Interactions among ecosystem services, ecosystem dynamics, and human outcomes and behavior

Submitted by the ILTER Science Agenda Committee

Introduction, problem statement, and cross-site comparison

This proposal is the first network-level attempt by the ILTER network to address the linkages between ecosystem services (ES) and human outcomes and behavior, and how they influence each other in biomes. The work will be conducted by developing site-specific feedback models for one selected site representing a biome for each member network. The feedback model framework was developed in 2007 under the US-LTER strategic research initiative "Integrative Science for Society and the Environment" (ISSE) (Collins et al. 2007, Appendix 1) and by several workshops on land use and ES.

The general objective of the study is to address to what extent cultural differences in the perception and use of ecosystem services constrain the resilience of social-ecological systems (SES). This objective will be met by comparing the use of ecosystem services (ES) as a function of perceived changes in the delivery of these ES in the same biome in different cultural settings.

To synthesize available knowledge on all study sites, the ISSE framework will be implemented to identify and characterize the relationships among social and ecological influences related to changes in the ES provided in the study areas.

Steps

The work will be conducted in four discrete steps:

1. Implementation of the ISSE framework for each study site. Each member network will choose a site representing one of the biomes used for the Millennium Assessment (Table 1, see end of document)

2. Identification of six critical ES at each site, direction of change, primary drivers of change, public awareness of the ES, and institution(s) that manage the ES.

3. Identification of threshold interactions between environmental and socio-economic dynamics at multiple scales, and forecasting the effects of these interactions on ecosystem services and ecological resilience.

4. Synthesis within and among biomes of culture-specific socio-economic dynamics leading to increases or decreases in resilience.

The ISSE framework, specific questions, and narrative (Step 1): the Niwot US-LTER (USA) example

Our efforts will test components of the ISSE framework developed with a 2-year NSF grant to the US-LTER Network (Fig. 1, Appendix 1) (http://www.lternet.edu/planning/). An integrative and iterative conceptual framework for social-ecological research was formulated that explicitly integrates socio-economic and ecological disciplines via a series of broad questions. A preliminary test of the framework has been conducted successfully by all US-LTER sites in 2007.

Using an expert-knowledge approach, each ILTER selected site is expected to produce site-specific: ISSE feedback loop model; detailed questions; and narrative summarizing the functioning of the study SES.

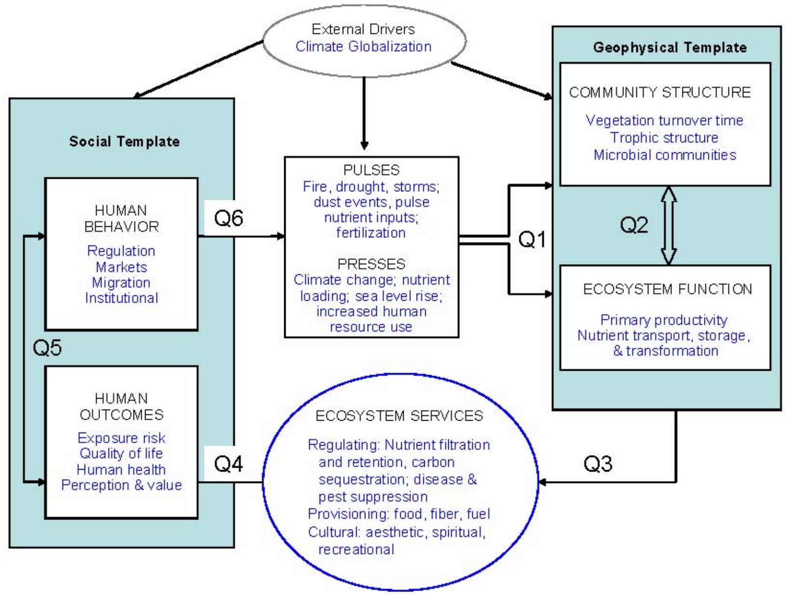

Figure 3.2 The ISSE framework provides the basis for our network-level research questions. The right-hand side represents the domain of traditional ecological research; the left-hand side represents human dimensions of environmental change; the two are linked by the services provided by ecosystems (at bottom), and by pulse and press disturbances influenced or caused by human behavior (at top). Q1-Q5 refer to integrating questions in Figure 3.3. From Collins et al. (2007).

Q1: How do long-term press disturbances and short-term pulse disturbances ***interact*** to alter ecosystem structure and function?

Q2: How can biotic structure be both a ***cause and consequence*** of ecological fluxes of energy & matter?

Q3: How do altered ecosystem dynamics affect ecosystem services?

Q4: How do changes in vital ecosystem services alter human outcomes?

Q5: How do perceptions and outcomes affect human behavior?

Q6: Which human actions influence the frequency, magnitude, or form of press and pulse disturbance regimes across ecosystems, and what determines these human actions?

Figure 1. Framework questions; see Appendix 1

NWT model, questions, and narrative

Here, we provide a specific example for the NWT LTER located in Colorado, USA. See Appendix 2 for a full narrative for NWT. For this work, we have identified an area that ranges from mid-elevation (2200 m) to the alpine zone (up to 4000 m) for developing the feedback loop conceptual model and formulating the six questions (Fig. 2, NWT questions). This level encompasses NWT LTER, including the alpine and subalpine zones. In addition, a large portion of Colorado Front Range forests fall within this elevation range, where substantial social and economic changes are taking place. The conceptual model illustrates how human systems interact with two key structural drivers: climate (patterns in the amount, timing, and form of precipitation) and landscape patterns of disturbances (fires).

Q1: How do the pulse disturbances of extreme drought and large/hot fires interact with long-term press disturbances, including frequency, severity, and seasonality of fires, and climate variability, to influence threshold behavior and associated state changes in ecosystem structure and function?

Q2: How are the feedbacks between landscape patterns and community structure (vegetation type and patch mosaic, stand structure, animals, and soil microbial communities) and function (ecosystem and hydrological budgets) affected by extreme and long-term changes in climate (temperature and precipitation), changing fire regimes, and land-use change?

Q3: How do ecological changes in land cover and hydrological budgets caused by changing climate, fire regime, and land use affect regional climate and fire regulation, regional water budget (quantity and quality), C storage, and the supply of economic and recreational resources to residents?

Figure 2. NWT SES

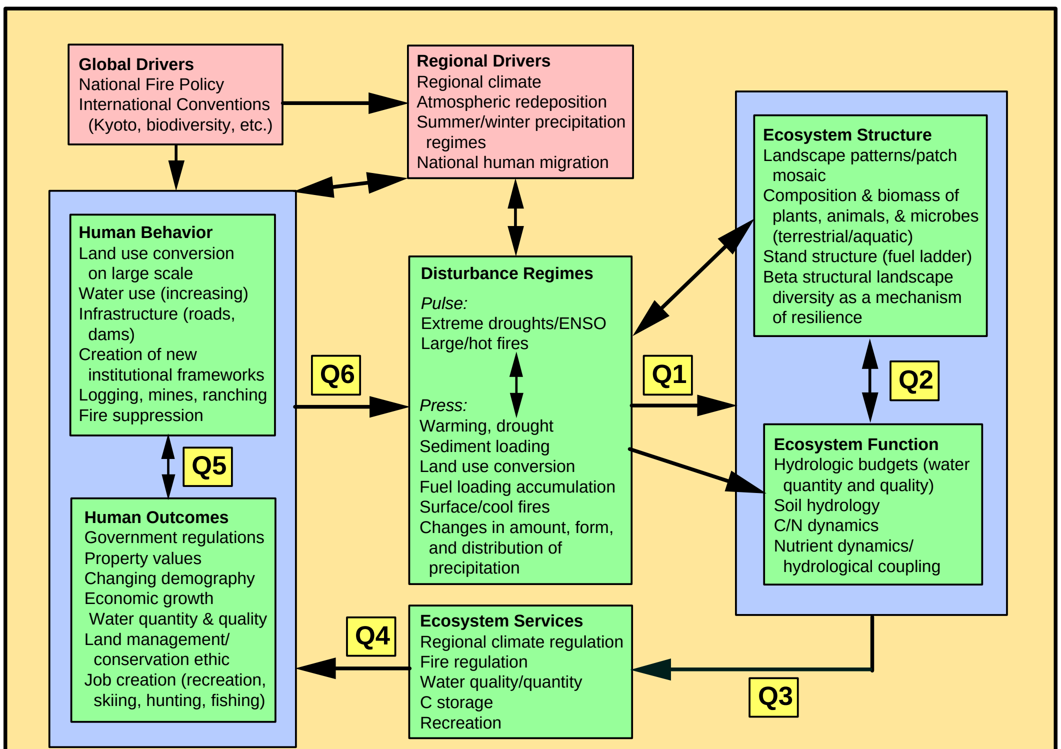

Figure 1. Regional socio-ecological systems in NWT and surrounding area.

Q4: How will the human population respond to recent and projected changes in ecosystem services, particularly water supply, including competition between different categories of users and potential large fires? More specifically, how will management of water systems and fire landscapes for products and amenities be adjusted to observed, perceived, and predicted changes?

Q5: How are management decisions affected by (1) ability-shaping factors such as knowledge, attitudes, and technology, and (b) attractiveness-shaping factors such as ownership regimes, property rights, market prices, and policy inducements?

Q6: Which combinations of individual and institutional decisions and actions affect the interactions between pulse/press disturbances by influencing landscape configuration, landscape connectivity, fuel loading, and fire regimes?

In Colorado, changes in climate variability, population increase, changing land use, and fire suppression combine to induce shifts in the structure and function of mountain ecosystems at all elevations and spatial scales (Q1). Extreme droughts combine with fuel loading increase (due to fire suppression, a function of federal, state, and county fire policies) and land-cover change (a function of land-use change, such as exurban and tourist-related development, functions of regional and national economies) to alter landscape patterns, stand structure, and hydrological budgets. Changes in landscape patterns and stand structure in turn create a positive feedback to fuel loading accumulation, and therefore likely influence the threshold behavior of fire intensity and size. Changes in disturbance regimes alter the dynamic linkages between ecosystem structure and function (Q2). For example, such landscape changes also affect patterns of snow redistribution and accumulation, thereby influencing hydrological budgets. Together, changes in landscape patterns and hydrological budgets have a potentially profound impact on all ecosystem services either directly (water, fire regulation; e.g., Spyratos et al. 2007) or indirectly (e.g., recreation) (Q3). The degree to which there is close coupling between human understanding and human responses to perceived and projected ecosystem services (Q4) will determine the further influence of combined regional and global human actions and decisions (Q5) on disturbance regimes and their interactions (Q6). Despite the widespread perception that remote ecosystems such as those located in the subalpine and alpine zones of Colorado are pristine, significant impacts due to human activities have occurred both on Niwot Ridge and in the valleys to the north and south. On Niwot Ridge, extensive logging occurred in montane and lower subalpine forests during the late 19th century. In the Green Lakes valley to the south of the ridge, the Albion townsite housed miners during the mid to late 19th century. Dams were constructed on creeks both to the north (Lefthand Reservoir) and south (Green Lakes 1, 2, and 3, Lake Albion, and Silver Lake), producing large areas denuded of vegetation due to construction activities such as road development and digging of borrow pits.

Identification of ES at each study site (Step 2)

An ES template will be used to identify all ES for the region represented by the study LTER sites (see a worked example in Appendix 3). The feedback loop implemented in the previous step will be used to specify the service(s) at each site, for example the types of foods produced; ways in which ecosystems regulate erosion; ecosystem attributes that lead to different recreational uses. Additionally, the following are requested:

a. Direction of change.
b. Primary drivers of change: e.g., climate, land-use change, urbanization.
c. Awareness by the public of the societal importance of this service: high (public keenly aware), medium (informed scientists, managers, and/or leaders aware), low (seldom considered in discussions or implementation of policies.

d. Institutions that manage: e.g., state agency, market processes, NGOs.

From this list, six critical ES will be identified. Table 2 (see end of document) indicates the six critical ES at NWT.

Identification of the threshold interactions between environmental and socio-economic dynamics at multiple scales, and forecasting the effects of these interactions on ecosystem services and ecological resilience (Step 3)

In this step, we will analyze the threshold interactions of ecological, social, and economic domains at three spatial scales. To guide the work, the NWT example is presented (Fig. 3). We have tentatively identified critical combinations of domains, scales, and interactions (e.g., regime shift at one scale combination triggering regime shifts at another) using the generalized model proposed by Kinzig et al. (2006) (Fig. 3). The arrows between boxes show interactions between thresholds. These interactions will be evaluated using the narratives developed in the preceding steps and models if available to determine whether and how cascading effects lead to more or less resilient regimes. Impact on the critical ES will be inferred.

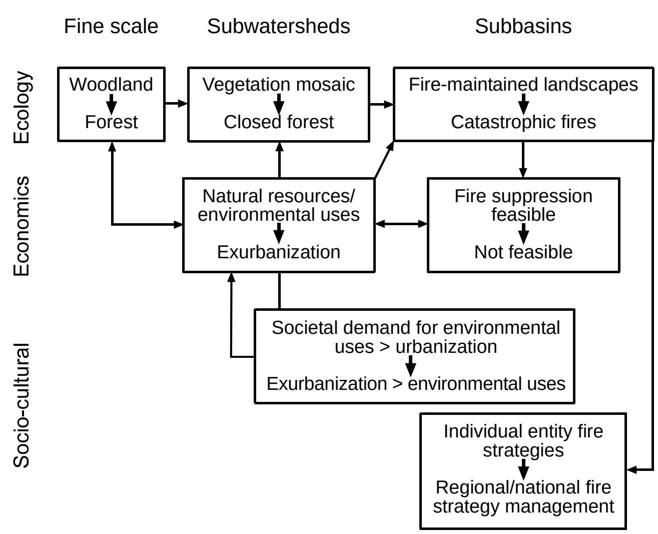

Figure 3. Key threshold interactions.

Synthesis within and among biomes of culture-specific socio-economic dynamics leading to increases or decreases in resilience (Step 4)

In this step, the frameworks developed for each sites will be synthesized by biomes. Finally, the individual biome results will be synthesized in a "general model".

Table 1 MEA Biomes

TUNDRA

BOREAL FORESTS

TEMPERATE CONIFEROUS FORESTS

TEMPERATE FORESTS, STEPPE, AND WOODLANDS

TEMPERATE BROADLEAF AND MIXED FORESTS

MONTANE GRASSLANDS AND SHRUBLANDS

DESERTS

MEDITERRANEAN FORESTS, WOODLANDS, AND SCRUB

TROPICAL AND SUB-TROPICAL MOIST BROADLEAF FORESTS

TROPICAL AND SUB-TROPICAL DRY BROADLEAF FORESTS

TROPICAL AND SUB-TROPICAL GRASSLANDS, SAVANNAS, AND SHRUBLANDS

TROPICAL AND SUB-TROPICAL CONIFEROUS FORESTS

FLOODED GRASSLANDS AND SAVANNAS

Table 2. List of 6 critical ES that the alpine/subalpine systems (high elevation mountains) provide in the CO Front Range.

Provisioning ES

- Fresh water: The mountains are the sole or main source of fresh water for a variety of human uses locally, regionally, and nationally (urban centers on the east and west sides of the continental divide; farming communities on both sides of the divide). Changes in climate variability and land use, and the interactions between the two, superimposed on growing demand for water, are likely to lead to degradation.

Regulating ES

- Water regulation: Mountain ecosystems regulate the timing of snowmelt and therefore the timing and magnitude of runoff and flooding, thereby regulating water quantity and quality. The ability of mountain ecosystems to regulate water is likely to be decreased by further changes in land use.
- Climate regulation (C storage): Same rationale as for water regulation.
- Natural hazard regulation (fire, avalanches): Fire suppression in all mountain ecosystems and ex/suburbanization are increasing the risk of catastrophic/extreme events beyond these ecosystems' historic range of variability.

Cultural ES

- Aesthetic value.

- Recreation/ecotourism: Although not degrading or locally improving, these services are extremely vulnerable on short time scales and large spatial scales to severe degradation due to climate change (e.g., less snow for ski resorts) or post-catastrophic disturbance (e.g., large fires leading to loss of tourist appeal, decline in recreational fishing, etc.)