Review and synthesis of long term experiment networks

Erik Meijaard and Douglas Sheil

Contents

Introduction

Sentinel landscapes

Increasing reliance on restricted funding has driven CGIAR research toward ever-shorter time horizons. The assurance of longer-term funding will enable CRP6 to put in place mechanisms for collecting long-term data sets and generating knowledge from global comparative research, including the establishment of "sentinel landscapes". Such research in sentinel landscapes will support the collection of the long-term data sets necessary to understand the drivers and impacts of land use change. Sentinel landscapes will also provide locations to foster dialogue among various stakeholders and to test models, thus facilitating consensus on contentious issues such as the sustainable exploitation of a disputed natural resource. They will also offer opportunities to implement experimental design to measure the uptake of research results and for overall impact assessment. Finally, sentinel landscapes will provide global focal points for multidisciplinary research; they will also provide spaces for engagement with the broader suite of researchers, development efforts and stakeholders working in rural areas, including other long-term site-specific research efforts being undertaken within the broader CGIAR network.

CIFOR envisage employing a number of benchmark sites to include permanent sample plots, repeated household surveys and stratified baselines. Research at such long-term socioecological research sites (LTSERs) would span disciplines and integrate political, socioeconomic, gender and biophysical sciences.

To achieve the desired results, CIFOR will cooperate with other partners to:

- identify a coherent set of sentinel landscapes for longitudinal (long-term) research where existing data sets and partnerships can be used to monitor the impacts of exogenous and endogenous change at the landscape scale;
- develop and apply field-tested and standardized research protocols to allow global comparative studies of forest transition stages, economic and demographic conditions, and climatic/biophysical determinants of environmental services and livelihood options;
- use participatory forms of action research to improve the general well-being and livelihoods of local people, while maintaining environmental services

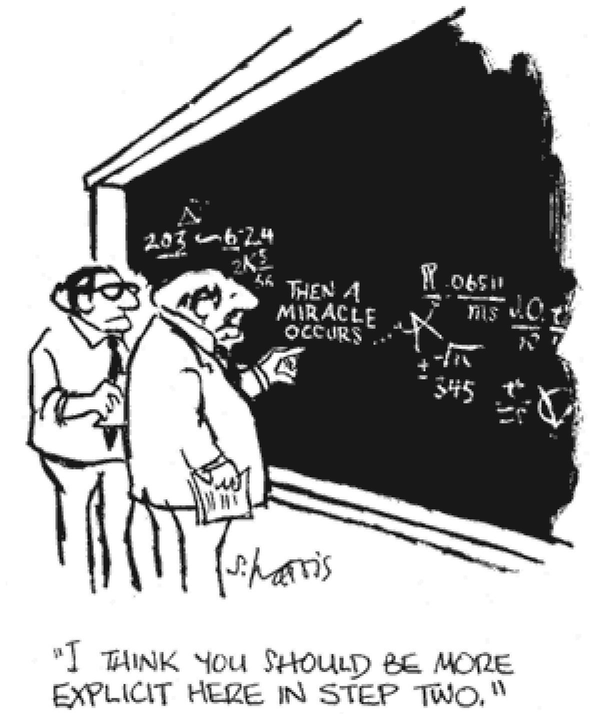
As much as possible, research questions posed by all five of the CRP6 research components would be addressed at each of the sentinel landscapes.

Justification for long-term research networks

The power of the networks derives from strong intellectual support by a variety of scientists from many disciplines, who are motivated by the excitement and importance of the research questions (Carpenter 2008). Networks facilitate inter-site comparisons by studying ecological patterns, processes and responses to experimental treatments at regional scales (e.g. the nutrient enhancement, species removal and experimental atmospheric CO_2 enrichment studies across the US). Networks also provide a foundation for new science initiatives and a valuable starting point for budding scientists. Not only is an infrastructure of potential sites available, but the research that has already taken place at the sites provides a powerful background on which new scientists can develop truly 'cutting edge' initiatives. Finally, networks can provide a strong basis for ecological monitoring and modelling at the regional scale (Grogan 2010).

Understanding challenges when designing and implementing sentinel landscapes

Sentinel landscapes are ambitious. The establishment, support and management of any such program of activities will involve a large number of choices, challenges and obstacles. Much can be learned based on the experiences of other large scale research and monitoring networks. The purpose of this review was to find these experiences and gather the lessons. Our approach was to identify networks and other "multi-site and multi-partner" projects that have characteristics that reflect aspects of the proposed network of sentinel landscapes and find what lessons have been documented. The size of the technical literature on research networks, cross-site studies and data management, required us to be selective. We focused on selected networks that address landscapes, development, environment, ecology and/or forests. We used web sources and papers published in the last 15 years or so. Additional papers highlighted in these sources were also sought when judged relevant. Over 200 papers were assessed based on their abstracts and the full texts of more than 50 were downloaded and reviewed in detail. In addition some 30 web sites were visited to characterise the selected networks. Our report is structured as follows: (1) A general review of studies addressing particular aspects of long-term ecological and socio-ecological networks and research programs; and (2) an overview of past and present networks for which we assessed a range of characteristics as listed in the Methods section below.



Methods

We reviewed the scientific literature and other published sources about long-term ecological and socio-ecological research programs, specifically focusing on terrestrial networks. For each network or program we assessed the following factors:

(1) **Design**. The research designs of each network and the nature of data. Specifically we determined the overall objective of the research and checked whether this was based on a broader research hypothesis. This indicated whether networks where specifically designed to address certain questions (i.e., did they have a shared method) or whether they had evolved in a more ad-hoc manner (e.g., through identification of a shared goal). We also assessed what kind of data gathering (biophysical, social, economic) the network focused on.

(2) **Integration**. The degree to which different data types had been formally integrated. An indication of this is for example the presence of a database in which social, biophysical, and economic data from certain areas are systematically linked.

(3) **Organization**. Organisation of the network, who is leading it and who are collaborating partners. This deals primarily with the formal structure of a network, addressing questions about whether funding is centralized or diffused, and what the official reporting lines are.

(4) **Ownership**. Data ownership and access rights. We assessed whether data resulting from research by network groups were publicly available, shared within the network, or generally not shared. We looked at who is managing data, checks data quality, and determines access for use.

(5) **Quality**. Specific measures undertaken to assure rigor and credibility, especially with respect to data quality and consistency of methodology. Is someone responsible for quality control?

(6) **Change**. Changes in the network over time, with respect to research design, geographical focus, organisational structure. We determined growth or decline of networks and changes in context.

(7) **Impact**. Achievements and successes of the network for advancing scientific knowledge, benefitting local communities and influencing national and global policies.

(8) **Funding**. What funding structures exist to finance network activities. Here we also determined whether particular networks were really designed for integrated research collaboration or more as funding streams.

(9) **Problems**. Whenever such information was available we described the problems and challenges encountered in the network.

A review of literature on long-term ecological networks

In a Special Issue of Frontiers (Carpenter 2008), diverse groups of environmental scientists discuss the current frontiers of research on continental change, focusing on North America. The framework for continental-scale science articulated brings together existing capacities, such as the National Science Foundation's Long Term Ecological Research network (http://lternet.edu), networks maintained by mission agencies of many countries, including Mexico's Commission for Knowledge and Use of Biodiversity (www.conabio.gob.mx), the Sub-global Assessments of the Millennium Ecosystem Assessment, international research networks such as the Global Lake Ecological Observatory Network (GLEON; http://gleon.org), and new networks currently under development, such as the National Ecological Observatory Network (NEON; www.neoninc.org). Other papers in this issue describe insights and opportunities for network research.

Interdisciplinary assessments to synthesize data in policy-relevant form place increasing demands on the environmental sciences. Yet a recent evaluation of global ecosystems performed by the Millennium Ecosystem Assessment found that data were variable in quality. It was even more troubling that current data were sometimes inferior to historical information, so that recognition and understanding of ecosystem transformation was deteriorating even as change accelerated (Carpenter 2008).

Long-term ecosystem research

In July 2001, an international conference reviewed progress in the field of long-term ecosystem research and monitoring (LTERM). Parr et al. (2003) provide examples which demonstrate the need for long-term environmental monitoring and research, for palaeoecological reconstructions of past environments and for applied use of historical records that inform us of past environmental conditions. LTERM approaches are needed to provide measures of baseline conditions and for informing decisions on ecosystem management and environmental policy formulation. They are also valuable in aiding the understanding of the processes of environmental change, including the integrated effects of natural and anthropogenic drivers and pressures, recovery from stress and resilience of species, populations, communities and ecosystems. The authors argue that, in order to realise the full potential of LTERM approaches, progress must be made in four key areas: (i) increase the number, variety and scope of LTERM activities to help define the operational range of ecosystems; (ii) greater integration of research, monitoring, modelling, palaeoecological reconstruction and remote sensing to create a broad-scale early warning system of environmental change; (iii) development of inter-disciplinary approaches which draw upon social and environmental science expertise to understand the factors determining the vulnerability and resilience of the nature–society system to change; and (iv) more and better use of LTERM data and information to inform the public and policymakers and to provide guidance on sustainable development (Parr et al. 2003).

Monitoring, research and modelling are closely inter-linked activities and all are required to detect and manage environmental change (Figure 1). One of the most important uses of monitoring data is to validate model predictions.

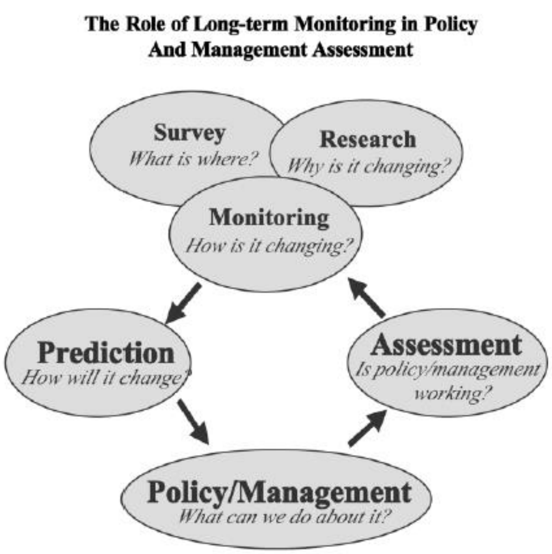


Figure 1. Relationship between monitoring and research in the environmental assessment process (Parr et al. 2003).

Large-scale observation networks are being developed but these must be strengthened through increased standardisation of methods, more free exchange of data and development of efficient data and information systems. This is particularly true in the case of the Global Terrestrial Observing System (GTOS, Gwynne, 1996) which relies on linking of existing local, national and regional programmes to meet global data requirements. Existing networks tend to be national in scale, e.g. the UKs Environmental Change Network or the Acid Waters Monitoring Network or confined to a particular sector e.g. European WaterNet, ICP-Forests (Parr et al. 2003).

LTERM is playing into a highly dynamic political context where relations between science and society are changing rapidly. Communicative strategies based on a topdown, one way process of 'information dissemination' need to be replaced by dialogue between different interests in a process of sharing knowledge and values to promote mutual learning. Two areas in which progress is being made to engage a wider range of stakeholders in LTERM are in relation to: (i) the use of indicators; and (ii) participatory monitoring (Parr, Sier et al. 2003).

To realise its full potential, new approaches to LTERM need to be developed. There is a particular need for LTERM to understand the processes of change in 'working landscapes' and to understand how system functioning might change in the future as a result of changing climatic boundary conditions. There is also a need to better integrate research and monitoring in different ecosystems or components of ecosystems. Key components of such approaches would be: networks of LTERM sites adopting harmonised procedures; inter-linked distributed data and information systems; and the development of high-level indicators as a means of tracking environmental change and generating appropriate social and political responses. To create such systems, research is required to understand how today's relatively independent activities of research, planning, monitoring assessment and decision support can be better integrated into systems of adaptive management and societal learning (Parr et al. 2003).

A review of the US Long Term Ecological Research (LTER) program (Johnson et al. 2010) applied network science measures to assess how the LTER program has achieved its mission using intersite publications as the measure of collaboration. As it grew, the LTER program evolved from a collection of independent sites (1981–1984) to multiple ephemerally connected groupings with a gradual increase in collaboration (1985 to about 1998) to then a largely collaborative, densely connected network (from approximately 1999 on). Collaborative efforts of LTER scientists included cross-site measurements and comparisons, information technology transfer, documentation of methodologies, and synthesis of ecological concepts. Network science provides insights that not only document the evolution of research networks but also may be prescriptive of mechanisms to enhance this evolution.

The initial call for proposals for LTER sites issued in 1979 pointed out that "attention must be given to the tasks of assuring information comparability and inter-project coordination". Despite that early focus on intersite comparison, significant interactions among sites took more than 10 years to develop, and only in the last decade were all sites in the network involved. Part of that time was dedicated to efforts to learn how to collaborate and to incorporate integrative approaches into our preferred methods of doing science. In retrospect, certain steps would have promoted more rapid development of a functional network. The article discusses some of these steps below to provide insight into how new synthetic networks could be constructed more effectively.

<u>Changing the mindset</u>. Most new participants in the collaborative network have been trained to conduct research as individuals or members of a laboratory directed by a single person. There is an initial tendency to think as an individual or as a member of a clan (site) rather than as a participant in a network, and this mindset takes time to evolve. Some members of the first LTER cohort resisted the concept of network coordination of research quite strongly at first, despite the fact that the importance of collaboration was at least implied in the first call for LTER proposals. Developing networks must have clear, well-understood expectations for collaboration that are apparent to groups seeking to join the network. Progress toward collaboration needs to be encouraged and reviewed from the beginning to ensure that all participants understand their responsibilities."

Characterizing new sites. Most sites, even well-established sites, require significant modifications or additions to research programs as the result of joining a network. In the case of LTER sites, this often involved the establishment of new measurements to address core areas or the extension of existing studies into new research sites. New LTER sites need to focus on getting their research programs established within three years to be ready for their first external review. Thus, intersite collaboration is often a secondary objective, at least initially. The need for an extended start-up period should be taken into account in the development of new networks.

Another important point about LTER site choice was made by Midgley et al. (2007). They noted that the placement of LTER sites to provide representivity of ecosystem types may unintentionally limit the detectability of climate change impacts, because change might best be detected in ecotonal or azonal environments. This could be overcome by additional experimental manipulations at LTER sites to 'force' anticipated changes and characterize species and ecosystem responses. A focus on the detection of climate change would sharpen an LTER programme's emphasis over time and provide policy advice, and science training rationales for the long term. It should especially interpret key information to decision-makers as a priority.

Building capacity. New networks require time to build the capacity for collaboration. Part of this capacity building involves the development of trust; after all, new collaborators were competitors a short time ago. Capacity building also involves the coordination of ideas, approaches, and technology, and requires meetings, workshops, and training. Researchers need to make compromises among existing techniques and discuss and agree upon techniques for new measurements or analyses. The bigger the network, the more effort must be expended in these early discussions. For example, agreements reached between the initial six LTER sites had to be renegotiated when five new sites joined the network in the second year.

Funding intersite work. LTER research is funded through awards to sites, and it is therefore appropriate for sites to focus on their own research programs first. The lack of a clearly demarcated, consistent source of funding for networked research has hampered the development of intersite studies. The early establishment of a funding stream for intersite research would have stimulated collaboration without detriment to site research efforts.

Planning the network. The original conceptualization of the LTER program did not define common research goals or questions, and therefore did not provide criteria for the construction of a network. In general no rules were ever established for the assembly of a network of sites to meet specific research objectives. The network’s current research objectives were established through identification of interests common to sites in the network as part of the process of self-evaluation. An earlier focus on network research might have accelerated the process of establishing collaborations, but it may have also detracted from individual successes by LTER sites.

Elsewhere, Knapp et al. (2012) argue that the scale and scope of global environmental change requires a more-coordinated multisite approach to long-term experiments, ideally, such an approach would include a network of spatially extensive multifactor experiments, designed in collaboration with ecological modellers that would build on and extend the unique context provided by the LTER Network.

A lack of comprehensive understanding occurs, in part, because ecologists have historically conducted disparate, largely independent experiments that tend to differ markedly with regard to (a) what is manipulated, (b) how much and for how long manipulations occur, and (c) what (and how) response variables are measured. This is certainly true of long-term experiments conducted in the LTER Network. As a result, syntheses across these studies can be difficult, since there is no way of knowing how much these different approaches contribute to the range of responses observed among ecosystems. Even similar projects are not often comparable unless effort and resources have been devoted to making them so. This inherent tendency away from comparability becomes more prominent among projects conducted at locations that are geographically and biologically disjunct (Knapp et al. 2012).

Small plot-based long-term experiments can be designed to be statistically robust with many replicates. This is not feasible with large-scale whole-watershed manipulations. Designing large-scale experiments will present many unique challenges, since they are not simply big versions of the small-scale manipulations that ecologists have conducted in the past. Innovation in experimental design, statistical analysis, and engineering will be necessary. With space set aside to accommodate unanticipated use, these networks of large-scale experiments would also serve as valuable research platforms for the broader ecological community. A highly coordinated and spatially extensive network of multifactor long-term experiments that adopts such a comparative approach would provide understanding and quantitative response data on ecological change at a temporal and spatial scale heretofore unavailable to ecologists (Knapp et al. 2012).

Focusing research. The initial LTER competitions established five common research areas to be addressed by each site, and emphasized information comparability and interproject coordination. The tendency to focus on site science was reinforced by the fact that individual LTER sites were selected, reviewed, and continued largely on the basis of the strength of their local science activities. Another approach that might have resulted in a more rapid development of collaborative efforts is the institution of specific common research questions rather than general research areas. The existence of such common questions could have resulted in parallel research efforts at sites and thus expedited collaborative science, while still maintaining individual creativity at sites. Such common questions might also have fostered quicker development of data standards and joint information-management approaches. As it is, the LTER Network has had to work hard to homogenize a broad range of data-management approaches that have been developed at individual sites.

Communicating. Collaboration among LTER sites and scientists has been enhanced by persistent efforts to provide opportunities for cross-site communication, principally through triennial all-scientist meetings. Personal experience tells us that meetings strongly stimulate interaction and collaboration. Despite the success of these meetings, many people within the LTER Network feel that communication among sites and scientists needs further effort, and that newsletters and Web pages are not enough, and that video teleconferencing does not replace face-to-face interaction. As the LTER Network has grown, communication has become more important and more of a challenge. The LTER Network recently completed a three-year self analysis to formulate a research plan for the next 10 years that emphasizes synthesis of information across sites and throughout the network. By identifying common research themes that link LTER sites and scientists, this plan should provide additional stimulus for intersite research in the LTER Network and should also influence the structure of the social network that has developed among LTER sites.

Benchmark Area Approach

Ecoregional research has the potential to help address some of the huge challenges facing agriculture in developing countries by developing technologies that work under different agro-ecological conditions, and the processes by which these technologies can be adapted to work in other areas with similar conditions. The CGIAR system has been developing ecoregional research as a new paradigm for over a decade. A paper by Douthwaite and colleagues (2005) evaluates one of the most ambitious of these initiatives called the Benchmark Area Approach (BAA) pioneered by the International Institute of Tropical Agriculture. They evaluate the BAA against nine good practice criteria for ecoregional research and finding that the approach is delivering, or has the potential to deliver, on all nine. Many of the lessons learnt from this evaluation will be relevant to current and future attempts to undertake co-ordinated multi-locational research for development.

Good practice INRM (Sayer & Campbell 2001), together with this understanding of scaling-out and scaling-up, gives us the criteria against which we can assess the BAA developed by IITA. To comply with best practice the BAA should:

1. Be able to blend together both ‘hard’ and ‘soft’ science in such a way as to develop at the local level technical solutions and processes that work and are adopted, and then to scale these experiences out and up.
2. Accept that there are multiple stakeholders with multiple realities, and that making sustainable improvements to rural peoples’ livelihoods requires understanding of many of these realities and engaging with many stakeholders.
3. Given this, attempt to effect change by helping stakeholders to envision preferred scenarios and then encourage the stakeholders to move in these directions through iterative and interactive experiential learning cycles. Involving higher level stakeholders early on is important to scaling-up (see Figure 1).
4. Accept that problems must first be solved, and processes developed, at the local level before they can be scaled-out and -up.
5. Support the central role of social and experiential learning though a number of tools, including monitoring and evaluation, based on commonly agreed indicators, and modelling future scenarios to support negotiation and decision-making.
6. Use characterization and Geographic Information Systems (GIS) that help change agents identify best bet technologies and processes.
7. Support the formation of knowledge networks1 built on a common set of concepts and databases that emerge from initial characterization work. The knowledge networks are the basis for scaling-up and -out.

8. Consider effects at different spatial and temporal scales using the systems hierarchy concept2.
9. Remain practical and problem-oriented – building researcher and resource-user partnerships requires researchers to come with something useful in the first place (Douthwaite et al. 2005).

Benchmark areas are supposed to be 'incubators' in which a critical mass of key research and extension stakeholders, NGOs, and IARCs work together with farmers to find and test solutions. In the process of working together, they set up knowledge networks. These are the channels through which people find out about new things, learn and exert influence. These knowledge networks link to policy makers at the village, local government, national government and regional levels, and this helps to create an enabling environment for these emergent solutions. Characterization is a means to this end first by helping to bring key stakeholders together in the process of negotiating and delineating a representative benchmark area, and then in developing a database and a shared set of concepts that nurture and facilitate the incipient collaboration."

Lessons learnt about benchmark areas

IITA's experience can give some useful guidelines to anyone wishing to carry out multi-site ecoregional research using benchmark areas.

1. Move quickly to doing collaborative research with partners and stakeholders to develop both technical solutions and the processes for their development and scaling-up. The success of a BAA will be assessed primarily on whether it is able to set up and operate a 'working R&D continuum' amongst the stakeholders that develops technologies and the processes for scaling them up. Research to remove a 'bottleneck' in current best processes should proceed in parallel with the operation of the R&D continuum and not hold it up. Proceeding with imperfect approaches is better than not working towards making a difference to farmers' livelihoods.
2. Start simple and small with a maximum of just two benchmark areas. It took two years and two rounds of 15 country trips for the EPHTA (=Ecoregional Program for the Humid and Sub-Humid Tropics of Sub-Saharan Africa) co-ordinator to meet key leaders before EPTHA was launched. Then the EPHTA proposal was not funded.
3. Build the BAA up from the bottom 'organically' rather than trying to impose an organizational blueprint from the top down.
4. Choose your benchmark sites in consideration of the key problems to be solved; a 'one size fits all' approach is likely to yield second best results.
5. Avoid large, unwieldy steering committees. While it is important to have a broad coalition of support at the beginning, this does not mean that every important stakeholder has to be involved in every decision. A horizontal structure where smaller groups of stakeholders coalesce around areas of interest and communicate with each other and with other stakeholders works better than a more hierarchical structure where a central committee controls communication and access to higher institutional levels.
6. Do not get bogged down in trying to develop a common set of concepts and seeking for the perfect characterization paradigm. The participatory process of developing concepts and agreeing on delineation and characterization approaches is probably more important than the intellectual elegance of the result.

7. Ensure that culture and ethnicity are part of the characterization paradigm.
8. Promulgate an understanding of the dynamic nature of farming systems; encouraging natural scientists to see their research taking place in an evolving context, where changes are being driven primarily by socio-economic factors, helps focus research.
9. Make sure you have people with the necessary process skills to work in a collaborative and participatory manner with your stakeholders. Seeing yourself as working as one actor in an innovation network requires a different mindset than seeing yourself as part of the 'centre of excellence' at the beginning of a technology research and transfer pipeline.
10. Make every effort to take others along with you, particularly people in your own institute. Keep a clear process paper trail so that people following after you can know the basis of decisions made.
11. Publish key concepts and approaches in peer-reviewed journals to show that your approach is sound. This will defend you against external criticism that might threaten the approach, as well as encouraging others to join in your collaborative effort.
12. Be flexible and learn as you go along. The INRM concept of adaptive management applies to this 'research on research' as well as to effective natural resource management by farmers. This paper represents part of the BAA learning cycle."

An intellectual challenge facing the BAA is to develop characterization approaches that take into account the social and cultural factors known to influence the likelihood of adoption. If this is successful, then it should be possible to use GIS to match not just a technology that is likely to work in a new area, but the extension approach required to construct it socially. A second challenge is demonstrating that scaling-up occurs after the 'best bet' innovations and processes have been developed and knowledge networks have been built.

Integration social sciences into ecosystem management research

Several papers argue for the benefits of including socials sciences data into ecosystem management research and what is required (Berdegué & Escobar 2002; Endter-Wada et al. 1998; Ostrom 2009; Redman et al. 2004). Most of the challenges mentioned are about interdisciplinary perceptions: Ecosystem management decisions based primarily on biophysical factors can polarize people, making policy processes more divisive than usual. Ecological data must be supplemented with scientific analysis of the key social factors relevant to a particular ecosystem. Objective social science analysis should be included on an equal basis with ecological science inquiry and with data from public involvement. A conceptual framework is presented to communicate to ecological scientists the potential array of social science contributions to ecosystem management (Endter-Wada et al. 1998).

There is an urgent need to link more effectively with the growing community of environmental social scientists to create more integrative, inter-disciplinary teams to deepen understanding of the factors determining the vulnerability and resilience of the nature–society system to change. The failure to engage seriously with the social and economic dimensions of environmental change is probably one of the main reasons why LTERM is currently undervalued as a policy-relevant field. Most existing programmes investigate the direct relationship between environmental change and their effects on ecosystems but do not consider the socio-environmental system of which they are part. A more holistic approach requires that the social and economic dimensions become an integral part of the whole system and that we take proper account of the interaction between people and environment. One consequence of this will be the need for LTERM to focus both on ‘working landscapes’ and ones that are closer to pristine conditions in cases where the latter can be used as references for more disturbed systems (Parr et al. 2003).

To meet the challenges of poverty and environmental sustainability, a different kind of research will be needed. This research will need to embrace the complexity of these systems by redirecting the objectives of research toward enhancing adaptive capacity, by incorporating more participatory approaches, by embracing key principles such as multi-scale analysis and intervention, and by the use of a variety of tools (e.g., systems analysis, information management tools, and impact assessment tools). Integration will be the key concept in the new approach; integration across scales, components, stakeholders, and disciplines. Integrated approaches, as described in this Special Feature, will require changes in the culture and organization of research (Sayer & Campbell 2001).

Ostrom (2009) emphasizes the importance of having a “common framework to organize findings, because isolated knowledge does not cumulate. She provides a summary table of variables or descriptors that can be used to describe social-ecological systems and elements within them (adapted from Ostrom 2007). She says “efforts are currently under way to revise and further develop the SES framework presented here with the goal of establishing comparable databases to enhance the gathering of research findings about processes affecting the sustainability of forests, pastures, coastal zones, and water systems around the world. Research across disciplines and questions will thus cumulate more rapidly and increase the knowledge needed to enhance the sustainability of complex SESs”.

Redman and colleagues (Redman et al. 2004) propose a list of core social science research areas, concepts, and questions; identify the need for multiscale investigatory frameworks crucial for implementing integrated research; and suggest practical approaches for integration. They introduce a conceptual framework based on a comparable list of broadly defined social patterns and processes (Figure 2) as a practical basis for integrating social, behavioral, and economic information into long-term ecological research.

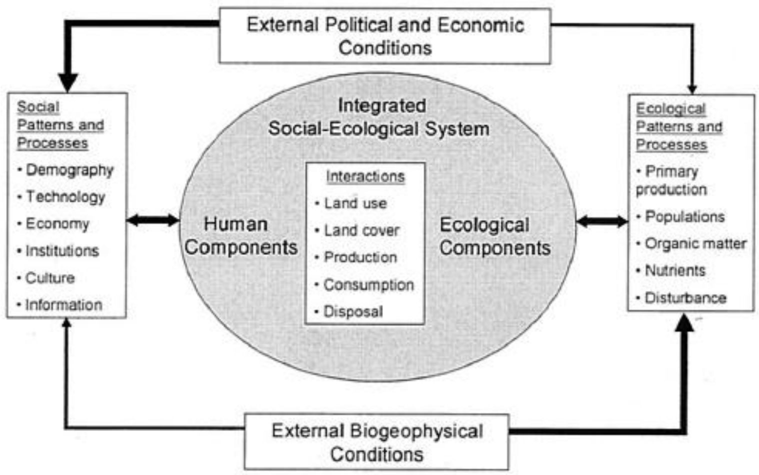


Figure 2. Conceptual framework for long-term investigations of social-ecological systems (SES) (Redman et al. 2004).

Long-term socio-ecological research

An article by Haberl et al. (2006) proposes novel concepts to substantially expand LTER by including the human dimension. Such an integration warrants the insertion of a new letter in the acronym, changing it from LTER to LTSER, "Long-Term Socio-ecological Research," with a focus on coupled socio-ecological systems (Table 1). The article discusses scientific challenges such as the necessity to link biophysical processes to governance and communication, the need to consider patterns and processes across several spatial and temporal scales, and the difficulties of combining data from in-situ measurements with statistical data, cadastral surveys, and soft knowledge from the humanities. It stresses the importance of including pre-fossil fuel system baseline data as well as maintaining the often delicate balance between monitoring and predictive or explanatory modelling. Moreover, it is challenging to organize a continuous process of cross-fertilization between rich descriptive and causal-analytic local case studies and theory/modeling-oriented generalizations. Conceptual insights are used to derive conclusions for the design of infrastructures needed for long-term socio-ecological research.

	LTER	LTSER
System studied	Ecosystem	Socioecological system
Humans are dealt with as...	...human populations, treated like populations of other species, causing disturbances in ecosystems.	...human societies/cultures engaged in an interactive process with their natural environment.
Methods/approaches	Natural sciences approach: observation–analysis–explanation. Intervention occurs only in controlled experiments.	Inter- and transdisciplinary approach: gets involved and is aware that the research may change the systems under investigation.
Products	Expertise, measurement data, models, understanding of system dynamics.	As LTER plus socioeconomic and statistical data. Actively uses research results as a basis for participation in decision making.
Basic epistemological assumptions	Natural—scientific values: aims at objectivity and reproducibility, may sometimes have the illusion to be independent of social values and norms.	Self-reflexivity: is aware that research is a social process inextricably entangled in historically contingent social values and norms.

Table 1. Comparison of key features of LTER and LTSER (Haberl et al. 2006).

Integration between LTSER platforms is another important issue (Haberl et al. 2006). In a globalizing world, isolated landscape-scale studies would fail to address important issues. National and supranational levels must be considered as well, and cooperation between LTSER platforms, e.g., in the form of comparative studies or meta-analyses are required. Especially important is the inclusion of pre-fossil fuel system baseline data and attention to the often-delicate balance between monitoring and analysis and modelling. It is essential that there be continuous cross-fertilization between rich descriptive and causal-analytic local case studies on the one hand, and theory and modelling oriented generalizations on the other, at multiple scales. Research networks such as the global, continental, and national LTER networks will play a crucial role in this process. Capitalizing on more than two decades of operative experience, important national networks are currently being redesigned. For example, the United States LTER is now adopting the so-called NEON concept (see below). This and other initiatives aim to include the human dimension. Such efforts help distinguish site specific from general patterns and processes. Broad, general insights are crucial for the whole global change research community. Integrated socio-ecological models will play a significant role in LTSER, for several reasons.

1. On a landscape scale it is impossible to achieve an integrated picture of ecological processes with measurements alone, so modelling tools, including process-based ecosystem models and GIS models, will be important.
2. Historical and statistical data are never sufficient to reconstruct past socioeconomic, let alone socio-ecological conditions. Various methods, ranging from crosschecks to full-blown integrated models will have to be applied to get a reasonably rich picture.
3. Models are important tools to integrate social, economic, and ecological parameters in a consistent way, thus aiding interdisciplinary analyses. For example, agent based modelling approaches have been combined with land-use studies (Parker et al. 2002) and may also be combined with stock-flow models to yield integrated representations of socio-ecological systems.
4. As one important goal of LTSER is to facilitate decision-making processes, models that immediately demonstrate the consequences of different decisions in an interactive process between researchers and stakeholders can be of great help.

Long-Term Socio-Ecological Research (LTSER) upholds a grand scientific vision bearing three main characteristics: interdisciplinarity, long-term field sites, and data sharing (Mauz et al. 2012). The way in which the three characteristics of the LTSER vision were put into practice was the focus of our investigation. This was done for three European LTSER sites.

As could be expected, they were not translated directly into reality. At first sight, they even had rather minor tangible effects. But the processes turned out to be as important as the products: the platforms provided the partners with an opportunity to learn to cooperate across disciplinary and institutional divides. When they occurred, these learning processes were situated. They were also ongoing and incomplete. This explains why the same grand visions were enacted in various ways and to different extents depending on the local contexts. The value of LTSER therefore lies not only in its ability to offer new research fields, instruments and data, but also in its potential to help researchers learn to collaborate with colleagues from other disciplines and institutions as well as with non-academic partners (Mauz et al. 2012).

The construction of a 'common pot', where data can be collected according to need, is viewed as a way of accelerating scientific progress through the construction of databases fed by and accessible to all. However, pooling and sharing practices are diverse. Data are certainly not shared as a matter of course: ''data friction'' is a major source of science friction. It would require a 'paradigm change' – a profound cultural change in the way researchers relate to their data. What was made available to the partners were the metadata, not the data themselves. Once they knew who held the data they were interested in, the members had to start negotiating access to these data. In many cases, the data were not readily handed over. The partners had various reasons for being reluctant. For instance, people working in data-producing institutions initially feared that their work would be used by scientists without proper acknowledgement, as this had already happened. To overcome their initial mistrust, the ecologists had to assure the botanists that they would be treated as genuine research partners and not as 'drudges'. In addition, some researchers, especially PhD and post-doctoral students, were afraid that they would be unable to publish if their data were pre-empted by colleagues, who were also competitors, before they could analyse them.

Cooperation with amateurs has become particularly important in the context of dwindling financial resources for data-collection by scientists. However, in this case, data pooling and sharing proved just as difficult as for other LTSERs. Volunteers were reluctant to share their data with researchers because they viewed it as a valuable good resulting from dedication and hard work, and deserving proper recognition. The scientists were buying a product and wanted good value for money. They expressed doubts about the quality of the product (''volunteers are unreliable'') and about the price (''recording societies are monopolists''). Volunteers often had very different interests with regard to what was to be monitored, how frequently and for how long. They were required to work in a highly standardised way, which often did not match their practices. Due to such tensions, the volunteers and their data were not formally integrated into the Dutch LTSER Platform, despite long-standing discussions on collaboration between the organisations involved. Experience shows that data collection aimed at statistical up-scaling of data notably incurs the risk of discussions and disappointments between collaborating parties. Trust is thus a prerequisite for collaboration, both between researchers, and between researchers and volunteers. Trust is therefore an important aspect of LTSER.

Informants mentioned the role of metadata and databases in stimulating discussions among the partners and drawing them together. Despite the incompleteness and imperfections of the metadata, being able to actually locate the data and their holders, and then launching negotiations, was seen as a big step forward. Even data, data sets and metadata enfold complex histories that must be understood if the data are to persist: how classification systems are arrived at, what the local coding culture is, what techniques were used. Thus, the organisational culture and history cannot be disentangled from data objects. Scientists at LTSER sites seem to be well aware of the historicity of the data sets they are building, which is productive in the sense that it leads them to pay attention to how and why they preserve and pool data.

The authors therefore claim that the value of LTSER does not lie only in its ability to offer new research fields, instruments and data. It should also be appreciated according to its potential (i) to help researchers learn to collaborate with colleagues from other disciplines and institutions, as well as with non-academic partners; (ii) to invite researchers and their non-academic partners to reframe and rephrase the goals, means and practices of science (Mauz et al. 2012).

Lessons learned from IFRI

Below in the overview of long-term ecological programs and network we discuss the International Forestry Resources and Institutions (IFRI) program, but here we specifically summarize some lessons learned through a review of this program published by Wollenberg et al. (2007).

<u>Select initial sites carefully</u>—IFRI's experience indicated the tension between donor interests and the need to choose sites strategically to represent a problem or population, allow comparison or have high visibility for policy impact, depending on the purpose of the monitoring. IFRI selected sites primarily according to where donors were willing to provide funding, so IFRI sites do not represent particular forests, populations, institutional conditions or threats. Once selected, it is difficult to change sites, since comparison over time will be limited. IFRI's experience suggests it is difficult to control site selection without significant funds. Given the small scale of most community managed forests, choosing sites that have high visibility, policy significance or are associated with development projects or universities that can help disseminate information further would help findings from monitoring have more impact.

<u>Balance the manageability and relevance of data collected</u>—Data needs to be manageable, cost effective and relevant to the questions of interest.

- <u>Minimal data sets</u> – IFRI seeks to collect the minimum set of data necessary for monitoring purposes. As with the selection of sites, the selection of variables has long-term implications. New data can always be added later, but then the period of comparison will be shorter and pre-existing cases will have missing cases for these variables. IFRI is consequently strict about minimizing changes to the data forms.
- <u>Data consistency</u>—One inherent drawback of most long-term monitoring is that it requires monitoring the same precise variables over time. This does not allow the addition of improvements, restricts the addition of new questions or variables that reflect changes in policy or new knowledge. These other issues can be addressed though by using complementary information sets.
- <u>Keep the option of adding more information—</u> IFRI case studies provided the most insights when additional data and methods were used to complement the core monitoring data. Thus while the core methods and database of a monitoring system should be managed conservatively and adjusted in only minor ways to ensure comparability over time, there should be flexibility for people to flesh out the monitoring data with data that is deeper and more comprehensive to allow relevance to emerging issues and new questions.
- <u>Be flexible to meet other users'</u> needs—It may be useful to have a minimum number of sites where core data sets are required as a minimum and work hard to maintain continuity at these

sites, while fostering more customizing of the monitoring instrument in other locations to local users' needs. Explicit attention should be given in training and meetings about whether and how to adapt a monitoring instrument in different settings.

Create a robust and common agreement about the indicators of sustainability—How can forests that are managed for different purposes with different species and in different ecosystems be compared? Forest health is the dependent variable of most interest to IFRI network. The variables IFRI scholars have used as proxies for biological measures of forest condition include subjective assessments by foresters and/or subsets of users. More recent work by IFRI scholars has begun to incorporate biological measures of forest condition into their analysis. IFRI uses a subjective evaluation by users and foresters to determine forest health in a way that normalizes differences across ecoregions and species. The subjective evaluations do not specify criteria. For any methods, there is a need to address forest variation and influences affecting forests—vegetation types, management types, soil types, patchiness and larger forest landscapes—in sampling and data collection. The current use of sample plots may not reflect larger landscape level changes in the quality of the forest.

Manage costs of collecting good ecological data about forests and invest in the commitment to interdisciplinarity—Some members tended to select sites with small forests to avoid the ballooning cost of sampling larger forests. Others, who did have interests in forest ecology, sometimes could not complete their studies because vastly more ecological data needed to be collected or felt that they had to sacrifice getting a higher resolution of data to answer IFRI questions. Species classification was especially time consuming in forests with high plant diversity (also see Meijaard & Sheil in press). Some (forestry!) students avoided using IFRI for their thesis because the forestry component was too daunting. Most members and people interviewed agreed that the forestry component of IFRI needs improvement to refine the indicators, reduce its cumbersomeness and make better use of the data. IFRI could benefit from a tropical forest specialist in the IFRI leadership team, more support of members with forest expertise and more links with the forestry community or others conducting ecological monitoring of forests. Biophysical explanations or causes should be included in the analysis.

Build capacity to compare and aggregate data—IFRI is still developing its capacities to use the database and the advanced statistical methods necessary to undertake broad scale comparative analysis. Many IFRI members have never tried to access the database. Most members have given priority to analysis of their own case study data. IFRI's experience suggests members of a monitoring and research network need to be encouraged from the start not only to enter data, but also to analyze it.

The difficulty of interpreting data across sites has also limited people's interest to producing syntheses. Rather than pooling data globally, one member suggested that the data should be pooled regionally (or by other shared characteristics) and then identify global trends. Research members producing the data should be included as authors or at the very least reviewers of any comparative or synthesis work conducted by other network members. Their participation is necessary for credible interpretation of their data, as well as an ethical measure for recognizing each member's contribution to the network.

Work to support regional capacities and differences in the Network—Using the comparative advantage that each CRC team and location offers to contribute to the general skills set and knowledge of IFRI.

- Developing more capacity in the regions for data analysis.
- Facilitating cross-visits for field work, capacity building and writing among CRCs. Give travel awards and organize regional conferences or field seminars for CRC people to attend. Create more opportunities for joint writing in the region. Take more advantage of CRC members who come for training to stay longer and conduct collaborative fund raising, analysis, or writing.
- Broadening involvement beyond CRC directors by having regional networks in which other CRC team members than just directors can participate.
- Further developing the functions of the steering committee and regional representation in it.
- Continuing regional training.
- Fundraising by CRCs.
- Overcoming language barriers by developing a publications programme in more than one language.

The IFRI training course has been a major influence in successfully disseminating IFRI concepts and methods. IFRI's experience in trying regionally based courses has improved access to the course reduced costs, enabling IFRI to have an even greater positive impact on capacity building.

IFRI's experience suggests that significant tradeoffs exist between an outward orientation necessary to link with the larger publics potentially interested in the network's research and findings, and an inward focus that may be necessary for the development of an integrated analytical framework that allows substantial research related to data collection and theoretical innovation. An initial inward focus may be essential to the early stages of a network's development. A concern for robust and empirically supported theoretical development was IFRI's initial cause for concentrating its efforts inward. Yet there is a risk of extending this inward focus indefinitely to improve methods yet further. Ultimately, the network and its members needed to identify a transition point from which to begin to more aggressively engage others interested in common research and policy issues. It has reached that point now. With the transition, the network will enter a new phase of development that may well generate quite different challenges (Wollenberg et al. 2007).

Ecoregional programs

In a meta-analysis of reviews and evaluation of Ecoregional Programs, Berdegué and Escobar (2002) (2002) make a number of insightful observations. Most of the reviews and evaluations coincided in identifying a few key strengths and weaknesses common to ecoregional programs.

Major challenges facing ecoregional initiatives—Ecoregional research has tended to over-emphasize characterization of agroecoregions and the development of new methods and tools, at the expense of focusing on strategic problems and opportunities and delivering scientific and technological results. The "human dimension" (i.e. socioeconomic and policy research) is underrepresented in the research programs of the ecoregional initiatives, to the extent that several of them are almost exclusively dedicated to working on biophysical issues2 A related issue is whether the programs strike an appropriate balance between upstream and downstream goals, or, in other words, between international research aimed at strategic products and results, and application oriented development work.

The work of some of the ecoregional programs shows that it is possible to strike this balance when the programs are designed with a clear focus on well-defined NRM problems and opportunities of international significance, related to sustainable agricultural production, food security and poverty alleviation. Early work by the programs, by necessity, concentrated on biophysical issues, while more recent work has concentrated more on socioeconomic and policy research.

The programs include appropriate and explicit strategies for ensuring application of research results Another important condition that would facilitate balance is the ability to extrapolate results. Yet there are few clear-cut success stories in this area. Part of the problem is that benchmark sites have sometimes been selected using poorly defined technical criteria. An added difficulty is that the methods and tools used to support extrapolation tend to be quite demanding of scientific knowledge, technical skills and sophisticated institutional environments.

Integration of biophysical, social and policy research—Ecoregional approach should integrate biophysical and socioeconomic and policy research. Yet many reviews conclude that the policy and socioeconomic dimensions of most ecoregional programs need considerable strengthening. Continuing weaknesses in this area will severely undermine the programs' impact.

Partnerships—Partnership-building has been the strong point of the ecoregional programs. There is some evidence in the reviews and evaluations to suggest that partnerships that developed before the ecoregional programs were launched tend to perform better than those that formed for the explicit purpose of obtaining funding for such a program. Most reviews emphasize the high transaction costs of consortia-based ecoregional research. These costs are probably inherent in all collaborative research endeavors, especially when they involve a broad range of partners, who may have different interests and may respond to different sets of incentives.

Governance—In most cases, ecoregional programs are governed through a system of steering committees and of coordination or facilitation units, often operating at different levels (consortia, countries, benchmark sites, etc). The major achievement of this approach has been to bring on board a large number of partners, all of whom are involved to some degree in decision-making.

These different partners bring different capacities to a consortium, but current governance arrangements are often organized on the false assumption of equality of contributions. The governance systems of ecoregional programs need to establish clear criteria, procedures and bodies, to take care of what should be four distinct stages in decision-making: consultation, decision-making (about priorities and objectives and the resources allocated to them), follow-up by management, and monitoring and evaluation of the results. Different partners in ecoregional consortia should play different roles at each of these stages, with well-defined rights and duties, and with procedures and criteria to ensure accountability.

Planning and priority setting—Three principles can be discerned. First, prioritization should follow clear criteria: (a) the importance of the NRM research problem in terms of sustainable increases in agricultural productivity, food security, poverty alleviation, and environmental protection, (b) the likelihood that an investment in strategic research will produce solutions to the problem, taking into account national research capacities, (c) the potential for producing international public goods with wide spill-overs across national boundaries, (d) the potential for applied R&D to have an impact in the short to medium term. Second, a strong socioeconomic and policy research component is needed to ensure adherence to these criteria. The work of this component needs to be closely integrated with that on biophysical problems. This implies a careful review of the institutions and disciplines represented in the planning process and in program implementation. Third, clear and frank application of the criteria in the planning and priority setting procedure probably requires that it be open to the participation of stakeholders outside those who are permanent partners in the program. Outsiders may be in a better position to ask the hard questions about relevance and potential impacts.

Monitoring and evaluation—Ecoregional initiatives often lack an effective monitoring and evaluation system and should establish monitoring and evaluation systems that meet the standards applied to the rest of the CGIAR. Lead Centers should consider organizing Internally Commissioned External Reviews (ICERs) of their ecoregional programs. This is especially important for those Centers whose ecoregional programs have not been reviewed for more than five years.

Funding—Levels and continuity of funding for ecoregional programs have been way below initial expectations. The consequences are aggravated by the fact that the ecoregional consortia have often not adjusted their operations. They have maintained the same goals, number of benchmark sites, number of projects, and so on.

Reviews and evaluations have been unable to understand or even describe how funds flow, who contributes and gets what, or even which resources belong to the ecoregional initiative as opposed to other projects and programs of the convening Centers. This leads to inefficiency, complicates the monitoring and evaluation of costs and benefits and probably discourages donors from making greater commitments. It is also a frequently mentioned source of friction among participants in the consortia, and in particular between the Center and national programs.

A well-designed and managed competitive fund requires that clear criteria of eligibility and merit be established to guide the allocation of resources. These need to be derived from the program's objectives. They could also allow the participation of a broader range of R&D organizations in the activities of the consortia, without having to incorporate everyone as a permanent member. And they could facilitate the task-specific participation of peer reviewers external to the consortium.

Division of tasks— There commonly is confusion in the contributions to be made by each partner, as well as in responsibilities and the allocation of funds to carry them out. A significant part of the problem of high transaction costs has to do with this lack of clarity. Once again, a system of project-based contracts between the consortium and ad-hoc task forces would go a long way in helping to solve this problem. With regard to the role of the CGIAR Centers, a well-planned process of 'devolution' of responsibilities is needed, so that the Center becomes just one more partner in the system.

Integration—The involvement of new partners, such as NGOs and private companies in all aspects of ecoregional programs is seen as vital. We believe that if this is taken care of, the second dimension of integration (multidisciplinarity) will follow. It may be that this integration is not yet happening today to the extent that it should, despite advances in multidisciplinarity in the CGIAR centers. Some ecoregional programs do not include enough researchers and other stakeholders with the interest, the perspective and the expertise to pursue "the human dimension". Competitive funds are likely to be a good mechanism for ensuring the integration of upstream and downstream objectives.

Utilization of results—To improve the utilization of results of ecoregional research, it is essential that such research be results-oriented! However, many applied R&D organizations in developing countries face significant internal weaknesses or operate in a socioeconomic or policy environment that constrains their ability to take advantage of research results. Ecoregional programs could seek to implement the new elements in the CGIAR vision and strategy, especially the greater involvement of applied R&D organizations. Secondly, they could invest more in developing the capacities of national and local partners.

Communication—Communication is almost always rated poorly in the reviews and evaluations. Some programs do not publish their results in international peer-reviewed journals. Another problem is there is sometimes little or no communication between staff of different ecoregional programs who are working on the same or similar projects, even when funded by the same donor. Most importantly, with the exception of a few programs, there appears to be little communication or systematic dialogue with decision-makers who hold the keys to the large-scale dissemination of research results.

Improving communication will require that specific staff and financial resources be devoted to this task, as it is unrealistic to expect researchers to have the time to do it.

Conclusions

1. Ecoregional programs have made major advances in improving interaction and networking between national programs and CGIAR Centers. This is a major contribution to the agricultural knowledge and information systems of the regions where it has occurred.
2. Few ecoregional programs have yet documented convincing evidence of impact. It is possible that some programs have placed too much emphasis on characterization, necessary though this is in the early stages of research.
3. Most programs could go further in integrating the biophysical and social sciences. Research on socioeconomic and policy issues remains weak in nearly all programs.

Recommendations

1. Each ecoregional program should issue a formal statement of its goals. This will improve the programs' ability to focus on major NRM research problems and opportunities and to generate relevant scientific and technological results.
2. Each program should also commit itself to improving the integration of biophysical research with socioeconomic and policy research.
3. TAC should commission an in-depth study on the strategies and methods that are most effective in building and sustaining ecoregional consortia.
4. ISNAR should develop guidelines for improving the integration of upstream and downstream objectives in research planning and priority setting. Such guidelines should consider the key question of how to bring in new applied R&D partners.
5. The CGIAR should issue guidelines to improve transparency, accountability, effectiveness and efficiency in the allocation of responsibilities and resources in ecoregional consortia. In developing these guidelines, the CGIAR should consider new institutions and funding mechanisms, including project-based contract systems, ad-hoc task forces and competitive funds.
6. Each program should put in place a formal monitoring and evaluation system. TAC should assist the programs by issuing guidelines on monitoring and evaluation in ecoregional consortia.
7. Ecoregional programs that have not been reviewed for several years should urgently organize a formal review and evaluation process.
8. All programs should take urgently needed steps to improve the communication of their results.

Researchers' experiences of integrated research programs

Despite the growing importance of integrative research, few studies have investigated researchers' experiences in these projects. A study by Tress et al (2005) assesses how researchers perceive the outcomes of integrative projects, or career effects? Do they view the projects generally as successes or failures?

Researchers experience participation in integrative projects as positive, in particular discussions among participants, networking, teamwork, and gaining new insights and skills (Table 2). Furthermore, most researchers perceive the projects as successful and as having a positive effect on their careers. Less positive aspects of integration relate to publications and merit points. Factors found to contribute to positive experiences include reaching a high degree of integration amongst the involved disciplines, common definitions of integrative research concepts, and projects that include a large share of fundamental research as well as projects with many project outcomes. It is thus important that projects plan for integration, facilitate discussions, and reach agreement on integrative concepts. Aspects of fundamental research should be included in integrative projects. Planning should be done at an early stage for peer-reviewed publications, to ensure that participants gain merit points from their participation in integrative research efforts.

No.	Question: ''What were the positive experiences in the project?''	Interviewee
1	''The amount of energy you get from other people. The inter-human part of it. And it gave me status. This project [gave] me the opportunity to battle and I learned [from] it.''	(B2)
2	''I gained respect during the project. At the beginning I was not more than the assistant, towards the end I was taken seriously. I also learned a lot of practical things. Well I hope that I can complete the dissertation in some time ... I learned to lead workshops, also I gained management experience.''	(C1)
3	''The most positive experience is what you learn when working transdisciplinary. You learn a lot from the others, whether they are scientists or practitioners. Of course, you learn more from someone who is not so close to your own field of research.''	(C2)
4	''Cooperation within the team and to see everything from many different perspectives. I have also learned... methods and new approaches.''	(C3)
5	''The motivation of all participants, everyone fully supported the project. In the end we had no money anymore, but we completed the project anyway.''	(D1)

Table 2. Positive experiences of selected interviewees (Tress et al. 2005)

Researchers had a more positive experience if:

- they reached a high degree of integration in their project;
- the project was largely fundamental research;
- the project resulted in significant scientific outputs (e.g., international peer-reviewed publications);
- the project had high output in terms of products (e.g., methods, tools, guidelines, advice, and specific outputs requested by funding body); and
- the project was highly productive in terms of education and training (e.g., in numbers of completed PhD and masters degrees, student exchange, and courses deriving from the project).

The positive experiences with ''discussions,'' ''teamwork,'' and ''networking'' are closely related to the positive experiences recorded for ''new insights'' and ''new skills.'' The sharing of knowledge, and thus gaining new insights and skills, takes place in the active exchange between disciplines, as manifested in discussions and teamwork. Both are media, which enable learning. As one interviewee said, you can learn the most from people outside your own disciplinary framework. For researchers, this satisfies intellectual demands, such as curiosity and inquisitiveness, and is, therefore, experienced as rewarding.

No.	Question: ''What were the negative experiences in the project?''	Interviewee
1	''It is not a project as we learned in project management. It is going in circles. You can only define an aim on the horizon and when you climb the first mountain, you can see further.''	(B1)
2	''It was a tough job, it took enormous energy. The administration of the project was chaos.''	(B2)
3	''You think you agree on things and you know what to do the next half year, but there are still people who see this totally different. In spite of the fact that you have discussed it again and again and again and again. It just does not stop.''	(C1)
4	''The need for discussions and communication in such a project is much higher than you can ever put in your budget. There are also limits in terms of efficiency.''	(D1)
5	''There was too short time to produce publications.''	(E1)
6	''I could not fulfil the scientific expectations placed on me by the institute solely from this project. ...For your scientific reputation you do not get much out of such [transdisciplinary] projects.''	(C5)

Table 3. Negative experiences of selected interviewees (Tress et al. 2005)

Researchers responding to the survey by Tress et al. (2005) perceived a positive career effect from integrative projects (Table 4). This contrasts with Bruce and others (2004, not seen), who mention the poor career structures for academic interdisciplinary researchers as one of the factors discouraging integrative research. Metzger and Zare (1999, not seen) state that researchers who propose interdisciplinary research programmes have and do put their careers at risk. Also, Jakobsen and others (2004) found that participants in integrative landscape studies perceive ‘‘insecurity regarding career implications’’ as a barrier to participation in integrative projects. Jakobsen and others (2004, not seen) linked this to the idea that it can be difficult to find journals in which to publish interdisciplinary articles and thus to gain merit points for career advancement. We also find evidence supporting a positive career effect of participation in integrative projects in the candidate qualifications mentioned in job advertisements. Furthermore, funding bodies broadly support integrative research, which is likely to lead to continued growth and thus increased career opportunities in integrative research fields.

Tress et al. (2005) interpret the low rating given to ‘‘merit points’’ and ‘‘publications’’ in integrative projects as a result of four factors:

1. Integrative projects, and certainly transdisciplinary projects, tend to be more applied in character than disciplinary ones. Tress and others (2005) found that funding bodies primarily support integrative studies to solve pressing societal-environmental problems. Advancing science is a subordinate goal.
2. It might be difficult to gain depth in integrative projects. Coming together from different disciplines, an interdisciplinary or transdisciplinary project team has to start from the smallest common understanding, rather than from the edge of the respective knowledge cultures. Daily and Ehrlich (1999) also conclude that it is more difficult to maintain high standards in interdisciplinary projects.
3. As integrative landscape research is a relatively new area, there is a lack of integrative methods and theories. Instead of relying on approved methods, integrative teams must first develop a set of tools. It might, thus, be more difficult to produce cutting-edge results that are suitable for submission to high-ranking journals.
4. Researchers might perceive the academic merit system as favouring disciplinary projects. This came to the fore in the interviews, where researchers said that integrative projects offered little scientific reward.

Perceived positive career effect is largely related to researchers’ broadened personal knowledge base, new skills, and insights derived from integrative projects. Researchers learn a lot in these projects and experience this as beneficial for their careers. But the positive effects are not based on traditional academic merit.

No.	Question: "Career-wise, what was your personal benefit from the project?"	Interviewee
1	"I got some contacts that I still keep and that I use to set up new projects."	(A2)
2	"If you aim at an academic career, for instance, as a professor, a transdisciplinary project might not be very helpful; it might even be counterproductive. If you do it because you are interested in this kind of research, and not in your career or in money, then it is a benefit. You get access to entirely different networks than before."	(C2)
3	"If I were to depend on this project for my career, [it] would be very poor. The scientific output was small. It is difficult to combine friendship and a good atmosphere with high personal ambitions. As long as the evaluation criteria remain as they are now, such a project is not good for your career."	(C5)
4	"I gained many experiences that were very helpful for other projects. Further, it had no career influence, but I did not hope for it either. For job applications I think it really would have a positive effect, it is no barrier that's for sure.	(D3)
5	"It was very important because I took my PhD [during the project] and I got the permanent position in a field I would not have expected. That was only due to the project. Otherwise I would not have gotten the position."	(E1)

Table 4. Career effects as experienced by selected interviewees (Tress et al. 2005)

From their research findings, Tress et al. (2005) distil results down to five key aspects related to positive experiences in integrative projects.

- Plan for Integration;
- Allow Space for Discussions. Discussions should not be left to formal presentations or occasional and spontaneous gatherings, but rather be part of the plan to reach integration;
- Facilitate a Common Definition of Integrative Concepts. Time must be allocated to this process without too much pressure put on participants;
- Balance Applied and Fundamental Research;
- Plan for Publications.

Consideration of scale

The growing need for interdisciplinary work across the natural/social science divide, however, demands that each achieve some common understandings about scaling issues (Gibson et al. 2000).

Definitions of key terms related to the concept of scales[a]

Term	Definition
Scale	The spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon.
Extent	The size of the spatial, temporal, quantitative, or analytical dimensions of a scale.
Resolution (grain)	The precision used in measurement.
Hierarchy	A conceptually or causally linked system of grouping objects or processes along an analytical scale.
Inclusive hierarchy	Groups of objects or processes that are ranked as lower in a hierarchy are contained in or subdivisions of groups that are ranked as higher in the system (e.g. modern taxonomic classifications — kingdom, phylum, subphylum, class, family, genus, species).
Exclusive hierarchy	Groups of objects or processes that are ranked as lower in a hierarchy are not contained in or subdivisions of groups that are ranked as higher in the system (e.g. military ranking systems — general, captain, lieutenant, sergeant, corporal, private).
Constitutive hierarchy	Groups of objects or processes are combined into new units that are then combined into still new units with their own functions and emergent properties.
Levels	The units of analysis that are located at the same position on a scale. Many conceptual scales contain levels that are ordered hierarchically, but not all levels are linked to one another in a hierarchical system.
Absolute scale	The distance, time, or quantity measured on an objectively calibrated measurement device.
Relative scale	A transformation of an absolute scale to one that describes the functional relationship of one object or process to another (e.g., the relative distance between two locations based on the time required by an organism to move between them).

[a] Sources: Turner et al., 1989a, p. 246; Mayr, 1982, p. 65; Allen and Hoekstra (1992).

Table 5. Definition of key terms related to the concept of scales (Gibson et al. 2000)

The relationship of analytical levels of human choice and geographic domains

	Conceptual levels of human choice		
Spatial levels of political jurisdictions	Constitutional-choice level	Collective-choice level	Operational-choice level
International	International treaties and charters and their interpretation.	Policy making by international agencies and multinational firms.	Managing and supervising projects funded by international agencies.
National	National constitutions and their interpretation as well as the rules used by national legislatures and courts to organize their internal decision-making procedures.	Policy making by national legislatures, executives, courts, commercial firms (who engage in interstate commerce), and NGOs.	Buying and selling land and forest products, managing public property, building infrastructure, providing services, monitoring and sanctioning.
Regional	State or provincial constitutions and charters of interstate bodies.	Policy making by state or provincial legislatures, courts, executives, and commercial firms and NGOs with a regional focus.	Buying and selling land and forest products, managing public property, building infrastructure, providing services, monitoring and sanctioning.
Community	County, city, or village charters or organic state legislation.	Policy making by county, city, village authorities and local private firms and NGOs.	Buying and selling land and forest products, managing public property, building infrastructure, providing services, monitoring and sanctioning.
Household	Marriage contract embedded in a shared understanding of who is in a family and what responsibilities and duties of members are.	Policies made by different members of a family responsible for a sphere of action.	Buying and selling land and forest products, managing property, building infrastructure, providing services, monitoring and sanctioning.

Table 6. The relationship of analytical levels of human choice and geographic domains (Gibson et al. 2000)

The survey presents the fundamentals of scale, examines four general scaling issues typical of social science, and explores how different social science disciplines have used scale in their research. Some useful for clarification of terms is offered (Table 5 and Table 6). The authors make the point that if researchers are to generate accurate analyses of environmental change, the first step, we believe, is to push beyond the present cacophony and construct a common understanding of issues related to scale."

Incorporation of market data

Measures of market access and market influence can improve our understanding about the drivers of environmental change, as they link regional and global economic activity to local environmental conditions. They can also help to assess, design and implement targeted measures to reduce environmental pressure and improve ecosystem services. Moreover, local market access is an important factor for economic development, poverty and food security. Aggregate, national figures, such as the human development index, do not provide sufficient detail. A new dataset (Verburg et al. 2011) could provide the basis for improved assessments of targeted infrastructure investment, which could help to reduce environmental degradation, promote economic development and alleviate poverty."

Commonly encountered problems and challenges in long-term ecological research

Data management in Palmer LTER and US JGOFS

Interdisciplinary science requires new ways of thinking about data and data management (Baker & Chandler 2008). With new data policies and growing technological capabilities, datasets of increasing variety and complexity are being made available digitally and data management is coming to be recognized as an integral part of scientific research. To meet the changing expectations of scientists collecting data and of data reuse by others, collaborative strategies involving diverse teams of information professionals are developing. These changes are stimulating the growth of information infrastructures that support multi-scale sampling, data repositories, and data integration. Two examples of oceanographic projects incorporating data management in partnership with science programs are discussed: the Palmer Station Long-Term Ecological Research program (Palmer LTER, see below) and the United States Joint Global Ocean Flux Study (US JGOFS). Lessons learned from a decade of data management within these communities provide an experience base from which to develop information management strategies—short-term and long-term, which are also relevant to the Sentinel Landscape program design.

For both programs, data management was part of the planning process and was recognized as integral to these scientific research processes and as requiring close partnership with investigators. Both established centralized local data repositories at the project start and subsequently developed data policies addressing agency, project, and institutional concerns. Data catalogs and sampling protocol summaries played an early part in efforts to create centralized data access points. Sampling grids, event logs, and local dictionaries are three coordinating mechanisms that represent best practices common to these two independent research programs. Cooperative planning of sampling strategies initiates cross-component discussions within the community, creates a shared understanding of measurements and informs subsequent data organization. Another product of cooperative planning was a sampling-event log with unique sequential identifiers to identify sampling activities during a research survey. In the absence of an event log, seemingly small differences in how data are gathered in the field (e.g., unsynchronized clocks and differing station-naming conventions) become progressively difficult to reconcile over time. Finally, the complex interdisciplinary investigations that are the hallmark of Palmer LTER and US JGOFS are facilitated by the availability of term dictionaries. In both programs, custom dictionaries were constructed in order to provide dataset columns with unique, well-defined names and a flexibility that accommodates local naming traditions.

A selection of information management strategies are presented

Short-term implementation
1. Local data repository development and maintenance
2. Metadata conventions and dictionaries development
3. Data access via Web interface to queriable data structure
4. Deliberate documentation, articulation and synthesis
5. Data quality procedures development
6. Online management of data by community members
Long-term implementation
7. Data policy implementation
8. Role development for information mediation
9. Collaborative structures and process development
10. Design process development for analysis and research
11. Reciprocal learning environment development
12. Long-term infrastructuring

All strategies have long-term ramifications.

Table 7. A selection of information management strategies (Baker & Chandler 2008)

With changing data practices as described above, new conceptual frameworks are needed that take into account the heterogeneity of data, complexities of data description, and sustainability of community efforts over time. See Table 7 for an overarching vision and strategies for information management.

Online data management – distributed vs centralized

Chinn and Bledsoe (1997) discuss three guidelines for the developing the online format for data management in long term research networks.

- The format should be humanly readable and intelligible; there should be no mistaking what each field contains. Success depends on the balance between clarity and conciseness in choosing the field labels.
- The format should also be machine readable. This factor will aid in importing selected citations into other (bibliographic) database systems.
- A good machine-readable format will also support the enhancement of the bibliography through the addition of improved, more sophisticated searches as new software is developed."

Chinn and Bledsoe (1997) also discuss lessons learned with regard to online data management:

- This project stimulated LTER sites to improve their site bibliographies.

- As scientists in the LTER Network increase their use of integrated online computer facilities, individual sites must exercise care to select software and design solutions appropriate for application in a networked organization. In addition, sites should design these systems to accommodate, rather than resist, the changes that inevitably occur in computer technology.
- A small team did all the programming, assembly, and updating. However, experience in managing the bibliography project over the last three years has made it amply clear that future "all-site" databases should be designed as distributed systems from the start, with each LTER site maintaining its portion of the particular database locally at the site, organized to facilitate integrated Internet access and searching (see below).
- Increasingly, the appropriate and satisfactory application of computers to the management of biological data requires a team effort. This is particularly true for data that may be used in comparative or synthetic work. Research has advanced beyond the time when individual biologists could fully exploit the potential of computer systems solely through their own programming efforts. The experience of LTER and others shows that development teams producing software tools need both biologically literate computer scientists and computer-savvy biologists to achieve the best results."

One decision facing managers of networked, computerized database systems is the choice between a centralized system and a decentralized, distributed one (Table 8).

Distributed systems	Centralized systems
Advantages • Most of the parts (the individual site bibliographies) will always be online, available for searching (i.e., they will not all be simultaneously offline). • Logically, that portion of the online, searchable bibliography for a particular site belongs at the site that maintains the original source database. • A distributed system reduces or eliminates the duplication of data, depending on the techniques used for database storage and access. • Reduced data duplication lowers the overall cost of disk storage capacity for the Network, a factor that is increasingly important as the size of biological databases grows • Giving the responsibility to each site for its portion of the All- Site Bibliography may encourage better maintenance of the original for easier conversion, thereby improving the quality of the online version. Disadvantages • Despite the final advantage, overall quality control (e.g., maintaining a single online format that is consistent across all sites and keeping the All-Site Bibliography up-to-date) is more difficult when responsibility is dispersed among many individuals located across an area the size of the United States.	Advantages • When maintained by a single individual or a small group at a single location, quality is easier to control. • Centralization relieves busy site data managers of the maintenance task. Disadvantages • There is less motivation to improve the site's primary bibliography for better and easier conversion to the online form (some-one else deals with the conversion difficulties). • It requires an individual or group to handle the entire project. • If the Network Office computer system is offline, the entire All-Site Bibliography is unavailable. • Data is duplicated. An official bibliography is present at the site, and a separate version of it is in the central bibliography. As a result, there is always the concern of how up-to-date the (centralized) All-Site Bibliography is. • As the amount of data grows, it becomes less feasible to store duplicate versions. The cost of the additional disk storage capacity becomes significant.

Table 8. Comparison between distributed and centralized data management systems (Chinn & Bledsoe 1997)

Information management in LTER

A paper by Michener and colleagues (2011) discusses in considerable detail the information management challenges in long term ecological research programs.

Extracting knowledge from the massive volume of disparate data collected across ecosystems and decades depends upon robust and evolving information management programs at each site as well as a growing, more centralized Network Information System that facilitates inter-site and network-wide data discovery, integration, and synthesis. This paper: (a) reviews the role of policies and governance in the evolution of LTER information management; (b) identifies the components of the human infrastructure that are employed to perform site- and network-level activities; (c) discusses information management functions that are supported at LTER sites grouped by data life cycle components-data acquisition, metadata annotation, incorporation into databases, data exploration/analysis/visualization, and data curation/preservation (Figure 3); and (d) presents the history of the evolution of network-level services within LTER and describes the overall architecture of the Network Information System. Finally, it reviews the factors that have driven the evolution of information management in LTER over the past three decades and postulate the factors that will guide further evolution of LTER information management during the upcoming decade.

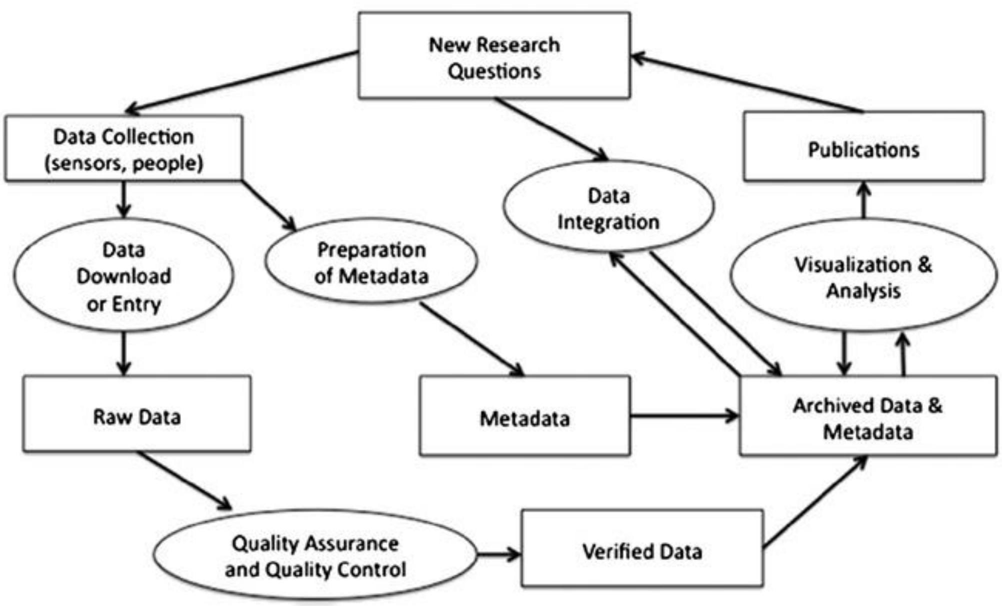


Figure 3. The data life cycle consists of two major loops. One follows the production of analysis-grade data from scientific question, to measurement, through quality control and assurance, analysis and publication, which then produce new research questions, starting the cycle all over again. However, for data that are archived and shared, a second cycle is possible. In that cycle, new research questions drive the integration of existing archival data, which then allows new analyses that result in additional publications and research questions (Michener et al. 2011).

In 1990 two major steps were taken. First, a data catalog containing ten core data sets from each LTER site was published. For the first time it was possible to explicitly identify which data were being collected where and by whom. Second, the governing body of the LTER Network laid out a set of guidelines for site data sharing policies, calling on individual LTER sites to compose and publish policies that would address issues of data accessibility. Allowing the data policy to evolve over time was necessary to get the critical buy-in from ecological researchers, and to allow development of an emerging set of ethical principles surrounding data reuse. The LTER-wide data policy, as modified in 2005, contains sections that define the responsibilities of the data collector, dictating how long data access can be restricted (2 years after collection), and identifying special conditions that may allow additional restrictions for a more extended period (e.g., locations of endangered species, human confidentiality). It also outlines the properties of the required metadata (http://www.lternet.edu/data/netpolicy.html). However, it does not end there. The policy also addresses the responsibilities of users of the data to properly acknowledge the efforts of the data collectors and provides rules regarding the redistribution of data and suggested forms of citation. Proper attribution of ideas and results is central to ethical scientific practice.

The development of metadata (i.e., data about data) standards is an ongoing process involving the LTER Network and its collaborators. Documentation elements used at each of the individual LTER sites were compiled and common elements identified, and in 1994 a "content-standard" for LTER metadata was adopted by the IMC. The information managers within the LTER Network have produced a "best practices" guide for creating EML metadata, and working groups continue to refine the standards and practices.

To support the development of the LTER Network, in particular with respect to information management, the LTER has developed a governance structure (Figure 4). The LTER Science Council (SC) consists of representatives from each of the LTER sites and is the core of the LTER governance system. The SC has a number of standing committees including the LTER Information Management Committee (IMC). Most day-to-day governance activities of the network are conducted by an Executive Board (EB), which includes an elected chair and rotating membership derived from the SC, along with an elected member from the IMC. Like the Science Council, the IMC has a representative from each of the LTER sites, and elects an executive group (IMExec) to conduct day-to-day governance activities.

The LTER Network Office (LNO) is overseen by the LTER Executive Board. The LNO hosts a variety of network-wide databases (e.g., LTER Data Catalog, All-Site Bibliography, and Personnel). The Network Information System Advisory Committee (NISAC) has members from each of those groups. A primary goal of NISAC is to assure that information management activities at all levels facilitate ecological research. All LTER sites have at least a half-time information manager. The information manager keeps abreast of new technologies and mechanisms for improving discoverability and accessibility of their site's data. Depending on the skill set of the information manager, web programming and custom tool development may be part of their job or may be delegated to student programmers. The information manager has the vision for how all the pieces of the information management system fit together.

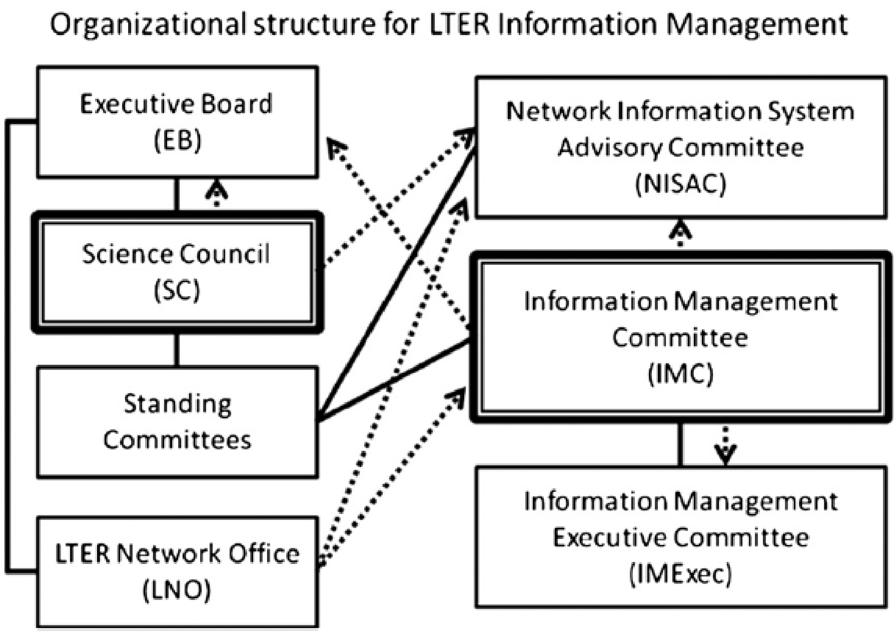


Figure 4. LTER governance structure. Boxes with bold boundaries indicate entities where each of the individual LTER sites has a representative. Dotted arrows indicate the source(s) of membership for entities (Michener et al. 2011).

Through the 1980s and until 1997, there were as many metadata formats as there were sites, but in 2004 this changed when the LTER information management community adopted Ecological Metadata Language (EML) as its metadata standard. EML uses eXtensible Markup Language (XML) schema to define content and structure, and consists of several modules to describe different aspects of the metadata. The adoption of EML as the metadata standard for the LTER has led to improved data curation, discovery, and access. The use of XML allows many different types of tools to be used to create and work with EML. The quality of LTER EML will further be improved by adoption of a controlled vocabulary which is presently under development. Use of the controlled vocabulary will improve discoverability of comparable datasets. The LTER Unit Dictionary, comprising the set of units in use by LTER sites and the best practices that support them, will also be implemented to ensure standardization of units in data sets. Standardization of units across the LTER will facilitate data synthesis."

Represented by the Data Loader and Data Cache in Figure 5, the Data Management Suite will be responsible for determining whether a data set described by metadata is "PASTA-ready". Through the use of the "EML Data Manager" library, a collection of tools written in Java to interact with EML described data, the Data Loader will parse dataspecific metadata fields, generate a corresponding data structure table in a relational database (the Data Cache), and then attempt to load the data into the database table from the site by using standard network protocols (e.g., HTTP, FTP). A successful data load will result in Level-1 or Level-2 data in the Data Cache. Services of the Data Loader will provide "structural" quality control and error detection of Level-0 data, thus enabling corrections and/or flagging of these data prior to being stored; corrected/flagged data will be characterized as Level-2 data. All errors or flagged data that produce Level-2 data will be reported to the Audit Services component of PASTA; sites will have access to this information through the Audit Services. The Data Loader service interface will also provide metadata/data quality checking capabilities (i.e., ensuring data formats comply with descriptions in metadata) to site information managers for pre-harvest evaluation of their metadata and data.”

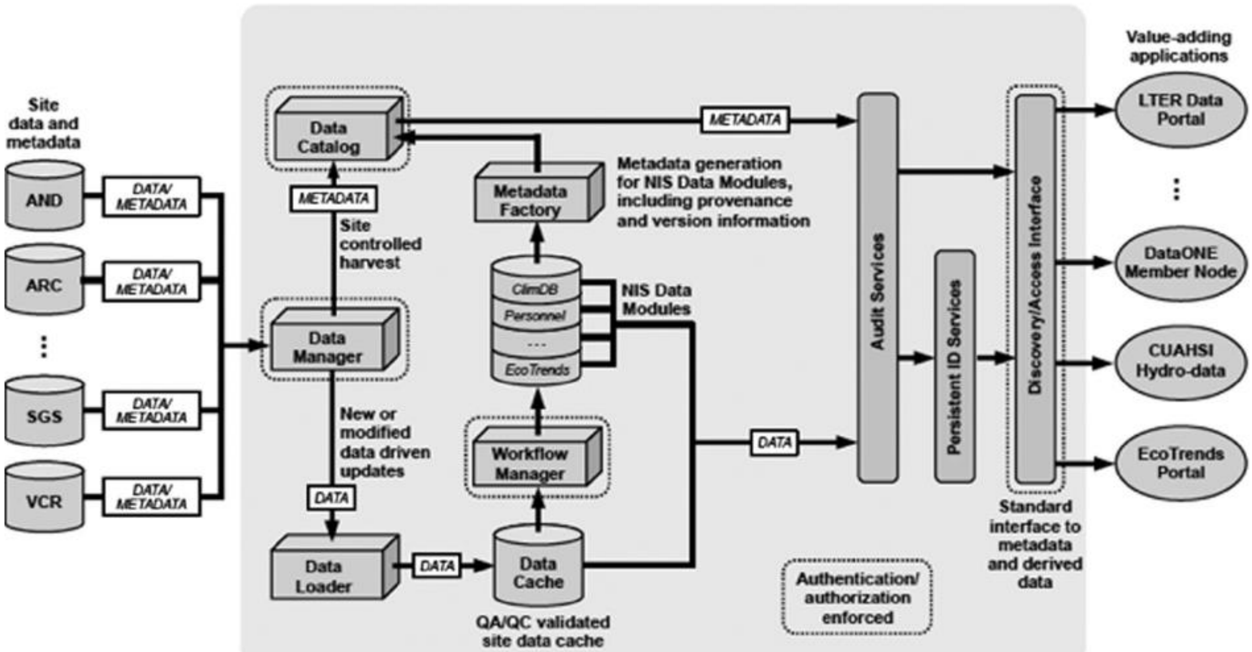


Figure 5. Metadata and data flow diagram of the LTER Network Information System and PASTA Frame (in gray). Site metadata and data are harvested and made available to workflow execution pipelines to generate derived and/or synthetic data products. A data portal user interface will serve as the primary access point for the general community, while a programmatic interface (“Discovery/Access API”) will provide access to more specialized functions of the PASTA Framework (Michener et al. 2011).

Michener et al. (2011) postulate that some of the principal information management tools needed for the next decade will include:

- a new class of user-friendly metadata management tools and standards that better enable understanding, use and re-use of data such as processes built into sensors and instruments that automatically capture metadata at the time of data generation; semantic mediation tools and approaches that facilitate data integration across multiple spatiotemporal scales and levels of biological and physical organization, including the automated encapsulation of data provenance;
- analysis and visualization approaches that support reasoning about and representing scientific uncertainty;
- tools that promote trust of information products such as automated quality assessment of data products/service providers, development;
- of recommender systems for scientific data, as well as development of security and identity-authentication systems that work world-wide;
- reward systems that promote recognition of good science practices through data citation and data use statistics; and

- downloadable and user-oriented videos, course modules, and best practices that engage and educate scientists, students, and the public.

Language differences

Natural language differences are common among ILTER country networks and seriously inhibit the exchange, interpretation and proper use of ecological data. Data sharing across communities each having its own natural language and cultural and historical background poses many semantic and technical challenges. One of the key issues causing ambiguity in multilingual and multicultural terminology is equivalence. Equivalence means that the target language contains a term that is identical in meaning and scope to the term in the source language. Units of measure are examples of equivalent concepts. Terms selected from more than one natural language vary in the extent to which they represent the same concept, and a continuum of equivalence ranging from exact equivalence to non-equivalence is recognized (Table 9). Inexact equivalence, for instance, refers to a term in the target language that expresses the same general concept as the source language term, although the meanings of the terms are not exactly identical. Partial equivalence means that a term in one language has a broader meaning than the same term in another language" (Vanderbilt et al. 2010a).

Comparison of the US English and Japanese "wetlands" concept.

Wetlands[a]	湿地 ("Shicchi" ≈ wetlands)[b]
● Marshes ○ Tidal ○ Nontidal ■ Wet meadows ■ Prairie potholes ■ Vernal pools ■ Playa lakes	● 湿原・塩性湿地 (Mires/salt marshes) ● 河川・湖沼 (Rivers/lakes and freshwater marshes) ● 干潟・マングローブ林 (Tidal flats/mangrove forests) ● 藻場 (Seaweed/seagrass beds) ● サンゴ礁 (Coral reefs)
● Swamps ○ Forested swamps ■ Bottomland hardwoods ○ Shrub swamps ■ Mangrove swamps	
● Bogs ○ Northern bogs ○ Pocosins	
● Fens	

[a] Classification by U.S. Environmental Protection Agency (EPA) (EPA, 2010).
[b] Types of wetlands in Japan (Biodiversity Center of Japan, Ministry of Environment, 2010a, b).

Table 9. Problems of equivalence in building cross-cultural research network (Vanderbilt et al. 2010b).

As a first step toward building a multilingual metadata catalogue, the ILTER has adopted Ecological Metadata Language (EML) as its standard, and ILTER members are asked to share discovery level metadata in English. Presently, the burden of translation is on the data providers, who frequently have few resources for information management. Tools to assist with metadata capture and translation, such as localized metadata editors and a multilingual environmental thesaurus, are needed and will be developed in the near future. In the longer term, ILTER will cooperate with other communities to develop ontologies that may be used to automate the process of translation and will produce the most linguistically and semantically accurate metadata translations (Vanderbilt et al. 2010a).

An overview of long-term ecological networks

International Long-term Ecological Research (ILTER)

Design – ILTER is a 'network of networks', a global network of research sites located in a wide array of ecosystems worldwide that can help understand environmental change across the globe. ILTER's focus is on long-term, site-based research. ILTER was founded in 1993 and involves projects in 32 countries. It focuses on 1) Pattern and control of primary production; 2) Spatial and temporal distribution of populations selected to represent trophic structure; 3) Pattern and control of organic matter accumulation in surface layers and sediments; 4) Patterns of inorganic inputs and movements of nutrients through soils, groundwater and surface waters; and 5) Patterns and frequency of site disturbances. It is not specifically driven by hypotheses, but has a set of network-wide goals (see http://www.ilternet.edu/about/mission).

The core strengths of the LTER Network in particular—its history of long-term, place-based studies; its community of scholars committed to integrative research across disciplines and service to society; and its diversity of landscapes, stakeholders, and disturbance regimes—make it ideally suited to leading scenario studies in each of the landscapes in which LTER sites are present. As such, we suggest that scenario studies be advanced in collaboration with many other research groups and agencies as a network-wide activity to promote research in socioecological systems and cross-site comparative analyses across the network (Thompson et al. 2012).

Integration – One of the goals of ILTER is to improve comparability of long-term ecological data from sites around the world, and facilitate exchange and preservation of these data. ILTER also aims to deliver scientific information to scientists, policymakers, and the public. ILTER's activities to improve access to long-term environmental datasets include establishing regional metadata caches, enabling online cross-site searches of a wide range of data. ILTER uses EML, a metadata standard developed by ecologists. EML from many sites can be put into a single database (a Metacat) so that cross-site searches for data can be done. All ILTER Metacats will be linked, so all metadata can be accessed from a single web page. Anderson and Likens (2008) suggested that integration of social and natural sciences with the humanitics and ethics can still be improved.

Organization – ILTER is governed by a Chair and Executing Committee (Figure 6). It has a Coordinating Committee, the governing body of the ILTER Network, which convenes annually at a meeting hosted by one of the Member Networks.

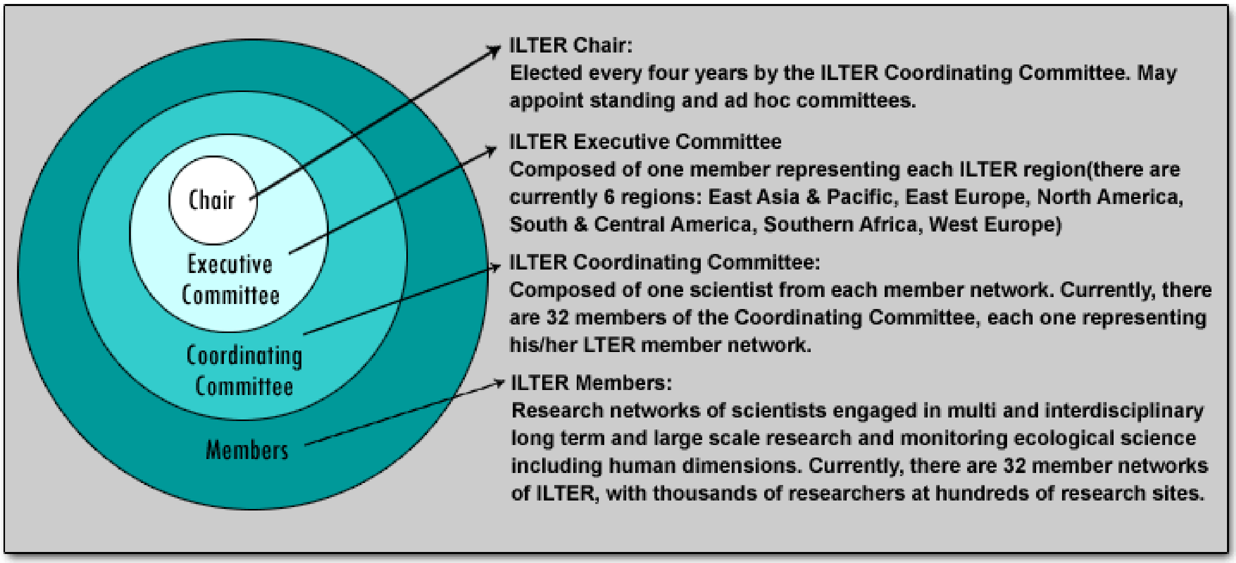


Figure 6. The structure of ILTER (http://www.ilternet.edu/about/organisation-1)

Ownership – Although it is stated in the ILTER website that "many datasets generated by ILTER members are freely available for research purposes" (http://www.ilternet.edu/research), it is not clear where these can be downloaded. An online searchable database of ILTER sites has been developed by the RED MEX-LTER network. It can be used to find network sites and to compare them according to their main environmental variables: longitude, latitude, altitude, annual precipitation and ambient temperature.

Olsen et al. (1999) present the following information about data access (Table 10), but it not clear whether this remains valid

1. There are two types of data: Type I (data that ae freely available within 2–3 years) with minimum restrictions, Type II [exceptional data sets that are avalable only with written permission from the PI/investigator(s)]. Implied in this timetable is the assumption that some data sets require more effort to get online and that no "blanket policy" is going to cover all data sets at all sites. However, each site would pursue getting all of their data online in the most expedient fashion possible

2. The number of data sets that are assigned TYPE II status should be rare in occurrence and that the justification for exceptions must be well documented and approved by the lead PI and data site manager. Some examples of Type II data may include: locations of rare or endangered species, data that are covered by copyright laws (e.g., TM and/or SPOT satellite data) or some types of census data involving human subjects

Table 10. Typical Primary and Secondary Data Processing Roles Performed by a Project Data and Information System and Types of Data and Information Processed at the Project Level (Olson et al. 1999).

Quality – It is not clear from publicly available sources how data quality is guaranteed. Some of the validation is done by KNB (see below).

Change – Since ILTER's establishment in 1993, global long-term ecological research programs have expanded rapidly, reflecting the increased appreciation of the importance of long-term research in assessing and resolving complex environmental issues. Presently, 32 countries have established formal LTER programs and joined the ILTER network. Several more are actively pursuing the establishment of national-level networks and many others have expressed interest. ILTER began grouping its national-level networks into regions in 1996, and now has five regional networks – East Asia/Pacific, Europe, Africa, North America, and Central/South America.

1. Problem identification	
Immediate necessity	Hosting ILTER annual meetings Management of ILTER Office (or Secretariat) Finding funding sources other than US NSF's sole support
Problems to overcome further	Network activities in different levels of development in regional and national networks Consensus to be made on the future shape of ILTER Services to society in a global sense to be identified Low level of recognition as an international organization Infrastructure as an international organization to be stabilized
2. The points to be considered in strategic planning	
To be considered as a true international organization	Low-level recognition from many governments (e.g., Japan, France, Italy, and Russia, among the G-8 Countries, do not even support LTER network activities officially, yet) Difficulties for the ecologists in many countries, including the countries above, to persuade their governments to support their LTER activities in national levels Identifying clear messages to give to decision makers in funding LTER activities in national, regional as well as international levels (e.g., in answering such questions as, 'What does ILTER do for the world?' Securing infrastructures for sustained management of the organization
3. Questions related to the criteria for evaluating successful management of ILTER Network	
Short term	Are ILTER annual meetings held with enough participants from the members? Does the ILTER Network have a sound strategic plan and enough means to implement it? Are the regional networks soundly managed under common strategy with the ILTER Network?
Intermediate term	Is the ILTER Network Office managed in a sustainable way? Is the ILTER Network addressing important issues of concern for the public in local, regional and global levels? How could regional ILTER activities be upgraded?
Long term	How could ILTER Network activities be upgraded to an officially international level?

Table 11. Suggested items for further consideration in strategic planning for the ILTER Network (Kim 2006).

As the ILTER Network is situated at a critical point, challenges for the ILTER Network are discussed with regard to its further development (Kim 2006). While ILTER Network is currently undergoing a 10-year strategic planning process, the author finds the following action items suggested in Table 11 important to ILTER strategic planning. In the establishment and implementation of strategic planning for the ILTER Network, these items might be used as criteria in evaluating further success of the ILTER Network.

Recently, the long-term ecological research (LTER) program in the US was evaluated (Ohl et al. 2010). In its 20-year review report, the National Science Foundation recognizes the achievements of the past and specifies guidance for future development. Among other aspects, research activities of the next decade should concentrate on a new core area: biological diversity, and, to inform environmental policy on the interrelationships and reciprocal impacts of ecological and human systems, LTER is requested "to partner with social scientists" at all existing or newly selected research sites. In Europe, LTER activities head in the same direction. To create durable integration of European biodiversity research capacity and to address biodiversity policy needs, long-term socio-ecological research (LTSER) sites should serve as real-world laboratories for interdisciplinary and policy relevant research.

Impact – Various papers and reports discuss the impact of ILTER and LTER sites (e.g., Driscoll et al. 2012), including a report by the National Science Foundation ("Broader Impacts of NSF's Long-Term Ecological Research Program"), and local studies such as those from ILTER sites in Brazil (Barbosa et al. 2004). Such studies show successful generation of new understanding which has supported decision-making as regards biodiversity conservation and watershed management at local and regional scales. What is not clear however is whether the integrated network approach has succeeded in answering questions of a more global nature and translating these into broader policy impacts.

Funding – In 2006, US NSF, which continues to support ILTER network activity in providing the services of a network office for the ILTER Network, changed its policy to be not the sole funder of ILTER Network activity (Kim 2006).

Problems – Some of the problems and challenges to ILTER that existed in 2006 were summarized by Kim (2006): (1) regular hosting of ILTER annual meetings; (2) management shortcomings in the ILTER Office (or Secretariat); (3) challenge to find funding sources other than US NSF's sole support; (4) low level of recognition as an international organization; (5) infrastructure as an international organization needs to be stabilized; (6) and need for clear messaging -- What does ILTER do for the world? Among the technical challenges are the difficulty of capturing meta data and issues with translation between different languages (Vanderbilt et al. 2010b)

Sources - http://www.ilternet.edu/. (Maass et al. 2010)

International Forestry Resources and Institutions (IFRI)

Design – The IFRI network is comprised of 13 Collaborating Research Centers (CRCs) located around the globe. The overarching plan for the IFRI program is that future research goals and objectives will be addressed by a network of CRCs and individual scholars who design and conduct studies within different countries in collaboration with colleagues at the Workshop in Political Theory and Policy Analysis (the Workshop). An IFRI CRC could be a research group associated with a university, a private association, a government research laboratory, or a consortium of individuals and agencies that have agreed to work together to collect, analyze, and archive IFRI data in a particular country or specific region of the world. Individual researchers who are working at a university or research institution completing their doctoral research or working independently may also be associated with IFRI. The IFRI research program was initiated in 1992 at Indiana University. It moved in 2006 to University of Michigan where it is currently housed at the School of Natural Resources and Environment and coordinated by Arun Agrawal.

Critical research needs on environmental degradation are challenging and require diverse approaches. One approach is that of global monitoring, relying primarily on national inventories and satellite imagery. A second approach is to link permanent forestry and agro-forestry Research Stations to foster more rapid exchange of scientific findings about how ecological systems are affected by (and affect) climate changes, increased pollution levels, and other environmental threats. A third approach-the one taken by the IFRI research program-complements the first two approaches and generates policy-relevant information not available from other strategies. The IFRI program provides an interdisciplinary set of variables about forest management and use that are assessed near the forest in relationship to the local communities utilizing and governing the forest. The effects of district, national, and international policies as they impact on a local setting can be assessed through this effort. The results of IFRI studies provide in-country information for policymakers at the local, district, regional, and national levels.

Integration – IFRI researchers use a common data collection method to ensure that sites can be compared across space and time (see for example Table 12). The IFRI database contains information about forest ecology, livelihood, governance arrangements, and forest user groups for over 250 sites in 15 countries between 1992 and the present. The design of the IFRI research instruments is based on the Institutional Analysis and Development (IAD) framework and previous theoretical and empirical studies. The IAD framework, developed by the Workshop in Political Theory and Policy Analysis at Indiana University, provides a unique way for researchers to transcend disciplinary boundaries. IFRI focuses and collects data on institutional, social, and ecological variables which can be stored in a single IFRI database, and analyzed to understand the inter-relationships among social and ecological processes and outcomes.

IFRI FORM	INFORMATION COLLECTED
Site Overview Form	site overview map, local wage rated, local units of measurement, exchange rates, recent policy changes, interview information
Forest Form	size, ownership, internal differentiation, products harvested, uses of products, master species list, changes in forest area, appraisal of forest condition
Forest Plot Form	tree, shrub, and sapling size, density, and species type within 1, 3, and 10 meter circles for a random sample of plots in each forest, and general indications regarding forest condition
Settlement Form	socio-demographic information, relation to markets and administrative centers, geographic information about the settlement
User Group Form	size, socioeconomic status, attributes of specific forest user groups
Forest User Group Relationship Form	products harvested by user groups from specific forests and their uses
Forest Products Form	details on three most important forest products (as defined by the user group), temporal harvesting patterns, alternative sources and substitutes, harvesting tools and techniques, and harvesting rules
Forest Association Form	institutional information about forest association (if one exists at the site), including association's activities, rules structure, membership, record keeping
Non-Harvesting Organization Form	information about organizations that make rules regarding a forest(s) but do not use the forest itself, including structure, personnel, resource mobilization, and record keeping
Organizational Inventory and Interorganizational Arrangements Form	information about all organizations (harvesting or not) that relate to a forest, including harvest and governance activities

Table 12. IFRI data collection forms and information collected as an example of the general type of information to be collected at each site.

Organization – The network is centrally coordinated by the School of Natural Resources and Environment at the University of Michigan.

Ownership – The IFRI website states that "The IFRI network is in the process of developing a data-sharing policy that will set the conditions whereby IFRI data will be made available for public use. As soon as we have developed a responsible policy, we will post it to this page. If you are interested in IFRI data or have questions about this policy, please contact us for further information." It therefore appears that data cannot yet be publicly accessed.

Quality – Nothing specific was found about data quality control.

Change –IFRI has been slowly adding new countries and partner organizations to its program, but the latest country addition (Guatemala in 2002) suggest that rapid expansion of the network is not sought. IFRI's leadership maintained clear control over IFRI's structure and research quality by raising funds for a significant proportion of the research conducted by the CRCs, but also through intellectual leadership of the research programme. IFRI's leadership makes the final decisions over changes to the IFRI research instruments with input from CRC members (Wollenberg et al. 2007).

IFRI was created with the expectation that the network would collect data for a minimum of 25 years. IFRI did not make their methods widely available until 2006. IFRI's original concern was that people not formally trained in the method would not able to interpret the variables accurately. In 2006, IFRI changed this policy and decided the methods would have more impact in the public realm (Wollenberg et al. 2007).

Impact – The Nobel Prize received by IFRI's founder, Elinor Ostrom, is an obvious success for the approach and thinking behind IFRI. No specific documentation was found that evaluated and demonstrated the impact of IFRI's approach in influencing forest policy and other target areas. IFRI researchers and affiliates have produced over 200 publications since 1994.

The continued reliance in the International Forestry Resources and Institutions (IFRI) on research designs with limited comparative scope reflects practical challenges that limit the quantity and geographic breadth of data that any one researcher can collect using field-based research (Poteete & Ostrom 2008). Poteete and Ostrom discuss the relative merits and shortcomings of two strategies for overcoming those challenges: Meta-databases constructed from existing qualitative studies and large-N field-based studies. Resource constraints, career incentives, and, ironically, collective action problems among researchers currently limit adoption of these strategies.

The near nonexistence of cross-national field based empirical research may not be surprising given the obstacles to large-scale data collection on subnational phenomena, but should be a cause for concern. Apparent patterns at one scale of analysis may not hold at other scales of analysis. Worse, analysis based on nonsystematic samples is vulnerable to selection bias and may be misleading. Given theoretical arguments and mounting evidence that institutions as well as ecological structure strongly influence outcomes, good science requires comparisons across a variety of institutional and ecological settings.

The IFRI research program built upon the theoretical framework, empirical findings, and database structure of the CPR and NIIS databases, but differs from these earlier efforts in three ways: (1) its primary reliance on fieldwork, (2) the shift in attention to more complex and multiple product forest resource systems, and (3) in organization as a research network. Many IFRI research teams collect supplemental data to address specific research questions. IFRI researchers conduct repeat studies of forest sites every three to five years. By mid-2006, data for 202 unique sites with 270 forests had been entered into IFRI's common database; the database also includes data for 44 repeat studies. IFRI is the only field-based research network of which we are aware that has accumulated sufficiently comparable data to support large- N analyses with a policy unit, ecological system, or actual or potential unit of collective action as the unit of analysis. Even so, IFRI studies often analyze a subsample of data from a single country. The use of common data collection protocols addresses problems of comparability in a technical sense, but does not eliminate the substantial challenges of drawing sound comparisons across cultural, ecological, and political contexts. Despite considerable challenges, cross-national analysis of IFRI data using an N of greater than 150 cases has begun.

Larger partnerships should be able to mobilize more resources and cover more cases with fewer compromises. Because the financial resources needed to conduct such studies are immense, any network that wants to engage in cross-national research needs a relatively large number of partners. As the number of partners in the network increases, however, so do the transaction costs of coordinating the network. In essence, researchers face a variety of coordination problems, and social dilemmas. Greater flexibility may facilitate consensus-building, but produces less consistent, and thus less comparable, data. Although more comparable data would be collectively advantageous, disciplinary conventions and individual career incentives encourage a proliferation of concepts and methods. IFRI adopted a modular approach that maintains comparability yet allows for some alternative conceptualizations. The MAS project sought a middle course with its loosely structured approach. Guidelines and checklists facilitate comparative research while leaving researchers with considerable flexibility to adapt their data-collection strategies to local conditions, or to supplement the basic set of issues to pursue local concerns. At the extreme, flexible collaboration differs only slightly from meta-analysis. With its large number of institutional members, broad geographic reach, and access to official sources of funding, CGIAR has the ability to undertake truly international and long-term research in this area. Yet its research activities are not usually based on a common set of research instruments, making it difficult to collate comparative results and identify cross-national patterns.

Career incentives that reward individual research more than collaborative research clearly discourage collaboration. These incentives are influenced by the policies of individual universities, governments, and granting agencies, but not determined by any single organization. Reversal of these incentives is not impossible; acceptance of collaborative work does vary over time and across disciplines. An explicit recognition of the value of collaborative research and its policy implications might encourage coordinated efforts to alter career incentives more systematically and rapidly.

Funding – IFRI is funded by a range of donors and institutions, including the International Initiative for Impact Evaluation, Gordon and Betty Moore Foundation, Bill and Melinda Gates Foundation, Rights and Resources Initiative, Center for the Study of Institutions, Population, and Environmental Change (CIPEC), Food and Agriculture Organization (FAO), Ford Foundation, MacArthur Foundation, National Science Foundation (NSF), and Workshop in Political Theory and Policy Analysis.

Problems – Wollenberg and her colleagues (2007) reported on some of the challenges faced by IFRI:

- Facilitating collaboration among multi-person teams in multiple locations.
- Ensuring rigorous and consistent application of the methods in each location.
- Comparing social and ecological variables among diverse
- Social, political and ecological contexts.
- Making the best use of vast amounts of data.
- Producing analytical and comparative products relevant to different members needs.
- Working in a funding environment that is not conducive to long-term research programmes that focus on the same set of issues over a long time

Sources – http://www.sitemaker.umich.edu/ifri/home

Knowledge Network for Biocomplexity (KNB)

Design – KNB is a national network intended to facilitate ecological and environmental research on biocomplexity. KNB is a tool that offers a significant advancement in synthesizing relevant environmental information to more thoroughly address this important ecological relationship and to gain a better understanding of the mechanisms that give rise to it (Andelman et al. 2004). It specifically deals with existing ILTER sites in the USA. The KNB is one of the several examples of new technologies for data dissemination and data integration, such as the Global Biodiversity Information Facility, the Knowledge Network for Biocomplexity, BioCASE. the British National Biodiversity Network (NBN), and the Netherlands National Database of Flora and Fauna (NDFF) (Veen et al. 2012).

Integration – In the ILTER network it was found that cross-site, interdisciplinary, synthetic research has resulted in a distributed set of valuable data that are largely inaccessible to anyone except the original investigators. The KNB was specifically set up to deal with the fact that network data are widely dispersed and heterogeneous, and that synthetic tools are needed to analyze them. This is addressed through more effective approaches to data access, information management and knowledge management (for technical details see http://knb.ecoinformatics.org/informatics/index.jsp).

Organization – A wide variety of organizations and sites have agreed to participate in the development and testing of the KNB. The LTER Network of over 24 research stations has agreed to fully participate in the network, along with a variety of sites from the Organization of Biological Field Stations (OBFS) and the UC Natural Reserve System.

Ownership – Some data are available for public download through the KNB website.

Quality – In the validation phase, we will assess the efficacy with which the KNB identifies and retrieves data on productivity and species richness from grassland Long-Term Ecological Research (LTER) sites, which previously were analyzed through efforts of a working group at the National Center for Ecological Analysis and Synthesis.

Change – The intention is to expand the network by affiliating additional field sites and also by getting individual researchers to upload their data sets using Morpho software.

Impact – This network appears to have overcome some challenges in data management and integration and provide useful insights for other networks.

Funding – Nothing specific was found about funding.

Problems – Nothing specific was found about problems and challenges.

Sources – http://knb.ecoinformatics.org/index.jsp

A Long-Term Biodiversity, Ecosystem and Awareness Research Network (ALTERNet)

Design – ALTER-Net is a network of 26 partner institutes from 18 European countries (Figure 7). ALTER-Net integrates research capacities across Europe: assessing changes in biodiversity, analysing the effect of those changes on ecosystem services and informing policymakers and the public about this at a European scale. This network is not hypothesis driven, but shares the goal to develop lasting integration amongst its partner institutes, and others, all of whom are involved in biodiversity research, monitoring and/or communication.

Integration – Development of the Infobase (a central meta data database (developed) presented via the internet – still in development). An ontology – SERONTO (Socio-ecological research and observation ontology) as a "basis to discover, retrieve and integrate distributed heterogeneous data" with the aim to integrate multiple ecological databases– still in development.

Organization – The network is managed by a Secretariat, currently provided by NINA, based in Trondheim, Norway. The Secretariat is supported by a Management Board (MB). Each board member had responsibility for one activity area. The Management Board's main function is to deliver ALTER-Net's annual action plan. The Board may make recommendations to the Network Council, which consists of high-level representatives of each partner organisation. The Council's function is to agree strategic decisions. It reviews and decides upon any recommendations made by the Management Board.

Ownership – One Work Package addresses communication and dissemination, and focused on communication of biodiversity research to the wider community, including other researchers, the media and policymakers. The second dealt with training and mobility issues, so that the necessary skills base for biodiversity research and communication could be strengthened. No obvious data portal exists.

Quality – Nothing specific was found about quality control.

Change – ALTER-Net began life in 2004 as an EU Network of Excellence. This ALTER-Net I phase ran until March 2009. The subsequently phase built upon the original project, and new sites are regularly added.

The year 2011 was used to restructure and organize Net after April 2012, when external funding for holding the secretariat ended. During 2011 it became clear that all partner institutes were willing to continue with ALTER-Net in the future, that the secretariat work would be outsourced to different institutes with a rotating system for especially the financial administration as to increase institutional participation (Van Dijk et al. 20112).

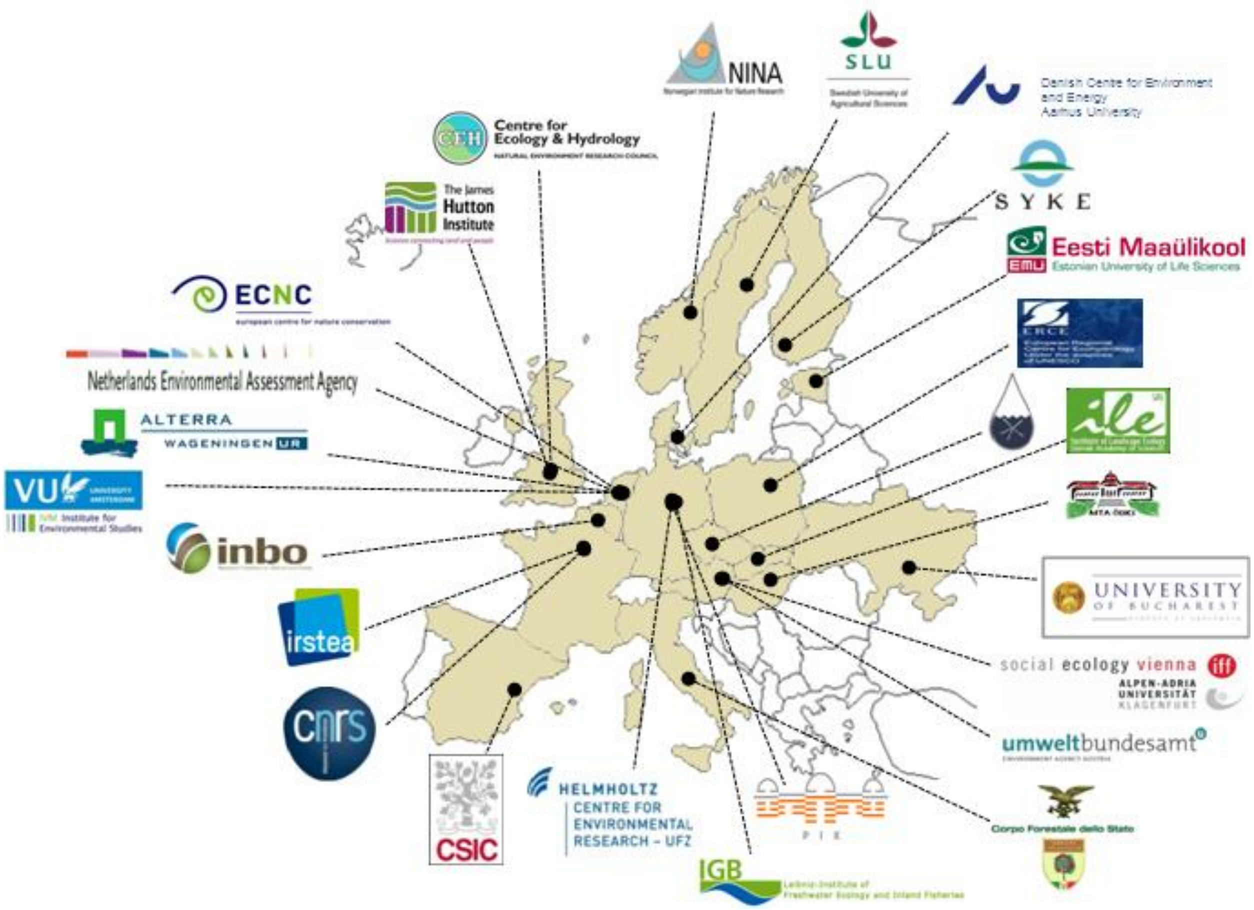


Figure 7. Participating organizations in ALTER-Net

Impact – Nothing specific was found about impact.

Funding – Originally funded by the European Union's Framework VI program to stimulate a collaborative approach, ALTER-Net is now operating independently. The ALTER-Net summer school and conferences were identified as key fundraising options to be sponsored by local/regional authorities and/or private sponsors. Total budget 2011-2012 was € 307,000, of which about 80% was spent (Van Dijk et al. 20112).

Problems – Fundraising challenges. The network also still needs to address the technical challenge of dealing with different domains (ecological, meteorological, chemical, geographical, sociological, economic, etc.), different languages (real language differences; scientific language differences), different scales (global, regional, site; surveys), different purpose (monitoring versus experiments; exploration versus parameter fitting), and different storage methods (spreadsheets, databases; local or distributed).

Sources – http://www.alter-net.info/

Terrestrial Ecosystem Research Network (TERN) – Australia

Design – The Terrestrial Ecosystem Research Network (TERN) is an overarching and integrated network designed to serve ecosystem research in Australia. It builds on significant past investments by scientists and governments to understand Australian ecosystems. It does this by focussing on collating, calibrating, validating and standardising existing data sets.

Integration – TERN is funding new research infrastructure and collection systems, expanding observation and monitoring programs into unrepresented ecosystems, and building digital infrastructure to store and publish this information in a form that can be searched and accessed freely under licenses that acknowledge the data provider(s) and build collaborative research (Figure 8). While TERN is essentially a network of infrastructure, the inherent collaboration between facilities also creates a network for sharing ideas. Thus, TERN is able to support high-level analysis and synthesis of complex ecosystem data across the science-policy-management continuum, which in turn helps advance ecosystem research.

By providing the means to share data sets and develop collaborations as part of our data sharing processes, TERN is the catalyst for a culture shift to more open and collaborative form of ecosystem science in Australia. The goal is to see more scientists working together, rather than in isolation, and being rewarded for sharing data and knowledge. Together, they will build knowledge more effectively to address key terrestrial ecosystem problems.

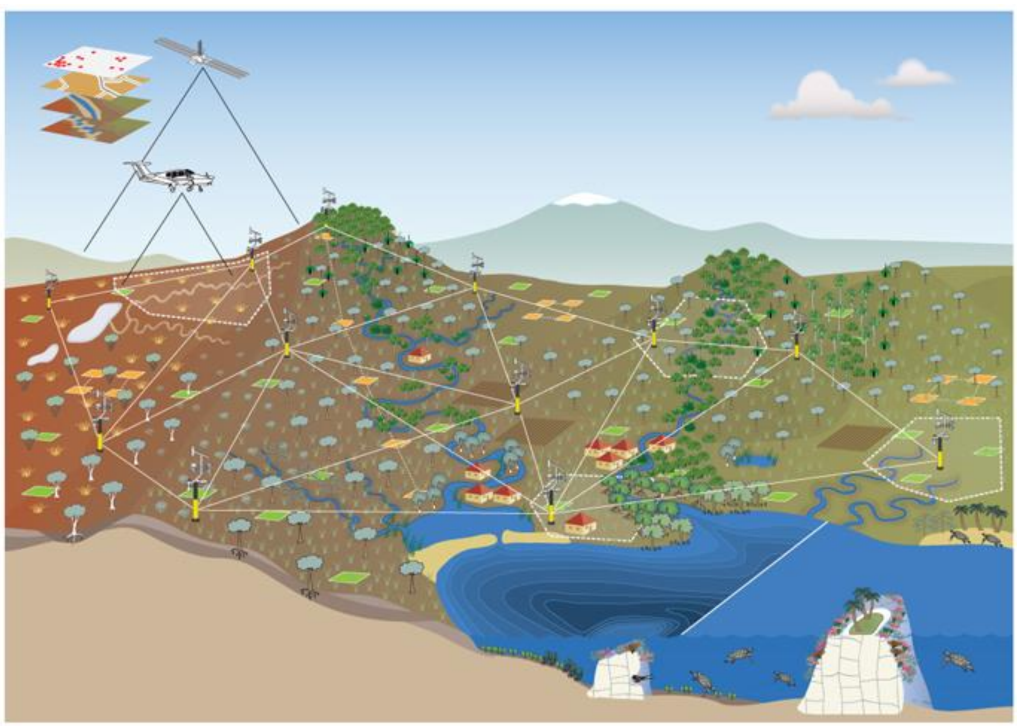


Figure 8. Type of data gathered and studies conducted within the TERN context.

Organization – TERN is managed and coordinated by the TERN Office, hosted by The University of Queensland. Specific research and coordination activities are delivered through the TERN Facilities. Governance of TERN takes place on several levels:

- The TERN Board which has primary responsibility for the overall strategic direction, management and performance of TERN;
- The Executive Advisory Committee which enables all TERN Facility Directors to communicate with the TERN Office, TERN Board and each other to maintain progress, share knowledge, develop TERN-wide standards, and solve operational/implementation problems;
- An Information and Infrastructure Development and Delivery Group (IIDDG), consisting of all TERN Facility Technical leads, plus key external technical partners to coordinate development of portals, data and metadata standards and licensing protocols; and
- An Advisory Panel for each TERN Facility, consisting of user groups (or equivalent), working with Facility Directors in the development of operational plans, associated user protocols and relevant technical matters, including training.

Ownership – TERN's principles and funding guidelines are to provide publicly accessible, free data, it is essential that the ecosystem science and management communities acknowledge the use of these data sets. Providing an appropriate and fair licensing framework is essential for establishing and maintaining long-term ecosystem monitoring data sets, and requires a significant shift in data sharing practices and in Australian governments and research institutions valuing research data that is published and shared.

This builds on several of TERN's principles of operation, namely:

- TERN data sets will be shared and used under appropriate licensing conditions that enable free and public access, but enables the data user and contributor to advance their work.
- TERN's success depends on individual ecosystem scientists being willing to share their knowledge and data, based on the understanding that it is contributing to the collective benefit of the ecosystem science community now and into the future.
- Establishing a network of like-minded scientists with common requirements for quality assured, archived, long-term data sets will increase our ability to act collaboratively when requesting research and infrastructure funding.

TERN and its Facilities will adopt a modified version of the Creative Commons licensing approach used in AusGOAL (Australian Government's Open Access and Licensing Framework). This approach will be applied to data submission and data retrieval operations through each TERN Facility's data portal. This will enable data providers to select an appropriate level of licensing and attribution to ensure they are properly acknowledged, and in some cases involved, in subsequent uses of the data they have provided. This approach enables data providers to be assured they will receive credit for sharing their data, and have the opportunity to collaborate on further use of their data.

Quality – Nothing specific was found about quality control.

Change – It is unclear what the plans are once main funding sources of TERN cease in 2013.

Impact – Nothing specific was found about impact.

Funding – TERN is supported by the Australian Government through the National Collaborative Research Infrastructure Strategy and the Super Science Initiative. Total budget for TERN is AU$ 49,730,000 (http://www.tern.org.au/Progress-pg17724.html).

Problems – Nothing specific was found about problems.

Sources – http://www.tern.org.au/

European network for a long-term forest ecosystem and landscape research programme (ENFORS)

Design – ENFORS had its origin from the Ministerial Conference on the Protection of Forests in Europe (Strasbourg 1990) and later resolutions (Helsinki 1993, Lisbon 1998, Vienna 2003) on sustainable forest management. These resolutions stress the need for better integration of European forest ecosystem research as well as with other disciplines in forestry. A network "European Forest Ecosystem Research Network, EFERN - was set up 1996." Approximately 100 research organisations, involving more than 300 researchers from 27 countries participated actively in the activities and the development of the network. It is, however, unclear whether this network is still active. Its websites (http://enfors.org and http://ifff.boku.ac.at/enfors) are inactive or not maintained, and the activities appear to have ended in 2005

Change – In reply to an email sent to the former chairman of ENFORS it mentioned that "when the programme was formerly ended we asked ECOFOR in Paris to take over the responsibility for the programme and asked them to continue if they had the ambition. ECOFOR can be considered as a stable organisation with its own funding.... Although the network is "sleeping" it represent a big value. I have been informed that there is a future interest in it. It has been especially expressed by the European Forest institute." From ECOFOR's website it is not clear whether the ENFORS had been maintained.

Impact – This 4-year program seems to have fizzled out and it is unclear whether it has had much impact.

Funding – ENFORS was funded by the European Cooperation in Science and Technology COST program, and presumably its funding was discontinued.

Problems – A paper in 2007 (Andersson & Mårell 2007) noted that ENFORS should in particular improve the link between policy and science (meaning that the knowledge base must be better recognised than today), and that the knowledge base itself needs to be maintained and also improved.

Source – http://ifff.boku.ac.at/enfors/documents.htm

National Ecological Observatory Network (NEON)

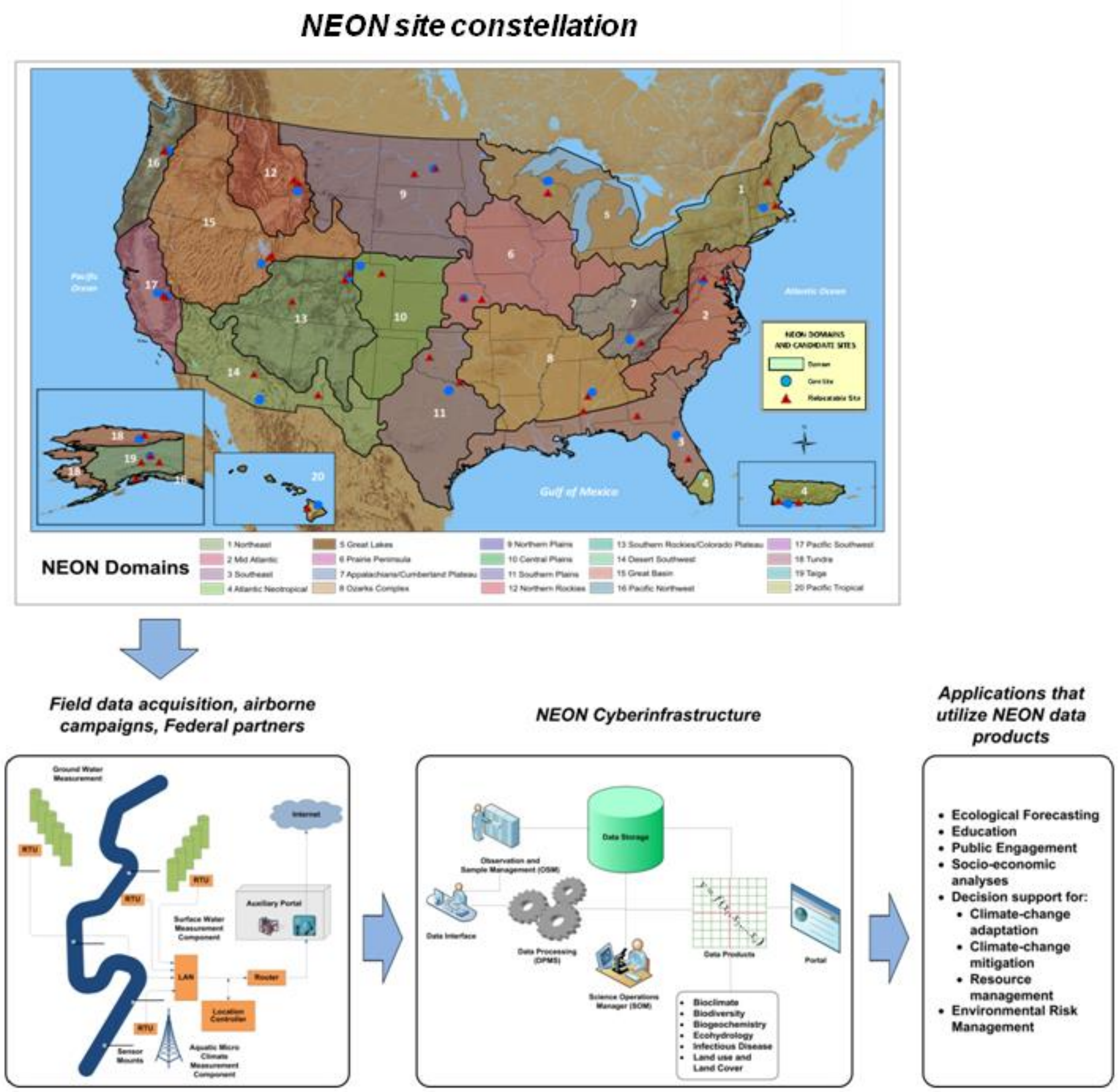


Figure 9. Domains and sites in NEON (http://cleanet.org/cln/ccep/national_ecolog.html).

Design – The National Ecological Observatory Network (NEON) is a new continental-scale observatory designed to gather and provide 30 years of ecological data on the impacts of climate change, land use change and invasive species on natural resources and biodiversity. It started in 2012. Projected to become fully operational in 2016, the NEON national network includes 20 domain sites of matching stationary and mobile field sensors, laboratories, archival data, synthesis and analysis centers, and education nodes, all linked through high-capacity cyberinfrastructure (Lowman et al. 2009). NEON is a project of the National Science Foundation, with many other U.S. agencies and NGOs cooperating. NEON will build 62 sites across the U.S. (including Alaska, Hawaii and Puerto Rico) to collect instrumental and field data (Figure 9). The sites have been strategically selected to represent different regions of vegetation, landforms, climate, and ecosystem performance.

The conceptual design of this network gives rise to several general questions (Keller et al. 2008): (1) How will the ecosystems (of the US) and their components respond to changes in natural- and human human-induced forcings, such as climate, land use, and invasive species, across a range of spatial and temporal scales? What is the pace and pattern of the responses? (2) How do the internal responses and feedbacks of biogeochemistry, biodiversity, hydroecology, and biotic structure and function interact with changes in climate, land use, and invasive species? How do these feedbacks vary with ecological context and spatial and temporal scales?"

To bridge this diversity of scales, NEON will approach such questions through an analysis of processes, interactions, and responses, including those mediated by transport and connectivity. A finite budget limits the number and the spatial extent of the fundamental observations; therefore, NEON uses a parsimonious continental strategy for placement of the observational units. This includes core sites (see Table 13) and relocatable sites. The latter will be moved on a 3- to 5-year rotation. The observatory design, including both permanent core sites and relocatable sites, allows for planned contrasts within domains. Mobile systems for short deployments (weeks to months) supplement the core and relocatable sites to explore details within these sites and to study discrete events and variability in the domains. Currently, there is approximately one planned mobile system per domain. The design is based on rigorous scientific priorities and scaled to maintain budget discipline. Present scientific questions guide the first cycle of deployment; additional questions will be implemented as the network matures (Keller et al. 2008).

(1) A wildland[1] site representative of the domain (vegetation, soils/landforms, climate, ecosystem performance).
(2) Provides access to relocatable sites that respond to regional and continental-scale science questions[2,3], including connectivity[4] within the domain.
(3) Year-round access, permitting available land tenure secure for 30 years, air space unimpeded for regular air survey, potential for an experimental set-aside.

Notes:
[1]Wildland is defined as "a predominantly unmanaged ecosystem that has vegetation characteristics representative of its domain".
[2]Science questions posed at the continental and domain scale:

- Land-use theme: what are the within-domain contrasts that can be studied with this site?
- Biodiversity–invasives–disease theme: what are the within-domain contrasts?
- Climate change–ecohydrology–biogeochemistry theme: what are the within domain contrasts?
- Climate change–ecohydrology–biogeochemistry theme: what are the across domain contrasts?

[3]Relocatable sites should generally be located within three hours' travel time of the core site.
[4]Connectivity is defined by NEON as "the linkage of ecological processes across space" (see www.neoninc.org/documents/NEONDESIGN-0001vA.pdf).

Table 13. Criteria for NEON candidate core sites (Keller et al. 2008).

Integration –NEON is a centrally operated user facility that enables responses to grand challenge questions in the environmental sciences and enables ecological forecasting. In contrast, the LTER program (see above) is a collection of individual investigator projects aligned with common themes. Each individual LTER site has its own realization of those themes. NEON and LTER are separate programs that operate separately, although NEON will certainly use the experience and knowledge gained through LTER research. NEON will provide infrastructure to enable hypothesis-driven basic biological and ecological research, with data and high-level data products available in close to real-time. NEON's synthesis, computation, and visualization infrastructure will create a virtual laboratory that will permit the development of a predictive understanding of the direct effects and feedbacks between environmental change and biological processes.

NEON has developed an preliminary (as of 2010) catalogue of high-level scientific data products that will provide synthesized information to ecologists, other scientists, educators, citizens, and decision makers. Currently, there are 100 high-level data products in the preliminary catalogue that are grouped into six data suites: Bioclimate, biodiversity, biogeochemistry, ecohydrology, infectious disease, and land use change. This dynamic catalogue will change as the state of ecological science advances. NEON is also developing a preliminary (as of 2010) catalogue of basic calibrated data products that will be used primarily by specialists. The 539 entries in this catalogue will be relatively stable throughout the lifetime of the observatory. The basic calibrated data are produced and organized by the NEON science sub-systems

Organization –NEON is managed by a Board of Directors, a Science, Technology, and Education Advisory Committee (STEAC), and a range of technical working groups.

Ownership –All NEON data and information products will be freely available via a public web portal. NEON's open-access approach to its data and information products will enable scientists, educators, planners, decision makers and the public to map, understand and predict the effects of human activities on ecology and effectively address critical ecological questions and issues.

NEON will make these data available to the community under its open data policy, but until the NEON information system is completed, distribution and documentation will be on an "as-is" basis. Prototype data sets, during 2011 through 2013, will be available to educational, technology and scientific users by request, and some data will be available online in a basic archive format. Interested users may request access to these prototype data sets via NEON's Prototype Data Sharing system. Also, see NEON copyright statement.

Quality – No specific statements were found about quality control

Change – This is a new network that has been in development for over 10 years.

Impact – Too early to say

Funding –NEON is a facility, not a funding agency. Research related to NEON may be supported through existing funding mechanisms at Federal agencies and through other funding sources. NEON recognizes the need to jump-start NEON-related research and is using NSF research coordination networks and other mechanisms to do that.

The planning phase is nearing completion, and NEON has now passed a final hurdle at NSF: The National Science Board (NSB), governing body of the NSF, has authorized the NSF Director, at his discretion, to make an award for construction of NEON. This action authorizes the NSF Director to provide NEON, Inc. an award not to exceed $433.7 million over five years to construct the observatory, contingent upon funding from Congress and compliance with the Endangered Species Act and National Historic Preservation Act for the 106 NEON sites. NEON has also been included as a line item in the Obama Administration's FY2011 budget proposal.

Problems – Too early to say

Sources – http://www.neoninc.org/;
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13440&org=DBI;

Global Lake Ecological Observatory Network (GLEON)

Design – Initiated in 2005, GLEON is a global grassroots association of limnologists, information technology experts and engineers who are building a scalable, persistent network of lake ecology observatories. Data from these observatories will help researchers better understand key processes, such as the effects of climate and land use change on lake function, the role episodic events such as typhoons in resetting lake dynamics, and carbon cycling within lakes. The observatories will consist of instrumented platforms on lakes around the world capable of sensing key limnological variables and moving the data in near-real time to web accessible databases.

GLEON members decide the science agenda and initiate activities, which leads to innovative science and enhances collaborative science. The structure also shortens lag time between ideas and action, and allows members to share expertise and experience.

Integration – GLEON has two data repositories, LakeBase and Vega. LakeBase has basic information about hundreds of thousands of lakes around the world, with a Google-like search interface as well as a map interface. Vega has hundreds of millions of sensor records from GLEON lakes.

Organization –GLEON has a Steering Committee (SC), with members and co-chairs nominated by all GLEON members and elected by the SC. It also has a Steering Committee for Sub-Committee Members, which is open to all members and coordinated by the SC. A set of detailed Operating Principles and Procedures are available. GLEON Sub-Committees are chaired by SC members and populated by both SC members and any other interested GLEON members. If you are interested in joining a committee, please contact the current GLEON SC Co-chairs: Paul Hanson and Kathie Weathers.

Ownership – GLEON has a Data Access Policy, which states that: "The GLEON Data Access Policy is designed to guide the use of GLEON data. GLEON members endorse the principle that data from the GLEON database should be openly available for academic, research, education, and other not-for-profit professional purposes to the maximum extent possible. We believe this sharing of data will foster collaborative scientific research and educational activities internationally. Each data set published on the web page should be accompanied by documentation (metadata), but please contact the responsible person for each GLEON site for further information. We encourage the use of our data sets but ask that users read and agree to our Data Use Agreement below, and adhere to the principle of acknowledging the use of data and its attribution."

Quality – Nothing specific could be found on quality control.

Change – The GLEON collaboration now has 22 members from nine countries participating, with more in the planning stages. Several sites in northern Europe were added; students and researchers from Sweden and Finland joined the project; and lakes in northern Scandinavia were instrumented with sensors and linked to the network. Argentina and Chile are expected to participate in the future. In addition, Lake Sunapee in New Hampshire has been set up to automatically download, archive, and publish sensor network data using technologies that conform to emerging GLEON standards. The expanded network will test the dataflow procedures developed to bring information from sensors to publicly accessible databases, as well as the event detection schema developed to help electronically distinguish between biological and physical events such as lake inversion after a storm and sensor failure. As more sensors come online and are linked to the network, it will become necessary to automate processes as data from thousands of sensors stream into the database.

Impact – Nothing specific was found about impact.

Funding – Funding for GLEON comes from many sources, including the Gordon and Betty Moore Foundation, the National Science Foundation, and sources within the individual participating countries.

Problems – Nothing specific was found about problems.

Sources – http://www.gleon.org/

Water and Environmental Systems Network (WATERS)

Design – The WATERS Network is a joint collaboration among the environmental engineering and science, hydrologic and related Earth science, and social science research communities and is funded by the National Science Foundation (NSF) Engineering and Geosciences Directorates. The vision for the Network is to construct a national-scale network of observational and experimental facilities, using NSF major Research Equipment and Facilities Construction funding, for systematic water measurements, data storage and curation, modelling and visualization that will enable science and engineering research that is not currently possible.

The WATERS Network was developed in 2005 as a combination of two national planning initiatives—CLEANER (Collaborative Large-Scale Engineering Analysis Network for Environmental Research) and the CUAHSI (Consortium of Universities for the Advancement of Hydrologic Science) initiative for hydrologic observatories. It is aiming to be fully operational by 2017 (http://www.watersnet.org/timeline.html).

Integration – The goal is to enable multi-scale, dynamic predictive modelling for water, sediment, and water quality by measuring or estimating fundamental properties such as the flux, hydrologic flow paths, residence times, and chemical/biological reaction rates. Much existing information is fragmented, site-specific, and not easily accessible to researchers interested in investigating multiscale environmental phenomena. To address this deficiency, the WATERS Network plans to deploy an integrated and distributed system of environmental observatories at sites across the country. The network will cover a range of spatial scales and climate and land use/land cover conditions and focus primarily on human-dominated landscapes. Individual sites may be compared either hierarchically as nested watersheds (from plot-scale to basin-scale) or across a single scale as "problemsheds". Research at these sites would be aided by tools for collection, storage, and dissemination of environmental data; interactive models that could be tested in real or near-real time; and an integrative cyberenvironment that would help multidisciplinary, geographically dispersed teams of researchers work together effectively.

The network also addresses social question with regard to water: Which human actions influence the availability of resources and disturbance regimes across aquatic and associated ecosystems? How do human-induced alterations to the environment lead to changes in ecosystem services? How do those changes in ecosystem services then affect humans and human values?

Organization –The network is managed by a management board with 5 members, and a project office with 1 staff.

Ownership – Nothing specific was found about data ownership and data sharing agreements.

Quality – Nothing specific was found about quality control of data

Change – The network is still under development.

Impact – Too early to say—the network is still under development.

Funding – Once approved by Congress, funding for the actual construction of the network will be distributed over 4 years and will come from the NSF Major Research Equipment and Facility Construction (MREFC) Program, an agency-wide special account set up to pay for the acquisition, construction, and commissioning of major scientific infrastructure and equipment. The MREFC account is designed specifically to prevent these larger obligations from disproportionately impacting individual directorate research budgets; ~$150–250 million per year is allocated for this purpose (Montgomery et al. 2007).

Problems – A review of the WATERS science plan in 2010 made several suggestions regarding the development of the network. (1) As the WATERS team goes forward, it should bolster its case that a national network of observatories is required to address the science questions that are posed. (2) Alternatively, a different funding mechanism within NSF might be considered, if feasible, for establishing a phased network of observatories that could address the questions posed in the WATERS Science Plan while taking better advantage of advances in technology over time. (3) To enhance coordination and integration, the WATERS team should involve appropriate federal agencies, state and local governments, organizations, and international programs at an early stage. It noted that many design challenges remain to be addressed in future planning efforts, including selecting observatory sites, determining second-level research questions, and developing a cyberinfrastructure plan.

Sources – http://www.watersnet.org/

Oceans Observatory Initiative (OOI)

Design – The OOI is a long-term, NSF-funded program to provide 25-30 years of sustained ocean measurements to study climate variability, ocean circulation and ecosystem dynamics, air-sea exchange, seafloor processes, and plate-scale geodynamics. In 2000, the OOI was approved by the National Science Board (NSB) as a potential Major Research Equipment and Facilities Construction project for inclusion in a future National Science Foundation budget, which allowed for focused planning efforts.

Integration – The OOI will build a networked sensor grid that will collect ocean and seafloor data at high sampling rates over years to decades. Researchers will make simultaneous, interdisciplinary measurements to investigate a spectrum of phenomena including episodic, short-lived events (tectonic, volcanic, biological, severe storms), to more subtle, longer-term changes or emergent phenomena in ocean systems (circulation patterns, climate change, ocean acidity, ecosystem trends). Through a unifying cyberinfrastructure, researchers will control sampling strategies of experiments deployed on one part of the infrastructure in response to remote detection of events by other parts of the infrastructure. Distributed research groups will form virtual collaborations to collectively analyze and respond to ocean events in near-real time. The long-term introduction of ample power and bandwidth to remote parts of the ocean by the OOI will provide the ocean science community with unprecedented access to detailed data on multiple spatial scales, studying the coastal, regional, and global-scale ocean, and using mobile assets (autonomous underwater vehicles, gliders, and vertical profilers) to complement fixed-point observations. For details see the OOI Science Prospectus.

Organization – The OOI Program is managed and coordinated by the OOI Project Office at the Consortium for Ocean Leadership, in Washington, D.C., and is responsible for construction and initial operations of the OOI network. Four major Implementing Organizations are responsible for construction and development of the overall program.

Ownership – All OOI data including data from OOI core sensors and all proposed sensors added by Principal Investigators, will be rapidly disseminated, open, and freely available (within constraints of national security). Rapidly disseminated implies that data will be made available as soon as technically feasible, but generally in near real-time, with latencies as small as seconds for the cabled components. In limited cases, individual PIs who have developed a data source that becomes part of the OOI network may request exclusive rights to the data for a period of no more than one year from the onset of the data stream.

Quality –Nothing specific was found about data quality management.

Change –The network is still under development.

Impact – The OOI Science Prospectus presents several use-case scenarios that exemplify how the OOI could have impact on policy, education, research and other target areas. In a Written Testimony of Dr. Timothy Cowles, Program Director, Ocean Observatories Initiative (OOI), he answers the question of "How do you work with NSF to ensure that the American taxpayer is getting a return on this investment?: The overarching scientific justification of the OOI project is the sustained delivery of many types of ocean data across a range of temporal and spatial scales, from the sea surface to the seafloor. This data delivery will have direct, short-term societal and economic benefits (coastal storm hazards, linkages between offshore and near-shore processes, improved ocean circulation modeling, seasonal ecosystem responses, etc), which will develop into long-term improvements in forecasting of ocean conditions. These connections between ocean research and 'broader impacts' are at the core of NSF's science objectives. The OOI is therefore perfectly poised to provide significant return on the taxpayer's investment."

Funding – In 2007, NSF's authorized capital investment for the OOI was $331M, with an anticipated $50M per year in 2013 dollars available as a continuing budget for steady-state operations and maintenance of the network.

Problems – In a Written Testimony of Dr. Timothy Cowles, Program Director, Ocean Observatories Initiative (OOI), he writes that "the project began construction in September 2009 with fewer staff than the work plan required. It was more difficult than anticipated to reach full staffing levels during the first year of construction. We addressed this challenge and reached our staffing targets by involving the institutional leadership of each Implementing Organizations in the solution. The OOI faced several challenges in environmental assessment during the first year of construction, particularly in responding to public comments and for completion of the environmental assessment within the project timelines. Through close coordination of informational events and public feedback events by the OOI team, NSF, and interested stakeholders, the project completed the environmental assessment and NSF signed a Finding of No Significant Impact for the OOI."

Sources – http://www.oceanobservatories.org/ and http://www.whoi.edu/ooi_cgsn/home

Palmer Long Term Ecological Research program (Palmer LTER) – Antarctica

Design – This is a good example of a research program specifically designed to answer sets of evolving research hypotheses that are revised every six years (see http://pal.lternet.edu/sci-research/). Although part of LTER, the research is focused on one site, the Palmer research station. Old Palmer Station was established in 1965 with the current Palmer Station occupied starting in 1967. The National Science Foundation Office of Polar Programs in collaboration with the Division of Environmental Biology designated Palmer in 1990 as the first polar biome LTER site in the Southern Hemisphere.

Integration – Palmer LTER centers on a unifying research question: How does changing sea ice cover affect the structure and function of the Antarctic Marine Ecosystem? Palmer LTER's information management strategy builds upon existing network structures, develops connectivity, creates a dynamic central hub with distributed, autonomous centers and establishes an accepted data and metadata policy. An electronic hub at the Institute for Computational Earth System Science at the University of

California, Santa Barbara provides immediate access and a long-term repository for Palmer LTER data and documentation.

Organization – Palmer is managed by a Steering Committee.

Ownership – A large number of data can be downloaded through a OOI Informatics Datazoo, which requires that users agree to a data use policy: "The data available here are intended for scholarly use by the academic research community, with the express understanding that data users will properly acknowledge the originating investigator. Use or reproduction of any material herein for any commercial or redistribution purposes is prohibited without prior written permission from the responsible party. By agreeing to this Data Use Policy, you are also agreeing to the respective data acknowledgment policies of each project."

Quality – Nothing specific was found about data quality management.

Change –The main change in the program is in the evolving research hypotheses.

Impact – Unclear. A government website discusses the anticipated benefits from the program but does not actually mention any such benefits.

Funding – Palmer station has received some USD 20,000,000 since its start in 1990 through different NSF grants (see http://osprey.bcodmo.org/project.cfm?flag=viewf&id=52&sortby=project).

Problems – Nothing specific was found about problems.

Sources – http://www.lternet.edu/sites/pal/ and http://pal.lternet.edu/.

Chinese Ecosystem Research Network (CERN)

Design – The National Ecosystem Research Network (CNERN) is an integrated platform of existing field stations supervised by various ministries within the Chinese government. This project represents a science and technology system that cuts across governmental departments, industrial sectors, regions, and jurisdictions and seeks to integrate observation equipment and data resources and standardize research methods, tools, and protocols. CNERN conducts network observation and experimentation across China's diverse ecosystems, serves as a nexus for national ecological research, promotes data sharing, and creates an educational center and collaborative base for ecological researchers. There are 40 field stations, 5 sub-centres and 1 synthesis centre (Fu et al. 2010) (Figure 10). A top-down approach, integrity of network, standardization of methodology, data management and managerial demonstration of ecosystems have been emphasized from the very beginning (see http://www.klter.org/EVENTS/Workshop98/doc/zhao.htm).

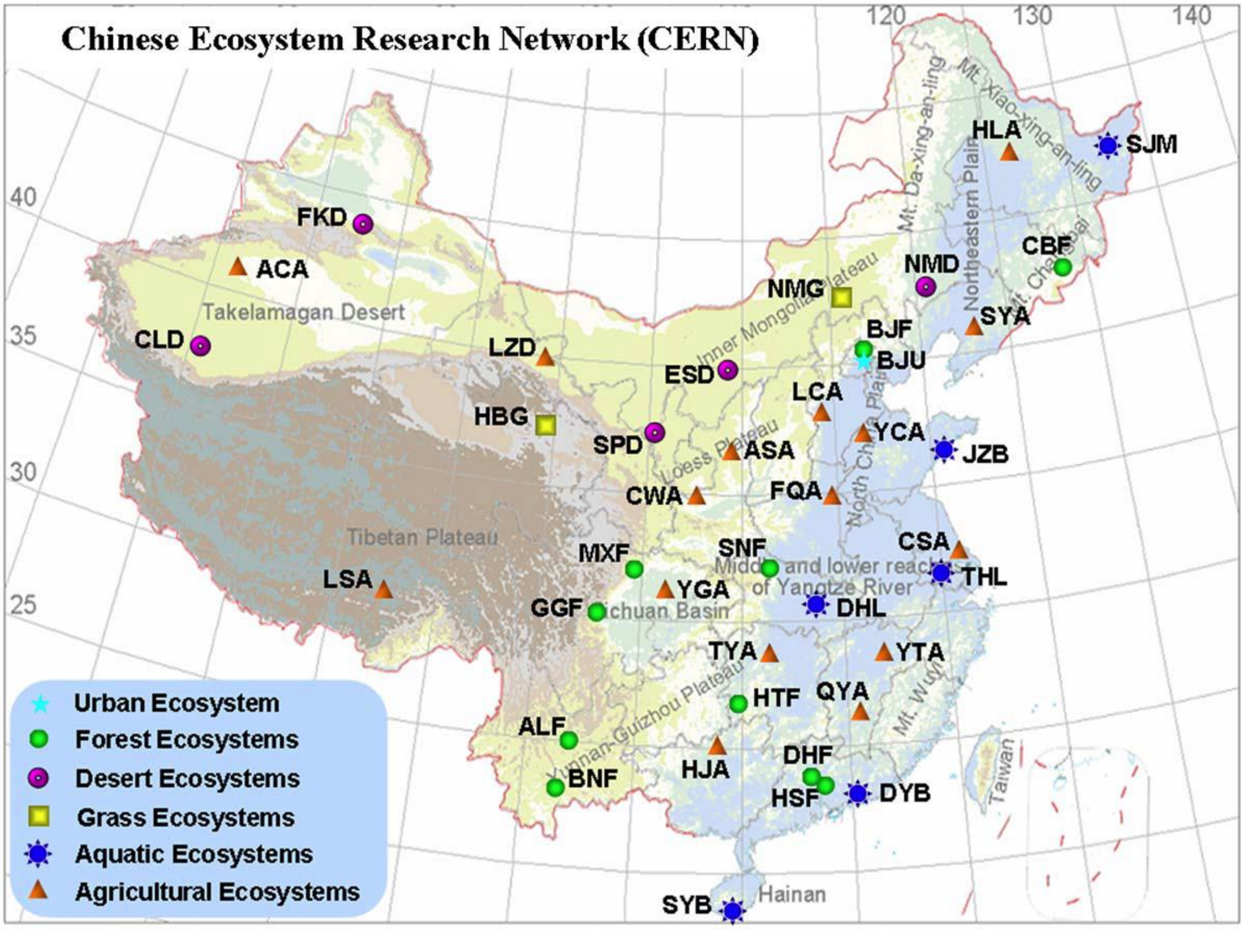


Figure 10. Field station distribution map of CERN (Fu et al. 2010).

Integration – The central, literal aim of CERN is to understand long-term changes in ecosystem pattern, processes and services and the underlying mechanisms under the conditions of natural environmental changes and human activities. While each site has its own scientific problem and specific regional characters, all sites are required to perform the following four common research areas to ensure cross-site and network-level comparisons: biotic communities composition, structure, biodiversity; ecosystem productivity, energy flow and materials cycles; human–environment–ecosystem interactions; ecosystem management and acclimation to global changes (Fu et al. 2010).

Since its establishment in 1988, CERN has collected a lot of monitoring and observation data through its field research stations and established a database at its Synthesis Research Center. In order to effectively manage the data and provide better service for scientists and researchers, many efforts have been made to standardize the long-term monitoring technique among all the CERN stations according to the ecological types of crop, forest, grassland, water, desert, swamp (marsh). Standardized techniques and methods for the collection, transfer, archiving, analysis and publication of data were applied to all the stations of CERN. The Standard of CERN's Long-term Monitoring Data has been published.

From 2001 to 2005, the Synthesis Research Center has, for the first time, achieved scientific management of long-term monitoring data from the 40 field stations. A three-tier (i.e. the field stations, sub-centre, and synthesis centre) data management system and an on-line information dissemination platform have been developed for the data managers to manage their own database at the field station, sub-centre and synthesis centre levels (Fu et al. 2010).

Currently, a series of datasets are available for the public users. These datasets include: (i) the long-term monitoring dataset of hydrological, pedological, meteorological, and biological features and processes at each station; (ii) geophysical and geomorphologic dataset of each ecological field station; (iii) the carbon budget and flux dataset of typical terrestrial ecosystems; (iv) land resources dataset, and (v) 1 km *1 km meteorological grid dataset of China, among others. Up till now, CERN has published the Spatial Information Atlas of CERN Field Stations and the Statistical Dataset for Water, Soil, Atmosphere and Biology of CERN (1998–2001). Some of those data (including the station historical records and background description (nature, social, economy and ecological situation)) are also accessible on CERN website (http://www.cern.ac.cn).

Organization – The management system consists of a steering committee and its secretariat.The steering committee, a decision-making body led by CAS academician Honglie Sun, composing seven academicians and known professors from different universities and research institutions, takes overall responsibility for the operation, monitoring, research, demonstration and policy consultation of CERN, The acting body under the steering committee is the secretariat of steering committee which is responsible for day-to-day management.

Ownership – The data sharing policy is to guarantee a free data flow between the CERN research stations and centers, and an enhanced service to national and international agencies, local authorities as well as the public. The overall purpose of formulating the three official guidelines is to encourage CERN to become an open forum for national and international ecological and related studies. Application can be made to the Synthesis Center for published data.

Quality – No specific information was found about data quality control.

Change – No specific information was found about changes in the research programs and network.

Impact – A review of progress made by CERN (Fu et al. 2010) did not specifically mention the impact of research on policy and other target areas.

Funding – CERN presumably gets most funding from the Chinese Government, although certain aspects of the network have been funded through World Bank loans.

Problems – No specific information was found on problems in CERN.

Sources – http://www.cern.ac.cn

Alternatives to Slash and Burn (ASB)

Design – ASB is a global partnership between international and national agricultural research institutes, universities, non-governmental organizations, community and farmers' groups working to address climate change while at the same time improving livelihoods in the agriculture-forest landscape of the humid tropics. Its goal is to raise productivity and income of rural households in the humid tropics without increasing deforestation or undermining essential environmental services.

ASB, which was founded as Alternatives to Slash-and-Burn in 1994, is currently focussed on reducing deforestation and emissions from land use change, including forestry and agriculture, while ensuring viable livelihoods and enhancing social and environmental co-benefits. The partnership includes over 90 research institutions, universities, non-governmental organizations, community organizations and farmers' groups operating worldwide.

Integration – ASB applies an integrated natural resource management (iNRM) approach to analysis and action through long-term engagement with local communities and policymakers at various levels: (1) Research on key questions related to deforestation, the agricultural intensification hypothesis, REDD+ and landscape approaches to reduced emissions and low carbon development pathway; (2) ASB's multi-site network helps to ensure that analyses of local and national perspectives and the search for alternatives are grounded in reality; (3) Participatory research and policy consultations guide the iterative process necessary to identify, develop, and implement combinations of policy, institutional, and technological options that are workable and relevant; and (4) Enhancing science-policy interactions at multiple levels especially within the United Nations Framework Convention on Climate Change (UNFCC) and Convention on Biological Diversity (CBD).

Organization – ASB has a multi-layer structure. Coordination and facilitation are provided by the ASB global coordination office, ASB regional facilitators and ASB national facilitators. The World Agroforestry Centre (ICRAF) has hosted the global coordination office since inception, in Nairobi, Kenya. The ASB Global Steering Group (GSG) is the main policy and decision-making body whose primary role is to provide overall governance and guidance to ASB. The GSG operates as a consultative group in determining priorities for the consortium. The GSG is comprised of representatives from four Consultative Group on International Agricultural Research (CGIAR) centres, the James Hutton Institute, and six national agricultural research systems. The Chair convenes the GSG meetings annually and as necessary. The GSG seeks decisions by building consensus. The GSG meetings help to provide guidance on science policies, budget and fundraising strategies.

Ownership – No specific information was found about data sharing and use rights. There does not appear to be a publicly accessible data portal for ASB.

Quality – No specific information was found on data quality control.

Change – From 1994, until 2007 ASB operated as a system-wide programme of the Consultative Group for International Agricultural Research (CGIAR). In 2008 it evolved to a new global partnership.

Impact – The ASB program is one of the few that has readily available information about its impact. During 2005, ASB underwent a comprehensive External Review and Impact Assessment. A central question addressed by the Review was "What is the value added by the ASB System-wide Programme, over and above other local, national and regional activities?"

- ASB provides an efficient and effective way to produce international public goods that could not otherwise be generated by any of the ASB partners acting alone.
- ASB has created the only global network devoted entirely to research on the tropical forest margins.
- ASB's work to generate new knowledge, its contributions to shaping policies and practices, and its capacity building activities all lead to the production of global public goods. Specifically, ASB's investments in capacity building are extremely well received by its partners. One indicator: more than 50,000 downloads of ASB's lecture notes.
- ASB's impact comes from a sustained commitment to 'crossing boundaries' regardless of scale (global, regional, national, local). ASB has had its major impacts where staff and partners are committed to activities that link iNRM science with policy formulation, development initiatives by governments and civil society organisations, and decision making by farmers and other natural resource managers. Two key examples are the Negotiation Support Initiative in Indonesia and the Sustainable Tree Crops Program.
- ASB's goal is of great importance for the world, (and is) well aligned with the Millennium Development Goals for the reduction of poverty and hunger (MDG 1) and ensuring environmental sustainability (MDG 7). The 2004 CGIAR review of system-wide programmes ranked ASB in the top category of highest potential impact.
- Clear communication strategies are central to achieving wider impact. ASB is working on a new communications strategy, which will assess the needs of different groups of users and develop and implement enhanced communications to reach wider audiences.

The Review Panel's Final Report is available here:

Funding – ASB is funded through the CGIAR system, but no specific information was found on budgets or donors on the ASB or CGIAR websites. The Millennium Ecosystem Assessment website mentions that :" Funding for this work was provided by grants from the Millennium Ecosystem Assessment, the World Bank-Netherlands Partnership Programme and the government of the Netherlands. Core support was provided by CGIAR, the World Agroforestry Centre and the Earth Institute of Columbia University. ASB partners funded the project with in-kind contributions."

Problems – No information was found on problems in this network.

Sources – http://www.asb.cgiar.org/homepage

Below Ground Biodiversity Network (BGB)

Design – Conservation and Sustainable Management of Below Ground Bio Diversity (CSM-BGBD) project's main goal is to “Enhance awareness, knowledge and understanding of below-ground biodiversity important to sustainable agricultural production in tropical landscapes by the demonstration of methods for conservation and sustainable management”. The project is exploring the hypothesis that, by appropriate management of above and below ground biota, optimal conservation of biodiversity for national and global benefits can be achieved in mosaics of land-uses at differing intensities of management and furthermore results in simultaneous gains in sustainable agricultural production.

Integration – Nothing specific was found about the degree to which different data types had been formally integrated. BGB has a data portal from which the public can download data, but at the moment the only data that can be accessed are from several field sites in Kenya from which socio-economic, crop management, biota and soils data can be downloaded. Raw data do not seem to be available though.

Organization – The Project is coordinated by the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT).

Ownership – The project has developed a detailed Project Data Sharing and Intellectual Property Rights protocol.

Quality – Nothing was found about data quality monitoring.

Change – Nothing specific was found on changes in the research program.

Impact – No specific information was found on impact but the project reports the following as its main achievements: (1) Internationally accepted standard methods for characterization and evaluation of BGBD, including a set of indicators for BGBD loss; (2) Inventory and evaluation of BGBD in benchmark sites representing a range of globally significant ecosystems and land uses; (3) A global information exchange network for BGBD; (4) Sustainable and replicable management practices for BGBD conservation identified and implemented in pilot demonstration sites in representative tropical forest landscapes in seven countries; (5) Recommendations of alternative land use practices and an advisory support system for policies that will enhance the conservation of BGBD; and (6) Improved capacity of all relevant institutions and stakeholders to implement conservation management of BGBD in a sustainable and efficient manner.

The project appears to be designed with a clear impact agenda. Specifically it aims to raise awareness of the economic importance of BGBD, and focuses on policy implications of its findings. It has developed a publicly accessible Monitoring, Progress Reporting, and Evaluation Plan, and annual progress reports (only available until 2008, see http://www.bgbd.net/Site_Themes/Project%20DocumentsNew.html).

Funding – The project is co-financed by the Global Environment Facility (GEF), which contributes more than US$9 million of the Project's budget of US$16.5 million. The Project also receives support in implementation from the United Nations Environment Programme (UNEP) and the participating countries.

Problems – Entries in the annual report indicate that continued funding is challenge for the program (see http://www.bgbd.net/Site_Themes/Project%20DocumentsNew.html). But as indicated above these reports are only available until 2008 and it is not clear what other challenges the project presently faces.

Sources – http://www.bgbd.net/

Tropenbos International (TBI)

Design – Tropenbos International (TBI) unites numerous partners behind a single objective: to ensure that knowledge is used effectively in the formulation of appropriate policies and managing forests for conservation and sustainable development. As an intermediary organization it links the demand for knowledge and capacity building from policy makers and forest users with research and capacity in the North and South. As facilitator it fosters multi-stakeholder dialogues as an effective means of communicating information needs, expertise, issues and solutions for forests and forest-dependent people. The Tropenbos Foundation was established in 1988 in order to continue and expand the international Tropenbos programme, originally set up by the Government of the Netherlands in 1986. TBI currently operates country programmes in Cameroon, Colombia, Democratic Republic of Congo, Ghana, Indonesia, Suriname and Viet Nam. Additionally, TBI participates in projects in Guyana and Bolivia.

Integration – To make good forest policies and wise use of forests we need good quality information. But good information and knowledge will only lead to better policies and wise use of forests if the research programmes designed to generate this information and knowledge meet certain requirements: (1) They answer questions, solve problems and open up new opportunities for those who use the forest or are responsible for formulating or implementing policies; and (2) research results are actively and interactively targeted towards those who need them or will benefit from them. These requirements are translated into the following key aspects of TBI's strategy:

- Local ownership of programme development
- Integration of research and capacity building
- Research targeted to the needs of forest users and policy makers - a development - oriented research agenda
- Capacity building in research relevant to forest users and policy makers
- Emphasis on the uptake of the programme's findings by forest users and policy makers
- Partnership between Southern and Northern research organizations

There does not appear to be a public data portal for TBI.

Organization – TBI is governed by an international General Board composed of reputable Dutch and international experts drawn from the research, policy, business and development communities. The

General Board of TBI consists of maximal 17 members which are selected on their personal title, taking into account their specific expertise on tropical forests, policy or business.

Ownership – Nothing was found on data ownership or use rights.

Quality – Nothing was found on any specific measures taken to guarantee data quality.

Change – TBI used to operate in Côte d'Ivoire and Guyana but is no longer active there.

Impact – No specific information could be found about impact evaluations of TBI's programs. Confidential impact assessments have been produced (e.g., an evaluation of the TB Columbia program in 1990), but these could not be accessed within the time frame of the present assessment.

Funding – Throughout the years the Tropenbos International programme and projects have been supported by various institutions, governmental and private sector organizations, conventions, foundations and individuals. Tropenbos International is financed by the following principal donors: Dutch Ministry of Foreign Affairs (Directorate-General for International Cooperation), Dutch Ministry of Economics, Agriculture, and Innovation, European Commission, and Netherlands Organization for International Cooperation in Higher Education.

Problems – Nothing specific was found about problems or challenges faces by TBI, but the maintenance of funding appears to be a challenge, with two former country programs no longer part of TBI and the Indonesia program appearing much reduced in size compared to the 1990s.

Sources – http://www.tropenbos.org/

Poverty Environment Network (PEN)

Design – Launched in 2004, PEN is the largest and most comprehensive global analysis of tropical forests and poverty. Its database contains survey data on 8000+ households in 40+ study sites in 25 developing countries. At the core of PEN is comparative, detailed socio-economic data that was collected quarterly at the household and village level by 50+ research partners using standardised definitions, questionnaires and methods. PEN aims to fill the gap in knowledge through the systematic collection of socio-economic data in a variety of tropical ecosystems, using similar data definitions and methodologies. This will make PEN the world's first global comparative and quantitative review of the role of tropical forests in poverty alleviation. PEN also represents a new and innovative way of doing research. The core of PEN is the individual field studies, in most cases done by PhD students. The best field studies are often done as part of a PhD thesis. At the same time the value-added of the individual studies can be substantially enhanced by using standardized definitions and methods, which permit comparative analysis. Thus, in addition to their own specific research questions and methodologies, each PhD student/researcher will contribute to the common data set on forests and poverty.

Integration – PEN's research focuses on the relationship between poverty and forests, using a common data format. It develops a global data set of about thirty case studies, each covering an average of 200-250 households, using the PEN prototype questionnaire. The study sites are, as far as possible, chosen to get a representative data set that cover different geographical regions, forest types, forest tenure regimes, levels of poverty, infrastructure, market access and population density. Based on the global data set and other forms of synthesis of the individual studies, the global analysis will explain how forests contribute to subsistence and cash income, asset building, security and welfare, and about the key determinants of this contribution. Each individual study will have its own distinct focus, and will yield critical insights that go well beyond what one can get in the global analysis. One way of synthesizing these findings will be by linking each study to a thematic group. The individual studies and the global syntheses will be designed to produce concrete recommendations that can be fed into policy processes at national and international levels. The country-level results, including identified options for forest-related pro-poor interventions, will be disseminated.

Organization – The PEN research team consists of three groups: (1) CIFOR scientists involved in the project; (2) resource persons outside CIFOR that in various ways have contributed to PEN and are part of the research effort; and (3) PhD students and other researchers responsible for collecting data along the PEN format, referred to as the PEN partners.

Ownership – The PEN website makes the following statement about data use: "The issue of intellectual property rights (IPR) to the data may cause some concern. Neither PEN partners nor CIFOR will be allowed to publish papers that use only one dataset without the written permission from the person responsible for the data collection. Exclusive rights for the study remain with the researcher(s).

CIFOR will hold the primary rights to publish synthesis analysis based on the full data set (or subsets, e.g., only for Africa). Scientists wanting to publish synthesis papers will, however, inform all participants about the proposed papers, and invite and include them as co-authors based on standard academic rules of co-authorship.

All IPR issues will be clearly spelt out in the contract established between PEN partners and CIFOR. As a "Centre without walls", CIFOR values work by collaborators as much as that carried out by CIFOR scientists, and in most cases publications by CIFOR scientists are done in collaboration with partners.

The question of originality may be another concern: how does the idea about a network on one topic, standardized data collection and research methodologies fit with the PhD requirement to produce original work? The answer is simple: the common data set suggested should be part of any basic survey on forests and poverty. Then, each thesis will have its own topic and apply more advanced theories and methodologies that take care of the requirement of originality."

Quality – PEN is one of the very few research programs and networks assessed in this study with a clearly documented and publicly available method for data cleaning and quality control.

Change – Nothing specific was found about change in the PEN approach.

Impact – Nothing specific was found about PEN's impact, although its findings have been widely reported (see, for example, this report in Nature and a range of other media venues: http://www.cifor.org/pen/news-events/london-conference/pen-uk-conference-media-summary.html).

Funding – Nothing specific was found about PEN funding, but presumably funding is obtained from [CIFOR's donors].

Problems – Nothing specific was found about problems and challenges in the PEN program.

Sources – http://www.cifor.org/pen

Tropical Ecology Assessment & Monitoring (TEAM)

Design – This program is devoted to monitoring long-term trends in biodiversity, land cover change, climate and ecosystem services in tropical forests. The idea behind TEAM is simple: to measure and compare plants, terrestrial mammals, ground-dwelling birds and climate using a standard methodology in a range of tropical forests, from relatively pristine places to those most affected by people. TEAM currently operates in sixteen tropical forest sites across Africa, Asia and Latin America supporting a network of scientists committed to standardized methods of data collection to quantify how plants and animals respond to pressures such as climate change and human encroachment.

Integration – By using a standard methodology at a global scale and by sharing data publicly, the TEAM Network is creating a new culture of ecology. The traditional portrayal of ecological study, in which a scientist at one site builds a career on the data from that site, has less relevance in today's world, where the environmental threats caused by people happen at large spatial and temporal scales—magnitudes too large for a single scientist at one site to observe. In another major departure from standard practice among ecologists, TEAM makes all of the Network data publicly available as it is collected, in near real time. Accessible, near real time data makes TEAM an early warning system for nature (Figure 11).

Figure 11. Schematic presentation of how TEAM works.

TEAM monitors the following metrics: (1) Terrestrial Mammal and Bird Diversity; (2) Tree and Liana Diversity; (3) Above Ground Carbon; and two main drivers of change: (4) Land Use Change; and (5) Climate. In addition, TEAM has designed supporting documentation and protocols to describe how data should be managed (Data Management protocol) and the specific methods that guide the Sampling Design of TEAM at a local scale (TEAM Network Sampling Design Guidelines). TEAM also has legacy protocols that are no longer part of core monitoring activities.

A TEAM protocol typically includes the following components:

- Protocol Implementation Manual: a document describing in detail how to implement the protocol from laying out the design and setup to field sampling and data processing.
- Field Form(s): Standardized data collection forms to be used in the field (paper based or electronic).
- Data Entry Form(s): Standardized electronic forms where the information contained in the Field Forms is transcribed into a digital format. These digital forms are then uploaded to the TEAM portal.
- Data Dictionary: Digital files that describe the data types and provide definitions for the Field Forms and/or Data Entry Forms.

Organization – TEAM is run by Coordinating Unit Staff based at Conservation International, which includes a Technical Director, Executive Directors, Project Manager, Director of Information Systems, Managing Director, Finance and Grants Coordinator, and GIS and Remote Sensing Specialist. The work of TEAM is overlooked by an 8-member Science Advisory Board.

Ownership – TEAM data are publicly accessible. Data use is directed by a detailed set of Data Use Terms and Conditions.

Quality – Quality control appears to be done by site managers.

Change – Nothing specific was found about changes in the TEAM program.

Impact – Nothing specific was found about the impact of TEAM's research.

Funding – TEAM is partly funded by Conservation International, the Missouri Botanical Garden, the Smithsonian Institution, and the Wildlife Conservation Society, and receives funding from the Gordon and Betty Moore Foundation, and other donors.

Problems – A scan of publicly available quarterly reports from the field sites, which include listings of problems encountered suggests that technical problems were most frequently encountered, including problems with data management, downloading data from data loggers, downloading climate station data, and issues with internet speed and capacity.

Sources – http://www.teamnetwork.org/

Smithsonian Tropical Research Institute (STRI)

Design – The Smithsonian Tropical Research Institution (STRI) in Panama, is a bureau of the Smithsonian Institution based outside of the United States, is dedicated to understanding biological diversity. What began in 1923 as small field station on Barro Colorado Island, in the Panama Canal Zone, has developed into one of the leading research institutions of the world. STRI's facilities provide a unique opportunity for long-term ecological studies in the tropics, and are used extensively by some 900 visiting scientists from academic and research institutions in the United States and around the world every year. The work of STRI's resident scientists has allowed us to better understand tropical habitats and has trained hundreds of tropical biologists. STRI aims to offer research facilities that allow staff scientists, fellows, and visiting scientists to achieve their research objectives. The 38 staff scientists reside in the tropics and are encouraged to pursue their own research priorities without geographic limitations. The continuity of their long-term programs enables in-depth investigations that attract an elite group of fellows and visitors. Active support for fellows and visitors leverages resources further and attracts more than 900 scientists to STRI each year. Although STRI is based in Panama, research is conducted throughout the tropics. STRI's Center for Tropical Forest Science uses large, fully enumerated forest plots to monitor tree demography in 14 countries located in Africa, Asia and the Americas. More than 3,000,000 individual trees representing 6,000 species are being studied. STRI's Biological Diversity of Forest Fragments project created experimental forest fragments of 0.01, 0.1, and 1.0 km 2 to study the consequences of landscape transformation on forest integrity in the central Amazon region. STRI marine scientists are conducting a global survey of levels of genetic isolation in coral reef organisms.

Integration – The Bioinformatics website is intended to become an access point to all of the STRI's scientific data and information. This site offers access to a number of site-or subject-focused databases, but it is not clear whether these effectively combine data for multi-site analysis. A selection of geographic information datasets can be downloaded from a mapserver but these also appear to focus on one site only (Panama and Meso-America). Overall a large number of different data sets can be accessed though the Bioinformatics website, mostly about Meso-America, but there does not appear to be a centralized data base where different data types are integrated.

Organization – STRI is managed by a Director and some 35 supporting staff.

Ownership – Many data sets are made publicly available. The terms of data use are provided online.

Quality – Nothing specific was found about data quality control.

Change – The STRI traces its 90-year history in Panama to the construction of the Panama Canal, when scientific interest in surveying the flora and fauna of the area grew for the purpose of controlling insect diseases such as yellow fever and malaria. The first director of the Barro Colorado Island research station in Panama was James Zetek (1923-1956). In 1957, Martin H. Moynihan, founding director of STRI, began employing the first permanent resident scientists and expanded the institute's research to other tropical countries. Under the direction of Ira Rubinoff since 1973, STRI has continued to expand its work in the tropics, and now conducts research throughout Latin America, Asia and Africa.

Impact – Barro Colorado Island is one of the oldest tropical research sites, and a vast amount of scientific understanding has been generated through research in this site. A search in the scientific literature database Current Contents found 607 peer reviewed publication published since 1993 with key word "Barro Colorado". A similar Web of Science search resulted in 722 publication since 1945, and these had been cited 22,877 times in other publications, suggesting the high scientific impact of this research.

Funding – No specific information was found about the funding sources of STRI, but the organization accepts private donation and presumable its funding comes from a mix of public and private sources.

Problems – No specific information was found on challenges and problems faced by STRI.

Sources – http://www.stri.si.edu/

Rewarding the Upland Poor for Environmental Services (RUPES)

Design – The "Rewarding Upland Poor for Environmental Services that they provide" (RUPES) is a long-term research program dedicated to developing practical environmental services schemes that can be adapted to work in different countries with different circumstances. Over five years from 2002-2007, the program's first stage, RUPES-I, built working models of best practices at six research action sites in Indonesia, Philippines and Nepal, and studied the experiences at another 12 'learning sites' across Asia. The program is now moving into its second phase. RUPESII will build on the successes and lessons learned in RUPES-I, consolidate its gains, and reach out to additional partners for widespread global adoption of rewards for environmental services schemes.

Integration – The level of formal integration of research methodologies is not clear from publicly available sources. It appears that RUPES uses specific methods in its various field sites, depending on local conditions, but that the research is not strongly hypothesis-driven and does not employ common methodologies across the network. No data portal appears to be presence of public data sharing.

Organization – RUPES is managed by a Program Manager who takes care of daily operations of RUPES activities under the direction of RUPES Project Coordinator.

Ownership – No specific information was found about data use rights and ownership.

Quality – No specific information was about data quality control.

Change – Change in programmatic focus and extent is described in the Design entry above.

Impact – RUPES-I has had significant achievements with schemes involving rewards for watershed related environmental services, such as water quality and quantity for hydro-electric power stations and downstream urban populations. One of the keys was defining the environmental services, where and how they originated and the beneficiaries. RUPES is a very applied research project seeking to have a significant impact on policy in at least six countries: China, India, Indonesia, the Philippines, Nepal, and Vietnam in collaboration with international and national partners at each country. National studies and regional workshops will support the exchange and comparison of policies and experiences, with the aim of integrating environmental services schemes into national economic development and conservation priorities.

Funding – RUPES appears to be funded by a range of organizations, who also function as project partners. These include Conservation International (CI) and Ford Foundation (FF).

Problems – No specific information was found about problems and challenges in the RUPES program.

Sources – http://rupes.worldagroforestry.org/

Smithsonian forest networks (SIGEO/CTFS)

The Smithsonian Institution Global Earth Observatory (SIGEO) are an outgrowth of and companion to the Center for Tropical Forest Science (CTFS). SIGEO builds on and expands the CTFS global network of forest plots, transforming it into a platform for a broader range of scientific investigations. CTFS research on tropical forest dynamics continues, but joins new initiatives to study carbon fluxes, temperate forests, and the impacts of climate change on biodiversity and forest function.

In the environmental sciences, SIGEO stands as one of the premier US-led international partnerships. Because of its extensive biological monitoring, unique databases, and the expertise of its partners, SIGEO promises to enhance society's ability to evaluate and respond to the impacts of global climate change.

Design – SIGEO aims to provide long-term objective data that will enable policymakers and scientists to distinguish the effects of climate change caused by human activities from those caused by natural planetary processes. This includes long-term global data on both the fluctuations of primary productivity in forests and changes in the abundance and distribution of biological diversity. SIGEO will provide those data by extending the CTFS network of tropical forest plots into the temperate zone and monitoring vertebrates, insects, and soil microorganisms throughout the network. Cutting-edge science within the SIGEO network will provide the real-time, detailed and structured data required to answer key questions and address the environmental impacts of a changing climate. SIGEO is about scientific collaboration

Integration – It is an international network of hundreds of collaborators from dozens institutions that have worked together for decades to conduct world-class science. The individual forest plots are led and managed in each country by one or more partner institutions. In conjunction with host-country partners, SIGEO coordinates plots in Asia through a partnership with the Arnold Arboretum of Harvard University. Data are collected according to a set of shared data collection protocols.

Organization – It appears that SIGEO is managed through CTFS by a director and supporting staff.

Ownership – Some data sets have been made available to the public (see http://www.ctfs.si.edu/group/Resources/Data), with specific data sets have their own use requirements (see for example the Terms and Conditions for the Use of BCI Forest Census Plot Data).

Quality – Nothing specific was found about data quality management in SIGEO.

Change – Nothing specific was found about change in the SIGEO network.

Impact – The following is reported about impact of SIGEO: "Over 200 scientists and policy analysts have published more than 1,000 scientific articles based on SIGEO data, many in the high-profile journals Proceedings of the National Academy of Sciences (US), Science, and Nature, attesting to the relevance and high impact of the science and policy issues being studied across the network. The number and high-profile nature of these publications demonstrate the value of long-term, high-quality, standardized data collected across a global network.

Scientific education and training have always been major components of SIGEO. Over decades, the network has developed capacity-building expertise around the world and the expanding research program creates new opportunities to employ that expertise and build further professional capacity in the developing world. Training workshops for local students and scientists will help ensure that the climate-change and biodiversity monitory that we initiate leads to sustainable management of natural resources in the countries where we work."

Funding – Nothing specific could be found about funding, but there doesn't appear to be overall funding for integrated research in the network.

Problems – Nothing specific was found about problems and challenges in SIGEO.

Sources – http://www.sigeo.si.edu/

Additional literature

Towards an integrated model of socioeconomic biodiversity drivers, pressures and impacts. A feasibility study based on three European long-term socio-ecological research platforms (Haberl et al. 2009).

This study proposes a conceptual model of socioeconomic biodiversity drivers and pressures. The model is based on the drivers-pressures-impacts-states-responses (DPSIR) scheme and on the socioeconomic metabolism approach. The aim of the model is to guide research aimed at improving our understanding of socioeconomic biodiversity pressures and drivers and to serve as a basis for the development of formal, quantitative models in that field. The analysis of the case studies underlines the potential utility of the conceptual model to guide future research into socioeconomic biodiversity drivers and pressures. However, considerable investments in monitoring and reconstruction of past trajectories as well as in model development will be required

Boundaries of LTSER platforms seldom coincide with administrative boundaries. On the one hand this means that the conceptual model presented here can easily be applied to regions of a similar size that coincide with one or several administrative units, at least as far as socioeconomic data are concerned. On the other hand this implies that socioeconomic trajectories within the region under consideration may not only depend on conditions of political or economic framework on higher levels (e.g., the province, the nation state or even supranational entities such as the European Union), they may even be influenced by different provinces or other administrative units if the region cuts across their respective territories.

These considerations were taken into account in forging the conceptual model displayed in Figure 12. Local socioeconomic drivers are influenced by socioeconomic drivers on other levels. These drivers result in pressures that affect the local environment ("local socioeconomic pressures"). At the same time, these pressures may directly (through pollution and greenhouse gas emissions) as well as indirectly (through trade) contribute to pressures on ecosystems and biodiversity outside the region's boundary. Local ecosystems and biodiversity are also affected by inflowing pollution as well as impacts of climate change.

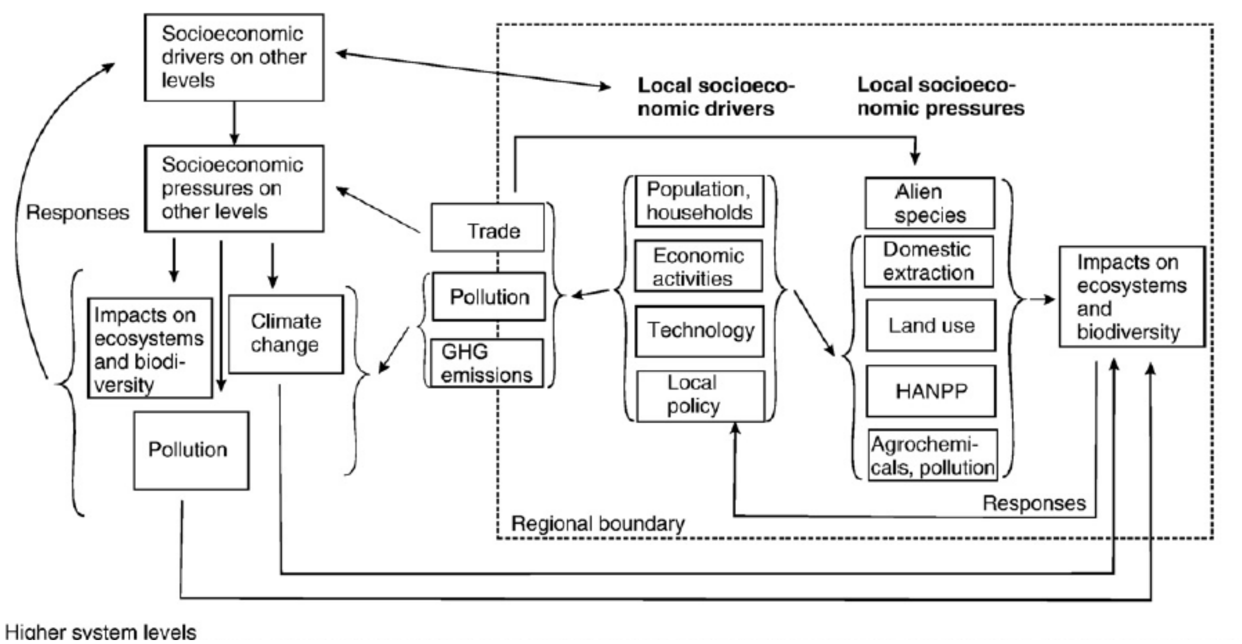


Figure 12. Socioeconomic biodiversity pressures and drivers — a conceptual model (Haberl, Gaube et al. 2009).

The metabolism approach has been seminal in generating tools to assess and monitor biophysical dimensions of socioeconomic change. The notion of a MEFA ("materials and energy flow analysis") framework was introduced as an attempt to systematize the accounts along the main dimensions of socioeconomic resource use:

1. Material flow analysis (MFA) is an accounting system to trace socioeconomic flows of materials from domestic extraction and import to export and emissions. It can also be used to establish consistent time series of important MFA-derived indicators.
2. Energy flow analysis (EFA) is an accounting method for socioeconomic energy flows. It is based on usual statistical data and conventional energy balances that are extended by additional accounts (above all of biomass) in order to be consistent with MFA and applicable in different societal contexts.
3. The land area needed for a society's resource consumption may be accounted for by calculating its "actual land demand." This indicator is conceptually related to the ecological footprint. Contrary to conventional ecological footprint accounts, the indicator "actual land demand" considers actually used hectares without application of weighting factors. The "human appropriation of net primary production" (HANPP) is useful to gauge the intensity with which that land is used. HANPP analyzes changes in the availability of trophic energy (biomass) in ecosystems resulting from land conversion and harvest. HANPP is a measure of socio-ecological material flows.

Another important challenge are the mismatches between the scale(s) on which biodiversity is monitored and analyzed, the scale(s) on which biodiversity is managed, and the scale(s) on which conservation policies are implemented

The need for inter- and transdisciplinary research (i.e. across scientific disciplines and with stakeholder involvement), is also crucial. The need for formal, i.e. computer-executable models, however, is rising as well, partly due to their capability to anticipate possible future biodiversity change under different assumptions on future socioeconomic trajectories (i.e., scenarios). Moreover, experiences in ongoing research projects discussed above (Section 5) suggest that such models can be helpful in integrating contributions from different disciplines in a consistent way, thus helping to promote the understanding of complex socioecological systems (van der Leeuw, 2004). Innovative models that combine agent-based approaches (McConnell, 2001; Manson and Evans, 2007) with stock-flow modules in a coherent model can be useful in that context. While we do not expect full-blown mathematical models covering all aspects shown in Fig. 3 to emerge in the near future, we nevertheless hope that the conceptual model discussed in this article will at least help to build simulation models of selected important parts of the interdependencies discussed here, to establish databases of available data required for such models, as well as schemes or programmes to monitor or reconstruct the development of important parameters that are at present not (sufficiently) covered. Experiences in the Eisenwurzen suggest that such models are feasible and could be highly useful in integrating stakeholders in participative research processes, thus also increasing the utility of the research for people living in the respective study regions.

We conclude that LTSER can help in supplying data and knowledge critical to better-informed policy- and decisionmaking, thus supporting sustainable development. Our analyses suggest considerable data gaps and therefore need for further research and monitoring and may thus be helpful in guiding ways forward to a more integrated scientific agenda to support biodiversity conservation and sustainability.

Towards an understanding of long-term ecosystem dynamics by merging socio-economic and environmental research criteria for long-term socio-ecological research sites selection (Ohl et al. 2007)

The inclusion of socio-economic dimensions into standard ecological research has been identified as a challenge in a new phase of development in Long-Term Ecological Research (LTER). Transformation from LTER to LTSER - Long-Term Socio-Ecological Research - raises questions about the comparability and compatibility of research, the need for indicators linking environmental and socioeconomic processes as well as criteria for launching research sites that focus on interaction between society and nature. The authors propose criteria designed to support the process of transformation of traditional research sites, with the aim of broadening their scope to a socio-economic dimension.

The paper distinguishes between two sets of criteria: local "site criteria" and network "pool criteria". They may be used both as a quality label for transition of traditional ecological sites and as a matrix for establishing and developing new research areas.”

What do LTER results mean - extrapolating from site to region and decade to century (Burke & Lauenroth 1993)

There is an increasing need to study and make predictions about how regions will change over relatively long periods. Such work requires that results be extrapolated beyond the bounds of an individual site. Although an individual site may represent a relatively small proportion of a region, results from a site or network of sites may be extrapolated in time and space through application of simulation models to regional spatial databases.

Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957-Present (Aronova et al. 2010).

This paper discusses the historical connections between two large-scale undertakings that became exemplars for worldwide data-driven scientific initiatives after World War II: the International Geophysical Year (1957-1958) and the International Biological Program (1964-1974). The International Biological Program was seen by its planners as a means to promote Big Science in ecology, but the International Geophysical Year provided scientists with an alternative model: a synoptic collection of observational data on a global scale. However, the program encountered difficulties when the institutional structures, research methodologies, and data management implied by the Big Science mode of research collided with the epistemic goals, practices, and assumptions of many ecologists. By 1974, when the program ended, many participants viewed it as a failure. However, this failed program transformed into the Long-Term Ecological Research program. Historical analysis suggests that many of the original incentives of the program (the emphasis on Big Data and the implementation of the organizational structure of Big Science in biological projects) were in fact realized by the program's visionaries and its immediate investigators. While the program failed to follow the exact model of the International Geophysical Year, it ultimately succeeded in providing a renewed legitimacy for synoptic data collection in biology. It also helped to create a new mode of contemporary science of the Long Term Ecological Research (LTER Network), used by ecologists today."

The U.S. LTER (Long Term Ecological Research) Network informatics group is developing, along with national and international partners, a Network Information System (NIS). The key element is the use of interdisciplinary NIS task groups composed of scientists from existing research groups, information managers, and computer scientists to design and implement various components of the system.

Spectral Network (SpecNet) - What is it and why do we need it? (Gamon et al. 2006)

SpecNet (Spectral Network) is an international network of cooperating investigators and sites linking optical measurements with flux sampling for the purpose of improving our understanding of the controls on these fluxes. An additional goal is to characterize disturbance impacts on surface-atmosphere fluxes. To reach these goals, key SpecNet objectives include the exploration of scaling issues, development of novel sampling tools, standardization and intercomparison of sampling methods, development of models and statistical methods that relate optical sampling to fluxes, exploration of component fluxes, validation of satellite products, and development of an informatics approach that integrates disparate data sources across scales.

Long-term forest experiments: The need to convert data into knowledge (Innes 2004).

To be successful, project managers must demonstrate that they can produce both short-term and long-term results. They need to involve interdisciplinary teams in the research, and preferably need to diversify their funding sources to ensure long-term funding stability. Many long-term experiments involve the accumulation of large amounts of data. Therefore, a strategy for ensuring the quality and long-term storage of these data is essential. The data need to be accessible to those capable of analyzing the material; these may not necessarily be the same people as those collecting the data. Greater use needs to be made of information management tools such as the Natural Resources Information Network (NRIN) and the Global Forest Information Service (GFIS), as well as ensuring that projects are registered with major international networks, such as the International Long-Term Ecological Research (ILTER) network. For the results of long-term experiments to be of value to the forestry community, an effective strategy is needed to ensure that the data are converted into knowledge and that this knowledge is conveyed effectively to the end-users. In the United States, this has occurred largely through the extension personnel of the land-grant universities, although these extension specialists have tended to work mostly with the private sector. There is a need to recognize that the potential end-users of the knowledge derived from long-term experiments are varied, and that the means to communicate that knowledge to them will differ accordingly.

Socio-ecological monitoring of biodiversity change - Building upon the world network of biosphere reserves(Lotze-Campen et al. 2008)

As a basis for improved management of biodiversity as a global, yet locally nested common good, we define the requirements for an integrated socio-ecological monitoring system, a "Sustainability Geoscope". Through a large set of comparative, interdisciplinary regional case studies a new quality of data integration and coverage at various spatial scales could be achieved. We propose to choose the World Network of Biosphere Reserves as an infrastructure of monitoring sites and discuss how such a Geoscope could be implemented and related to existing initiatives.

GEOS and its US and European components: Challenges and impact (Nardon 2006).

The Centre Francais sur les Etats Unis (CFE) held a day-long workshop on GEOSS, GMES and IEOS on 17 January 2006. Sponsored by Arianespace, the invitation-only roundtable drew some 50 participants from European and US administration, industry and academia. The programme and the presentations are on the CFE web site: www.cfe-ifri.net.

Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis (Ostrom & Cox 2010).

The complexity of working institutions, however, presents a challenge to scholars who equate scientific knowledge with relatively simple models that predict optimal performance if specific institutional arrangements are in place. Dealing with this complexity has led to the development of frameworks as meta-theoretical tools. The institutional analysis and development (IAD) framework has been used over the last three decades as a foundation for a focused analysis of how institutions affect human incentives, actions and outcomes. Building on this foundation, the social-ecological systems (SES) framework has recently enabled researchers to begin the development of a common language that crosses social and ecological disciplines to analyse how interactions among a variety of factors affect outcomes. Such a framework may be able to facilitate a diagnostic approach that will help future analysts overcome the panacea problem. Using a common framework to diagnose the source, and possible amelioration, of poor outcomes for ecological and human systems enables a much finer understanding of these complex systems than has so far been obtained, and provides a basis for comparisons among many systems.

Characterizing and measuring sustainable development (Parris & Kates 2003).

The study concludes that there are no indicator sets that are universally accepted, backed by compelling theory, rigorous data collection and analysis, and influential in policy. This is due to the ambiguity of sustainable development, the plurality of purpose in characterizing and measuring sustainable development, and the confusion of terminology, data, and methods of measurement. A major step in reducing such confusion would be the acceptance of distinctions in terminology, data, and methods. Toward this end, we propose an analytical framework that clearly distinguishes among goals, indicators, targets, trends, driving forces, and policy responses. We also highlight the need for continued research on scale, aggregation, critical limits, and thresholds.

Staying afloat in the sensor data deluge (Porter et al. 2012).

Developments in sensor design, electronics, computer technology and networking have converged to provide new ways of collecting environmental data at rates hitherto impossible to achieve. To translate this 'data deluge' into scientific knowledge requires comparable advances in our ability to integrate, process and analyze massive data sets. We review the experience of one large project and provide a synopsis of innovative approaches being used to confront the information management and analytical challenges posed by massive volumes of data.

References

Andelman, S. J., C. M. Bowles, M. R. Willig, and R. B. Waide. 2004. Understanding environmental complexity through a distributed knowledge network. Bioscience **54**:240-246.

Anderson, C. B., G. E. Likens, R. Rozzi, J. R. Gutierrez, J. J. Armesto, and A. Poole. 2008. Integrating Science and Society through Long-Term Socio-Ecological Research. Environmental Ethics **30**:295-312.

Andersson, F., and A. Mårell. 2007. A European Network in Support of Sustainable Forest Management. Journal of Sustainable Forestry **24**:279-293.

Aronova, E., K. S. Baker, and N. Oreskes. 2010. Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957-Present. Historical Studies in the Natural Sciences **40**:183-224.

Baker, K. S., and C. L. Chandler. 2008. Enabling long-term oceanographic research: Changing data practices, information management strategies and informatics. Deep-Sea Research Part II-Topical Studies in Oceanography **55**:2132-2142.

Barbosa, F. A. R., F. R. Scarano, M. G. Sabara, and F. A. Esteves. 2004. Brazilian LTER: Ecosystem and biodiversity information in support of decision-making. Environmental Monitoring & Assessment **90**:121-133.

Berdegué, J., and G. Escobar. 2002. Meta-analysis of Reviews and Evaluation of Ecoregional Programs. RIMISP.

Burke, I. C., and W. K. Lauenroth. 1993. What do LTER results mean - extrapolating from site to region and decade to century. Ecological Modelling **67**:19-35.

Carpenter, S. 2008. Emergence of ecological networks. Frontiers in Ecology and the Environment **6**:228-228.

Chinn, H., and C. Bledsoe. 1997. Internet access to ecological information - The US LTER all-site bibliography project. Bioscience **47**:50-57.

Douthwaite, B., D. Baker, S. Weise, J. Gockowski, V. M. Manyong, and J. D. H. Keatinge. 2005. Ecoregional Research In Africa: Learning Lessons From Iita's Benchmark Area Approach. Experimental Agriculture **41**:271-298.

Driscoll, C. T., K. F. Lambert, F. S. Chapin, D. J. Nowak, T. A. Spies, F. J. Swanson, D. B. Kittredge, and C. Hart. 2012. Science and Society: The Role of Long-Term Studies in Environmental Stewardship. Bioscience Biotechnology and Biochemistry **62**:354-366.

Endter-Wada, J., D. Blahna, R. Krannich, and M. Brunson. 1998. A framework for understanding social science contributions to ecosystem management. Ecological Applications **8**:891-904.

Fu, B., S. Li, X. Yu, P. Yang, G. Yu, R. Feng, and X. Zhuang. 2010. Chinese ecosystem research network: Progress and perspectives. Ecological Complexity **7**:225-233.

Gamon, J. A., A. F. Rahman, J. L. Dungan, M. Schildhauer, and K. F. Huemmrich. 2006. Spectral Network (SpecNet) - What is it and why do we need it? Remote Sensing of Environment **103**:227-235.

Gibson, C. C., E. Ostrom, and T. K. Ahn. 2000. The concept of scale and the human dimensions of global change: a survey. Ecological Economics **32**:217-239.

Grogan, P. 2010. Long-term ecological research sites. Current Science **98**:1159.

Haberl, H., V. Gaube, R. Diaz-Delgado, K. Krauze, A. Neuner, J. Peterseil, C. Plutzar, S. J. Singh, and A. Vadineanu. 2009. Towards an integrated model of socioeconomic biodiversity drivers, pressures and impacts. A feasibility study based on three European long-term socio-ecological research platforms. Ecological Economics **68**:1797-1812.

Haberl, H., V. Winiwarter, K. Andersson, R. U. Ayres, C. Boone, A. Castillo, G. Cunfer, M. Fischer-Kowalski, W. R. Freudenburg, E. Furman, R. Kaufmann, F. Krausmann, E. Langthaler, H. Lotze-Campen, M. Mirtl, C. L. Redman, A. Reenberg, A. Wardell, B. Warr, and H. Zechmeister. 2006. From LTER to LTSER: Conceptualizing the socioeconomic dimension of long-term socioecological research - art. no. 13. Ecology & Society **11**:13.

Innes, J. L. 2004. Long-term forest experiments: The need to convert data into knowledge. Pages 25-31 in C. E. Peterson, and D. A. Maquire, editors. Balancing Ecosystem Values: Innovative Experiments for Sustainable Forestry.

Johnson, J. C., R. R. Christian, J. W. Brunt, C. R. Hickman, and R. B. Waide. 2010. Evolution of Collaboration within the US Long Term Ecological Research Network. Bioscience **60**:931-940.

Keller, M., D. S. Schimel, W. W. Hargrove, and F. M. Hoffman. 2008. A continental strategy for the National Ecological Observatory Network. Frontiers in Ecology and the Environment **6**:282-284.

Kim, E. S. 2006. Development, potentials, and challenges of the International Long-Term Ecological Research (ILTER) Network. Ecological Research **21**:788-793.

Knapp, A. K., M. D. Smith, S. E. Hobbie, S. L. Collins, T. J. Fahey, G. J. A. Hansen, D. A. Landis, K. J. La Pierre, J. M. Melillo, T. R. Seastedt, G. R. Shaver, and J. R. Webster. 2012. Past, Present, and Future Roles of Long-Term Experiments in the LTER Network. Bioscience **62**:377-389.

Lotze-Campen, H., F. Reusswig, and S. Stoll-Keemann. 2008. Socio-ecological monitoring of biodiversity change - Building upon the world network of biosphere reserves. Gaia-Ecological Perspectives for Science and Society **17**:107-115.

Lowman, M., C. D'Avanzo, and C. Brewer. 2009. A National Ecological Network for Research and Education. Science **323**:1172-1173.

Maass, M., R. Diaz-Delgado, P. Balvanera, A. Castillo, and A. Martinez-Yrizar. 2010. Networks and Socio-Ecological Research Long Term Ecological LTER and LTSER in Ibero-America: The cases of Mexico and Spain. Revista Chilena de Historia Natural **83**:171-184.

Mauz, I., T. Peltola, C. Granjou, S. van Bommel, and A. Buijs. 2012. How scientific visions matter: insights from three long-term socio-ecological research (LTSER) platforms under construction in Europe. Environmental Science & Policy **19–20**:90-99.

Meijaard, E., and D. Sheil. in press. The dilemma of green business in tropical forests: How to protect what it cannot identify. Conservation Letters.

Michener, W. K., J. Porter, M. Servilla, and K. Vanderbilt. 2011. Long term ecological research and information management. Ecological Informatics **6**:13-24.

Midgley, G. F., S. L. Chown, and B. S. Kgope. 2007. Monitoring effects of anthropogenic climate change on ecosystems: A role for systematic ecological observation? South African Journal of Science **103**:282-286.

Montgomery, J. L., T. Harmon, W. Kaiser, A. Sanderson, C. N. Haas, R. Hooper, B. Minsker, J. Schnoor, N. L. Clesceri, W. Graham, and P. Brezonik. 2007. The WATERS Network: An Integrated Environmental Observatory Network for Water Research. Environmental and Technology **October 2007**:6642-6647.

Nardon, L. 2006. GEOS and its US and European components: Challenges and impact. Space Policy **22**:149-151.

Ohl, C., K. Johst, J. Meyerhoff, M. Beckenkamp, V. Grusgen, and M. Drechsler. 2010. Long-term socio-ecological research (LTSER) for biodiversity protection - A complex systems approach for the study of dynamic human-nature interactions. Ecological Complexity **7**:170-178.

Ohl, C., K. Krauze, and C. Grunbuhel. 2007. Towards an understanding of long-term ecosystem dynamics by merging socio-economic and environmental research criteria for long-term socio-ecological research sites selection. Ecological Economics **63**:383-391.

Olson, R. J., J. M. Briggs, J. H. Porter, G. R. Mah, and S. G. Stafford. 1999. Managing Data from Multiple Disciplines, Scales, and Sites To Support Synthesis and Modeling. Remote Sensing of Environment **70**:99-107.

Ostrom, E. 2007. A diagnostic approach for going beyond panaceas. Proceedings of the National Academy of Sciences of the United States of America **104**:15181-15187.

Ostrom, E. 2009. A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science **325**:419-422.

Ostrom, E., and M. Cox. 2010. Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis. Environmental Conservation **37**:451-463.

Parr, T. W., A. R. J. Sier, R. W. Battarbee, A. Mackay, and J. Burgess. 2003. Detecting environmental change: science and society—perspectives on long-term research and monitoring in the 21st century. Science of The Total Environment **310**:1-8.

Parris, T. M., and R. W. Kates. 2003. Characterizing and measuring sustainable development. Annual Review of Environment and Resources **28**:559-586.

Porter, J. H., P. C. Hanson, and C. C. Lin. 2012. Staying afloat in the sensor data deluge. Trends in Ecology & Evolution **27**:121-129.

Poteete, A. R., and E. Ostrom. 2008. Fifteen years of empirical research on collective action in natural resource management: Struggling to build large-N databases based on qualitative research. World Development **36**:176-195.

Redman, C. L., J. M. Grove, and L. H. Kuby. 2004. Integrating social science into the long-term ecological research (LTER) network: Social dimensions of ecological change and ecological dimensions of social change. Ecosystems **7**:161-171.

Sayer, J. A., and B. Campbell. 2001. Research to Integrate Productivity Enhancement, Environmental Protection, and Human Development. Page 32. Conservation Ecology

Thompson, J. R., A. Wiek, F. J. Swanson, S. R. Carpenter, N. Fresco, T. Hollingsworth, T. A. Spies, and D. R. Foster. 2012. Scenario Studies as a Synthetic and Integrative Research Activity for Long-Term Ecological Research. Bioscience **62**:367-376.

Tress, B., G. Tress, and G. Fry. 2005. Researchers' experiences, positive and negative, in integrative landscape projects. Environmental Management **36**:792-807.

Van Dijk, J., K. Ulvund, L. Braat, A. Sier, M. Mirtl, A. Watt, T. Peltola, and B. Delbaere. 20112. ALTER-Net, a long-term biodiversity, ecosystem and awareness research network - Year 8. NINA Report. NINA Trondheim, Norway.

Vanderbilt, K. L., D. Blankman, X. Guo, H. He, C.-C. Lin, S.-S. Lu, A. Ogawa, É. Ó. Tuama, H. Schentz, and W. Su. 2010a. A multilingual metadata catalog for the ILTER: Issues and approaches. Ecological Informatics **5**:187-193.

Vanderbilt, K. L., D. Blankman, X. B. Guo, H. L. He, C. C. Lin, S. S. Lu, A. Ogawa, E. O. Tuama, H. Schentz, and W. Su. 2010b. A multilingual metadata catalog for the ILTER: Issues and approaches. Ecological Informatics **5**:187-193.

Veen, L. E., G. B. A. van Reenen, F. P. Sluiter, E. E. van Loon, and W. Bouten. 2012. A semantically integrated, user-friendly data model for species observation data. Ecological Informatics **8**:1-9.

Verburg, P. H., E. C. Ellis, and A. Letourneau. 2011. A global assessment of market accessibility and market influence for global environmental change studies. Environmental Research Letters **6**:034019.

Wollenberg, E., L. Merino, A. Agrawal, and E. Ostrom. 2007. Fourteen years of monitoring community-managed forests: learning from IFRI's experience. International Forestry Review **9**:670-684.