A Systematic Review and “Meta-Study” of Meta-Analytical Approaches to the Human Dimensions of Environmental Change

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Abstract

The human dimensions of environmental change across various spatial and temporal scales have formed a fast-growing field of study in the past decades. Given the large accumulation of scientific studies on this topic, a logical research question is whether we can draw out common patterns of causal relationships from this diverse body of literature. Meta-analysis provides a particularly useful tool for summarizing and integrating results across studies. Although there has been a growing number of meta-studies on the interrelationships between social and environmental changes, meta-analysis as a research strategy is still relatively underused in this field. Additionally, few studies have systematically examined the set of meta-analytical methods suitable to investigate relevant research questions. We used a meta-analysis framework to review and extract data on analytical approaches from 43 meta-studies published in selected peer-reviewed environmental social science journals during 2000–2014. The analysis revealed general patterns of research topics and analysis procedures, as well as associations between study characteristics and specific meta-analytical methods. These findings contribute to a better understanding of the current use and further development of the meta-analysis strategy in interdisciplinary human dimensions research.

Keywords: human–environment interactions, meta-analysis, meta-knowledge, synthetic research, systematic review

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Introduction

Ecological transformations at various spatial and temporal scales entail a wide spectrum of physical, economic, and sociocultural origins and implications. The human dimensions of environmental change (HDEC) have recently formed a fast-growing field in interdisciplinary environmental science research (Dietz & Rosa, 2002; Moran, 2010). There has been an increasing number of studies on the social causes and consequences of biophysical changes such as global warming, loss of biodiversity, and deforestation over the past decades. Given the considerable accumulation of scientific studies and the multiplicity of disciplines represented in the HDEC community, a logical research question is whether we can draw out common patterns of causal relationships from this diverse body of literature.

Meta-analysis provides a particularly useful tool for summarizing and integrating results from previous research. This research strategy normally involves pooling together findings from a set of studies to examine whether causal relations described in individual research hold more generally across the existing literature (Rudel, 2008). Originally introduced in experimental/intervention social sciences such as education and psychology (Glass, 1976; Smith & Glass, 1977), the concept of meta-analysis reflects a trend of scaling up from disparate studies to synthetic analyses in science (Magliocca et al., 2015; Poteete & Ostrom, 2008), and has been widely used in both social and natural science disciplines. Recent literature on meta-analysis has explored its applicability in new areas such as ecology, land change, environmental conservation, environmental education, and social work (e.g., Barth & Thomas, 2012; Fazey et al., 2004; Gates, 2002; Lundahl & Yaffe, 2007; Magliocca et al., 2015; Pullin & Stewart, 2006). However, relatively few studies have systematically investigated the methodology of meta-analysis in research on the interrelationships between social and environmental changes.

The purpose of this article is to explore what types of methods would be appropriate for the meta-analysis of the HDEC literature through an overview of major synthetic approaches already adopted in this field. We used a meta-analysis framework to review and extract data on analytical methods from 43 meta-studies published in selected peer-reviewed environmental social science journals during 2000–2014. The analysis revealed general patterns of research topics and analysis procedures, as well as associations between study characteristics and specific meta-analytical techniques. These findings contribute to a better understanding of the current use and further development of the meta-analysis strategy in interdisciplinary HDEC research. In the rest of the paper, we first discuss the use of meta-analysis to analyze HDEC problems, and describe major approaches employed in this emerging literature. The Methods

section details the processes of sample study selection, data extraction, and statistical analysis. The main results of our meta-analysis are then presented and interpreted. Finally, we conclude with reflections on the limitations and implications of this study.

The use of meta-analysis in HDEC research

Social science meta-analysis, in its conventional definition, refers to a research process of integrating the findings of a collection of relevant studies through the aggregate statistical analysis of quantitative results from individual experiments (Glass, 1976; Glass et al., 1981). In most cases, meta-analysis is embedded in the systematic review of prior research on a given topic (Littell et al., 2008). Nevertheless, systematic literature reviews emphasize organized and rigorous procedures of locating and synthesizing previous research findings, and do not always involve meta-analysis (Gates, 2002). In the field of HDEC, the term "meta-analysis" or "meta-study" is often used more loosely and represents any systematic attempt to identify repeatable patterns across different studies (Rudel, 2008). Prokopy et al. (2008) argued traditional, narrative literature reviews could also be considered as a simplistic form of meta-analysis.

Meta-analysis research and methodology in applied social sciences have seen substantial progress since the 1970s. This is evidenced by the large number of recently published research articles using this tool and relevant methodological textbooks (e.g., Cooper, 2010; Lipsey & Wilson, 2001; Littell et al., 2008; Rosenthal, 1991; Rothstein et al., 2005). Moreover, systematic reviews and meta-analyses have been coordinated by particular professional associations or networks (such as the Cochrane Collaboration and the Campbell Collaboration) in health, education, social welfare, and other related disciplines. Although the body of HDEC meta-studies has developed significantly in recent years, meta-analysis as a research strategy is still relatively underused in this field. There have been only a few efforts to advance the methodology of meta-analysis for analyzing human–environment interactions. These include a proposed portfolio approach (including meta-analysis) to integrating scientific knowledge on land use and land cover change (Magliocca et al., 2015; Young et al., 2006) and the design of standard guidelines for systematic reviews and meta-analyses in the area of environmental conservation and management (Pullin & Stewart, 2006).

Much of the research on the human dimensions of regional and global environmental change is place based. Rudel (2008) developed a seminal protocol of meta-analyses of case studies for analyzing the trends and drivers of forest cover change. A case in this type of meta-analysis is usually defined as a particular situation or incident (e.g., a land tenure form or a community-

based forestry project) at a specific study site and time, which is comparable to a distinct experiment or data set in the statistical meta-analysis of psychological and medical sciences. Thus, a single study may include data of multiple cases for a given meta-analysis. This comparative approach has deep roots in the tradition of case-oriented research in social sciences (Ragin, 1987), and resembles the case survey method used to aggregate the findings of business management or public policy case studies (Larsson, 1993; Yin & Heald, 1975). Although meta-analysis provides a useful technique to explore commonalities and discrepancies across a large number of studies with small samples, its use in investigating the social and policy dimensions of environmental change encounters many obstacles such as varying data quality, inconsistent conceptual approaches, and incomparable measurement and analysis protocols (Poteete & Ostrom, 2008). Other major criticisms of existing meta-studies in this field center on the overreliance on descriptive approaches and the limited number of factors included in analyses (Young et al., 2006).

Meta-analytical approaches in HDEC research

The main procedures of meta-analysis in social, behavioral, and medical sciences include the formation of research topics and analytical protocols, selection of relevant studies, data extraction (coding of collected studies), integration of research findings, and the interpretation and dissemination of meta-analytical results (Cooper, 2010; Lipsey & Wilson, 2001; Littell et al., 2008; Rosenthal, 1991). Most of these processes are readily applicable to the synthetic research of HDEC. However, due to the diversity of research areas and the distinct nature of data related to human–environment relationships, a variety of meta-analytical approaches have been identified for this field of inquiry.

Meta-analyses in the study of HDEC, particularly those based on case studies, pool findings on the linkages among important factors rather than the data or statistical results in different studies (Rudel, 2008). For most of the research questions related to HDEC, there is potentially a large number of explanatory variables. As an important tool for communicating across disciplines in society–environment studies (Heemskerk et al. 2003), interdisciplinary conceptual frameworks can be used to guide the integration of empirical data from varied social, economic, and ecological contexts. The development of conceptual specification in meta-analysis is normally an iterative process. While analytical models provide a good starting point for data extraction, new factors identified through systematic reviews can help further improve the conceptualization of causal linkages in the original frameworks.

Recent HDEC meta-analyses have moved beyond narrative literature review to adopt more innovative analytical techniques. Results of qualitative studies can be synthesized with a "syndrome" approach which identifies a typical co-occurrence of symptoms describing complex anthropogenic and natural phenomena (Manuel-Navarrete et al., 2007). In contrast to causal relationships within specific contexts, syndromes are integrated and consistent patterns that can be generalized to broader settings. This approach is very similar to the "constant comparative method" of "meta-ethnography," in which researchers create theoretical categories through comparing the similarities and differences of cases (Glaser & Strauss, 1967; Noblit & Hare, 1988). Although effective in capturing dynamic interrelations among components of coupled social-ecological systems, these qualitative comparative methods are essentially built on descriptive reviews and hence are limited in terms of the number of studies that can be included in the meta-analysis.

By contrast, qualitative comparative analysis (QCA) provides a more sophisticated approach to identifying general patterns of conjunct causation (Ragin, 1987). This method requires the construction of a raw data matrix (truth table) with a series of binary variables indicating the presence or absence of particular conditions, and is especially suitable for small- to medium-sized samples of case studies. QCA uses Boolean logic to reveal limited combinations of drivers that cause or correlate with certain outcomes. It has also been improved with the inclusion of fuzzy sets to demonstrate the classification of cases in a more probabilistic manner (Ragin, 2000), and with the alternative of setting multiple values (instead of dichotomous ones) for explanatory factors (Vink & van Vliet, 2009).

Vote counting provides another useful way to summarize results from different studies. This method normally involves tallying the frequencies with which key factors are included in selected studies and the counts of significant or insignificant relationships between these variables. Despite being criticized for its potential bias (Hedges & Olkin, 1985; Stanley, 2001), this approach has been commonly used in recent applications of meta-analysis in the HDEC literature (e.g., Hofmann et al., 2011; Misselhorn, 2005; Romero-Lankao et al., 2012). Since variables and measurement vary greatly across studies, it is unfeasible to pool actual data or statistical results together in many research areas of HDEC. Vote counting can include a large number of relevant studies in a meta-analysis and allows for high transparency in the interpretation of research findings (Prokopy et al., 2008).

Typical statistical techniques can also be employed in the meta-analysis of HDEC case studies. Researchers adopting these approaches usually first code collected studies following some standard protocols, and then carry out descriptive, bivariate, and/or more advanced multivariate analyses to assess the relationships

between constructed variables (Rudel, 2008). This group of analytical methods is useful for synthesizing both quantitative and qualitative studies. When using such approaches, analysts treat extracted cases as independent subjects in the resulting meta-analysis data sets and generate new statistical results with the factors coded for individual studies.

Finally, statistical meta-analytical tools have been increasingly used to integrate quantitative results across studies on human–environment interactions. This approach requires the estimation of an effect-size statistic which quantifies the direction and strength of the relationships between major variables (Lipsey & Wilson, 2001; Littell et al., 2008). In addition to the computation of effect sizes, statistical analyses are conducted to assess the publication bias and consistency (sensitivity analysis) in the estimated effects (Rothstein et al., 2005). A series of techniques (e.g., subgroup analysis and meta-regression) are also available to examine the potential influences of methodological factors (moderators), such as research design and sample characteristics, on the variations in effect sizes (Littell et al., 2008). Although moderator analysis uses similar statistical techniques (e.g., analysis of variance (ANOVA) and multiple regression) as those meta-studies conducting statistical analysis of coded data (see above), the logics behind these two types of analyses are fundamentally different.

In summary, while the meta-analysis strategy in HDEC research shares many similarities with established meta-analysis practices, it also shows distinct features in terms of specific analysis procedures, particularly analytical models and methods. Generally speaking, the data requirement for meta-analyses is less stringent in this field than in health and applied social sciences, and multiple techniques can be used to compare and combine qualitative and/or quantitative data extracted from individual studies. This article contributes to the further advancement of meta-analytical research on HDEC by conducting a systematic review and “meta-study” of analytical approaches adopted in this growing literature.

Methods

Selection of studies

Since the field of HDEC involves a range of research topics cutting across multiple disciplines, there were no obvious keywords to be used for the search of relevant studies for our meta-analysis. In order to broadly represent the human dimensions research community, we first selected 30 peer-reviewed journals with the highest impact factors in the “Environmental Studies” subject category of the *2012 Journal Citation Reports (JCR)—Social Sciences Edition*.

Because statistical meta-analytical techniques have been commonly used by systematic quantitative reviews in economic research to synthesize econometric estimates and evaluate specification biases (Stanley & Doucouliagos, 2012), we chose to restrict our literature search to the 23 non-economic journals within the JCR sample. Table 1 presents the list of those journals included in our preliminary screening.

Table 1. Journals included in the literature search^a

Journals included in the initial screening	Journals added in the follow-up search
<i>Annual Review of Environment and Resources</i>	<i>BioScience</i> (2)
<i>Carbon Management</i>	<i>Conservation Biology</i> (2)
<i>Computers, Environment and Urban Systems</i>	<i>Environment and Behavior</i> (2)
<i>Corporate Social Responsibility and Environmental Management</i>	<i>Food Policy</i> (1)
<i>Ecology and Society</i> (4)	<i>Human Ecology</i> (1)
<i>Energy Policy</i> (1)	<i>Human Ecology Review</i> (1)
<i>Environmental Impact Assessment Review</i>	<i>Journal of Environmental Education</i> (1)
<i>Environment and Planning A</i>	<i>Journal of Environmental Management</i> (2)
<i>Environment and Planning D</i>	<i>Journal of Soil and Water Conservation</i> (1)
<i>Global Environmental Change</i> (10)	<i>PLOS ONE</i> (1)
<i>Global Environmental Politics</i>	<i>Proceedings of the National Academy of Sciences</i> (1)
<i>Journal of Environmental Psychology</i> (4)	<i>Society and Natural Resources</i> (1)
<i>Journal of Regional Science</i>	<i>The Geographical Journal</i> (2)
<i>Land Use Policy</i> (3)	<i>World Development</i> (2)
<i>Landscape and Urban Planning</i>	
<i>Marine Policy</i> (1)	
<i>Nature Climate Change</i>	
<i>Population and Environment</i>	
<i>Progress in Planning</i>	
<i>Regional Environmental Change</i>	
<i>Tourism Management</i>	
<i>Urban Forestry and Urban Greening</i>	
<i>Wiley Interdisciplinary Reviews: Climate Change</i>	

^a Journals are arranged in alphabetical order. Numbers of articles selected from individual journals are given in parentheses.

The selection process included various types of synthetic analyses identifying common patterns across individual studies. We used a general term "meta-*" (covering "meta-analysis," "meta-analyses," "meta-study," and "meta-studies") to search the title, abstract, and keywords sections of the selected journals in the

Scopus database. This criterion might have excluded some studies that could be technically counted as meta-analyses (e.g., narrative literature reviews) but which were not self-identified as such. Because meta-analysis is a relatively new tool in HDEC research, we also limited our search to articles published in or after 2000. The initial section identified 96 articles, which were then assessed for relevance to our interest in the drivers, impacts, and management of environmental change. Studies focusing solely on the biophysical processes or economic aspects of environmental systems were removed from the selections. In total, 23 meta-analyses were chosen from six journals in this phase.

The next stage of our literature search mimicked a snowball sampling approach: We checked the reference lists of the 23 articles for additional relevant meta-studies, and then repeated this process with newly included studies. As a result, we added 15 more meta-analyses to our sample. Finally, we replicated the whole literature search procedure using the databases of the 14 journals in which these 15 articles were published (Table 1), and included five new studies based on the same criteria. Through this stepwise, iterative selection process (completed in March, 2014), 43 meta-studies of HDEC issues appearing in 20 journals were identified for our systematic review and analysis (Tables 1 and 2). Review of the titles and abstracts of these articles suggested several common themes (further discussed below). As a final check of sample quality, we created a group of keyword combinations (“meta-” AND “conservation”/“resource, management”/“environmental, management”/“community, management”/“environmental, behavior”/“environmental, psychology”/“environmental, education”/“deforestation”/“land, change”/“vulnerability”/“adaptation”/“environmental, change”), and searched for articles with these terms included in titles using the ScienceDirect database. This process did not retrieve any other relevant HDEC meta-analyses.

Table 2. List of studies included in the meta-analysis

Meta-analytical methods ^a	Articles ^b
Narrative review	Abrahamse et al. (2005); *Glasmeier & Farrigan (2005); Zeppel (2008)
Comparative review	Manuel-Navarrete et al. (2007); *Oberlack & Eisenack (2014); Penker (2009)
Qualitative comparative analysis	*Robinson et al. (2014)
Vote counting	Carmenta et al. (2011); Cox et al. (2014); Evans et al. (2011); Geist & Lambin (2002); *Geist & Lambin (2004); Hirschnitz-Garbers & Stoll-Kleemann (2011); *Hofmann et al. (2011); *Keys & McConnell (2005); Knowler & Bradshaw (2007); *Misselhorn (2005); Munteanu et al. (2014); Pagdee et al. (2006); Pleasant et al. (2013); Poteete & Ostrom (2008); *Prokopy et al. (2008); *Romero-Lankao et al. (2012); Rudel et al. (2009); Schmidt-Vogt et al. (2009); van Vliet et al. (2012)

Meta-analytical methods ^a	Articles ^b
Descriptive/bivariate/ multivariate statistics	*Andrade & Rhodes (2012); Brooks et al. (2012); *Carmenta et al. (2011); Clark & Kozar (2011); *Cox et al. (2010); Cox et al. (2014); Delmas et al. (2013); Mascia et al. (2010); *Pagdee et al. (2006); Poteete & Ostrom (2008); Robinson et al. (2014); Rudel (2007); *Rudel et al. (2009); *Seto et al. (2011); *van Vliet et al. (2012)
Statistical meta-analysis	Abrahamse & Steg (2013); Bamberg & Moser (2007); *Baumgart-Getz et al. (2012); Delmas et al. (2013); Hawcroft & Milfont (2010); *Klöckner (2013); *Lokhorst et al. (2013); Maliao et al. (2009); Osbaldiston & Schott (2012); Stamps (2004)

^a Meta-analytical methods are discussed in detail in the "Meta-analytical approaches in HDEC research" section. See Table 3 for more specific definitions.

^b Six sample studies (Hofmann et al., 2011; Manuel-Navarrete et al., 2007; Misselhorn, 2005; Poteete & Ostrom, 2008; Prokopy et al., 2008; Romero-Lankao et al., 2012) are included in the list of references. See Appendix A for the full citations of the remaining articles.

* Articles of particular interest in terms of meta-analysis procedures. The present study also showcases the combined use of vote counting as well as descriptive and bivariate statistics in meta-analysis research.

Data extraction and coding of variables

The data extraction process built on an analytical scheme including major meta-analysis procedures in HDEC research: the development or adoption of a conceptual framework, literature search, variable coding, and data analysis and synthesis (Rudel, 2008). These categories informed the design of an article review template (or coding manual) which also incorporated the following general information of the selected meta-studies: publication year, journal title, research topic, number of reviewed studies, geographic area covered in the meta-analysis, unit of analysis, and the number of units included in the analysis. This template was then used in a systematic review of the 43 sample articles. Only the first author reviewed all these papers since the definitions of the coded variables were unambiguous and the examination of method-related information involved little subjective judgment. Nevertheless, five articles randomly chosen from the pool were inspected by the second author to ensure the accuracy of constructed data. The two researchers' coding for these five studies was identical, suggesting a very high intercoder reliability (Neuendorf, 2002). Relevant qualitative data extracted from the collected studies were coded into a series of categorical or numerical variables (Table 3). The eight meta-analytical method measures were derived based on the approaches outlined in the previous section, and each was coded as: 1 = yes (adopted) and 0 = no (not adopted). A new numerical indicator was calculated as the sum of analytical methods adopted in a selected study.

Table 3. Measurement of major variables

Variables	Measurement
Publication period	1 = 2000–2007, 2 = 2008–2014
Research topic	1 = resource conservation and management, 2 = land cover change, 3 = environmental psychology and behavior, 4 = vulnerability and adaptation, 5 = others
Analytical model	Whether or not developed or adopted a conceptual model for the analysis? 0 = no, 1 = yes
Literature search	Whether or not used scientific database(s) in literature search? 0 = no, 1 = yes
Number of reviewed studies	Number of studies included in a meta-analysis
Geographic range	The geographic area covered in a meta-analysis: 1 = nation (a single country), 2 = region (multiple countries within one continent), 3 = pan-region (multiple countries in more than one continent), and 4 = globe (multiple countries in all continents)
Unit of analysis	The basic entity being analyzed in a meta-study: 1 = independent data observation (an individual data set, treatment, etc.), 2 = case (a particular situation or incident at a specific study site and time), 3 = article (an article selected for a meta-analysis) ^a
Number of units	Number of units included in a meta-analysis
Variable construction	The degree of variable coding or computation based on relevant information from the studies selected for a meta-analysis: 0 = none, 1 = simple variable coding or computation (e.g., presence/absence of a driver, positive/negative/no relationship between some variables), 2 = more complicated variable coding or computation
Coding of methods	Whether or not coded the method-related information of selected studies? 0 = no, 1 = yes
Meta-analytical method variables	Whether or not used the corresponding analytical method? 0 = no, 1 = yes
Narrative review	Traditional, narrative literature review (qualitative)
Comparative review	Identify general patterns or types through comparing similarities and differences of individual cases (qualitative)
Qualitative comparative analysis	Qualitative comparative analysis using Boolean logic (qualitative–quantitative)
Vote counting	Tally relevant factors and their relationships (frequency distribution) based on the results of selected studies (qualitative–quantitative)
Descriptive statistics	Conduct descriptive statistical analysis (e.g., mean and range) using variables coded for selected studies (quantitative)
Bivariate statistics	Conduct bivariate statistical analysis (e.g., chi-square test and Pearson's <i>r</i> correlation) using variables coded for selected studies (quantitative)
Multivariate statistics	Conduct multivariate statistical analysis (e.g., multiple regression) using variables coded for selected studies (quantitative)
Statistical meta-analysis	Conventional, statistical meta-analysis involving the estimation of an effect-size statistic based on quantitative results from individual studies (quantitative)
Total number of analytical approaches	A composite measure calculated as the sum of the eight dichotomous method variables above

^a In a meta-analysis, a single article may include multiple data observations or cases.

Data analysis

The analysis of the constructed data set included two major steps. First, frequency distributions and simple descriptive statistics were computed for major variables to present a general picture of current HDEC meta-studies. Bivariate statistical analyses (chi-square test, ANOVA with post hoc Tukey's test, independent *t*-test/Mann–Whitney *U* test, and Pearson's *r* correlation test) were then conducted to explore the relationships between study characteristics and key meta-analysis procedures, as well as the connections among different meta-analytical approaches.

Results

Descriptive analysis

Results of the descriptive analysis for major variables are presented in Table 4. The number of meta-analyses of human dimensions clearly increased between 2000 and 2014. The majority of the 43 selected meta-studies (72.1%) were published in the second half of the study period (2008–2014). Four major peer-reviewed journals in the field of human–environment interactions—*Global Environmental Change* (23.3%), *Ecology & Society* (9.3%), *Journal of Environmental Psychology* (9.3%), and *Land Use Policy* (7.0%)—together accounted for nearly half (48.9%) of these studies. Existing HDEC meta-analyses focused mainly on four topical areas: natural resource conservation and management (39.5%), land use and land cover change (23.3%), environmental behavior and psychology (20.9%), and vulnerability and adaptation to environmental change (11.6%). Although statistical meta-analyses have been widely conducted in educational and health sciences (including environmental health), only one article was found for each of environmental education and human health in our sample.

Most of these meta-studies (72.1%) developed or adopted an analytical framework to guide the processes of systematic review and data extraction. A vast majority of the articles (90.7%) used academic databases in literature searches. However, the screening process was not always clearly explained in the final publication. Among the 30 meta-studies which indicated geographic coverage, a large portion (66.7%) of them integrated research findings from countries in more than one continent ("pan-region") or all continents ("globe"). On average, the reviewed meta-analyses included about 77 studies and 104 units (i.e., article, case, or independent data observation) in the analysis, but these numbers varied greatly across the sample (with a range of 10–268 studies and 10–326 units).

Table 4. Descriptive summary of major variables

Variables	Frequencies	% total ^a
Publication period		
2000–2007	12	27.9
2008–2014	31	72.1
Research topic		
Resource conservation & management	17	39.5
Land cover change	10	23.3
Environmental psychology & behavior	9	20.9
Vulnerability & adaptation	5	11.6
Others (environmental education, human health & well-being)	2	4.7
Geographic range		
Globe	6	14.0
Pan-region	14	32.6
Region	6	14.0
Nation	4	9.3
Unspecified	13	30.2
Unit of analysis		
Article	14	32.6
Case	20	46.5
Independent data observation	9	20.9
Variable construction		
More complicated variable coding/computation	21	48.8
Simple variable coding/computation	9	20.9
None	13	30.2
Meta-analytical methods^b		
Vote counting	19	44.2
Bivariate statistics	13	30.2
Statistical meta-analysis	10	23.3
Multivariate statistics	6	14.0
Descriptive statistics	6	14.0
Narrative review	3	7.0
Comparative review	3	7.0
Qualitative comparative analysis	1	2.3

^a Numbers may not add up to 100% due to rounding.

^b The sum of percentages here is more than 100% because some selected studies used multiple analytical methods.

Almost half (46.5%) of the selected 43 meta-studies had case as the basic unit of analysis. Additionally, the bulk of the studies (69.7%) involved variable coding or computation to some degree, while about one third (30.2%) coded methodological features. Vote counting, bivariate statistics, and statistical meta-analysis (effect-size estimation) were the three most common analytical approaches. In general, quantitative methods were used more often than qualitative ones in the analyses. The total number of analytical approaches employed by the selected meta-analyses ranged from 1 to 4, with a mean of nearly 1.5 per article. The results also suggest a trend of increasing adoption of statistical meta-analytical techniques in recent years. Seven out of the 10 articles using this approach were published in or after 2010.

Bivariate statistical analysis

This section summarizes important correlations between major variables included in our meta-analysis. Table 5 presents the results related to general study characteristics and several key meta-analysis procedures prior to the data analysis stage. The table shows there were some obvious differences among the study categories of publication time and research topics. Generally, meta-studies published during 2008–2014 were almost significantly more likely than those in 2000–2007 to build more complex variables and create indicators related to methods. As for the variations across different topical groups, all the 10 selected articles on land use change used case as the unit of analysis, and on average had a larger number of units in the meta-analysis than those examining resource conservation and management. Sample papers addressing environmental psychology and/or behavior issues mostly analyzed independent data sets or interventions included in reviewed studies. Both case and article were common units of analysis for meta-studies in the areas of resource conservation and of vulnerability and adaptation. Meta-studies in environmental psychology and behavior tended to involve the lowest degree of variable construction but were most likely to code methodological factors. Additionally, the numbers of studies and units included in meta-analyses were highly correlated with each other. Both of them increased with the use of scientific database searches, but were negatively associated with the use of analytical models. A broad literature search process was also logically related with a larger geographic area and more complicated variable building. Finally, meta-studies employing case as the unit of analysis generally had higher levels of variable construction but less coding of methods-related information than other selected studies, while the number of units in the analysis was nearly significantly and positively correlated with the degree of variable construction.

Table 5. Bivariate correlations among study characteristics and selected meta-analysis procedures (N = 43)

Variables	1	2	3	4	5	6	7	8	9
1. Publication period									
2. Research topic									
3. Analytical model									
4. Literature search									
5. Number of reviewed studies			2.25 ^{c*}	-5.21 ^{c***}					
6. Geographic range				8.19 ^{ab*}					
7. Unit of analysis		37.23 ^{ab***}							
8. Number of units		3.12 ^{ab*}	1.85 ^{c(*)}	-5.59 ^{c***}	0.87 ^{d***}				
9. Variable construction	5.19 ^{ab(*)}	14.45 ^{ab*}		4.79 ^{ab(*)}			7.64 ^{ab(*)}	2.97 ^{b(*)}	
10. Coding of methods	3.79 ^{ab(*)}	8.02 ^{ab(*)}					12.07 ^{ab**}		

^a Given as chi-square test statistics. Fisher's exact test was used when 25% or more of the cells had expected count less than 5.

^b Given as ANOVA *F*-test statistics.

^c Given as independent *t*-test statistics. A negative *t* value means the second group has a higher mean than the first group, while the opposite is true for a positive value. Significant results were verified with the non-parametric Mann-Whitney *U* test when small group samples ($N \leq 5$) were involved.

^d Given as Pearson's *r* coefficients.

Marginally significant ($p < .10$) results are also included considering the exploratory nature of this study.

(*) $p < .10$, ^{*} $p < .05$, ^{**} $p < .01$, ^{***} $p < .001$

The bivariate analysis revealed several general trends of study characteristics and procedures associated with meta-studies using different analytical methods (Table 6). First, comparative review was used relatively more frequently in the area of vulnerability and adaptation than in others. In contrast, meta-analyses related to environmental psychology and behavior were less likely to use the vote-counting approach but relied significantly more on statistical meta-analytical tools than other studies. Second, adopting a comparative review approach was generally accompanied with reduced likelihood of searching relevant literature in scientific databases, and with limited numbers of studies and units that could be pooled in the analysis. While on average statistical meta-analytical studies also tended to integrate fewer articles than those using other methods, the presence of bivariate and multivariate statistics in meta-analysis was correlated with a larger amount of reviewed literature and/or more units in the analysis. Third, meta-studies adopting narrative review, vote counting, multivariate statistics, and conventional statistical meta-analysis had article, case/article, case, and independent data observation respectively as the primary unit of analysis. Fourth, narrative, comparative, and statistical meta-analytical approaches were less likely to involve variable construction than other categories, while the use of vote counting or bivariate statistics was related with an increased degree of building variables. Moreover, the coding of method-related indicators was only strongly associated with statistical meta-analysis. Overall, the total number of analytical approaches used in a meta-analysis was significantly associated with the publication period (larger in 2008–2014 than in 2000–2007), the number of units included in the analysis (positively correlated with each other), and the level of variable coding or computation (larger for studies with more complicated construction than for those with no or simple construction).

As shown in Table 7, the results also indicate some interesting relationships between specific analytical methods. Among the selected studies, vote counting was normally not used together with other meta-analytical approaches, particularly descriptive statistics of coded variables and statistical meta-analysis; while bivariate statistics were included more often than not in those meta-studies which conducted descriptive or multivariate statistical analysis. The composite meta-analytical method variable (total number of analytical approaches) showed a negative relationship with the presence of narrative and comparative review methods, but was positively related with the use of the QCA technique and with descriptive, bivariate and multivariate statistical analyses. The correlations involving the narrative, comparative, and QCA approaches should be interpreted cautiously due to the small group sample sizes. Nevertheless, the results suggest some of these analytical tools can be more readily included in a mixed meta-analysis research design than others.

Table 6. Bivariate correlations between meta-analytical methods and study characteristics as well as other meta-analysis procedures ($N = 43$)

Variables	Publication period	Research topic	Analytical model	Literature search	Number of reviewed studies	Geographic range	Unit of analysis	Number of units	Variable construction	Coding of methods
Narrative review							4.77 ^{a*}		5.28 ^{a*}	
Comparative review		6.28 ^{a(*)}		12.58 ^{a*}	5.93 ^{c***}			6.91 ^{c***}	5.28 ^{a*}	
Qualitative comparative analysis										
Vote counting		11.43 ^{a*}	3.41 ^{a(*)}				5.13 ^{a(*)}		11.71 ^{a**}	
Descriptive statistics										
Bivariate statistics	3.79 ^{a(*)}							-1.87 ^{c(*)}	8.97 ^{a**}	
Multivariate statistics					-1.98 ^{c(*)}		6.61 ^{a*}	-2.40 ^{c*}		
Statistical meta-analysis		22.20 ^{a***}			2.62 ^{c*}	5.26 ^{a(*)}	16.27 ^{a***}		4.80 ^{a(*)}	9.77 ^{a**}
Total number of analytical approaches	-2.77 ^{c**}			-3.82 ^{c***}				0.32 ^{d*}	3.81 ^{b*}	

^a Given as chi-square test statistics. Fisher's exact test was used when 25% or more of the cells had expected count less than 5.

^b Given as ANOVA F -test statistics.

^c Given as independent t -test statistics. A negative t value means the second group has a higher mean than the first group, while the opposite is true for a positive value. Significant results were verified with the non-parametric Mann-Whitney U test when small group samples ($N \leq 5$) were involved. The association between the total number of analytical approaches and the use of scientific databases for literature searches became non-significant according to the Mann-Whitney U test.

^d Given as Pearson's r coefficients.

Marginally significant ($p < .10$) results are also included considering the exploratory nature of this study.

(*) $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

Table 7. Bivariate correlations between meta-analytical method variables (N = 43)

Variables	1	2	3	4	5	6	7	8
1. Narrative review								
2. Comparative review								
3. Qualitative comparative analysis (QCA)								
4. Vote counting								
5. Descriptive statistics				5.52 ^{a*}				
6. Bivariate statistics					9.32 ^{a**}			
7. Multivariate statistics						9.32 ^{a**}		
8. Statistical meta-analysis				10.32 ^{a**}				
9. Total number of analytical approaches	3.80 ^{b***}	3.80 ^{b***}	42.00 ^{c***}		-2.88 ^{b*}	-7.68 ^{b***}	-2.88 ^{b*}	

^a Given as chi-square test statistics. Fisher's exact test was used when 25% or more of the cells had expected count less than 5.

^b Given as independent *t*-test statistics. A negative *t* value means the second group has a higher mean than the first group, while the opposite is true for a positive value. The correlations between the total number of analytical approaches and the adoption of narrative and comparative review methods became non-significant according to the Mann-Whitney *U* test.

^c Given as the Mann-Whitney *U* test statistic. The independent *t*-test was not performed here since there was only one study in the QCA group. The mean numbers of analytical approaches for the QCA and non-QCA groups were 4.0 and 1.4, respectively.

p* < .05, *p* < .01, ****p* < .001

Discussion

Responding to the shift from a focus on individual local-level studies to integrative analyses in the general scientific enterprise and in the research on human–environment interactions in particular (Poteete & Ostrom, 2008), this research assesses the portfolio of analytical approaches deployed in recent meta-analyses of HDEC problems. Soundly designed and implemented systematic reviews and meta-analyses can synthesize the existing knowledge base, identify areas of strength and weakness, and pinpoint directions for future research endeavors. Our analysis revealed that the recent journal literature of HDEC meta-analyses highly concentrated on several topical areas. A variety of analytical methods were used in the 43 meta-studies selected for this review. These methods are located on a full continuum from qualitative to quantitative techniques, and are associated with specific study characteristics, data requirements, and analysis procedures.

Since research data and measurement are more diverse in HDEC research than in experimental environmental and social sciences, synthesizing the results from the large numbers of studies in this interdisciplinary field necessitates the use of a range of analytical methods in addition to the statistical estimation of cumulative effect sizes. In this sense, human dimensions research can make a special contribution to the development of a more comprehensive meta-analysis methodology. Meta-analysis has gained wide currency in recent research on society–environment relationships (Rudel, 2008; Young et al., 2006). Current studies on the meta-analysis strategy in environmental sciences focus on the adoption of statistical analytical methods from medicine and health research (e.g., Fazey et al., 2004; Gates, 2002; Magliocca et al., 2015; Pullin & Stewart 2006). Our study extends this line of research by systematically reviewing the set of meta-analytical approaches appropriate for analyzing human–environment interactions. The HDEC community has already accumulated a large number of informative small-scale studies. A more complete understanding of potentially useful meta-analytical approaches in this field can help to enable creative “data-intensive” research that may not otherwise be possible.

Findings from this study confirm some typical characteristics of particular meta-analytical methods, such as the relatively smaller numbers of included studies and cases in comparative reviews, and the correlation between the coding of method-related variables and the adoption of statistical meta-analysis (Table 6). Although well established in several relevant disciplines such as psychology and economics, statistical meta-analytical tools are not necessarily more suitable for HDEC research than those methods relying more on qualitative information. In fact, the selection of analytical approaches in meta-analysis research is largely determined by the features of the research topics and empirical scientific data in

question. The results suggest that currently available meta-analytical approaches are seldom used together, except for those common statistical techniques (descriptive, bivariate, and multivariate analyses) applied to variables coded for collected studies (Table 7). Nevertheless, some of the simple quantitative methods, like vote counting, can be improved by statistical analysis estimating common effect parameters such as the significance and direction of variable correlations (Hedges and Olkin, 1985). To understand the dynamic interrelationships within complex social–ecological systems and inform evidence-based management and decision-making, it is usually more effective to take a mixed-method approach combining multiple, complementary meta-analysis tools.

The meta-analyses reviewed in this paper can all serve as good references on how to conduct meta-studies on HDEC topics (see asterisked ones in Table 2 particularly). The results suggest statistical meta-analysis is relatively underused in analyzing the social and policy dimensions of environmental systems. This is mainly due to the obstacles resulting from the varied data forms and variable measurements across studies, but may also partly reflect the lag of meta-analysis training and practice in non-economic HDEC subfields. Although effect-size estimation was one of the major analytical methods identified in our review, relevant standard meta-analytical procedures, such as the assessment of publication bias and sensitivity analysis, were followed in less than half (40%) of the 10 selected studies taking this approach. The bivariate and multivariate statistical techniques used in HDEC meta-analyses of case studies also often encounter the problems of small sample size and low statistical power. Additionally, since reviewed articles and the observations extracted from them cannot be treated exactly as randomly selected cases, meta-analysts should be cautious in drawing any general causal conclusions based on the results of such statistical analyses.

Conceptual models play an essential role in systematic reviews and meta-analyses (Littell et al., 2008). However, this procedure was not involved in all the meta-analyses reviewed in this study. Our analysis suggested the adoption or derivation of conceptual frameworks was not restricted to any particular meta-analytical approaches to HDEC research questions. It should be noted that the negative correlation found between the use of conceptual models and the number of studies or units included in meta-analyses does not necessarily indicate any causal relationship between them. On the contrary, a well-developed model can be used to provide a common analytical scheme for synthesizing diverse research findings from studies that have already been conducted. Focusing on the linkages among conceptual constructs instead of specific variables should loosen the typically strict data requirements for meta-analysis, and increase the number of studies that can possibly be included in the analysis.

Moreover, shared conceptual frameworks can facilitate future meta-analytical work by laying solid groundwork for the development of standardized research procedures in major topical areas.

A holistic methodological strategy in the study of HDEC calls for better cooperation among researchers and replicating research designs and instruments across different socioeconomic and environmental contexts (Luloff et al., 2007). It is unsurprising that current meta-analyses in this field have been concentrated in several areas which have formed strong theoretical foundations and involved large numbers of researchers and practitioners. These lines of synthetic research can be substantially advanced if coordinated by some well-established professional networks in relevant scientific communities (e.g., the Ostrom Workshop in Political Theory and Policy Analysis organized by Indiana University and the Population and Environment Research Network hosted in Columbia University), or by a new international collaboration especially founded to promote HDEC systematic reviews and meta-analyses.

While the diversity of analytical approaches to human–environment interactions enriches the conventional, quantitative meta-analysis methodology, further meta-studies in this field can benefit greatly by linking with relevant literature of psychological, educational, and health sciences in which meta-analysis protocols are more established. Increased knowledge of general meta-analytical processes and available tools may also guide the formulation of research questions and objectives, and improve future practices of data generation and management. Standard statistical meta-analytical techniques (e.g., the estimation of effect sizes and moderator analysis) would be readily applicable to analyzing HDEC problems if research designs were more comparable across studies. Sufficient information on statistical results and sample characteristics should also be included in all publications and research reports, provided as online supplementary data, or made available by authors upon request to facilitate the use of this type of quantitative meta-analytical tool.

Concluding remarks

Although this study elaborates on the overall patterns of current meta-analytical approaches in HDEC research, there are several possible limitations that need to be considered. First, since we limited our literature search to 37 journals in environmental social science, we might have missed some relevant studies in the selection. However, the set of recent publications included in our analysis should still be representative of the literature of non-economic HDEC meta-analyses. Including environmental economic journals and articles in this study would make the distribution of analytical approaches highly skewed toward

conventional statistical meta-analysis, but the results related to other methods should remain similar. Next, as we restricted our search to research articles published in English peer-reviewed journals, there existed some potential publication bias in our analysis. Our findings and interpretations should therefore be qualified within this context. Nevertheless, given our primary objective of investigating appropriate meta-analytical approaches, selection bias is of less concern for this study than for other meta-analyses on concrete research topics. In addition, the power of our statistical analysis was restrained due to the relatively small number of existing, non-economic meta-studies on HDEC issues. The results are likely to change with the addition of new research in the analysis. Since meta-analysis has been increasingly used as an integrative approach to analyze coupled human–natural systems, follow-up methodological reviews are needed to monitor and advance the progress of systematic reviews and meta-analyses in the HDEC field.

Finally, while developing a list of detailed guidelines for the meta-analysis of human dimensions–related research questions is beyond the scope of this article, we conclude with some general comments on the direction of future work. Meta-analysis originally focused on the pooling of research data from individual studies to create larger samples, and there is a reemergence of this interest in the efforts to better conserve and reuse data among information and climate change social scientists (Qin et al., 2014). However, for a field as diverse as HDEC, it should be more feasible and productive to integrate findings rather than the actual data sets across studies at present. Furthermore, recent literature on integrative science suggests an emerging trend of moving beyond typical meta-analysis to "meta-knowledge" research investigating the effects of scientific context on knowledge generation (Evans & Foster, 2011). Meta-knowledge analysis complements meta-studies by examining the influences of disciplinary matrices and regularities on research contents. This reflexive perspective on the process of scientific inquiry reflects a long-standing tradition in the sociology of knowledge (Coser, 1977; Zhao, 1991), and echoes the wide interest in different vulnerability research lineages (natural hazards, political economy or ecology, and ecological resilience) in global environmental change science (e.g., Adger, 2006; Eakin & Luers, 2006; Romero-Lankao & Qin, 2011). A recent study by Janssen et al. (2006) also explored the role of collaboration networks in knowledge production within three major domains of HDEC research: resilience, vulnerability, and adaptation. All analytical methods reviewed in this article, particularly the statistical moderator analysis technique, can be used to examine the possible effects of research paradigms and instruments on the results of previous studies. A combination of meta-analysis and meta-knowledge strategies can provide better evidence on the multifaceted human dimensions of environmental change and management.

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Appendix A—Sample studies not included in the list of references

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