Designing a System for Land Change Science Meta-Study

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Abstract
In this work-in-progress paper, we present GLOBE, a system that enables the quantitative comparison and synthesis of local case study data to support meta-analyses of global environmental change. Using data from a workshop on the state-of-the-art of meta-study in the land change science research community, we highlight the limitations of current approaches and illustrate how our system can be designed to enhance data accuracy and produce globally relevant results.

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Land Change Science, Meta-Study, Sustainability

ACM Classification Keywords
H.5.m. Information interfaces and presentation: Miscellaneous.

Introduction
Human-driven changes to the terrestrial surface have raised concerns not only for the sustainability of Earth's ecosystems, but also for our own well-being. In response, a community of interdisciplinary researchers, known as *Land Change Scientists* (LCS), has emerged "to understand the dynamics of land cover and land use as a coupled human-environment system to address theory, concepts, models, and applications relevant to environmental and societal problems, including the

intersection of the two" [8]. LCS research is undertaken within a broad range of scientific communities, including political ecology, landscape ecology, institution governance, biogeography, integrated assessment, and remote sensing [8], emerging as a fundamental component of global environmental change and sustainability research [5].

A primary method of analysis used in LCS research is the single-site case study. An increasingly important analytic approach is the meta-study [2,9]. The meta-study synthesizes global and regional knowledge from large sets of individual case studies [6]. LCS researchers extract knowledge from published local case-study evidence and synthesize the results to produce a regional and global picture of the effect of human land use on environmental change. Examples of LCS meta-studies include assessments of tropical deforestation [2], paths of destruction and regeneration in tropical forests [7], drivers, impacts and changes in Swidden cultivation [9], and causes of agricultural change [3].

Despite these notable examples, LCS meta-studies remain limited, particularly when compared to meta-analyses produced in related disciplines [e.g., 4]. This partially stems from the fact that few adequate tools exist to enable LCS researchers to quantitatively identify similar case studies and to assess those cases relative to each other and their global relevance. In response to this need, we are currently designing and developing GLOBE [1].

Figure 1: GLOBE case collection view, with [9] as an example.

Methods

To understand the processes by which LCS meta-studies are currently produced, we held a one and a half-day workshop in conjunction with the annual meeting of the Scientific Steering Committee of the Global Land Project (GLP)[1] in Amsterdam in May 2012. Working in partnership with the GLP and an international network of researchers on Coupled Human and Natural Systems (CHANS-Net)[2], we invited nine LCS meta-study experts to discuss what it meant to them to conduct a LCS meta-study. First, we asked participants to describe sample meta-studies, and the spatial units of the individual studies used in their analysis. Next, they discussed what they considered to be the ideal meta-study and how this could be made more efficient and effective. The nine presentations were 15 minutes in length with room for questions. Approximately 25 GLP members listened to the presentations and participated in the discussions.

[1] http://www.globallandproject.org/

[2] http://chans-net.org/

The next day, the invited meta-study experts met separately to discuss the state-of-the-art, and to produce a report outlining LCS meta-study best practices.

Two researchers took detailed field notes on the workshop activities, with a particular focus on questions and answers. This was triangulated with a document review of the presentations and the meta-studies discussed. These notes were then compared to identify common themes, trends and issues. The observations revealed four categories of findings, discussed in detail below.

Findings: The LCS Meta-Study

Current Approaches to Meta-Study Research

In the traditional meta-study process, the researcher defines the selection criteria, either searches for cases or selects a canonical study site and compares the study site to other personally selected case studies, and then makes inferences (see Figure 2). In the first part of our workshop, participants described a number of approaches used to conduct their meta-studies. Two participants reported using keyword searches; the first participant reported using the Web of Science to locate case studies that described impacts and drivers of change in their area of focus. The second participant reporting using Science Direct and Web of Science to locate case studies. She reported coding her data following a standard protocol, and employing regression analysis to estimate probability of conversion in the area under study. A third participant reported using Qualitative Comparative Analysis (QCA), a formalized version of the Delphi technique used to poll experts about a subject. QCA provides analytic tools to compare models across case studies and to group cases into sets with similar characteristics. A fourth participant called for the need for a conceptual framework for land-use modeling. She suggested interviewing five to seven people on their case studies to confirm if cross-site comparison was possible and then to develop a theory of commonalities in case studies for LCS. The LCS meta-study approaches described by participants were all predominantly qualitative in nature, particularly with regards to decisions about case study selection, coding and comparisons.

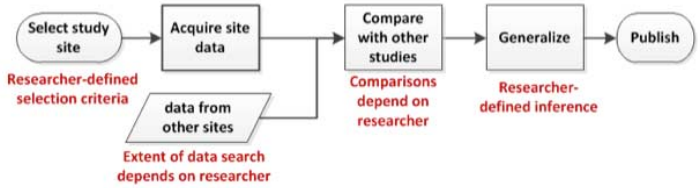

Figure 2: The Traditional LCS Meta-Study Workflow

Limitations to Current Approaches

Our participants identified a number of limitations with current meta-study approaches, which brought into question the strength of their own meta-studies. For example, one participant noted that important scales and measures indicated in one study were frequently absent in another study, and different scales and measures would frequently show up as important in different articles. Another participant noted that it was often difficult to find articles that contained a full picture of trends, drivers and impacts. He questioned how to *count* variables such as conflicts and health impacts. This participant also wondered how to treat cases that were not comparative – for example, where one case showed an increase of some variable and another case showed no increase in the same variable.

Current Meta-Study Approaches:

- Keyword searches in Web of Science & Science Direct.
- Coding cases using standardized protocols.
- Regression analysis to estimate probability rates.
- Qualitative Comparative Analysis.

Limitations to Current Approaches:

- Different factors important in different studies.
- Important factors not consistent across studies.
- Full details on trends, drivers & impacts not available in articles.
- Concerns about reporting accuracy.
- Unclear provenance.

Ideal Meta-Study Approaches:

- Clearly defined research questions.
- Precise study objectives.
- Easier access to cases, including data, models and outputs.
- Standard meta-data reporting scheme.
- Ability to contact authors.

Participants raised concerns about the accuracy of case study reporting, and suggested that the only way to confirm whether or not a case has been represented appropriately in an article is to ask the author directly.

State-of-the-Art of the LCS Meta-Study

In the last part of our workshop, the invited meta-study experts met to discuss the state-of-the-art of the LCS meta-study. Participants agreed that meta-studies are essential to LCS as they allow for a connection to be made between actors and environmental changes. However, they raised concerns about the degree of rigor currently employed, and suggested that current approaches to conducting meta-studies may be difficult to follow as a result. One participant raised issues with the use of cross-national data crunching, noting that this approach does not allow the researcher to identify actors and the processes that produce outcomes of interest. He contended that researchers choose to use this approach because the data are accessible; however, the data are not site specific and does not provide a depth of cases. Another participant commented on the number of disconnected case studies and the limited efforts to connect them. One participant called for the need for comparisons to be made between CHANS and LCS.

Participants raised concerns about knowledge generation and synthesis in LCS. They noted that criteria were needed to differentiate different types of generation. In particular, they called for a distinction to be made between meta-studies and non-meta-study generalization approaches, such as the review article, cross-site comparisons, and cross-national data crunching. One participant suggested that a meta-study was distinct from other approaches in that it allows for controlled post-hoc observations across a set of individual case studies.

Participants also discussed methods for conducting LCS meta-studies, including processes for searching for cases, accepting or rejecting cases, coding, treatment of meta-data, data reporting, and data sharing. They discussed the degree of transparency needed in reporting and questioned whether full disclosure on how cases were coded would open 'Pandora's Box'. In particular, they raised logistical concerns regarding how to treat instances where cases were improperly coded, and where case study authors ask for their cases to be recoded. In addition, they also suggested that case study authors may distrust meta-studies if they deemed cases to be improperly coded: "You got my case wrong, which means you got all other cases wrong, which means that your study is not valid."

The Ideal Meta-Study: Areas for Improvement

In response to these limitations, workshop participants identified a number of areas for improvement. They suggested the need for more clearly defined research questions; precise and specific study objectives; easier access to cases, including data, models and outputs; a standard meta-data reporting scheme; and the ability to contact authors about their studies. One participant suggested that case studies should be based on a standard protocol, similar to the protocols used by Center for International Forestry Research and the International Forestry Resources and Institutions. Another participant contended that ideal LCS meta-studies should include a sufficient number of cases, at least 100. This participant also suggested that it would be useful to create a system that made it easier to find cases. Moreover, to assist the meta-study process and

make it more effective, one participant suggested a number of improvements that could be made to the individual case study, namely a clearer description of the study area; inclusion of treatments, sample design and timeframes; inclusion of plot size, sample size and number of observations; and, inclusion of raw data, statistics, and statistical methods applied.

The GLOBE System

To address many of the limitations identified by our workshop participants, we are designing and developing the GLOBE system. GLOBE will serve as a repository for LCS specific metadata and case studies, eliminating the need to manually search for relevant case studies in online databases such as Web of Science and Science Direct. Using advanced comparison algorithms, the system will enable researchers to select sites with similar characteristics and to compare sites based on global relevance. This will help address challenges with inconsistent factor selection and factor reporting across different case studies, as identified by our workshop participants, by algorithmically selecting case studies with similar factors or characteristics to be used in analysis.

In particular, GLOBE will enable LCS researchers to easily compare case studies with other studies at sites with similar characteristics, which we term a similarity analysis, and to group, weight and synthesize across a set of case studies in order to support more advanced models of human-environment interaction, which we term a representativeness analysis (see figure 3). In addition, GLOBE will make it easier for LCS researchers to select highly representative sites and to identify understudied sites or regions.

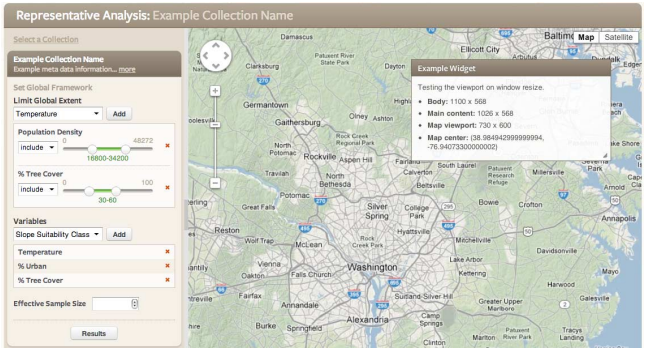

Figure 3: GLOBE representativeness analysis interface with functionality for weighting variables across a set of cases.

To assist in discovery, GLOBE will employ machine learning to help identify gaps in the knowledge base and highlight opportunities for new studies and new scientific workflows. GLOBE will also employ social computing tools to rapidly and meaningfully connect researchers and studies, as well as provide access to researcher contact information to enable open dialogue between researchers and potentially foster scientific collaboration. In this way, GLOBE will support the discovery of new studies, new sites, and new relationships.

Additionally, GLOBE will help address participants' concerns about data reporting accuracy and case study quality. First, case study authors will be contacted to verify whether or not their cases have been appropriately represented in GLOBE. Second, case studies in GLOBE will be assigned 3 system generated quality scores based on measures of provenance (i.e., how and by whom the site was mapped), clarity (i.e., how well the geometry is described) and conformance (i.e., how well the shape files conform to the

geographic entities). Third, all cases entered into the GLOBE system will be initially validated by an internal GLOBE cases review team to ensure case completion and accuracy.

Conclusions

GLOBE intends to transform the current LCS meta-study processes by enabling researchers to find similar sites and better assess the global relevance of their case study data. It will revolutionize knowledge generation in LCS by enabling new scientific workflows that will allow for rapid and straightforward quantitative global synthesis across large sets of local and regional case studies. LCS researchers will be able to more easily locate case studies, compare case studies for similarity, select highly representative cases, and identify underrepresented study sites. In addressing the limitations of current LCS meta-study approaches, the GLOBE system will therefore help strengthen LCS researchers' results, providing a more accurate and relevant picture of global environmental change.

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