conservation be successful at broad scales. Scenario-building provides a framework for both.

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