Integrating Expert Knowledge into a Model of Land Cover Change: A Case Study from Michigan's Upper Peninsula

Jessica Price[1], Janet Silbernagel[1], Randy Swaty[2]

[1]University of Wisconsin-Madison, [2]The Nature Conservancy

Motivation

Figure 1. Local experts and conservation practitioners showing researchers around the study area during an in person workshop.

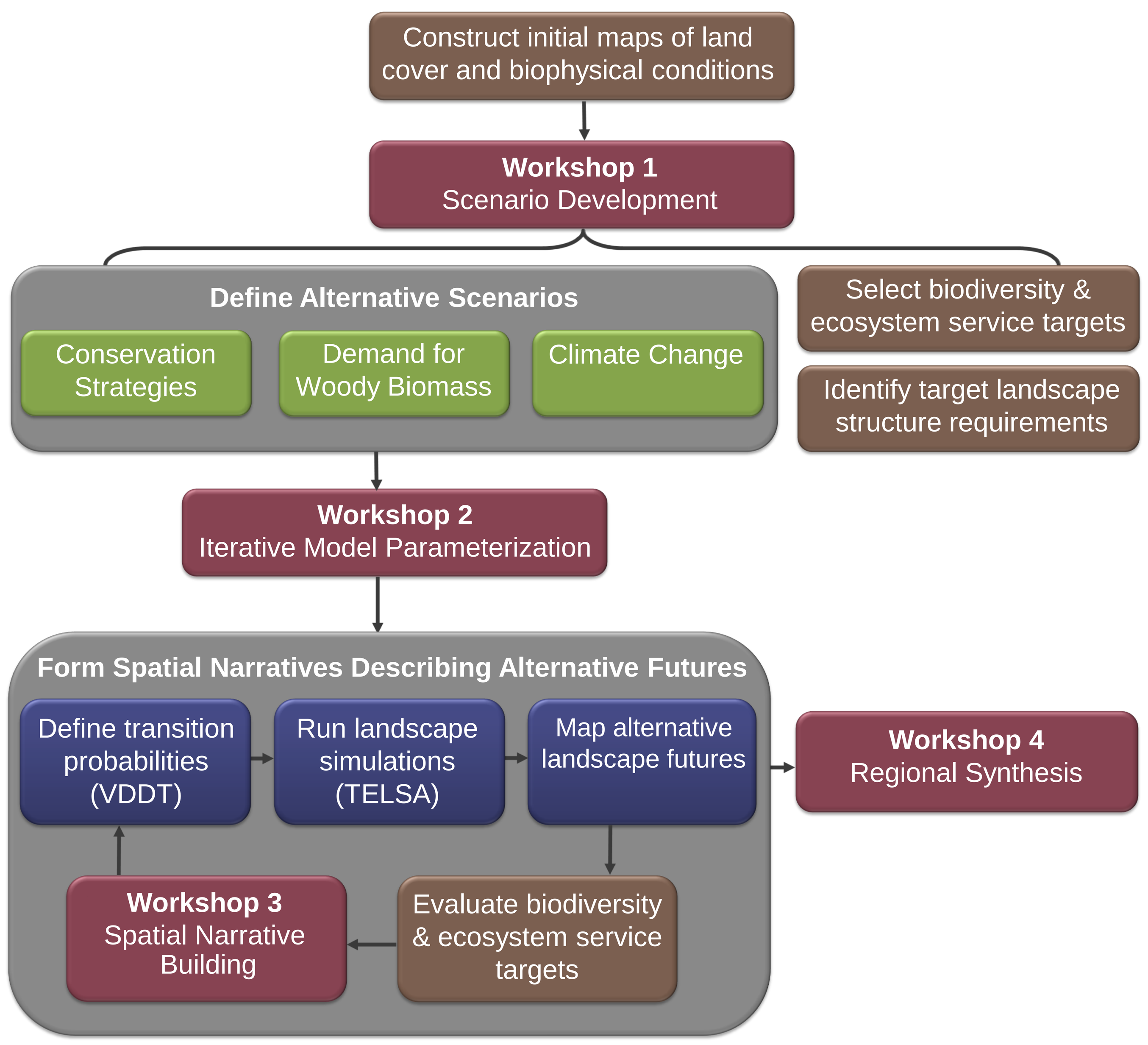
Landscape scenario analysis provides a way to visualize and compare the outcomes of a variety of management strategies and to develop more resilient conservation policies when faced with the irreducible uncertainty associated with changing climate, ecosystem, and socioeconomic conditions (Peterson et al., 2003, Nassauer and Corry, 2004).

We demonstrate the elicitation and integration of expert knowledge to develop, model, and analyze scenarios of landscape change in a collaborative project by the Wisconsin and Michigan Chapters of The Nature Conservancy (TNC) and landscape ecologists at the University of Wisconsin at Madison. This project aims to evaluate the effectiveness of various conservation strategies under conditions of climate change and demand for woody biomass for energy production.

Expert knowledge was infused into the scenario-building and modeling process (Fig. 2) in three key stages—(1) scenario development, (2) model parameterization, and (3) spatial narrative building. A variety of methods was utilized at each of these stages, including in-person workshops with local experts, web-based workshops with regional experts, one-on-one interviews, and an online collaborative tool.

Approach

Figure 2. A flow chart illustrating the collaborative scenario-building and landscape modeling approach.



Selection of Experts

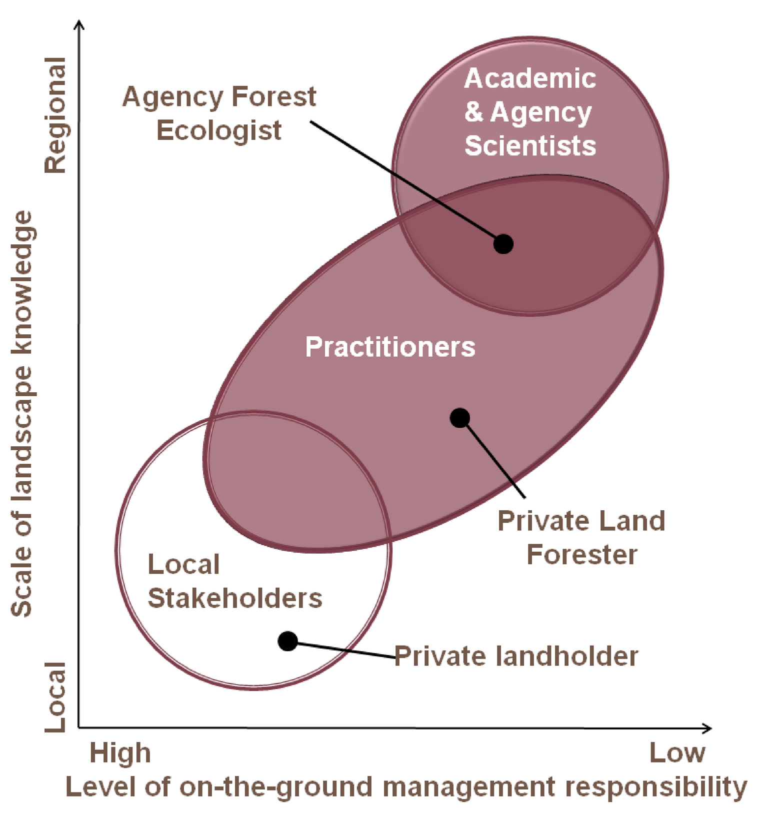
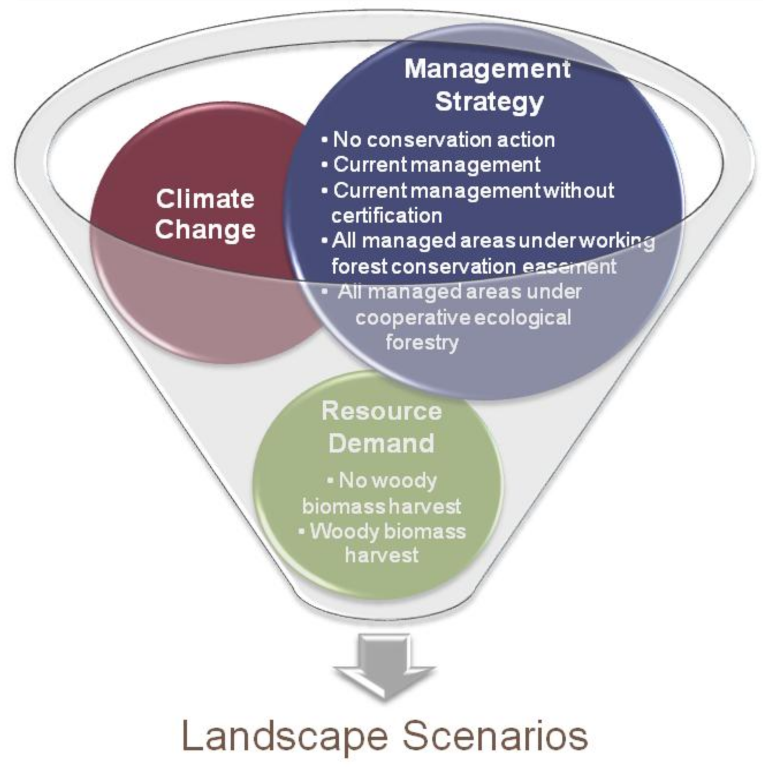


Figure 3. Experts involved in scenario development and modeling can be divided into stakeholders, practitioners, and academic and agency scientists, separable by the scale at which they understand the landscape and the level of their management responsibility.

- Local experts: Practitioners with local knowledge base and affiliation with the agencies and organizations responsible for managing the study area.
- Regional experts: Academic and agency scientists involved in regional forest management and monitoring.
- Stakeholders: Landowners or others with a local, non-professional land interest.

This composition (1) increased the likelihood that experts would incorporate project results into management decisions and (2) decreased biased toward a single set of goals or values.

Scenario Development



We developed exploratory scenarios (Carpenter et al. 2006, Gustafson and Crow 2006, Mahmoud et al. 2009, Peterson et al. 2003) in collaboration with local experts in an in-person workshop at the study location (**Fig.2, Workshop 1; Fig. 4**).

Experts at this workshop included forestry practitioners, land managers from timber operations and the Department of Natural Resources, and academic and agency scientists (**Fig. 3**).

Figure 4. Workshop participants were asked to identify the most important climate variables to consider and management strategies that might be applied in this landscape, and to assess the demand for woody biomass for energy production in the area. Then, they were asked how each of these three components might influence forest dynamics in the study area.

Model Parameterization

To define model parameters (**Table 1**), including ecological pathways of disturbance and succession, influences of projected climate variables and resource demand, and management strategies, we gathered information from local and regional experts in two web-based workshops and a series of one-on-one interactions (**Fig. 2, Workshop 2**). Though these parameters are based on the principles of forest and landscape ecology, expert knowledge of local and regional dynamics was crucial to capture the details and interactions of disturbance, succession, and management for each scenario.

One-on-one interactions were also used to capture detailed, quantitative information too narrow or technical to be adequately addressed in workshop format.

Landscape scenarios were modeled using the VDDT/TELSA modeling suite (ESSA Technologies Ltd. 2010). State and transition models for each land cover type were developed in VDDT (based on existing LANDFIRE models, LANDFIRE 2007, TNC 2009) and combined with current land cover data in TELSA to generate spatially explicit maps of possible land cover 25, 50, 75, and 100 years into the future.

Table 1. Parameters incorporated into each component of the modeling interface.

Parameters	VDDT	TELSA	Source
Stand development			
Seral stages—defines ecological succession in each modeled cover type	• Define age and structural character • Assign succession pathway		Existing LANDFIRE models, current land cover maps
Natural disturbances			
Fire, wind, flooding, and insect infestation	• Define intensity and transition pathways • Assign return interval via probability and proportion	• Define size and spatial distribution	Existing LANDFIRE models, state records, scientific literature, local & regional experts
Management			
Timber harvest and forestry practices—thinning, selection cutting, clear cutting, plantation management, restoration forestry, biomass harvest	• Define transition pathways	• Define stand age and size limits, return interval, spatial distribution for each cover type and management unit	Local and regional experts

Narrative Building

Simulated land cover maps (**Fig. 5**) and summary statistics alone do not provide a complete description of the possible future conditions resulting from each scenario. Therefore, a second in-person workshop (**Fig. 1, Workshop 3**) was held in which experts worked with the project team to build spatial narratives, or storylines, around the projected landscape futures. These narratives describe hypothesized human-ecological dynamics behind the simulated landscape change (Silbernagel, 2005, Cork et al. 2006).

Experts helped distinguish plausible from implausible scenarios and identified the most likely origin of implausible results. In this way, expert input from Workshop 3 guided model revisions to produce more realistic simulations of possible future landscapes.

An online collaborative tool, Data Basin by the Conservation Biology Institute, was used to share spatial and non-spatial data with experts outside of scheduled interactions. With this tool, experts could review model inputs and interactively map results without the need for GIS experience or software.

Insights and Outcomes

The benefits and considerations associated with each method of expert knowledge elicitation employed at each stage of the project are shown below (**Table 2**). Given the varied types of expert input required in collaborative scenario-building and modeling, we anticipate an approach utilizing multiple modes of interaction will be most effective. Carefully planned interactions with experts, combined adaptability and a willingness to follow unexpected leads, can provide a more thorough understanding of the implications of conservation actions.

These simulated spatial outputs and narratives will be used to assess the effectiveness of each conservation strategy at protecting biodiversity and ecosystem service targets in the study area.

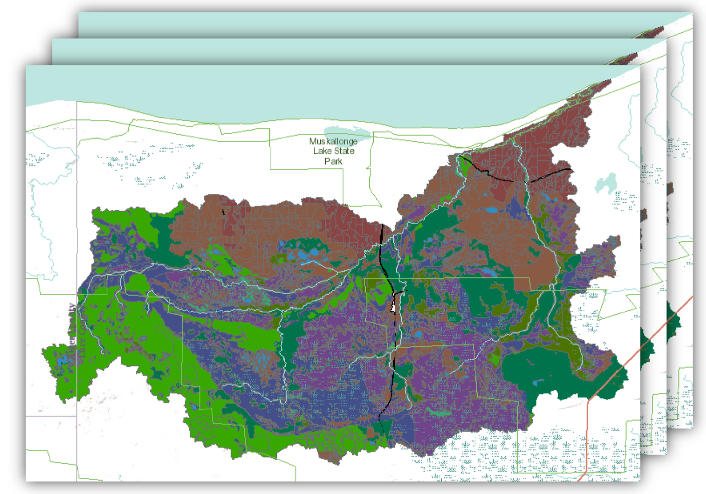


Figure 5. Simulated land cover maps for each scenario will be supplemented by spatial narratives to evaluate the effectiveness of each conservation scenario.

Table 2. Benefits and considerations associated with each method of expert knowledge elicitation.

Project Stage and Methods	Benefits	Considerations
Scenario development		
In-person workshop	• Gathers input from many experts • Establishes rapport • Opportunity to visit study areas • Enables multimedia presentations	• Time consuming and expensive to plan and host • May require travel
Model parameterization		
Web-based workshops	• Easier to schedule than in-person workshops • Gathers input from many experts • Inexpensive • Good for gathering general or 'ballpark' figures for parameters • Ideal for presenting results easily conveyed in digital format	• Multiple workshops for model parameterization • Participation is limited • Requires access to and comfort with web conference technology • Best following in-person interaction
One-on-one interactions	• Greater flexibility in scheduling, location, and topics • Facilitates gathering detailed information for parameterization not captured in peer-reviewed or agency publications • Lack of formal agenda enables gathering unanticipated input • Builds rapport with experts	• Time consuming • Relies on a single expert as the source of reliable information
Spatial narrative building		
In-person workshop	• Conducive to sharing map output • Enables discussion and debate among experts	• See above
Online collaborative tool (Data Basin)	• Facilitates continued expert participation • Allows experts access to project information and results • No need for access to or experience with GIS software	• Significant time for startup and maintenance, perhaps third-party assistance • Maintaining expert participation is challenging • Best as supplement to other elicitation modes

Acknowledgements

This research was supported by the NSF IGERT Fellowship Program, the Doris Duke Conservation Fellowship Program sponsored by the Doris Duke Charitable Foundation, The Nature Conservancy's Rodney Johnson and Katherine Ordway Grant, the USDA Forest Service State and Private Forestry Redesign, and the University of Wisconsin at Madison.

References

Cork, S., Peterson, G. and al, e., 2006. Synthesis of the storylines. Ecology and Society, 11:11.

Carpenter, S., Bennett, E. and Peterson, G., 2006. Scenarios for ecosystem services: an overview. Ecology and Society, 11:29.

ESSA Technologies Ltd. (2010) Vegetation Dynamics Development Tool and Tool for Exploratory Landscape Scenario Analysis. Available online at: http://www.essa.com/tools/.

Gustafson, E., Sturtevant, B. and Fall, A., 2006. A Collaborative, Iterative Approach to Transferring Modeling Technology to Land Managers. In: A. Perera, L. Buse and T. Crow (Editor), Forest Landscape Ecology: Transferring Knowledge to Practice. Springer, New York, pp. 43-64.

LANDFIRE, 2007. Homepage of the LANDFIRE Project. Department of Agriculture, Forest Service; U.S. Department of Interior. Available online at: http://www.landfire.gov/.

Mahmoud, M., Liu, Y.Q., Hartmann, H., Stewart, S., Wagener, T., Semmens, D., Stewart, R., Gupta, H., Dominguez, D., Dominguez, F., Hulse, D., Letcher, R., Rashleigh, B., Smith, C., Street, R., Ticehurst, J., Twery, M., van Delden, H., Waldick, R., White, D. and Winter, L., 2009. A formal framework for scenario development in support of environmental decision-making. Environmental Modelling & Software, 24:798-808.

Nassauer, J. and Corry, R., 2004. Using normative scenarios in landscape ecology. Landscape Ecol, 19:343-356.

Peterson, G., Cumming, G. and al, e., 2003b. Scenario planning: a tool for conservation in an uncertain world. Conserv Biol, 17:358-366.

TNC, 2009. Adapting LANDFIRE Vegetation Dynamics Models Manual v.1. TNC Global Fire Initiative, Tallahassee, FL.

Silbernagel, J., 2005. Bio-regional patterns and spatial narratives for integrated landscape research and design. In: G.T. B. Tress, G. Fry and P. Opdam (Editor), Landscape Research to Landscape Planning: Aspects of Integration, Education, and Application. Springer, Dordrecht, pp. 107-118.