Introduction

The Harvard Forest LTER Site Review was conducted June 24 - 25, 2009 at the Harvard Forest in Petersham, MA.

The site review team was composed of the following individuals:
Jess Zimmerman – University of Puerto Rico; *Forest ecology and social sciences integration*
John Porter – University of Virginia; *Information management*
John Marshall – University of Idaho; *Water relations and isotope ecology*
Angela Kent – University of Illinois at Urbana-Champaign; *Microbial ecology*
Janis Boettinger – Utah State University; *Soil science (Pedology)*

This report was prepared following one and one-half days of presentations by site scientists intermixed with visits to numerous monitoring and experimental sites in nearby forested locations. The site review team also met with REU and graduate students as well as with individual investigators during their review.

The Harvard Forest LTER site (HFR) was evaluated with respect to the following five criteria:

- Site-based science
- Network participation and synthesis activities - *Focused on science in a larger context, including cross-site, international, and non-LTER involvement.*
- Information management and technology
- Site management - *Including personnel, fiscal, institutional and logistical issues*
- Education/outreach

Each of these five criteria is evaluated with respect to quality, productivity, and impact.

Site-based science

Strengths
Research conducted at the Harvard Forest (HFR) has repeatedly transformed the way we think about ecological systems. The HFR and its Fisher Museum focused on educating researchers and foresters alike about the history of land use in New England, showing that a landscape that was once dominated by agriculture is now a forest. The recognition that standing forests are the product of past land management, and hurricane disturbance, has changed the way we think about these forests. With the inception of the HFR LTER, the importance of land-use and other disturbance legacies in modern landscapes has been recognized and incorporated into contemporary concepts of landscape dynamics. That tradition has extended itself into, among other things, the longest running record of net carbon uptake anywhere in the world and experiments on nitrogen saturation, soil warming, and hurricane disturbance that have been in place for up to 20 years.

Most of the individual research projects that we reviewed were outstanding. The team enjoyed the thought-provoking research presentations, discussions, and field trips. Specific instances are outlined below.

We noted the success of HFR LTER scientists at leveraging funds from diverse sources. In fact, we realized early in the review that we needed to ask to understand how the LTER funds were used within the context of the greater enterprise. As we learned more about the role of the LTER funds within the mix, we grew comfortable with the way the funds were being applied to the science objectives. With such a high degree of leverage, there is some risk of dilution of effort. However, thus far, the HFR LTER researchers have done an excellent job selecting projects that complement, not dilute, the mission of the HFR LTER.

In addition, HFR has been very successful at recruiting and retaining investigators from multiple institutions. The interactions among investigators were smooth enough that it was difficult for the outsider to identify which scientists had their primary affiliation with HFR and which were employed elsewhere. It was good to see that everyone, from PI's to students, seemed aware of the work being conducted by other researchers in the program.

In the midst of this diversity of people and projects, the forest has been able to maintain a comfortable and productive balance of LTER and non-LTER activities. Those activities also include a balanced portfolio of monitoring, experiments, and modeling. Not only are they balanced, but in many cases the various projects are arranged so that they can be stitched together into synthetic products.

Among the syntheses emphasized by the current award is the regional collaboration among the HFR, Hubbard Brook Experimental Forest LTER, and Plum Island LTER sites. Based on this collaboration, the group has tried to regionalize the results of their site-based studies. The review team was especially excited by the new modeling work relying on remote-sensing (i.e., albedo) to derive canopy N concentrations, which are then used to drive ecosystem models. This approach seems novel, defensible, and suitable for scaling from site to region.

We also applaud the continuing support for long-term experiments and the establishment of new experiments. The soil warming experiments seem to be generating data that will inform models of climate change and illuminate our incomplete understanding of the nitrogen cycle. Likewise, the N saturation experiment has yielded insight while simultaneously highlighting knowledge gaps. A relatively new study combines N additions and soil warming in a single experiment under the direction of a new researcher with expertise in microbial ecology. The new hemlock removal experiment also contributes to this tradition, though it has the additional advantage of providing a proactive approach to answering a question of great social relevance. Studies of invasive species are addressing the understory invasion of exotic garlic mustard using novel and exciting field experiments.

Weaknesses

The integration of the atmosphere/biosphere/hydrosphere will require a rigorous description of the site's hydrology. We recognize the complexity of the geologic substrate and the influence of root channels and other macropores on water flow through the forest. Nonetheless, we discussed alternative methods for assessing subsurface flow, including the use of tracers and isotopic analyses of stream hydrographs. These methods would constrain the water budget. We recognize the difficulty of fulfilling this request, but note that the detailed and long-term records of biosphere-atmosphere exchange should spark the interest of hydrologists, simplifying recruitment of collaborators in this area.

The use of stable carbon isotope techniques could provide a critical description of the coupling of the carbon and water budgets. We understand that some isotopic work is underway and more is planned. We agree that this is likely to be fruitful.

We were concerned about the incomplete integration of ecosystem monitoring and modeling and individual species biology. This concern arose from the exceptional record of work on the biosphere-atmosphere fluxes and soil biogeochemistry, which served as background for the proposal's emphasis on native and foundation species. In addition, the regionalization of the site-specific results was to be conducted, at least in part, by ecosystem models. Such models have limited ability to predict species composition and most also have limited capacity for species-specific parameterization. We would have been reassured by a bit more discussion of how this translation would occur, but welcomed the notion of using hyperspectral remotely sensed data as a means of parameterizing species composition.

The review team was interested in the "missing N story" that has come out of the nitrogen saturation experiments, pointing to a gap in our understanding about how nitrogen cycles in forest ecosystems. This seems like a subject that needs further exploration, especially as it belies the predictions of nitrogen saturation, but also because it underlies regional decisions about forest harvesting and watershed management. In fact, the HFR long-term dataset is just one among several in the region that have identified this missing N. Although the current work has contributed in important ways to the description of the problem, it would be exciting to see the HFR move toward experiments that will help to explain it. The team was particularly interested in the possibilities for denitrification losses to the atmosphere and geochemical sinks for the nitrogen. The currently funded HFR LTER proposal acknowledges the potential importance of denitrification and the microbial communities responsible for that process, but recent research has not focused on microbial N transformations. More effort in this area will be needed to resolve the N cycle at HFR. If the "missing N" is not found, its disappearance will limit the scope and impact of future syntheses.

Recommendations
Recruit a hydrologist with expertise in the measurement of subsurface flow in complex substrates.

Put more effort into finding the missing N, focusing on denitrification, the linkage of inorganic and organic components and processes, and accounting for the physical substrate, landscape position, and soil properties.

Suggestions
The site review committee was concerned that multiple funding sources could dilute the LTER focus at HFR. We currently find no evidence of this but wish to suggest due diligence in avoiding the situation of the "tail wagging the dog," that is, the need for funding from numerous sources might tend to drive the conceptual development of site science. So far researchers at the site have avoided this pitfall, but continued vigilance is required.

Network participation and (regional) synthesis activities

Strengths
The HFR clearly demonstrates strong participation in LTER network and regional synthesis activities.

We commend HFR for its collaborations with other LTERs in region, particularly Hubbard Brook Experimental Forest LTER (HBR) in New Hampshire and Plum Island Ecosystem LTER (PIE) in southeastern Massachusetts. HFR is also interested in proposed collaboration in a Boston metropolitan area ULTRA project, establishing an urban-rural gradient.

The HFR is an enthusiastic participant in LTER network activities. HFR personnel have worked on projects in other LTER sites and are involved in LTER leadership activities.

We were particularly impressed with regional scenario analysis and planning within Massachusetts, and the trajectory of work that includes the public throughout the region. The use of contrasting sets of existing data, regulatory information, and information delivery structures and mechanisms among Massachusetts, New Hampshire, and Vermont is an excellent approach for scenario analysis and planning for forest management.

The integration of social science (i.e., land use management and social/demographic information) and geographic information appears to be an effective approach for developing alternative scenarios for interpreting and influencing regional land use/land cover trends.

We commend HFR on the publication of high quality synthesis products (i.e., books, papers) that deliver data produced at the HFR LTER to a wider audience of scientists and the public. The workshop on “Scenarios of Future of Landscape

Change" demonstrated HFR's commitment to LTER sites driving changes in land use policy.

Weaknesses
The one area in which we think there could be improvement is in the documentation and use of information on physical substrate, such as geology, geomorphology, and soils, which could facilitate and enhance cross-site comparisons with HBR and PIE and other sites.

Recommendations
We recommend that HFR sustain their current momentum in LTER network participation and regional synthesis activities.

Suggestions
The HFR is successful as a network participant and in regional synthesis studies. We caution against allowing future LTER regional activities to be driven excessively by NEON priorities. The complementarity of NEON (i.e., continental scale studies) and LTER regional studies was emphasized during discussions with site scientists. We simply wish to urge caution as NEON comes online to ensure that this does not detract from what we perceive to be a successful and compelling regional research effort.

Information Management and Technology

The HFR information management system meets the requirements for LTER, as specified in the "Review Criteria for LTER Information Management Systems" and recent recommendations from the LTER Executive Board.

Strengths
Strong points of the information management component of the HFR LTER include:

- Assembly of a strong information management team, with diverse skills and duties, that serves both LTER and non-LTER data
- A strong commitment (going back more than 100 years) by HFR to archival storage of documents and samples. The archival ethic remains strong in the current team
- Recent, and arduous, upgrading of the metadata to conform to LTER standards with EML level 5 metadata, incorporating both discovery and use metadata
- Much improved linkages between information-base elements, such as the linkage of datasets to publications, projects and people
- Recent efforts to improve compliance by researchers with the LTER data sharing policies by linking it to the recently upgraded Research Project Approval system, thus providing an effective "carrot and stick" approach to assuring that data is not lost
- Strong support by site management for IM activities

- Strong participation and leadership by the site in LTER-wide information management initiatives
- Excellent facilities for archiving physical materials

The team applauded efforts by the IM-Team (particularly Emery Boose) for working on educational efforts to promote acculturation into the proper IM mindset for SLTER, REU and graduate students. We anticipate that exposure to ideas regarding data sharing and an archival mindset will have long-lasting benefits for the students and science in general.

Weaknesses
We see some areas where improvement is still possible. Although the IM team is strong, it has not been particularly ambitious in the testing or adoption of new technologies, tools and approaches. Dedicating some time to experimenting with new tools and approaches may have some long-term benefits, and may enable the site to take a leadership role in Information Management within the LTER Network.

The data page on the web site is functional for providing access to site data, but is relatively austere, providing few graphical forms of information (e.g., site maps) that would help researchers unfamiliar with Harvard forest to locate data. Spatial-based queries for data would also be desirable, and should be relatively easy to implement given the coordinates already contained in the site metadata.

Suggestions
The review team suggests that, although researchers are ultimately responsible for their data, the IM team can help with quality control and quality assurance by preparing statistical summaries and plots based on the EML metadata, and that the resulting graphs could also be added to the web site to provide better "suitability for use" information for data users. In addition, there are some minor corrections that need to be made to the web site, such as cross-linked or miscategorized datasets.

The site IM team requested guidance from the review committee regarding the preferred form of the data retrieved from the site. Should it be in the form of well-structured data tables that would be downloaded *in toto*, or a queriable database that allows users to select specific fields or records for retrieval? It was the sense of the committee (and many of the graduate and undergraduate users we queried) that for many of the datasets (especially the shorter ones) the existing form of retrieval was sufficient. However, we suggest that the HFR executive group and IM-team experiment with database approaches for sharing large or complex datasets. They should also consult with the LTER Network Office and the LTER Information Management Committee on the possibility of a network-wide solution that would avoid duplication of effort at multiple LTER sites on this issue.

We also suggest that providing online indices for physical samples would be a valuable adjunct to the datasets and catalog of the document archive.

The review team also raised the issue of saving versions of data, so that a publication could be directly linked to the specific data used in the paper. This is a complex topic, especially for datasets that are updated frequently (i.e. daily or higher). The review team suggests that the site investigate efficient ways of providing such timestamped data, perhaps using SVN and other software typically used for maintaining versions of software. However, as only a few sites in the LTER Network currently provide these capabilities, this need not be a high priority.

Some additional challenges face the site, as LTER IM is a constantly evolving landscape. Some specific issues include the upgrade to EML 2.1, participation in new databases (e.g., projectDB), and LTER-wide initiatives (e.g., keyword controlled vocabulary, unit dictionary). We encourage the HFR IM team to continue its efforts in confronting these challenges.

Recommendations
In preparation for the site's 2012 renewal proposal we recommend that the site continue its efforts at making sure that all data collected by the LTER (and affiliated projects) continues to be included in the database in a timely manner. We applaud the recent linkage of project approvals at the HFR to evidence of conformance to data policies, and hope that such conformance will continue to be required in the future.

Site management

Strengths
The site review team found that the administrative structure of the LTER was clear and effective. Research direction and focus is provided by Lead PI Foster and other senior researchers, helping to maintain the LTER core mission, but also taking advantage of opportunities that arise over time. The PIs and other researchers have used the LTER platform to leverage additional funding to expand the research portfolio at the HFR. Their guidance and enthusiastic participation by all researchers has resulted in the HFR LTER becoming a regional leader in forest ecology and management.

HFR LTER includes a mix of junior and senior scientists. Younger scientists are active in core LTER projects, and also initiate and oversee new projects within the LTER framework. These new projects expand the research presence of HFR LTER, bring in additional funding, and offer the younger researchers experience in project leadership. In addition, HFR LTER is very open to the participation of researchers from other universities. The "open door" policy with regard to use of HFR LTER site was clearly articulated, and participation of non-LTER researchers is perceived as adding value to LTER experiments.

The review team was favorably impressed with the practice of sharing of personnel resources among projects. This has clearly been an effective way to

provide high quality statistical, IM, GIS, and technical support to many projects while minimizing the impact on individual project budgets.

Weaknesses
The design of the site review process could have been improved. The review team felt that additional information specifically prepared for the site review could have been provided prior to the site visit. In particular, information highlighting accomplishments in the current funding cycle would have been helpful. Although the presentations gave an excellent overview of the diverse research being conducted at the HFR LTER, the site review team found it difficult to assess which research activities were carried out in the previous 3 years (as part of LTER IV). Specific focus on this, either in the research presentations, or preferably in a briefing booklet prepared for the site review, would have assisted our efforts to evaluate the research connected to the most recent funding cycle.

Recommendations
In preparation for the site's 2012 renewal proposal, the site review team cautions the HFR researchers against resting on their previous accomplishments, which we think leads to the confusion between what has been done and what is being done (or is proposed). We recommend that the renewal proposal include increased efforts to integrate research on individual species with ecosystem-level monitoring and modeling efforts. The renewal proposal should also include a clearly written justification for proposed LTER activities, whether a continuation of existing measures or new activities. We also recommend that the proposal for funding renewal should be organized such that individual components and interconnections are more apparent.

Suggestions
The review team suggests that the HFR executive group should clearly articulate their thoughts as to future leadership of the LTER. Junior researchers should be encouraged and mentored in leadership roles.

Education and Outreach

Strengths
The Schoolyard LTER at Harvard Forest is a model program for integrating science and education at the grade school level. Three site scientists (one now retired) have dedicated themselves to this effort and the coordination provided by Pamela Snow is strong. Schoolyard LTER activities are strongly integrated with IM such that students and teachers are able to identify their role in site science through their participation in data collection.

The REU site program is also highly effective. The program receives numerous applications, a result of a strong recruiting program. There is excellent participation by students from underrepresented minorities, a direct result of recruiting visits by the program director, Aaron Ellison, to minority institutions. The REU students cited strong mentoring by scientists and a good series of seminars as major contributions to this successful program.

The site has an award-winning RET participant who has contributed strongly to site science and integration with her local elementary school.

There is a small cadre of very dedicated graduate students at HFR. In our conversation, the graduate students cited their frequent interactions with site scientists and excellent facilities as contributing to a positive environment for learning and conducting science. A number of the students are from traditionally underrepresented groups.

The site review committee lauds efforts by HFR to expand the MS degree program beyond the current forestry focus. This new program, involving a wide range of departments at Harvard University, would constitute a unique role for the unit in contributing to graduate education at Harvard University. Effectively, it would put HFR in the position of training not only the next generation of Ph.D. students but also the next generation of planners, managers, and conservationists. The University should be supportive of these efforts.

The Wildlands and Woodlands program is representative of the strong efforts made by the site to ensure that knowledge of the historical and ongoing landscape dynamics in the region contributes to the effective conservation and management of natural areas in the state of Massachusetts and throughout New England.

Weaknesses

REU and graduate students were not clear about the overarching goals of the LTER Program although at least one student (an REU) was able to identify land use legacies as a key component of site science. Compared to other LTER sites, there is relatively low participation by graduate students at the site. Much of this arises from limitations on graduate student funding at Harvard University, a fact identified by the site scientists and one that is apparently frequently communicated to the university administration.

More importantly, there appeared to be a lack of cohesion among the few participating graduate students, in part a result of the fact that many of the students are based at other universities and their residence at the site frequently does not overlap. Graduate students found the restriction of annual symposia to pre-identified topics to be a limitation on their participation.

Suggestions

As strong and effective as the Schoolyard LTER appears to be, some efforts need to be made to assess the effectiveness of its activities and outcomes. This will require outside funding and there is the possibility that this effort could be coupled with a network-wide assessment of Schoolyard LTERs and their activities.

There are a number of ways in which the site could foster increased interactions and cohesion among participating graduate students. Increasing the leadership role of the LTER network graduate student representative is one way to do this. Another mechanism is to create a dedicated email alias or website to increase information flow among the graduate students. A poster session dedicated to graduate student projects at the annual research meeting is another way to accomplish this.

Summary & Future Directions

We have the following specific recommendations:

Improve the rigor of hydrological studies, i.e., recruit a hydrologist with expertise in the measurement of subsurface flow in complex substrates, possibly incorporating isotopes and tracers.

Place more emphasis on the "geochem" in biogeochemistry, i.e., better defining linkages with inorganic (mineral) materials, processes, and physical landscape setting.

Discontinue treatment of the damaged pine plots in the N saturation study. The storm damage, along with other among-site differences have compromised the experimental design and reduced the value of these sites. Seek out new, innovative ways to address the "missing N" story.

Organize a multidisciplinary effort to find the missing N. This should expand upon 1) the inorganic drivers, processes, and components and 2) the microbial processes and populations involved in N biogeochemistry, especially related to denitrification. Although the N saturation work has contributed in important ways to the description of the problem, the solution is likely to require a new set of sites, collaborators, and techniques. Enhancing the N cycling work would contribute to the integration of community ecology and biogeochemistry at HFR, and would strengthen the 2012 renewal proposal.

The site review team was excited by the new opportunities and current thinking for the next proposal. Research topics with much promise include: hydrology, missing N, remote sensing (e.g., albedo) and regional N dynamics, linkage between social drivers and regional land use change, foundation species, invasive species, and impacts of moose colonization.