Report to the LTER network office on the <u>Scenarios of Future Landscape Change</u> working group meeting

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Long Term Ecological Research Includes Scenarios of Future Landscape Change

Predicting the future condition of landscapes, based on explicitly defined forcings, is one of the gold standards in ecology. While our ability to predict ecological futures over large areas is improving (*1, 2*), coupled human-natural systems often yield surprises (*3*), and surprises are, by definition, unpredictable. This is the realm of scenario planning. When prescient thinking is needed but true prediction is impossible, scenario planning can be an effective strategy for describing plausible future conditions under different suites of assumptions. Scenarios are simply stories about the future with a logical plot and narrative governing the way events may unfold (*4, 5*). Used in conjunction with simulation models, scenarios can be a valuable tool for testing assumptions in coupled human-natural and other systems characterized by high levels of irreducible uncertainty and low levels of controllability (*6*).

There is tremendous enthusiasm within the LTER Network for scenario planning and forward-looking regional analyses generally. The veracity of this point was made plain during the planning stages of the "Scenarios of Future Landscape Change Workshop"—notably when more than 90% of the researchers contacted accepted the invitation to attend. In early April 2009, Harvard Forest hosted this two-day workshop with the participation of a diverse group of 32 social and ecological scientists who collectively represent sixteen LTER sites, and are actively engaged in some phase of scenario research for the region surrounding their site

A pre-workshop survey helped reveal the variety of scenario research that is ongoing at LTER sites. For example, researchers at the Harvard Forest are developing scenarios to examine different trajectories of suburban development, timber harvest, and conservation and the associated impacts on the eastern carbon sink. Meanwhile, researchers at Konza Prairie are developing plausible agricultural scenarios and the expected impacts on watershed hydrology. Despite the diversity of landscapes and drivers of change with their scenario research, participants found plenty of common ground. For instance, more than 70 percent of sites are interested in future changes to forest ecosystems. However, the representation of forests ranges from simply "forest cover" to detailed ecophysiological forest processes. Stochastic natural disturbances are included in almost all the LTER scenario projects, including: fire, windthrow, insects, and flooding. Anthropogenic disturbances are also integrated into most scenarios, including: land-use change (> 50%), timber harvest (≈25%), and fuels management (≈25%). With regard to ecosystem services, carbon sequestration was far and away the most frequently cited (≈65%), followed by biodiversity and habitat (≈25%), water quality and quantity (≈25%), and soil conservation (≈25%).

None of the participants has taken a strictly narrative approach to scenario planning (sensu, *7*). Instead, they all find some method to integrate qualitative assumptions about how the future may unfold into quantitative analysis—typically using spatial simulation models. Indeed, LTER scientists are employing an alphabet soup of simulation models to project potential changes in landscape conditions, including: ALFRESCO, BIOME-BCG, ED, ENVISION, GEOMOD, LANDIS, LAMPS, PNET, SLEUTH, SWAT and others. Not surprisingly, the research and the models operate across a range of spatial and temporal scales depending on the questions. Study extents range from a single watershed to the entire eastern seaboard and the spatial grain of analysis ranges from less than a square meter to one-degree grid cells (Figure 1).

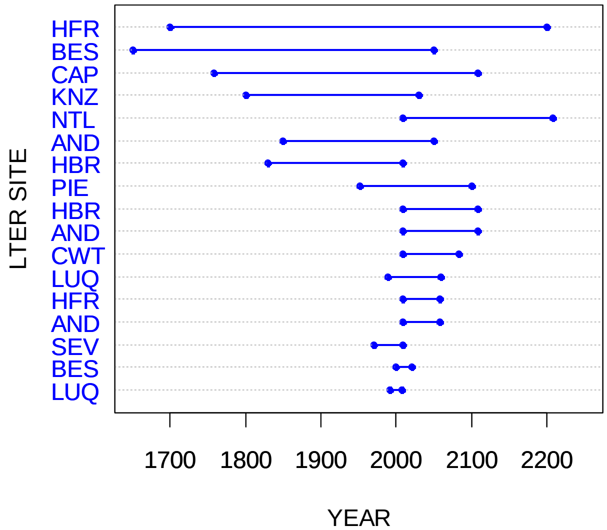

Figure 1. Ongoing scenario research by participants at the Scenarios Workshop showcase a wide diversity of approaches. For example, the temporal scope of analyses varies over orders of magnitude.

The diversity of approaches outlined in the pre-meeting survey underscored what was to become a recurrent theme during the workshop: there is no one right way to conduct scenario analysis.

WORKSHOP STRUCTURE

The two-day workshop relied heavily on break-out groups to address ten topics that had been identified by the pre-meeting survey and then refined by the Workshop Organizing Committee. The first day's break out topics dealt with technical, "nuts and bolts" types of issues, while the second day's topics dealt with conceptual, "big picture" issues. Each group created an outline describing the major considerations related to their topic and then all participants were asked to provide written comments on the outlines. What follows is a summary of the findings of the break out groups.

Day One "Nuts and Bolts" Break outs:

Accounting for carbon and other biogeochemical cycles within scenarios

Scenarios for LTER regions should consider how potential trajectories of future land use and land cover change may affect future C sequestration and N retention in vegetation and soils. Doing this well will mean asking: How will the magnitude of these changes compare to those brought about by other factors including climate change, rising CO_2, air pollution, and disturbance? In addition, scenarios should address how the location, orientation and spatial heterogeneity of land cover changes influence C and N retention of the landscape overall. More subtle changes within cover types will likely also be important. These may include future changes in landscape management practices, such as: the types of crops produced, the production of food versus bioenergy, timber versus bioenergy, fertilizer use, or tree species composition. The extent to which the effects of these factors can be evaluated will depend on the spatial and temporal resolution of future land use classifications and the depth of our understanding of ecosystem processes within the relevant cover types.

Accounting for water quality and quantity

Scenarios should identify changes in the biophysical and human environment that push systems/LTER sites to water limitation and affect water quality and quantity. They should have the capability to identify nonlinearities and tipping points. Important drivers in any LTER scenario should include human population growth, land-cover change, and changes in climate. Interesting scenarios may include plausible future changes in water rights or water pricing that affect agriculture. Scenarios should operate on regional to local scales because stakeholders and water needs are local and climate change impacts on hydrology are highly variable across space.

Accounting for natural and anthropogenic disturbances

The nature of disturbance varies substantially across LTER regions but, in all cases, future scenarios should consider potential interactions between natural and anthropogenic disturbances. Scenarios should explore potential changes in the influence or intensity of “press” types of disturbances (e.g. climate change, agricultural conversion, and rising CO_2) and changes in the frequency and intensity of “pulse” types of disturbances (e.g. harvesting and fire). Moreover, by looking across several LTER regions, scenarios may describe a gradient of conditions that span a range of magnitude and endurance of past disturbance. For example, BES and CAP have experienced relatively large and enduring disturbances whereas BNZ and HBR have experienced comparatively small and abrupt disturbances. Scenarios can be used to portray our best guess as to the effects of disturbance where uncertainty is high. They can also inform the manner in which policies and social drivers might influence disturbance regimes.

Accounting for future changes in land use and land cover (LULC)

The majority of LTER sites surveyed anticipate that land cover changes toward more developed uses will be among the dominant changes on the landscape in the coming decades. Not surprisingly, LULC change is a topic that has received considerable attention within the broad scenario-planning research community. Scenarios can be used to help identify the likely results of “smart growth” policies or to address questions of how different rates of population growth might influence ecosystem services. In addition, scenarios can help stakeholders anticipate how LULC change may interact with climate change and natural and anthropogenic disturbances. For example, how might sea-level rise or regional drought shift patterns of future development? Or, how might changes in development patterns influence the pattern of timber harvesting? All scenarios of LULC change must wrestle with the fact that past patterns of land use may not be good predictors of the future.

Incorporating and working with stakeholders

As LTER science moves outside the traditional boundaries of ecological research sites and starts to consider scenarios of future landscape change, the universe of stakeholders—the people who use and have influence over the research—will expand greatly. Ideally, LTER scenario planning will be a long-term, place-based, socio-ecological research activity. To achieve that goal, a diversity of stakeholders will need to be involved in all stages of scenario research. At the onset, there needs to be deliberate consideration of who the stakeholders are and how they are enlisted to participate. Stakeholders can provide critical information that informs the scenario narratives and helps define the suite of scenarios to explore. They also benefit directly from the results of the scenario findings. In most cases, though, stakeholders will provide more information than they receive. As such, a protocol that engages the full range of stakeholders from the very beginning is most likely to succeed. Further, scientists need to realize that they, too, are influential stakeholders in the scenario process. Finally, is important to consider how the research methods and findings are communicated to all stakeholders and how this information is perceived.

Day Two -- "Big Picture" issues:

Dealing with climate change when climate is not the primary driver

In any credible scenario of future landscape change, climate must be included as pervasive and dynamic, regardless of whether or not it is considered the dominant agent of change. Climate change has direct and direct impacts on land use patterns, ecosystem composition and structure, natural disturbances (e.g. fire, insects, disease etc), and hydrology. Fortunately, several climate scenarios already exist (i.e. IPCC) and can be incorporated into simulations to interact with scenarios of land use change, invasive species, or disturbances.

Tipping points, feedbacks, and unintended consequences

At their best, scenarios can help ward-off surprises or at least identify causal chains that lead to previously unexpected outcomes (*4*). Often, by the time evidence of tipping points, feedbacks, and unintended consequences are apparent, it is already too late to change the trajectory by practicing adaptive management. Ideally, scenarios can act as early warning systems for approaching changes and may also help convince people that long-term processes (e.g. sea-level rise) that may not have serious effects in the immediate future are still important to think about well in advance of their potentially dire consequences. However, there is also a risk of extending scenarios too far into the future where increasing levels of uncertainty can undermine their potential utility. Finally, we must be cautious that, in our efforts to make scenarios simple and easy to communicate, we do not systematically avoid thinking richly enough about connections to identify unintended consequences.

Managing and Measuring Uncertainty

Scenario analysis can be a valuable method to explore the space of uncertainty. This, after all, is the rationale for using scenarios as opposed to attempting to make true predictions. However, it is not simply the future that is uncertain. Scenario developers have to wrestle with uncertainties surrounding data, incompleteness, and future processes. Uncertainty in data concerns the amount of error in an information database. There are conventional statistical ways to address this first type. Incompleteness involves the aspects of the system that are excluded from the modeling process. Uncertainty in processes concerns whether processes that are in a particular model will continue to influence a system into the future. It may be impossible to rigorously quantify uncertainty due to incompleteness and future processes. Scenario researchers should be explicit about the types of uncertainties encountered and attempt to rank their magnitude. It may also be helpful to state that a scientist believes the overall direction of change (e.g based on expert opinion), while having relatively little confidence in the specific values produced by the analysis. In addition, it is important to remember that stake holders often perceive uncertainty differently than scientists and can have different expectations about how uncertainties are quantified. For example, while the public routinely deals with uncertainty in weather forecasts, they may discount an entire scenario if they find one pixel on a model output map if they know it to be wrong.

Connections to managers and policy-makers

Managers and policy makers are a special class of stakeholders that have long utilized scenarios for anticipatory policy assessments—from the alternatives analyses required by NEPA within federal Environmental Impact Assessments, to the detailed scenarios completed for the 2005 Millennium Assessment. Ideally, policy makers and managers should play an important role in the scenario planning process around LTER sites—both in providing and consuming information. Their participation can help to ensure that at least some of the scenarios developed are relevant to existing policy proposals. However, there may also be times when scenario development should not be constrained by existing policy incentives because doing so could limit consideration of processes that have been identified by scientists, but are not yet part of a broader social dialogue. At local to national levels, scenarios can be an effective decision-support tool for examining policy and management alternatives and thinking through the consequences of new management schemes. For example, scenarios may have been used to help anticipate the unintended consequences of the recent subsidization and promotion of corn biofuel. Further, managers and policy makers (and potentially conservation groups) can provide crucial long-term institutional support to maintain models and analysis teams.

Selecting a suite of scenarios

Scenarios are typically analyzed in sets of three or four, where the assumptions within the scenarios are deliberately contrasted against each other. The process of selecting scenarios must be inclusive to all stakeholders, as this process can effectively constrain the decision space available to managers and policy makers. Sharp contrasts between scenarios can clarify the consequences of policy and management choices. Plausibility is often an implicit goal of scenarios, but this may constrain imagination and our ability to identify potential surprises, thresholds, and non-linearity. One possible way to pick scenarios around multiple LTER sites would be to define LTER regions that consist of a landscape large enough to include an urban area, a natural resource base, and an aquatic transport system, in addition to the “classical” LTER sites. The ISSE framework (*8*) can operate as a common conceptual model to investigate scenarios about socio-ecological systems.

Future Steps for LTER Scenarios

The LTER network has several attributes that give it an obvious niche within the growing scenario-planning community: it is committed to long-term, place-based studies, it has amassed data and built instrumentation that can inform scenarios, and it consists of researchers with diverse specializations within the social and ecological sciences. Not surprisingly, there was broad agreement among workshop participants that Scenarios of Future Landscape Changes should be a network-wide activity and that it could be used to help implement the ISSE Decadal Plan, lending site-specificity and relevance to the six questions. (*8*). In fact, the overarching question raised at the conclusion of the meeting was: why haven't we been doing this all along?

Participants were enthusiastic about comparing future scenarios across several LTER sites. The Biocomplexity AG-TRANS project (*9*) was cited as an instructive of how a small set of LTER sites with a common history conducted comparative research. It was also noted that several additional ways exist to define a constellation of sites for a comparative scenario research. For one, scenarios could be built around a common "problem space," such as shared expectation of future suburban land use changes. Alternatively, comparisons may be made based along a continuum of ecosystem service availability, such as water (dry to wet), or carbon sequestration (high to low). Or, simple geographic clusters of sites may also be instructive, such as among the three LTER sites in New England. Regardless of the final unifying theme (or themes), participants are already beginning to seek ways to fund and implement comparative scenarios.

As a first step toward that goal, the group suggested that it may be productive to start simple and to allow qualitative work to begin and operate on a parallel but separate tract as the development of quantitative models. For example, once a group of sites has been identified for comparison of future scenarios—but before data needs and the challenges of parameterizing simulation models threaten to swamp the project—simple narrative scenarios could be constructed (sensu, *7*). Focus groups that include LTER PIs, regional community leaders, planners, landscape architects, environmental historians, and other stakeholders who have a deep perspective on the landscape could engage in a series of strategic conversations about the future. Through this process, scenario-planning researchers can identify the expectations and fears that exist regarding the future of our landscapes. This type of qualitative comparison of narratives across multiple sites will undoubtedly yield interesting insights, even before the simulations come online. In addition, having a deep qualitative understanding of anticipated future changes will facilitate an efficient transition to the quantitative analyses of possible landscape dynamics.

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