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Ambiguous Geographies: Connecting Case Study Knowledge with Global Change Science

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Case studies have long been a gold standard for investigating causal mechanisms in human–environment interactions. Yet it remains a challenge to generalize across case studies to produce knowledge at broader regional and global scales even as the effort to do so, mostly using metastudy methods, has accelerated. One major obstacle is that the geographic context of case study knowledge is often presented in a vague and incomplete form, making it difficult to reuse and link with the regional and global contexts within which it was produced and is therefore most relevant. Here we assess the degree to which the quality of geographic description in published land change case studies limits their effective reuse in spatially explicit global and regional syntheses based on 437 spatially bounded cases derived from 261 case studies used in published land change metastudies. Common ambiguities in published representations of case geographic contexts were identified and scored using three indicators of geographic data quality for reuse in spatially explicit regional and global metastudy research. Statistically significant differences in the quality of case geographic descriptions were evident among the six major disciplinary categories examined, with the earth and planetary sciences evidencing greater clarity and conformance scores than other disciplines. The quality of case geography reporting showed no statistically significant improvement over the past fifty years. By following a few simple and readily implemented guidelines, case geographic context reporting could be radically improved, enabling more effective case study reuse in regional to global synthesis research, thereby yielding substantial benefits to both case study and synthesis researchers.
Key Words: geographic representation, GIScience, metastudy, research synthesis, scale.

案例研究对于探讨人类—自然互动的因果机制而言, 长期作为黄金标准。但普遍化各个案例研究, 以在更广泛的区域及全球尺度中生产知识仍是个挑战, 尽管多半运用后设研究方法的努力已不断增加。其中一个主要的困难在于, 案例研究知识的地理脉络, 经常以模糊且不完整的形式呈现之, 使其难以被再利用, 并难以连结至其被生产、因此最为相关的区域及全球脉络。我们在此根据已出版的土地变迁后设研究所使用的二百六十一个案例研究中, 衍生而出的四百三十七个在空间上受限之案例, 评估在已出版的土地变迁案例研究中的地理描绘之质量, 限制它们在空间明确的全球及区域综合中有效再利用的程度。我们运用三项在空间明确的区域与全球后设研究中, 再利用的地理数据质量指标, 指认已出版的案例地理脉络再现中的普遍模糊性。在我们所检视的六大主要领域范畴中, 案例地理描绘质量中的显着统计差异相当明显, 其中地理与地球科学, 呈现出较其它领域更高的清晰度与一致性分数。案例地理学报告的质量显示, 过去五十年来在统计上并没有显着的进步。透过追踪数个简单且已实施的指导方针, 案例地理脉络报告可彻底改进, 并促成区域到全球综合研究中更有效的案例研究再利用, 因而同时对案例研究与综合研究者带来实质的益处。 *关键词： 地理再现, 地理信息科学, 后设研究, 研究综合, 尺度。*

Los estudios de caso han sido desde hace mucho tiempo el estándar dorado para investigar los mecanismos causales en las interacciones humano-ambientales. Sigue siendo un reto, sin embargo, generalizar de los estudios de caso para generar conocimiento a escalas más amplias regionales y globales, aun si el esfuerzo para lograrlo, principalmente usando métodos de metaestudio, ha sido incrementado. Un obstáculo mayor es que el contexto geográfico del conocimiento por estudio de casos a menudo se presenta de forma vaga e incompleta, haciendo difícil reusar y ligar con los contextos regionales y globales dentro de los cuales aquel fue producido, por lo que tiene mayor relevancia. En este artículo evaluamos el grado con el que la calidad de la descripción geográfica en estudios de casos publicados sobre cambios de la tierra restringe su reutilización efectiva en sínteis globales y regionales, espacialmente explícitas, basadas en 437 casos espacialmente demarcados, derivados de 261 estudios de caso publicados en metaestudios sobre cambios de la tierra. Las ambiguedades comunes en representaciones publicadas de casos de contexto geográfico fueron identificadas y calificadas usando tres indicadores de calidad de los datos geográficos para reutilización en investigación de metaestudios regionales y globales espacialmente explícitos. Diferencias estadísticamente significativas en la calidad de descripciones geográficas de caso fueron evidentes entre las seis mayores categorías disciplinarias examinadas, con las ciencias de la tierra y las planetarias evidenciando mucha mayor claridad y marcas de conformidad que otras disciplinas. La calidad de los

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informes sobre la geografía de casos no mostró una mejora estadísticamente significativa en los pasados cincuenta años. Siguiendo unas pocas instrucciones simples y de fácil implementación el reporte del contexto geográfico del caso podría ser mejorado radicalmente, posibilitando un reuso del estudio de caso más efectivo en la investigación de síntesis de lo regional a lo global, generando de ese modo beneficios sustanciales para los investigadores y para los estudios de casos y síntesis. *Palabras clave: representación geográfica, ciencia SIG, metaestudio, síntesis de investigación, escala.*

Synthesis research aimed at understanding the causes and consequences of global social and environmental change is increasing rapidly, supported by metastudy analysis of case study research at local to regional scales (Turner et al. 1990; Rindfuss et al. 2004; Rudel 2008; Cox 2015; Magliocca et al. 2015; van Vliet et al. 2016). Although case study research remains one of the most popular research methods for understanding human–environment interactions, translating knowledge produced through local case studies into data for broader-scale research synthesis efforts is confronted by a variety of methodological challenges (Rindfuss et al. 2004; Keys and McConnell 2005; Turner, Lambin, and Reenberg 2007; Magliocca et al. 2015). Here we assess the degree to which one of these challenges, ambiguities in the geographic representation of case study knowledge, might affect case study reuse in global and regional synthesis research. We do so using a metastudy approach to describe and evaluate the quality of geographic representations across a set of 437 cases extracted from 261 case studies used in highly cited metastudies in the field of land change science (Globe Cases Team 2015).

The research presented here is motivated by two basic research questions: (1) Do patterns in the quality of geographic description exist across the case study literature of land change research and, if so, why? and (2) How might a more systematic approach to such descriptions facilitate more robust and precise reuse of case study knowledge in spatially explicit global and regional synthesis research? To examine these research questions, we applied a systematic quality coding procedure to the 437 cases examined here to evaluate the quality of their geographic descriptions. Motivated by our research questions, we tested the following four hypotheses:

1. Case quality scores vary across major academic disciplines, with higher scores in the more geospatially oriented disciplines.
2. Case quality scores differ by geographic entity type, with higher scores among entity types with clearer and more replicable boundaries (e.g., administrative units or watersheds compared to villages or pastures).
3. Case quality scores vary by land use type, with higher scores among more intensively managed land use types (e.g., dense settlements compared to rangelands).
4. Case quality scores improve over time based on publication date, with more recent studies producing higher quality scores.

Informed by our results and the experiential knowledge acquired through the process of case scoring, we also present readily implemented guidelines for describing the geographic context of case studies to improve their effective reuse in regional and global research synthesis.

Representing Case Study Space

Our primary research questions are motivated by a desire to better understand how the quality of geographic descriptions might affect research synthesis efforts based on the reuse of empirical knowledge reported in published case studies. The process of defining the geographic context within which case study knowledge has been gained in terms of an area of Earth's land surface sets the terms by which this knowledge can be interpreted and used by others (Keys and McConnell 2005; Downey 2006; Kwan 2012; Karl et al. 2013). Defining the unit of analysis of a case study, or "bounding of the case," is considered an essential step in the development of a case study protocol (Yin 2013, 33). Most recently in relation to case study synthesis research, Cox (2014) raised the distinction between case studies (a unit of observation) and cases (a unit of analysis). A case study typically takes the form of a published paper or report and might include one or more cases that a researcher conducting synthesis research can both extract data from and apply coding procedures to. The boundaries of a case might be spatial, temporal, or present in the form of another concrete delineation between who or what is being analyzed in a case analysis and who or what is excluded (Yin 2013). Yet to date, guides on case study design and reporting have paid insufficient attention to characterizing the appropriate geographic descriptors for cases that are spatially bounded in both the case study literature and across the empirical environmental social sciences (Ragin and Becker 1992; Flyvbjerg 2006; Yin 2013; Cox 2014, 2015).

Although the past two decades have seen a flourishing body of research problematizing and theorizing on scale and spatial representation, particularly within human geography (for a review of some key works, see Marston 2000; Brenner 2001; Marston, Jones, and Woodward 2005; Sayre 2005; Miller 2007; Moore 2008; among others), for researchers investigating human–environment interactions with cumulative global consequences, such as the loss of carbon or biodiversity in response to land change, there remains the practical problem of adequately identifying a study's geographic extent on the Earth's surface so that its spatially explicit regional and global contexts can be assessed and integrated into synthesis research (Turner et al. 1990; Karl et al. 2013; Magliocca et al. 2015). The field of land change science in particular, with its focus on patterns and processes of land use and modification of land systems, has long sought to draw generalizable patterns and trends of human–environment relations out of locally conducted case studies (Turner, Hanham, and Portararo 1977; Rindfuss et al. 2004; Turner, Lambin, and Reenberg 2007; Rudel 2008; Magliocca et al. 2015; Verburg et al. 2015; van Vliet et al. 2016). It is therefore necessary to distinguish and describe those aspects of case knowledge that have localizable spatial contexts so they can be used in generating spatially explicit regional and global knowledge of land change processes. Although there are important ethical considerations researchers must consider when choosing how to describe the geographic context of a case, there are simple and basic improvements most researchers can and should employ in describing the geographic context of case research.

Geographic Context in Synthesis Research

Accurate geographic descriptions of the boundaries of case knowledge are especially important in metastudy synthesis research on environmental change. Metastudies of case studies are increasingly used to make general inferences on land change patterns and processes at global and regional scales using empirical data drawn from case studies conducted at more localized spatial scales (Lambin and Geist 2006; Rudel 2008; Verburg, Neumann, and Nol 2011; Cox 2015; Magliocca et al. 2015; van Vliet et al. 2016). Land change scientists are interested in a diversity of factors shaping land systems, including demographic, economic, cultural, institutional, technological, and ecological mechanisms, and their interactions at multiple spatial and temporal scales (Lambin and Geist 2006). The influence of many of these factors on land system dynamics has been found to be scale dependent and nonstationary over space (e.g., population density and market access [Verburg, Ellis, and Letourneau 2011]; agricultural intensity [Laney 2002]). Spatially explicit and accurate reporting of a case's geographic extent is therefore especially important for metastudy research in which studies across multiple sites and geographic locations are compared and integrated (Karl et al. 2013; Magliocca et al. 2015).

Despite an acceleration of synthesis research in land change science using local case knowledge (Magliocca et al. 2015), the challenges to synthetic knowledge creation across different scales of observation and analysis are exposed in the persistent difficulties in "scaling up" case study research to gain broader insight on patterns of environmental change (Sayre 2005). Although there is a long history of comparative case study research in the social sciences (e.g., Murdock and White 1969) and there have been recent advances in case study synthesis methods such as the social–ecological systems meta-analysis database (e.g., SESMAD; Cox 2014), the difficulties of engaging in research to make broader observations on land change through synthesis research remain. One of the greatest barriers to such synthesis efforts is the comparability of individual cases and the relative facility for other researchers to extract data from published studies for secondary analysis (Magliocca et al. 2015). Nevertheless, metastudies of case study research conducted at local to regional spatial scales remain an important and growing research strategy for generating regional and global understanding of coupled human and environmental systems, as it is otherwise difficult to observe the coupling of social and environmental patterns and processes by other methods, despite the promise of remote sensing and volunteered geographic information (Rindfuss et al. 2004; Goodchild and Li 2012; Magliocca et al. 2015).

Exploring Ambiguous Geographies

This article is based on geographic descriptions provided in a set of 437 cases compiled, coded, and mapped as part of the GLOBE project (Ellis 2012) by a team of trained students at the University of Maryland, Baltimore County. Common ambiguities in the reporting of case geographic contexts are identified and scored relative to the degree to which the quality of their geographic reporting enables their reuse for spatially explicit regional and global metastudy synthesis. Variation in the quality of case geographic representation is assessed as a function of discipline, time, geographic entity type, and land use system, demonstrating a remarkably consistent lack of clarity in these descriptions across most disciplines that has changed little over the past fifty years.

In the process of mapping these cases, the diversity and commonality of ambiguous geographic descriptions was made clear, as illustrated in Figure 1, demonstrating the importance of precise in-text and geospatial representation of case geographic context, especially when findings on multiple cases are presented within the same publication. The causes of this widespread and continuing ambiguity are evaluated and discussed together with readily implemented strategies for improving the communication of the spatial contexts of case study research in an effort to advance spatially explicit regional to global metastudy synthesis research within land change science and broader spatial sciences communities.

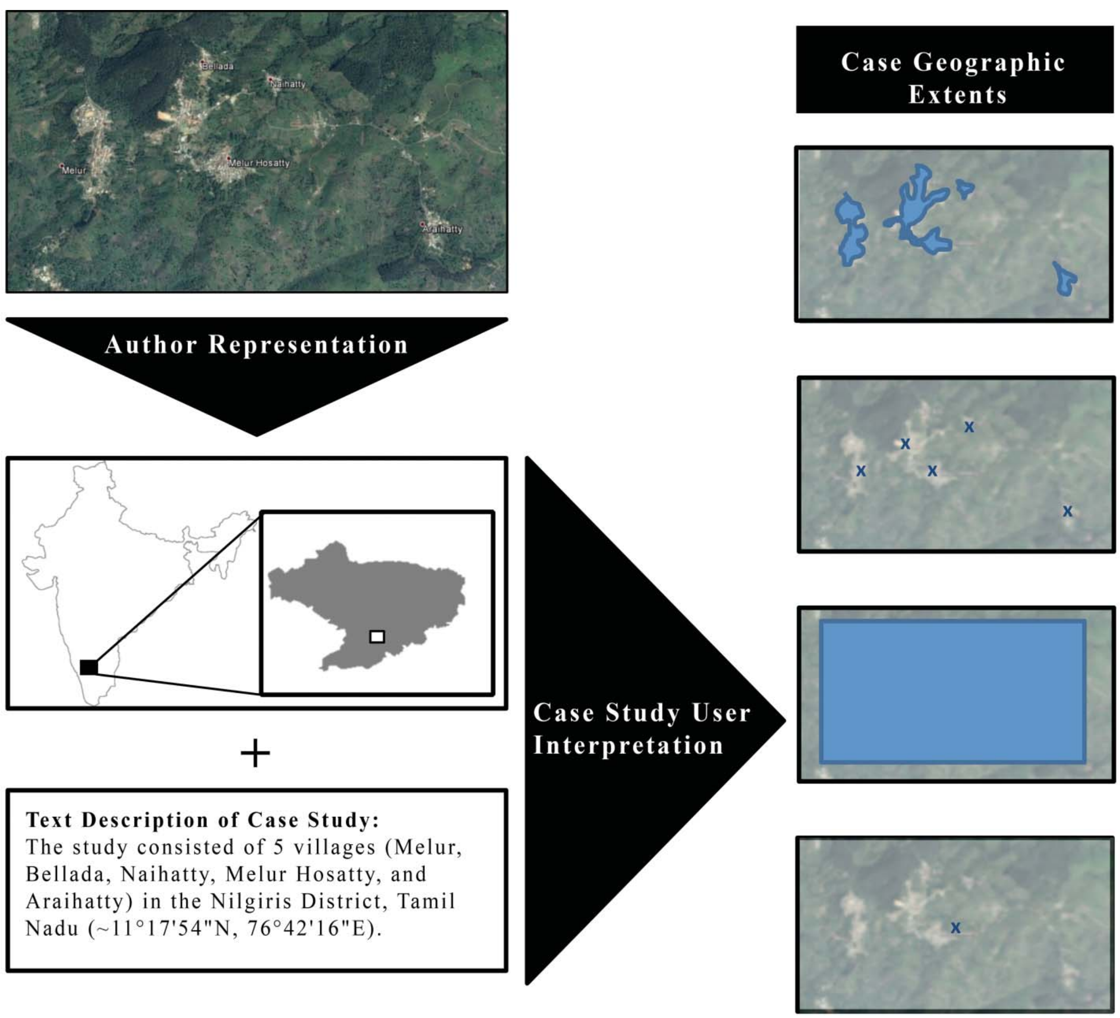

Figure 1. Example of geographic ambiguities emerging through translating local case study geographies for use in metastudies. In this example, a fictitious case study of five villages is translated in four different ways based on a map and in-text description of the study sites. The subsequent depictions (displayed on the right) were produced by three different undergraduate students at the University of Maryland, Baltimore County, when provided the initial fictitious description (left). Both the illustrative map and in-text description represent common forms of representing case geographies based on our review of 437 cases analyzed in this article. (Color figure available online.)

Method

Case Study Acquisition

A total of 444 cases were identified for research by reproducing the case study collections used in eight published metastudies chosen for their subject breadth across land change science, ranging from biofuel production, deforestation, and agricultural abandonment in the tropics to cropland change and risk management in pastoral systems (Table 1). Cases were selected from published metastudies as these were assumed to represent cases especially suitable for metastudy synthesis. The original source of each case study (journal articles, book chapters, books) was acquired in hard copy or electronically. Cases were excluded from analysis when no original source could be located (one case), the original source was located but there was insufficient geographic information included in the source to map the case location (two cases), and their geographic extent exceeded 5 million km^2 (the approximate size of the Amazon rainforest), a limit imposed to exclude large regional studies (four cases), producing a total collection of 437 cases. Many individual case study sources reported on multiple cases, in which data were presented for more than one geographic extent. For instance, an urban land change study might produce multiple unique cases based on separate cities for which data were reported. Individual cases were identified within sources to correspond with the same number of cases utilized in the original metastudy they were used in, based on analysis of source text, figures, and tables.

Case Preparation Procedure

Cases were prepared for analysis using procedures for spatially explicit case study entry into the online case database of the GLOBE project, as described later (Global Collaboration Engine; Ellis 2012; Schmill et al. 2014; Young and Lutters 2015). Full bibliographic information on the published study from which each case was derived was first entered into GLOBE, followed by a map of the geographic extent of the case and an automated scoring of case geography data quality pedigree (Table 2), as detailed in the following section and in greater detail in Figure A1 in the Appendix. Cases were entered into GLOBE between March 2012 and March 2014 by a trained team of nine undergraduate and graduate students from the Department of Geography and Environmental Systems at University of Maryland, Baltimore County. All of the students had at least an introductory course in geography and geographical techniques at the time of coding cases. Additionally, seven of the students had taken at least two geographic information systems (GIS) courses (many of whom were working toward certification) and thus understood the requirements of georeferencing the geographic extents of cases contained within a case study.

Case geographic extents were mapped based on the clearest geographic description of the spatial extent of each case for which data were utilized in the original citing metastudy, based on thorough study of the text, tables, and figures within each original source. The first step in mapping case geographic extents was to identify the geographic entity (e.g., forest, watershed,

Table 1. List of eight metastudies from the field of land change science and topics of extracted case studies

Meta-study	Topic	No. of cases (coefficient of variation = 0.83)
Turner, Lambin, and Reenberg (1977)	Relationships between population density and agricultural intensity	28
Keys and McConnell (2005)	Agricultural intensification in the global tropics	93
Kauffman, Hughes, and Heider (2009)	Rates of deforestation and resulting carbon emissions as well as land-use changes including agricultural abandonment in the neotropics	19
Achten and Verchot (2011)	Implications of land-use change emission on the climate-change mitigation potential of different biofuel production systems	16
Moritz et al. (2011)	Social risk-management strategy variations within pastoral systems in the neotropics	22
Eclesia et al. (2012)	Replacement of native vegetation by pastures and tree plantations	54
Van Vliet et al. (2012)	Trends, drivers, and impacts of changes in swidden cultivation in tropical forest-agriculture frontiers	156
Van Vliet, Reenberg, and Rasmussen (2013)	Cropland change as well as their driving forces and perceived impacts within the Sahel region of Africa	49

Table 2. Case quality scoring rubric for describing data quality of cases based on how well the geographic entity for which case study knowledge is reported (the source data) is described as a spatial unit of Earth's land surface (case geometry)

Score	Provenance	Clarity (case contributor is the author/site expert)	Clarity (case contributor is not the author/site expert)	Conformance
4	Geometry created by author/site expert	Geographic entity conforms perfectly with the data provided in the source	Geographic entity and geometry fully and professionally described in original source or correspond precisely to entities for which precise geographic data are available	Geometry is entered by uploading an SHP file or an existing geometry is selected, the area of the geometry entered into GLOBE agrees with that reported in the geographic description, and a polygon or precise point geometry is used to represent the site
3	Geometry not entered by author/site expert, and polygon or precise point geometry is used to represent the site	N/A	Geographic entity and geometry are clear in original source, but mapping of the site geometry requires some interpretation before it can be mapped	Geometry is entered using the map draw function, the area of the geometry entered into GLOBE agrees with that reported in the geographic description, and a detailed polygon or precise point geometry is used to represent the site
2	Geometry entered by trained GLOBE team member, approximate point geometry is used to represent the site	Geographic entity conforms roughly to the data provided in the source	Geographic entity described roughly in original source	The area of the geometry entered agrees with that reported in the geographic description, but the Clarity Score is less than or equal to 2
1	Geometry entered by a contributor without direct site knowledge, approximate point geometry is used to represent the site	Geographic entity does not clearly conform to the data provided in the source	Geographic entity not clearly described in original source	The area of the geometry entered does not agree with that reported in the geographic description; that is, the spatial scales do not match
0	Source of the case geometry is unknown	Data provided in the source do not clearly conform to geographic entities that can be described here	Geographic entity description missing or completely ambiguous	Geometry type is unknown or no data were entered

Note: See Appendix for more detailed information on case quality scoring algorithm.

village; Table A1 in the Appendix) and the reported area (km^2) of the extent for which case data were presented as the basis for determining the optimal type of geographic representation (points, lines, polygons; relative spatial scale of each geographic entity). The geographic entity of each case was then mapped in the GLOBE online database either by scanning, registering, and digitizing published maps in a GIS (shapefiles uploaded into GLOBE), identifying known places and digitizing these in a GIS or directly in GLOBE using online vector mapping tools or by selecting existing published kml or shapefiles of known places (Global Administrative Areas 2012; International Union for Conservation of Nature and United Nations Environment Programme-World Conservation Management Center 2015). Geographic coordinates and point geometries were used if no more complete geographic information were available in the source. The final source data, data quality scores (additional information later), and geographic representation (online map) were then validated by the mapping team leader before the case was committed to the database. The full collection of 437 cases used in this study are shared online with the public in the GLOBE system for interactive geovisualization, analysis, and downloading (Globe Cases Team 2015).

Case Geography Data Quality Scoring

To test for systematic biases in case geographic representation across academic disciplines, geographic entity types, land systems, and time, a data quality pedigree system was used to score the quality of the conformance, provenance, and clarity of geographic representation for each case, using the data quality pedigree rubric specified in Table 2 and the algorithm implemented in GLOBE as detailed in Figure A1[1] (Funtowicz and Ravetz 1990; Costanza, Funtowicz, and Ravetz 1992). Conformance scores were automatically computed by the GLOBE system and used to rate spatial agreement between the source reported area of the case and the geographic area of the case as computed from the mapped geographic entity, as well as the appropriateness of the geography type (point, polygon, line) for the reported geographic entity. Provenance scores rated the relative expertise of the case contributor (study author, expert on site, GIS expert, nonexpert, etc.) and were automatically assigned by the GLOBE system based on the case contributor's indication of whether or not they were an author of the case source. This was not a useful metric in this study, however, as all cases were contributed by the GLOBE Cases team and thus granted the same score. Clarity scores rated how clearly the geographic entity was described in the source such that the highest scores required precise geographic descriptions in either detailed maps, GIS files, or precise coordinates.

Unlike conformance and provenance scores, clarity scores were determined by the GLOBE Cases team. Clarity scores were vetted through an iterative consensus-based process. Students were provided with a data pedigree rubric (Table 2) developed by the GLOBE team. Explanations of the process through which each student arrived at a given clarity score were recorded and provided as Contributor's Notes (which are viewable to the public online) for every case. Weekly team meetings were held to review each coded case and the Contributor's Notes that each student provided. Each case was presented to the rest of the team and the scoring logic critiqued. When disagreements about the case scoring emerged, the group vetted alternative scoring rationales and settled on a final scoring by consensus. Final commitment of each case into GLOBE was then conducted by one of two team leaders (article coauthors). Thus, quality assurance and score validation were performed in an iterative and participatory manner, which ultimately resulted in 100 percent concordance among student scorers, eliminating the need for intercoder reliability metrics. The iterative group process was the most appropriate approach due to the inherently subjective nature of study site representation, and it also helped to refine the data pedigree and ensure scoring decisions that accounted for a diversity of perspectives.

Disciplinary Coding

To test the hypothesis that case quality scores vary among academic disciplines, cases were coded based on the major disciplinary and subdisciplinary affiliation of the journals in which the studies were published following the coding protocol of Magliocca et al. (2015). Cases not obtained from peer-reviewed journals (books, theses, reports, etc.) were coded based on title publication for major disciplinary type only. A standard set of disciplines and subdisciplines was taken from www.journalseek.net and cross-referenced with the journal subject area database found at www.scimagojr.com when multiple journals were classified by multiple disciplines. Only journals explicitly categorized as multidisciplinary or interdisciplinary (e.g., *Science*, *Nature*, *Human Ecology*, etc.) are reported here as multidisciplinary.

Statistical Analysis

Statistical analysis was conducted using SPSS version 22 (IBM, Armonk, NY, USA). The original clarity and conformance score range from 1 to 4 (low to high) was collapsed into a dichotomized low–high scoring rubric owing to the low frequency of 1 and 4 clarity scores ($N = 43$) and 1 and 3 conformance scores ($N = 90$). Scores of 1 and 2 were reclassified as 0 (low), and scores of 3 and 4 were reclassified as 1 (high). The decision to collapse the scoring categories was made to maximize the sample size of categories compared in subsequent analyses to test Hypotheses 1 through 4. Statistical comparisons among dichotomized clarity and conformance scores across disciplinary categories, geographic entity, time periods, and land use types used the Kruskal–Wallis H test (one-way analysis of variance on ranks; Kruskal and Wallis 1952). The Kruskal–Wallis H test was selected as the most appropriate nonparametric method to compare distributions of scores across independent samples owing to the test's statistical power when comparing more than two samples with small sample sizes in multiple pairwise comparisons (Kruskal and Wallis 1952).

Across all tests, statistical distributions of clarity and conformance scores differed across independent variable groups as assessed by visual inspection of boxplots Pairwise comparisons among categorical groups used Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons as a post hoc analysis; adjusted p values are presented throughout the results section and in the figures and tables. It is important to

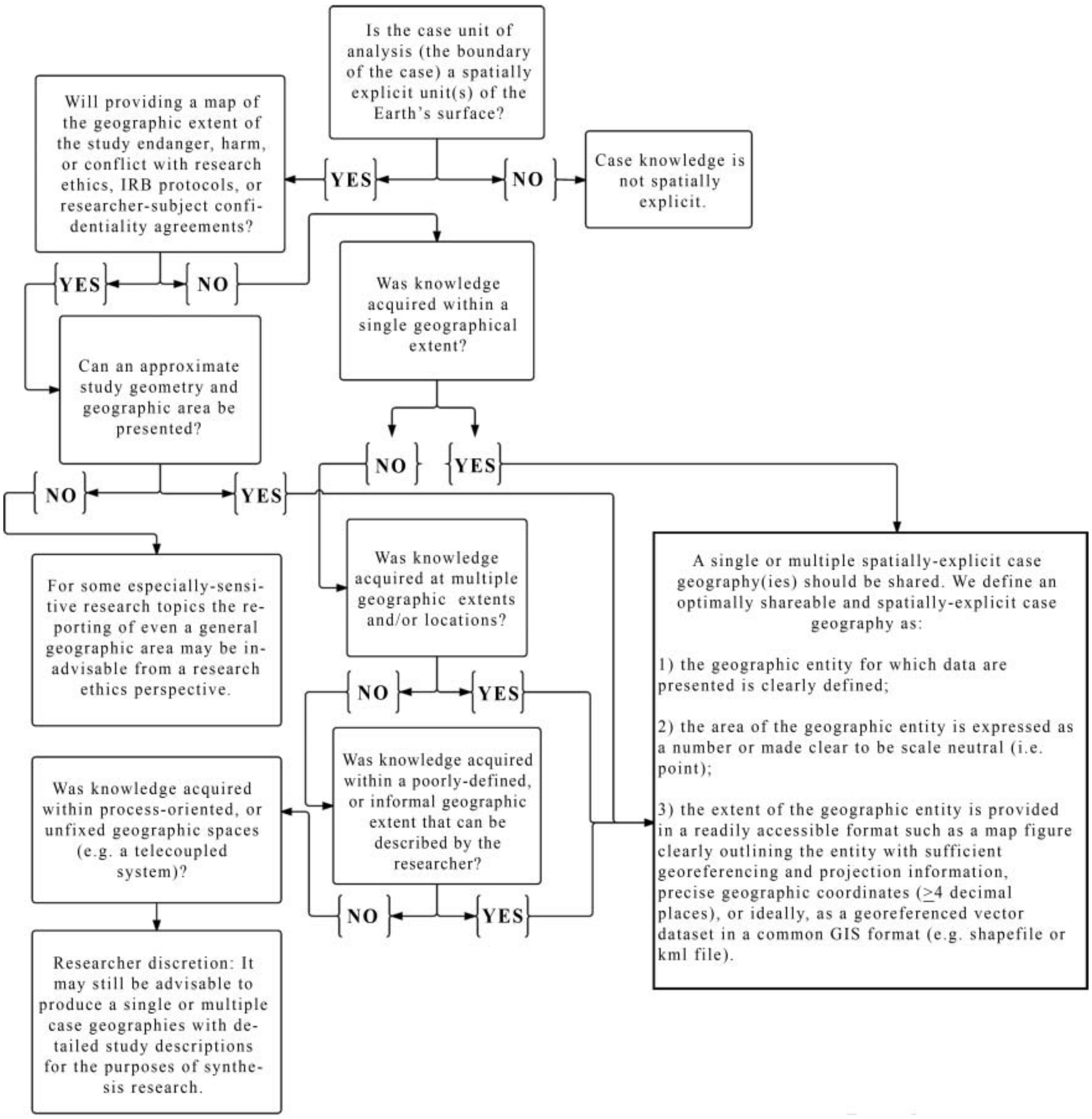

Figure 2. Concept diagram for determining whether a case meets criteria for spatially explicit sharing of case study knowledge. The concept diagram was developed through an iterative and reflexive research process following the compilation, synthesis, and reproduction of 437 cases as well as their geographic descriptions and spatial extents.

note that when unadjusted *p* values are corrected for multiple comparisons they can obtain a value of 1.0 after adjustment if the unadjusted *p* value multiplied by the number of categories being compared exceeds 1.0. Asymptomatic test statistical significance levels are reported as the value of the chi-square statistic rather than the Kruskal–Wallis H statistic, but they are the same value using this statistical test (Kruskal and Wallis 1952).

Dichotomous clarity and conformance scores before ($N = 228$) and after the year 2005 ($N = 209$; the year Google Earth was introduced, a popular, free, and relatively precise online mapping tool) were compared using the Mann–Whitney U test, which is the equivalent nonparametric statistical test to the Kruskal–Wallis test for when there are only two groups being compared (Wilcoxon–Mann–Whitney test; Mann and Whitney 1947). This statistical analysis was conducted to test the hypothesis that there would be statistically significantly higher quality scores after the introduction of Google Earth (studies after 2005) given its ability to offer researchers lacking more advanced geospatial skills a simple and relatively precise tool for describing the geographic context of case studies.

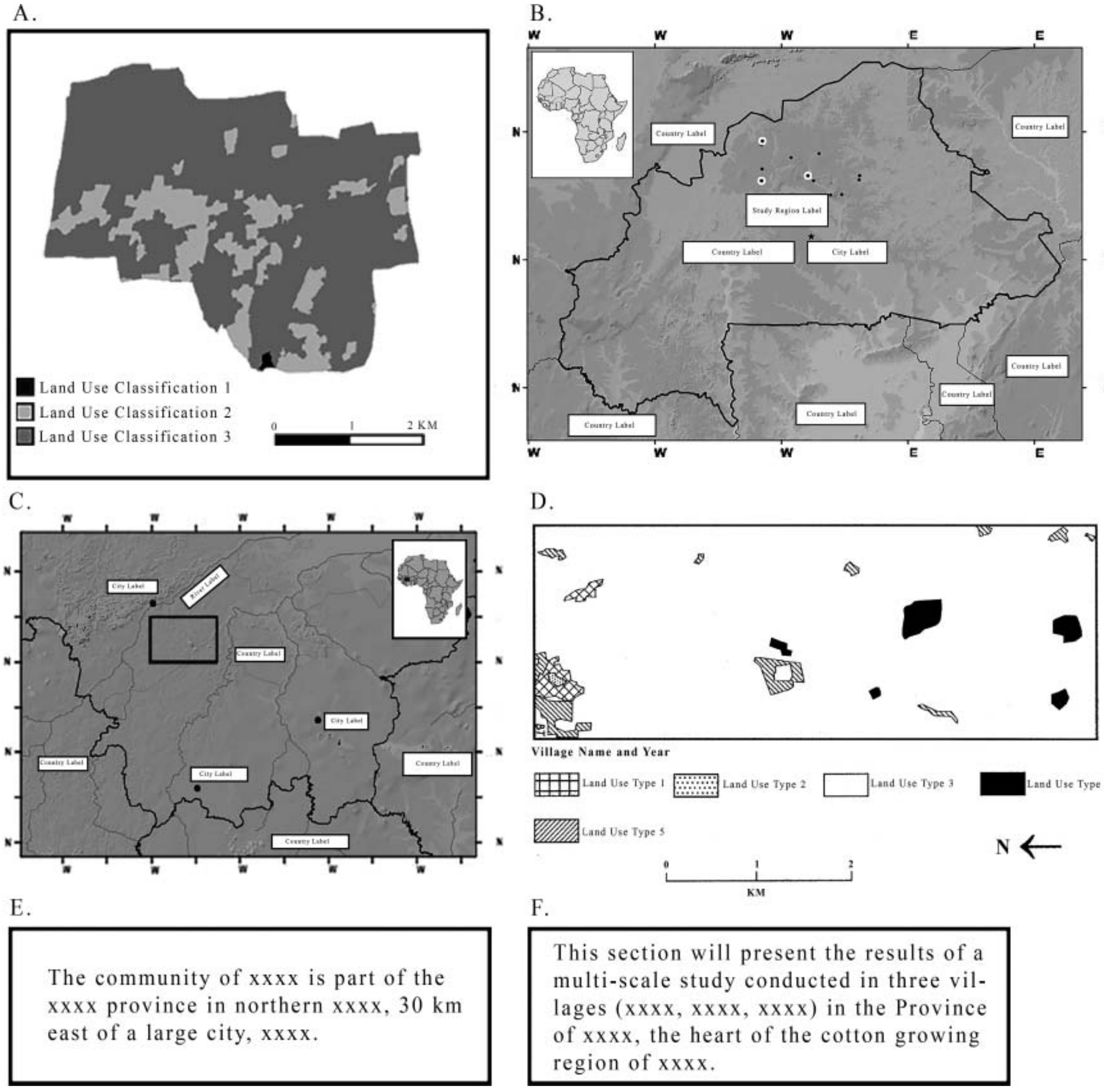

Figure 3. Illustrations of several of the most common forms of ambiguous geographies encountered during the process of reproducing 437 case geographies. The reproduced geographic descriptions (four map descriptions, two in-text descriptions) display common ambiguities as described in detail Table 3.[2] The illustrations highlight how case geographic descriptions that might appear adequate to authors and reviewers often lack sufficiently detailed information to reproduce and reuse these in spatially explicit metastudy research. (A) A common geographic description of remote sensing studies in which the border of the case is also the border of the figure (boundary representation). (B) A common representation of village studies in which the village or villages are only depicted with point locations at the country scale (point vs. nonpoint geographies, scale of representation), and only coarse geographic coordinates of study locations are provided (coordinates). (C) An example of a common representation of villages where only a coarse study area boundary is provided without the precise location of study villages (area value, scale of representation, local landmarks). (D) A local case description lacking sufficient geographic context or description for reproducing a study area (coordinates, scales of representation, local landmarks, boundary representation). (E) and (F) Two common forms of in-text descriptions of case geographic areas that are insufficient for precise georeferencing of case geographic areas without additional maps and geographic information (in-text descriptors, ephemeral or colloquial descriptors).

Results

Through the iterative process of coding and mapping 437 cases, general patterns of ambiguity in case study geographic descriptions were identified, revealing that basic guidelines for these descriptions might help to overcome barriers to case study knowledge reuse in spatially explicit synthesis research. Statistical results are then presented to test our four main hypotheses, that case quality scores would vary across major academic disciplines, by geographic entity type, by land use type, and over time based on publication date (and, relatedly, that scores would be higher after the availability of Google Earth in 2005).

Table 3. Common sources of geographic ambiguities in case studies and suggested improvements for the spatially explicit sharing of case study knowledge

Typology of ambiguity	Specific form	Description	Limitation	Suggested improvement
Descriptive	In-text description	Only in-text description of study area provided for spatially explicit (e.g., nonpoint) geographic areas	Limits ability of other researchers to georeference a spatially explicit study area	In-text study area descriptors should be accompanied by a map or set of maps
	Ephemeral or colloquial descriptors	In-text description of study area only reports colloquial or ephemeral study area names	Study area might be inaccurately mapped due to confusion over location (e.g., a colloquial name might be very common and a study might be mapped to the wrong location)	Additional (e.g., formal administrative names) should also be reported alongside colloquial or ephemeral study area names
Geographic	Area value	No area value of study provided for a spatially explicit case geography	Area values allow other researchers to check the accuracy of their own georeferencing of a study and improve accuracy of geographic reporting	Report study area values for spatially explicit case geographies
	Point versus nonpoint geographies	Studies include a point-based geography when they should include a line or polygon geography for a study occurring over a spatially explicit area	Point geographies do not accurately describe geographic areas except for very small study sites. Reporting point geographies instead of nonpoint geographies limits replicability and reduces the accuracy of a case geography	Unless a study area is very small (typically < 1 km^2), a nonpoint geography is most likely a more accurate representation of a study area
Georeferencing	Coordinates	Only rough estimates of latitude and longitude coordinates for a study are provided	Providing one set of coordinates (latitude, longitude) for a large study area limits the ability of other researchers to accurately locate or georeference a study area	The most specific coordinates possible should be provided rather than one set of coordinates intended to represent a large area
	Local landmarks	Local landmarks are not provided as geographic context in study area maps	Local landmarks (e.g., rivers, administrative boundaries, etc.) improve the ability of other researchers to accurately georeference a study area	Include local landmarks on study area maps whenever possible to increase the accuracy of georeferencing
	Scale of representation	Only including one scale of visual representation of a study geography is provided	Often sources provide either a localized geometry or a regional one when both would be better for accurate georeferencing	Include both a local study geographic extent as well as map with greater geographic extent whenever possible and appropriate
	Boundary representations	The border of the figure is also the study site boundary	When the study site boundary is used as the outermost border in a study area's map, other researchers have little peripheral information to use for georeferencing the study (common in remote sensing studies)	Place study area within broader geographic extent when visually describing the area of interest

In the process of mapping the geographic contexts of 437 cases, a systematic understanding was developed of the most common ambiguities in case study geographic descriptions that have the potential to hinder accurate and precise reproduction and reuse of case studies in spatially explicit regional and global research synthesis efforts. This process also enabled us to understand what geographic information is most useful for authors to share in case studies to reduce imprecision and error when individual cases are reused in synthesis research. The information presented in Figures 2 and 3 and Table 3 was developed through an iterative and consensus-based research process involving both the study authors and the team of graduate and undergraduate students involved in the mapping and coding of cases examined in this study.

In Figure 2, we present a practical rubric for deciding what elements of a spatially bounded case can and should be shared for reuse in spatially explicit regional and global knowledge generation. To overcome the challenges of vague or ambiguous presentations of case geographies, Figure 2 also provides three basic requirements for researchers determining whether a specific case meets the essential criteria for sharing a spatially explicit case geography, and Table 3 describes simple improvements that can be made to case geographic descriptions by case creators. Illustrative visual examples of cases exhibiting many of these forms of ambiguous geographic representation described in Table 3 are presented in Figure 3 through six different geographic depictions, with ambiguity types corresponding to those listed in Table 3 indicated in parentheses in the figure legend. These results are intended to assist case study researchers in both avoiding the presentation of ambiguous or imprecise geographic information with case studies (Table 3 and Figure 3), as well as basic guidelines for determining whether and what geographic information should be presented in spatially explicit case study research publications (Figure 2).

Quality Scores by Discipline

The distribution of 437 cases across major and minor disciplines is shown in Figure 4. Dichotomized clarity scores were statistically significantly different across disciplines ($p < 0.0005$, Kruskal–Wallis H test). Dichotomized conformance scores were also statistically significantly different across disciplinary categories ($p < .0005$, Kruskal–Wallis H test). Earth and planetary sciences mean rank dichotomized clarity and conformance scores were statistically significantly higher than all other major disciplinary groups ($p < 0.05$, Kruskal–Wallis H test; Table 4). Mean clarity and conformance values with confidence intervals by discipline are displayed in Figure 5. Based on these

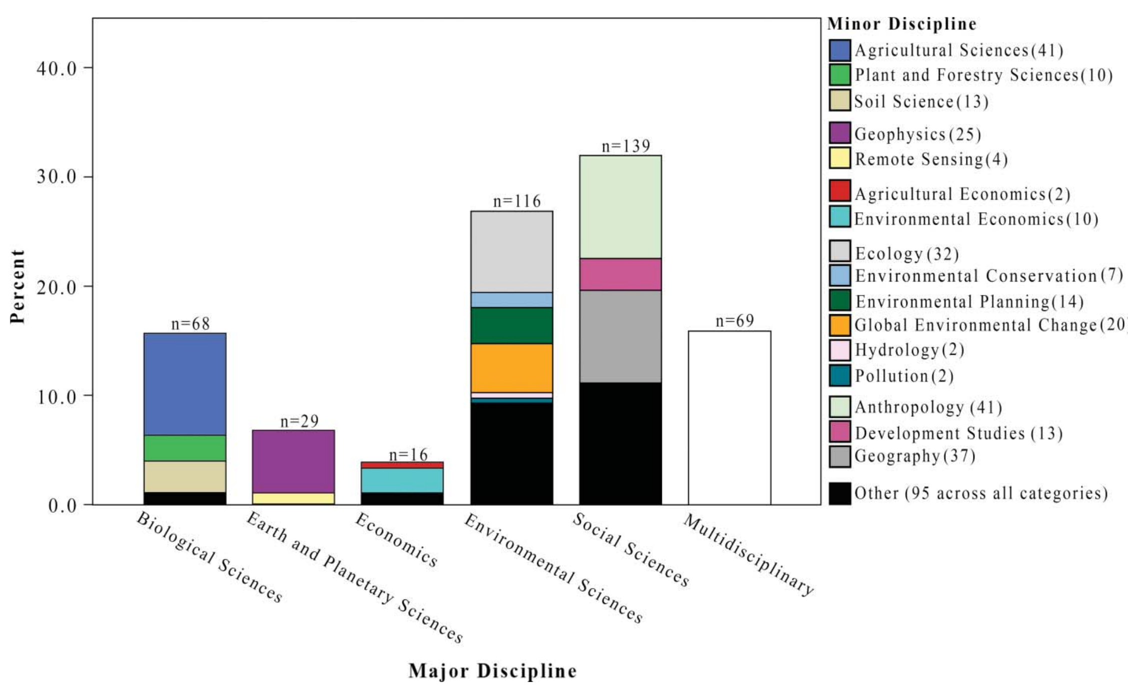

Figure 4. Number (%) and distribution of 437 cases extracted from eight land change science metastudies coded by major and minor disciplinary categories. (Color figure available online.)

Table 4. Matrix showing results with adjusted p values with a Bonferroni correction for multiple comparisons for major disciplinary categories ($N = 437$) for dichotomous clarity (top) and dichotmous conformance (bottom) scores

Clarity	Multidisciplinary	Economics	Environmental sciences	Biological sciences	Social sciences	Earth and planetary sciences
Multidisciplinary		1.0	1.0	0.266	0.061	**0.0001**
Economics			1.0	1.0	1.0	**0.026**
Environmental sciences				1.0	1.0	**0.0001**
Biological sciences					1.0	**0.018**
Social sciences						**0.01**
Earth and planetary sciences						

Conformance	Multidisciplinary	Economics	Environmental sciences	Biological sciences	Social sciences	Earth and planetary sciences
Multidisciplinary		1.0	1.0	0.228	**0.024**	**0.0001**
Economics			1.0	1.0	1.0	**0.02**
Environmental sciences				1.0	0.616	**0.0001**
Biological sciences					1.0	**0.005**
Social sciences						**0.004**
Earth and planetary sciences						

Note: Statistically significant different pairwise comparisons are shown in bold ($p < 0.05$, Kruskal–Wallis H test).

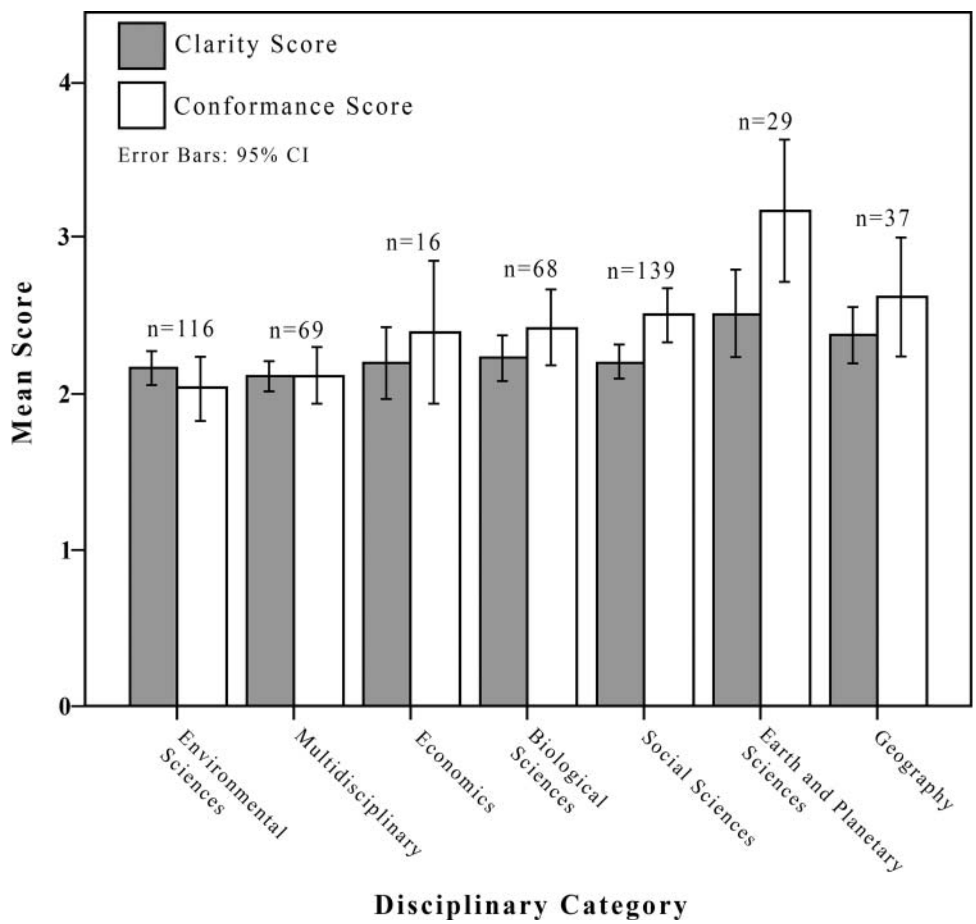

Figure 5. Mean conformance and clarity scores by major discipline type with standard error bars (confidence interval = 95 percent) for 437 cases from eight land change science metastudies. Geography is displayed on the right side of the graph for comparative purposes but those cases are included under the social sciences category for all statistics presented in the article and were not tested as a statistically independent sample.

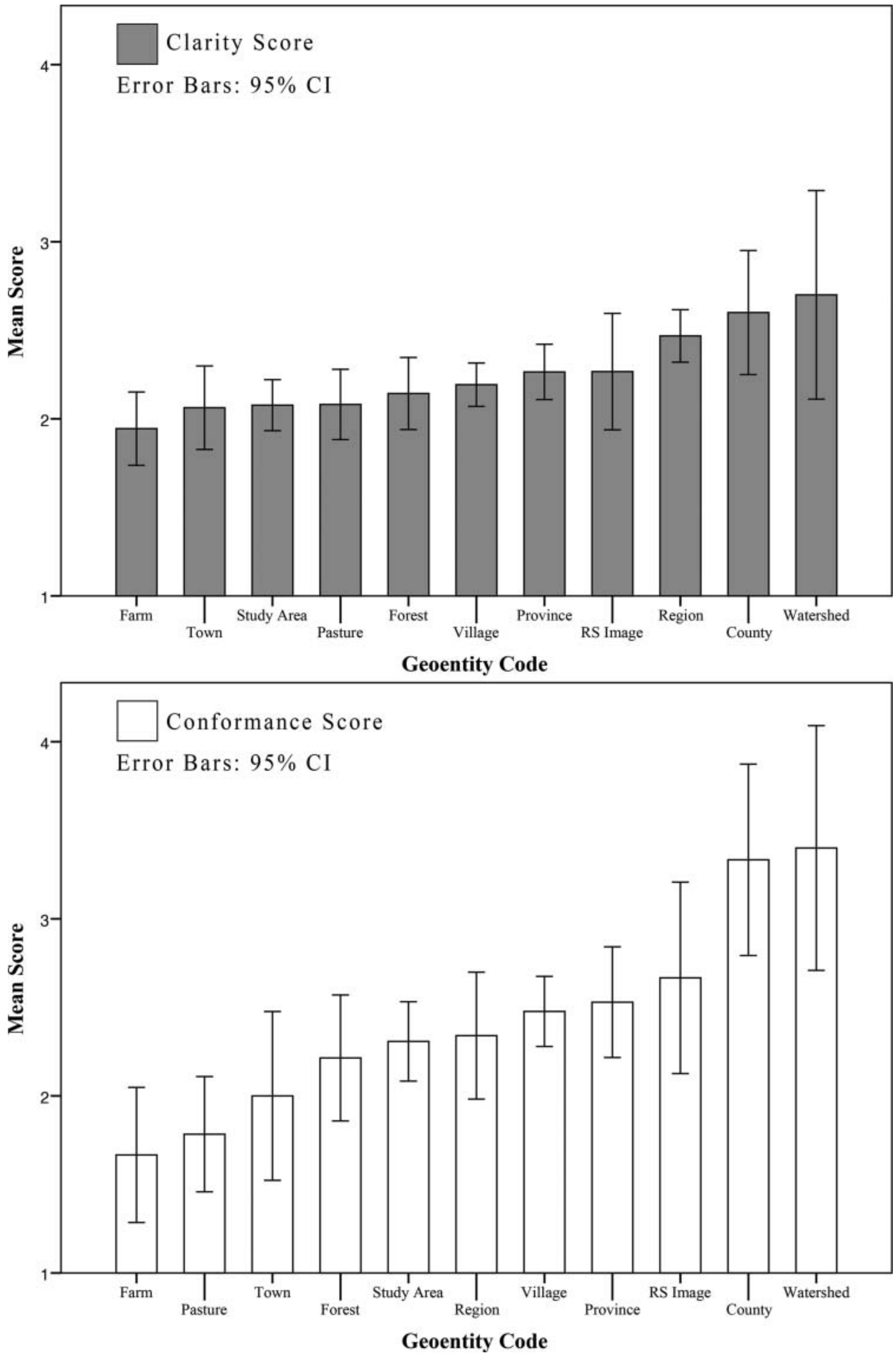

Figure 6. Mean clarity (top) and conformance scores (bottom) by most common geographic entity types with confidence interval error bars (confidence interval = 95 percent) for 381 cases from eight land change science metastudies. Bars ordered from lowest to highest mean scores.

results, we were able to accept the hypothesis that there are disciplinary differences in the quality of geographic reporting of case studies, with geospatial disciplines (earth and planetary sciences) evidencing higher quality scores than other disciplines.

Quality Scores by Geographic Entity Type

Statistically significant differences in clarity scores were observed across the eleven most common geographic entities in the collection (N = 381; sixteen

Table 5. Matrix showing results with adjusted *p* values with a Bonferroni correction for multiple comparisons for eleven geographic entity types ($N = 381$) for dichotomous clarity (top) and dichotomous conformance (bottom) scores

Clarity	Farm	Town	Study area	Forest	Pasture	Province	Village	Remote sensing image	Region	County	Watershed
Farm		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	**0.007**	**0.019**
Town			1.0	1.0	1.0	1.0	1.0	1.0	0.525	0.054	0.1
Study area				1.0	1.0	1.0	1.0	1.0	0.074	**0.013**	**0.047**
Forest					1.0	1.0	1.0	1.0	1.0	0.110	0.217
Pasture						1.0	1.0	1.0	0.672	0.071	0.165
Province							1.0	1.0	1.0	0.252	0.448
Village								1.0	1.0	0.267	0.563
Remote sensing image									1.0	1.0	1.0
Region										1.0	1.0
County											1.0
Watershed											

Conformance	Farm	Town	Study area	Forest	Pasture	Province	Village	Remote sensing image	Region	County	Watershed
Farm		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	**0.005**	**0.014**
Town			1.0	1.0	1.0	1.0	1.0	1.0	1.0	**0.042**	0.079
Study area				1.0	1.0	1.0	1.0	1.0	1.0	**0.009**	**0.036**
Forest					1.0	1.0	1.0	1.0	1.0	**0.036**	0.086
Pasture						1.0	1.0	1.0	1.0	0.055	**0.013**
Province							1.0	1.0	1.0	0.206	0.376
Village								1.0	1.0	0.219	0.476
Remote sensing image									1.0	0.485	0.798
Region										1.0	1.0
County											1.0
Watershed											

Note: Statistically significant different pairwise comparisons are shown in bold ($p < 0.05$, Kruskal–Wallis H test).

entities with fewer than eleven cases were omitted from analysis; $p < 0.0005$, Kruskal–Wallis H test).[3] There were also statistically significant differences in conformance scores across the eleven most common geographic entities in the collection ($p < 0.0005$, Kruskal–Wallis H test). Entity types watershed and county had the highest mean clarity and conformance scores (Figure 6). Statistically significant differences in mean rank dichotomized clarity and conformance scores between entity types are indicated in Table 5 ($p < 0.05$, Kruskal–Wallis H test). Mean and mean rank clarity and conformance scores by geographic entity are presented in Table 6.

To expand the sample size of categories by entity types and look for further patterns in the data set, geographic entities were recategorized by a broader

Table 6. Mean and mean rank clarity and conformance scores across the eleven most frequent geographic entity types ($N = 381$), sorted high to low by mean rank clarity score (Kruskal–Wallis H test)

Geographic entity	Mean clarity score	Mean rank clarity score	Mean conformance score	Mean rank conformance score
Watershed	2.7	267.9	3.4	271.9
County	2.6	261.5	3.3	265.5
Region	2.5	223.7	2.9	199.3
Remote sensing image	2.3	198.0	2.7	202.0
Village	2.2	193.9	2.5	197.9
Province	2.3	184.9	2.5	188.9
Pasture	2.1	175.7	1.8	179.7
Forest	2.1	175.3	2.2	172.5
Study area	2.0	167.5	2.3	171.5
Town	2.2	158.3	2.0	162.3
Farm	1.9	145.1	1.7	149.1

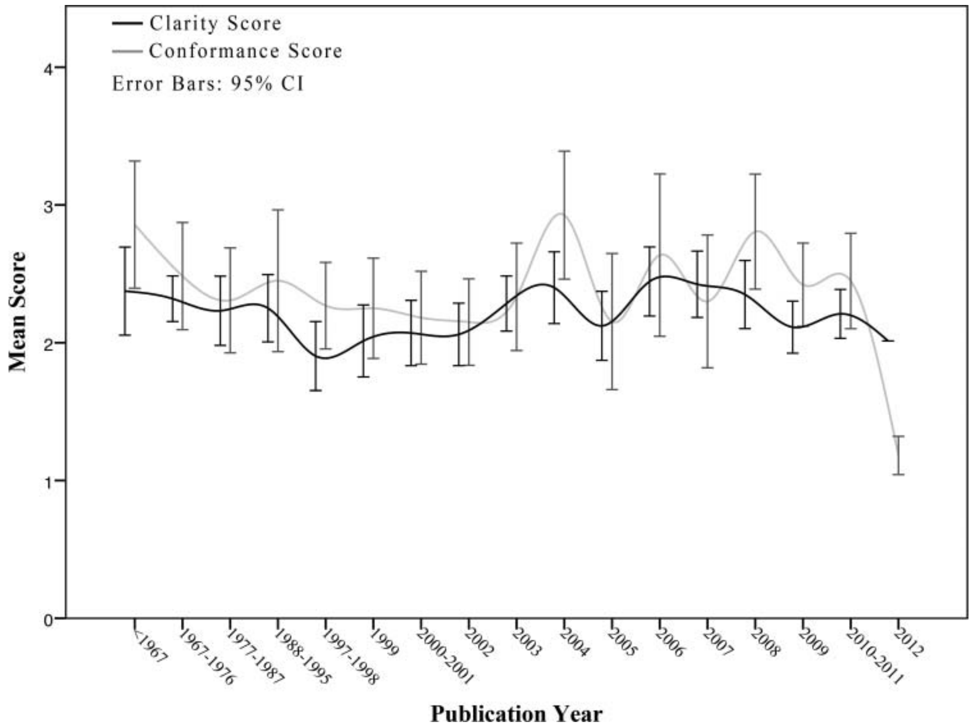

Figure 7. Ninety-five percent confidence intervals of mean clarity and conformance scores for 437 cases across seventeen equal percentile bins (5.56 percent of cases per bin). Mean interpolation lines across bins are presented as a visual aid.

typology into political, observational, and land units; no statistically significant differences in clarity or conformance scores among these categories were observed (Table A.2, $p > 0.05$, Kruskal–Wallis H test).

Quality Scores by Anthrome

The anthrome level classification of 437 case locations was determined (Ellis et al. 2010; Schmill et al. 2014). Cases spanned all six anthrome levels—wildlands ($n = 13$), seminatural ($n = 184$), rangelands ($n = 110$), croplands ($n = 76$), villages ($n = 39$), and dense settlements ($n = 15$; Ellis et al. 2010)—but no statistically significant differences were observed among their dichotomous clarity or conformance scores ($p > 0.05$, Kruskal–Wallis H test). We were therefore unable to accept the hypothesis that more intensively managed land use types (e.g., dense settlements, villages) would have statistically significantly higher quality scores than less intensively managed land use types (e.g., wildlands or rangelands).

Quality Scores by Publication Date

We failed to accept the hypothesis that clarity and conformance scores would improve over time. Clarity and conformance scores showed no general temporal trend but did show statistically significant differences based on the publication date of cases when tested across seventeen temporally binned groups using an equal percentile binning strategy as shown in Figure 7, but we found no interpretable trend in the results over time (5.56 percent of total cases per bin; $p < 0.0005$, Kruskal–Wallis H test). Number of bins was selected based on an iterative visual binning of the data across time to ensure a sufficient number of temporal cutpoints to capture changes in geographic quality reporting over time alongside the rapid acceleration of geospatial tools beginning in the 1990s. When tested for a change in clarity and conformance scores before and after the introduction of Google Earth in 2005, no statistically significant differences in dichotomized scores were observed between cases published before versus after 2005 ($p > 0.5$, Mann–Whitney U test).

Discussion

For case study researchers who define spatially explicit units of knowledge sharing in their published work, the basic requirements outlined in Figure 2 are straightforward and relatively easy to meet with techniques commonly available to all. It is therefore all the more striking that these simple methods for geographic data sharing are not consistently applied in the published case study literature. A frequent example is the use of point locations, rather than polygons, to describe geographic entities that cover significant areas of the Earth's surface. In sixty-seven cases, geographic descriptions did not allow the geographic context of a case to be reproduced in greater detail than as a point (area covered $= 0$ km^2) despite the presentation of case knowledge representing a geographic entity such as a city or forest that quite likely covered areas of at least a square kilometer or greater. Except for cases with very small geographic extents, such as studies of individual fields or ecological observational plots, studies with spatial units of knowledge generation covering geographic extents of one hectare and greater should utilize polygon representations, not points. Although it is understandable that case study researchers might sometimes feel that coupling their case study knowledge sharing within spatially explicit areas of the Earth's surface will inadequately or incompletely describe the geographic contexts of their work, for the many studies meeting the criteria in Figure 2, the sharing of precise geographic contexts together with case knowledge would greatly improve ongoing spatially explicit regional and global synthesis efforts across the land change and environmental social sciences.

Spatial Social Sciences Need to Do Better Geography

The results of this study indicate that some disciplines are more inclined to publish more precise geographic descriptions than others, with cases published in journals categorized within earth and planetary sciences producing clearer and more easily reproducible spatially explicit case geographic descriptions than those published in other journal disciplinary categories (Table 4). Likely, this finding is explained by the common use of GIS and other geospatial tools in this disciplinary category (satellite imagery, remote sensing scenes, etc.) and a general familiarity with producing and using spatially explicit knowledge and data at regional to global spatial scales. Surprisingly, cases published in journals categorized within geography (presented within the broader category of social sciences; see Figure 4) tended toward lower clarity and conformance scores than earth and planetary sciences, but the differences between scores for geography cases as a subdiscipline ($n = 37$) and earth and planetary sciences were not statistically significantly different when compared as independent categories in a separate statistical test ($p > 0.05$, Kruskal–Wallis H test).

The reasons why the clarity of geographic descriptions published in an explicitly spatial discipline might be lower than those of other disciplines cannot be decided from the data presented here owing to a relatively small sample size and the absence of more detailed factors in this study. The interdisciplinary nature of geography and its diversity of methodological approaches is one possibility (Kwan 2004), along with the possibility of a bias toward the study of types or scales of geographic entities, land systems, or geographic extents that are more difficult to spatially delineate compared with those commonly used in other disciplines. The median reported geographic extent of cases in geography (19.5 km^2) was much smaller than those of the earth and planetary sciences (1,250 km^2), and the majority of cases in geography represented knowledge from sites scaled from 1 ha to 100 km^2 (56 percent). Yet the complete set of studies conducted at this scale ($N = 118$) had modestly higher conformance scores than those at larger scales (>100 to 1,000 km^2). It is possible that further studies specifically examining these relationships within the discipline of geography might reveal intradisciplinary biases in geographic extents or entities leading to lower clarity and conformance scores.

Fuzzy Boundaries Produce Fuzzy Data

The hypothesis that quality scores would differ by geographic entity type is supported by the results presented in Table 5 ($p < 0.0005$). As frequently mapped units, it is intuitive that watershed (reproducible based on terrain data maps in a GIS) and county (an easily reproducible administrative unit) would receive higher clarity and conformance scores compared to more ambiguous geography types such as farm, town, or study area that have less explicit spatial delineations and are more difficult to map and reproduce from published studies (Tables 5 and 6). To further investigate this hypothesis, a post hoc analysis combining entity types into broader categories (political, observational, and land units) was conducted but did not reveal significant differences or further explain differences in scores across entity types ($p > 0.05$, Table A2). Qualitatively, there were no apparent patterns between geographic entities with higher quality scores and disciplines with higher scores, but the limited number of cases across entity types by disciplines prevented quantitative comparison (Table A3).

The results of the statistical tests do raise the issue of how one should best represent geographic entities with fuzzy boundaries or with multiple ways of demarcating boundaries. For example, villages represent a particularly fuzzy form of geographic entity (e.g., the boundary of a village could be based on an administrative boundary, informal local knowledge, or parcel sizes; Figure 1), and we recommend that researchers be explicit in describing how such boundaries are defined. We are not advocating, however, for a one-size-fits-all approach to how the boundaries of such an entity should be defined; such decisions need to be made by individual researchers informed by the context of the study. Instead, individual cases should sufficiently describe how a boundary was selected, and present sufficient information to improve the clarity and reproducibility of the geographic extent of the case (Figure 2).

Geographic Description Has Not Improved Over Time

We were surprised by the finding that clarity and conformance scores did not improve over time (Figure 7). The dramatic growth in availability of geospatial tools, including Global Positioning System (GPS), GIS, and especially free and open-source mapping programs such as QGIS and Google Earth, was expected to cause long-term increases in case geographic quality scores over the time frame of this study (1936–2012). The absence of any statistically significant upward trend in the quality of case geographic representation was therefore both unexpected and striking (Figure 7). What is clear is that the remarkable advances in geospatial tool availability of recent decades have, in themselves, had little effect on the quality of geographic representation in published case study research. This statistical finding mirrors the subjective experience of the team in mapping the 437 cases employed in these analyses and helped drive us to elaborate these widespread long-term practices of ambiguous geographic description in Table 3 and Figure 3.

A Persistent Problem: Ambiguous Spatiality Challenges Synthesis Research

There are many different reasons why studies operating within a spatial context might be difficult or even impossible to describe within Cartesian space, justifiably leading to ambiguous geographic descriptions (Figure 2). In studies emphasizing interactive processes, spatial fluidity, and the interconnectivity of sites, these spatially delimited approaches to geographic representation might be impossible to reconcile with some research agendas and might even be seen as promoting notions of hierarchical scale that certain studies seek to deconstruct or critique. Nevertheless, for many researchers, including critical scholars and human geographers, the boundaries of political administrative units, biophysical areas, or artificial study plots might also be essential to a study's design or even the object of study itself. Accurately and precisely mapping these boundaries and sharing this information with others has the potential to enable broader and more general analyses aimed at understanding how global processes and flows are acted out on and across social sites globally and within multiple geographic contexts.

It is relevant to note how other spatially oriented disciplines have also grappled with questions of scaling between local and global research in efforts to produce generalizable theories on environmental change (Rindfuss et al. 2004, 2007; Lambin and Geist 2006; Verburg, Neumann, and Nol 2011; Verburg et al. 2012). Although physical geography and land change science might engage less critically in their conceptualizations of scale and space as analytical tools (Moore 2008), there is nevertheless a robust literature outside the remit of human geography asking related questions about spatial representation and linkages between fine-grained studies of relatively small geographic extents and global patterns and processes (Jelinski and Wu 1996; Geist and Lambin 2002; Kwan 2004; Lambin and Geist 2006; Goodchild, Yuan, and Cova 2007; Turner, Lambin, and Reenberg 2007; Goodchild 2004; Karl et al. 2013). In the GISciences, theoretical and technological research has advanced methodologies for selecting and demarcating the appropriate spatiotemporal contexts exerting influence on study subjects (Kwan 2012, 2013). Kwan (2000, 2012, 2013) and Goodchild (2004, 2012) described how the GISciences and new spatial technologies such as GPS tracking can help reconcile issues related to the modifiable areal unit problem (MAUP; Openshaw 1984) and the more recently described uncertain geographic context problem (UGCoP) to improve the selection of appropriate spatiotemporal contexts and zones of analysis used in social science studies. These advances in describing and conceiving of temporal units of case analysis present additional challenges in how case researchers make clear the boundaries of a case both spatially and temporally. By highlighting the persistent problem of ambiguous geographic description in the reporting and sharing of spatially explicit case study knowledge, our work aims to complement rather than conflict with efforts to advance these important theoretical and methodological engagements with scale and spatial representation.

Improving the Representation and Sharing of Spatially Explicit Knowledge

Despite the finding that earth and planetary sciences studies appear to represent case geographies in a more spatially explicit and clear manner compared with other major disciplines, our results have not revealed any specific causal relationships that might explain differences in the relative quality of geographic descriptions across land change science metastudies. Still, by metastudy and exploration of case study geographic reporting, it has become absolutely clear that there is a basic need to overcome disciplinary cultural tolerances to ambiguous geographic representation in spatial research. As has been previously demonstrated for ecological studies, even the inclusion of accurate geographic coordinates representing a study area's centroid as a scale-neutral point are often lacking from published studies, a relatively poor form of geographic representation for spatially bounded cases covering an area of the Earth's surface greater than one hectare (Karl et al. 2013). The results presented here reinforce the notion that there is a need for greater development of common language and guidelines for describing the geographic context of spatially explicit case research. We believe that the guidelines presented in this article begin to address this particular barrier to knowledge synthesis.

In addition to the recommendations outlined in Figure 2 and Table 3, there are other practical opportunities for improving the replicability of spatially explicit knowledge and how it is shared across a diversity of spatially oriented scholarship. First, we believe that it is essential that more scholarly journals and their publishers enable—or, better, require—researchers to share and make available for free downloadable spatial files (shapefiles or kml) of the geographic extent of studies. Although an increasing number of journals and publishers offer this option, many, including top-tier geography journals such as the *Annals of the American Association of Geographers* and *The Professional Geographer* do not explicitly do so. This will enable synthesis researchers to understand the geographic extent across which the findings of a study are valid and avoid producing errors in attempting to reproduce case geographies themselves. In the meantime, we encourage researchers to make such files available and downloadable through their own personal or institutional Web sites.

Second, recently developed tools such as GLOBE (globe.umbc.edu) and JournalMap (www.journalmap.org) are important new platforms in which researchers can share, compare, and download the geographic location or extents of case studies and conduct analyses connecting local case study research with global data sets (Ellis 2012; Karl et al. 2013). Such efforts represent an important development for spatially oriented disciplines to understand the global and regional contexts of local case study research in a spatially explicit manner. We hope that more researchers will consider using such platforms to share their research in a spatially explicit manner that preserves the geographic fidelity of their work. Third, we note that open data sharing has been shown to provide significant benefits to the authors of published studies, by increasing the reuse and citation of published work, a fundamental reason why individual case study researchers should embrace the processes of open sharing of their published work in the most data-rich formats available (Piwowar and Vision 2013).

Conclusions

The divide between local and global knowledge generation in the social and environmental sciences is likely to persist. This study, however, identifies one source of this division and helps to bridge this divide by enhancing the spatially explicit reuse of knowledge generated at more local geographic extents in global and regional scale synthetic research. Although our analysis draws on a limited set of cases used in eight land change metastudies, its results are more broadly relevant to all who produce case studies in local geographic contexts and to those who use them to synthesize broader scale insights. Although critiques of scale specificity are merited, there is a clear lack of significant improvement in case geographic descriptions over time, despite advances in widely available tools to support this. We suggest that the prevalence of ambiguous geographic representations observed over time has little to no relation to the scale-theoretical concerns of case study researchers but rather has resulted from the tolerance of ambiguous geographic descriptions in the publications of some disciplines, geography among them, even when the geographic contexts of case knowledge are explicit in principle. We hope that in highlighting practical strategies for clear and concise case geographic context reporting, this work will help to improve efforts to connect fine-grained and coarser-grained research agendas and toward an overall improvement in how social and environmental scientists report on and use the geographic contexts of their research.

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Notes

1. Additional case scoring documentation is available at http://globe.umbc.edu/documentation-overview/cases-documentation/.
2. Maps and descriptions are reproductions of actual geographic descriptions encountered during research. To retain author and publication confidentiality, place names, land use classification types, coordinates, and locations on continent-scale maps (7b, 7c) were removed and replaced with generic placeholder text. All figures presented here demonstrate common forms of case geographic descriptions encountered during the review and reproduction of 437 cases. The descriptions selected and presented here were chosen for their clear depiction of these issues, not because they represented especially poor case geographic descriptions. Bibliographic information for figure sources is not included to protect the identities of the authors but is available on request from the first author.
3. Geoentity analysis excludes fifty-six studies from less common entity types: basin ($n = 2$), catchment ($n = 5$), city ($n = 2$), country ($n = 4$), district ($n = 9$), island ($n = 3$), municipality ($n = 4$), parcel ($n = 1$), park ($n = 2$), plot ($n = 3$), protected area ($n = 5$), quadrat ($n = 2$), river ($n = 1$), state ($n = 3$), and unknown ($n = 10$) geographic entities.

References

Achten, W., and L. Verchot. 2011. Implications of biodiesel-induced land-use changes for CO_2 emissions: Case studies in tropical America, Africa, and Southeast Asia. *Ecology and Society* 16 (4): 14.

Brenner, N. 2001. The limits to scale? Methodological reflections on scalar structuration. *Progress in Human Geography* 25 (4): 591–614.

Costanza, R., S. O. Funtowicz, and J. R. Ravetz. 1992. Assessing and communicating data quality in policy-relevant research. *Environmental Management* 16 (1): 121–31.

Cox, M. 2014. Understanding large social-ecological systems: Introducing the SESMAD project. *International Journal of the Commons* 8 (2): 265–76.

———. 2015. A basic guide for empirical environmental social science. *Ecology and Society* 20 (1): 63.

Downey, L. 2006. Using geographic information systems to reconceptualize spatial relationships and ecological context. *AJS: American Journal of Sociology* 112 (2): 567–612.

Dunn, O. J. 1964. Multiple comparisons using rank sums. *Technometrics* 6 (3): 241–52.

Eclesia, R., E. Jobbagy, R. Jackson, F. Biganzoli, and G. Pineiro. 2012. Shifts in soil organic carbon for plantation and pasture establishment in native forests and grasslands of South America. *Global Change Biology* 18 (10): 3237–51.

Ellis, E. C. 2012. The GLOBE Project: Accelerating global synthesis of local studies in land change science. *Newsletter of the Global Land Project* 8:5–6.

Ellis, E. C., K. Klein Goldewijk, S. Siebert, D. Lightman, and N. Ramankutty. 2010. Anthropogenic transformation of the biomes, 1700 to 2000. *Global Ecology and Biogeography* 19 (5): 589–606.

Flyvbjerg, B. 2006. Five misunderstandings about case-study research. *Qualitative Inquiry* 12 (2): 219–45.

Funtowicz, S. O., and J. R. Ravetz. 1990. *Uncertainty and quality in science for policy*. (Vol. 15). New York: Springer.

Geist, H. J., and E. F. Lambin. 2002. Proximate causes and underlying driving forces of tropical deforestation. *BioScience* 52 (2): 143.

Global Administrative Areas. 2012. GADM database of Global Administrative Areas, version 2.0. http://www.gadm.org (last accessed 2 January 2016).

Globe Cases Team. 2015. Margulies case collection. *GLOBE Collection of Georeferenced Case Studies*. http://globe.umbc.edu/app/#/manager/collections/view/990 (last accessed 5 December 2015).

Goodchild, M. F. 2004. GIScience, geography, form, and process. *Annals of the Association of American Geographers* 94 (4): 709–14.

———. 2012. The future of Digital Earth. *Annals of GIS* 18 (2): 93–98.

Goodchild, M., R. Haining, and S. Wise. 1992. Integrating GIS and spatial data analysis: Problems and possibilities. *International Journal of Geographical Information Systems* 6 (5): 407–23.

Goodchild, M. F., and L. Li. 2012. Assuring the quality of volunteered geographic information. *Spatial Statistics* 1:110–20.

Goodchild, M. F., M. Yuan, and T. J. Cova. 2007. Towards a general theory of geographic representation in GIS. *International Journal of Geographical Information Science* 21 (3): 239–60.

IBM Corp. Released 2013. IBM SPSS Statistics for Macintosh, Version 22.0. Armonk, NY: IBM Corp.

International Union for Conservation of Nature and United Nations Environment Programme-World Conservation Management Center. 2015. The world database on protected areas (WDPA). Cambridge, UK: United Nations Environment Programme-World Conservation Management Center. http://www.protectedplanet.net (last accessed 2 January 2016).

Jelinski, D. E., and J. Wu. 1996. The modifiable areal unit problem and implications for landscape ecology. *Landscape Ecology* 11 (3): 129–40.

Karl, J. W., J. E. Herrick, R. S. Unnasch, J. K. Gillan, E. C. Ellis, W. G. Lutters, and L. J. Martin. 2013. Discovering ecologically-relevant knowledge from published studies through geo-semantic searching. *BioScience* 63:674–82.

Kauffman, J., F. Hughes, and C. Heider. 2009. Carbon pool and biomass dynamics associated with deforestation, land use, and agricultural abandonment in the neotropics. *Ecological Applications* 19 (5): 1211–22.

Keys, E., and W. J. McConnell. 2005. Global change and the intensification of agriculture in the tropics. *Global Environmental Change* 15 (4): 320–37.

Kruskal, W. H., and W. A. Wallis. 1952. Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, 47 (260): 583–621.

Kwan, M. P. 2000. Analysis of human spatial behavior in a GIS environment: Recent developments and future prospects. *Journal of Geographical Systems* 2 (1): 85–90.

———. 2004. Beyond difference: From canonical geography to hybrid geographies. *Annals of the Association of American Geographers* 94 (4): 756–63.

———. 2012. The uncertain geographic context problem. *Annals of the Association of American Geographers* 102 (5): 958–68.

———. 2013. Beyond space (as we knew it): Toward temporally integrated geographies of segregation, health, and accessibility. *Annals of the Association of American Geographers* 103 (5): 1078–86.

Lambin, E. F., and H. J. Geist. 2006. *Land-use and land-cover change: Local processes and global impacts*. New York: Springer.

Laney, R. M. 2002. Disaggregating induced intensification for land-change analysis: A case study from Madagascar. *Annals of the Association of American Geographers* 92 (4): 702–26.

Magliocca, N. R., T. K. Rudel, P. H. Verburg, W. J. McConnell, O. Mertz, K. Gerstner, A. Heinimann, and E. C. Ellis. 2015. Synthesis in land change science: Methodological patterns, challenges, and guidelines. *Regional Environmental Change* 15 (2): 211–26.

Mann, H. B., and D. R. Whitney. 1947. On a test of whether one of two-random variables is stochastically larger than the other. *The Annals of Mathematical Statistics* 18 (1): 50–60.

Marston, S. A. 2000. The social construction of scale. *Progress in Human Geography* 24 (2): 219–42.

Marston, S. A., J. P. Jones, and K. Woodward. 2005. Human geography without scale. *Transactions of the Institute of British Geographers* 30 (4): 416–32.

Miller, H. 2007. Place-based versus people-based geographic information science. *Geography Compass* 1 (3): 503–35.

Moore, A. 2008. Rethinking scale as a geographical category: From analysis to practice. *Progress in Human Geography* 32 (2): 203–25.

Moritz, M., J. Giblin, M. Ciccone, A. Davis, J. Fuhrman, M. Kimiaie, S. Madzsar, K. Olson, and M. Senn. 2011. Social risk management strategies in pastoral systems: A qualitative comparative analysis. *Cross-Cultural Research* 45 (3): 286–317.

Murdock, G. P., and D. R. White. 1969. Standard cross-cultural sample. *Ethnology* 8:329–69.

Openshaw, S. 1984. *The modifiable areal unit problem*. Norwich, UK: Geo Books.

Piwowar, H. A., and T. J. Vision. 2013. Data reuse and the open data citation advantage. *PeerJ* 1:e175.

Ragin, C. C., and H. S. Becker. (Eds.) (1992). *What is a case? Exploring the foundations of social inquiry*. Cambridge, UK: Cambridge University Press.

Rindfuss, R. R., B. Entwisle, S. J. Walsh, C. F. Mena, C. M. Erlien, and C. J. Gray. 2007. Frontier land use change: Synthesis, challenges, and next steps. *Annals of the Association of American Geographers* 97 (4): 739–54.

Rindfuss, R. R., S. J. Walsh, B. L. Turner, J. Fox, and V. Mishra. 2004. Developing a science of land change: Challenges and methodological issues. *Proceedings of the National Academy of Sciences of the United States of America* 101 (39): 13976–81.

Rudel, T. K. 2008. Meta-analyses of case studies: A method for studying regional and global environmental change. *Global Environmental Change* 18 (1): 1825.

Sayre, N. F. 2005. Ecological and geographical scale: Parallels and potential for integration. *Progress in Human Geography* 29 (3): 276–90.

Schmill, M. D., L. M. Gordon, N. R. Magliocca, E. C. Ellis, and T. Oates. 2014. GLOBE: Analytics for assessing global representativeness. In *2014 Fifth International Conference on Computing for Geospatial Research and Application*, 25–32. Washington, DC: IEEE.

Turner, B. L., II, R. O. Hanham, and A. V. Portararo. 1977. Population pressure and agricultural intensity. *Annals of the Association of American Geographers* 67 (3): 384–96.

Turner, B. L., II, R. E. Kasperson, W. B. Meyer, K. M. Dow, D. Golding, J. X. Kasperson, R. C. Mitchell, and S. J. Ratick. 1990. Two types of global environmental change: Definitional and spatial-scale issues in their human dimensions. *Global Environmental Change* 1:14–22.

Turner, B. L., II, E. F. Lambin, and A. Reenberg. 2007. The emergence of land change science for global

environmental change and sustainability. *Proceedings of the National Academy of Sciences* 104 (52): 20666–71.
van Vliet, J., N. R. Magliocca, B. Buchner, E. Cook, J. M. Rey Benayas, E. C. Ellis, A. Heinimann, et al. 2016. Meta-studies in land use science: Current coverage and prospects. *Ambio* 45 (1): 15–28.
van Vliet, N., O. Mertz, A. Heinimann, T. Langanke, C. Adams, P. Messerli, S. Leisz, et al. 2012. Trends, drivers and impacts of changes in swidden cultivation in tropical forest-agriculture frontiers: A global assessment. *Global Environmental Change* 22 (2): 418–29.
van Vliet, J., N. R. Magliocca, B. Büchner, E. Cook, J. M. Rey Benayas, E. C. Ellis, A. Heinimann, et al. 2016. Meta-studies in land use science: Current coverage and prospects. *Ambio* 45 (1): 15–28.
van Vliet, N., A. Reenberg, and L. V. Rasmussen. 2013. Scientific documentation of crop land changes in the Sahel: A half empty box of knowledge to support policy?. *Journal of Arid Environments* 95:1–13.
Verburg, P. H., N. Crossman, E. C. Ellis, A. Heinimann, P. Hostert, O. Mertz, H. Nagendra,et al. Forthcoming. Land system science and sustainable development of the earth system: A global land project perspective. *Anthropocene*. Advance online publication.
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 (3): 034019.
Verburg, P. H., K. Neumann, and L. Nol. 2011. Challenges in using land use and land cover data for global change studies. *Global Change Biology* 17 (2): 974–89.
Verburg, P. H., S. van Asselen, E. H. van der Zanden, and E. Stehfest. 2012. The representation of landscapes in global scale assessments of environmental change. *Landscape Ecology* 28 (6): 1067–80.
Yin, R. K. 2013. *Case study research: Design and methods*. 5th ed. Thousand Oaks, CA: Sage.
Young, A. L., and W. G. Lutters. 2015. (Re)defining land change science through synthetic research practices. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, ed. D. Cosley, A. Forte, L. Ciolfi, and D. McDonald, 431–42. Vancouver, BC, Canada: ACM.

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Appendix

An analysis reclassifying all of the GLOBE geographic entities types into political units, observational units, and land units revealed no statistically significant differences in dichotomous (high–low) clarity and conformance scores based on a Kruskal–Wallis H test (Figure A2). The binning structure is described in Table A2. A Kruskal–Wallis H test was conducted to determine if there were differences in dichotomous clarity and conformance scores between observational unit ($n = 72$), land unit ($n = 112$), and political unit ($n = 243$) geographic entity categories. Values are mean ranks unless otherwise stated. Distributions of unit scores were not similar for all groups, as assessed by visual inspection of a boxplot. Unit scores increased from observational units (200.41), to land units (205.28), to political units (222.05) based on clarity scores and from observational units (204.41), to land units (207.38), to political units (219.90) based on conformance scores, but the differences were not statistically significant for clarity, $\chi^2(2) = 3.914$, $p = .141$, or conformance, $\chi^2(2) = 2.165$, $p = .339$.

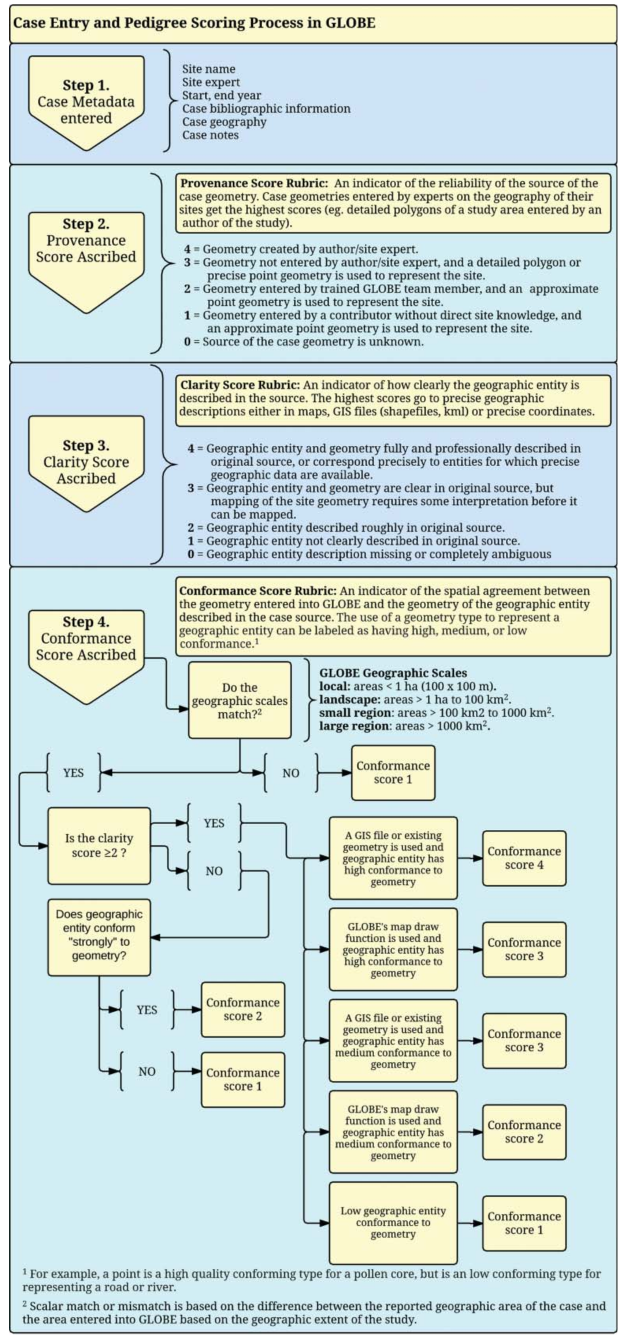

Figure A1. Conceptual flowchart and algorithm visualization for how GLOBE case quality scores are generated based on a pedigree scoring rubric (outlined in Table 2). (Color figure available online.)

Table A1. Geographic entity types with definitions and examples as employed in the coding and case creation procedure for 437 cases

Name	Definition	Examples
Archaeological site	An archaeological site with area less than 100 ha	Archaeological research sites < 100 ha (larger, see archaeological complex)
Archaeological complex	An area of archaeological observation with area greater than 100 ha	An archaeological site group, or large urban complex or cluster
Built structure	Human built structures, including buildings, airports, dams, hospitals, etc. *Note*: Linear structures including irrigation canals have their own geoentity	School, hospital, power station, airport
Catchment	An area of land where surface water converges to a single point at a lower elevation, usually the exit of the basin, where the waters join another water body	Map or geometry of drainage basin, catchment area provided
City	A relatively large human settlement with an administrative or political boundary	Paris, New York City, Baltimore, Oxford
Country	Most commonly a sovereign state, or a state occupied by another sovereign state	Germany, Algeria, Mexico
County	County/parish (political unit), could include a large city	Geometry of county area provided or administrative boundary of county available; for example, Baltimore County
District	An administrative division	Congressional districts (United States), Arrondissement (Belgium)
Farm	Land managed for agriculture by some entity, could be composed of multiple parcels	Household farms, commercial farms, or state farms
Farm field	A single managed field within a farm	Map or geometry of field area provided or exact location of field provided
Forest	Administrative area defined as forest or managed for forestry	Map or geometry of forest boundaries provided or administrative boundaries of forest available; for example, Sequoia National Forest
GPS point	Point location(s) obtained from GPS	Geographic coordinates are presented and there is no area defined for them (i.e., plots, parcels, etc.)
Island	Any subcontinental land that is completely surrounded by water	Hawaiian islands
Lake	A body of water surrounded by land larger and deeper than ponds that are not part of an ocean	Lake Michigan
Linear built structure	Human built linear structures including railroad lines, walls, and irrigation canals that are best described by a line geometry	Railroad lines, irrigation canal
Municipality	Usually an urban administrative division having corporate status and usually powers of self-government or jurisdiction. Also refers to third-order administrative divisions	Cities and towns with self-governing powers
Pasture	An area of land used to graze livestock	Map or geometry of pasture area provided or exact location of pasture provided
Principality	Either a monarchical feudatory or a sovereign state, ruled or reigned over by a monarch	Monaco
Parcel	An area of land with known boundaries and ownership	Geometry of parcel area provided or exact location of parcel provided
Park	Land managed for public use by some entity	Map or geometry of park area provided or administrative boundaries of park available. Example: Yosemite National Park
Plot	Small areas used for research or monitoring purposes (<1 GLU)	Geometry of plot area provided or exact location of plot provided

(*Continued on next page*)

Table A1. (*Continued*)

Name	Definition	Examples
Point area	Area around defined center point	Example: From fu_2009: "Area of #ha around point XY," or "Area within #km of point XY," "Village covering #ha, centered at point XY"
Populated point	Approximate point location of an unspecified populated area. Used when it is not known whether the populated area is a city, town, village, or other agglomeration of built structures where people live and work that would be better described by a geoentity with a spatial extent but is lacking sufficient geographic information. Populated points automatically receive clarity scores of 2 and conformance scores of 1	A city, town, village, or other populated place whose source is lacking sufficient geographic information to describe with a spatially explicit geographic area
Protected area	Must be defined using standards	Standards for defining and mapping protected areas are at http://www.wdpa.org/
Province	Province or state (United States; political unit)	Manitoba, Canada; Maryland, United States
Quadrat	Square sample areas used for research	Geometry of quadrat area provided or exact location of quadrat provided
Region	Larger area, defined by some formal or common designation (political, environmental, cultural)	Amazonia
River	A flowing body of water larger than a stream	Amazon River
Road	Road, highway	Interstate 95
Remote sensing image scene	Footprint of a remotely sensed data scene. This could include LandSat, SPOT, IKONOS, etc.	Geometry or exact location of remote sensing scene area provided
Sample point	Location of a sample point	Soil samples, vegetation samples (areas too small to map)
Sediment archive	A single sediment core, or set of cores obtained within a 100 ha area	Sediment archives, including soil pollen and charcoal cores or samples for paleoecological analysis
State	A state is an organized community living under one government. The term is also applied to federated states that are members of a federal union, which is the sovereign state	Ohio (United States), France (a sovereign state; but see country)
Stream	A flowing body of water smaller than a river	The Tilla Stream
Study area	Author-defined study area (>1 GLU) without formal designation	Larger areas drawn on map by author in a publication
Terrain feature	Physiographic features, including hill, mountain, beach, etc. *Note*: Watershed, wetland, stream, and river have geoentities	Hill, beach, valley, cove, peninsula, etc
Town	A human settlement smaller than a city with an administrative or political boundary	Taos, New Mexico (United States)
Unknown point	Point location(s) derived from an unknown method	
Unknown	No information on geographic entity available	Only a place name is provided but no other information, and it is clear that the study does not refer to the entire place
Village	Village (political unit)	Geometry of village area provided or administrative boundary of village available. Example: Xiejia Village
Watershed	Area that makes up the watershed of a body of water	Chesapeake Bay watershed
Wetland	A land area that is saturated with water, either permanently or seasonally, such that it takes on the characteristics of a distinct ecosystem	Florida Everglades (United States), The Pantanal (Brazil)

Note: GPS = global positioning system; GLU = global land unit.

Table A2. GLOBE geographic entity types were reclassified as shown into three categories

Observational unit ($n = 112$)	Land unit ($n = 112$)	Political unit ($n = 243$)
Plot	Field	City
Quadrat	Protected area	Country
Remote sensing image	Farm	County
Study area	Park	District
	Pasture	Municipality
	Basin	Parcel
	Catchment	Province
	Forest	Region
	Island	State
	River	Town
	Watershed	Village

Note: *Observation units* refers to abstract units of analysis produced either by the researcher in an experimental design or based on the application of a spatial technology (e.g., remote sensing image). *Land units* refers to spatial units of analysis that represent a biophysical feature. *Political units* refers to units of analysis designated by governments as administrative units.

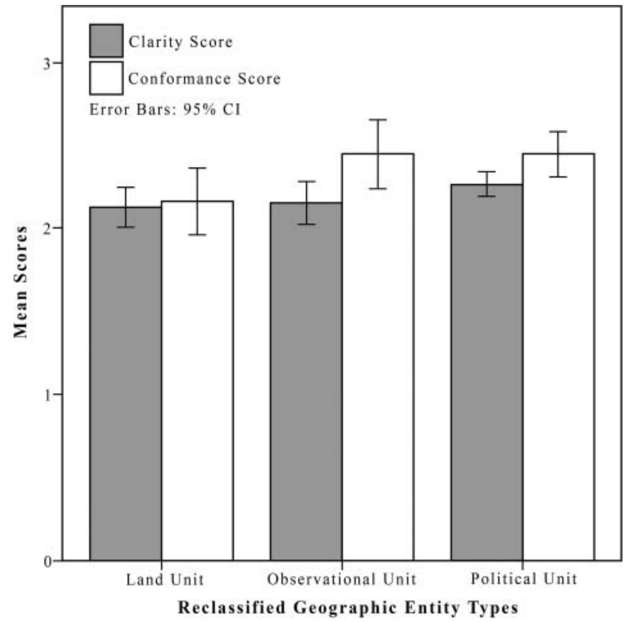

Figure A2. Mean clarity and conformance scores for geographic entity types binned into three units of analysis. Ten cases with "unknown" geographic entities were excluded from the analysis ($N = 427$).

Table A3. Cross-tabulation count of eleven most common geographic entity types ($N = 381$) by major disciplinary category

Geographic entity	Biological sciences	Earth and planetary sciences	Economics	Environmental sciences	Multidisciplinary	Social sciences	Total
County	1	2	0	3	3	6	15
Farm	7	0	0	9	1	1	18
Forest	17	0	0	11	0	0	28
Pasture	10	1	0	23	0	3	37
Province	4	0	2	8	20	0	34
Region	3	12	2	14	9	7	47
Remote sensing image	1	5	0	3	0	6	15
Study area	1	0	2	3	11	35	52
Town	2	0	0	1	4	9	16
Village	12	8	7	17	13	52	109
Watershed	1	0	0	3	2	4	10
Total	59	28	13	95	63	123	381