The Canadian Geographer
Le Géographe canadien
Canadian Association of Geographers
Association Canadienne des Géographes

Intervention: Critical physical geography

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The Canadian Geographer / Le Géographe canadien 2013, xx(xx): 1–10
DOI: 10.1111/cag.12061

A recent opinion piece rekindled debate as to whether geography's current interdisciplinary make-up is a historical relic or an actual and potential source of intellectual vitality. Taking the latter position, we argue here for the benefits of sustained integration of physical and critical human geography. For reasons both political and pragmatic, we term this area of intermingled research and practice critical physical geography (CPG). CPG combines critical attention to power relations with deep knowledge of biophysical science or technology in the service of social and environmental transformation. We argue that whether practiced by individuals or teams, CPG research can improve the intellectual quality and expand the political relevance of both physical and critical human geography because it is increasingly impractical to separate analysis of natural and social systems: socio-biophysical landscapes are as much the product of unequal power relations, histories of colonialism, and racial and gender disparities as they are of hydrology, ecology, and climate change. Here, we review existing CPG work; discuss the primary benefits of critically engaged integrative research, teaching, and practice; and offer our collective thoughts on how to make CPG work.

Keywords: physical geography, critical human geography, transdisciplinarity, anthropocene

Intervention en géographie physique critique

Un article d'opinion paru récemment est à l'origine de la relance d'un débat qui pose la question à savoir si le fondement interdisciplinaire actuel de la géographie serait une relique historique ou une source réelle et potentielle de vitalité intellectuelle. En prenant la défense de la seconde position, nous militons en faveur des bénéfices découlant de l'intégration soutenue de la géographie physique et de la géographie humaine critique. Pour des raisons à la fois politiques et pragmatiques, nous avons nommé ce domaine de recherche et de pratique enchevêtré la géographie physique critique (GPC). C'est au service de la transformation sociale et environnementale que la GPC intègre un regard critique sur les relations de pouvoir à la connaissance profonde de la science ou de la technologie biophysique. Que se soient des individus ou des équipes qui la pratiquent, les travaux de recherche en GPC peuvent contribuer à l'amélioration de la qualité intellectuelle et à l'élargissement de la pertinence politique de la géographie humaine critique et géographie physique, compte tenu que la séparation de l'analyse des systèmes naturels et des systèmes sociaux pose des difficultés d'ordre pratique. À l'origine des paysages sociobiophysiques se trouvent autant les relations inégales de pouvoir, les histoires de colonialisme et les disparités raciales et entre les sexes que l'hydrologie, l'écologie et les changements climatiques. Dans cette partie de l'article, nous passons en revue les travaux actuels en GPC, nous engageons une discussion sur les principaux avantages des approches intégratives et véritablement critiques en recherche, dans l'enseignement et dans la pratique, et nous proposons nos réflexions collectives sur la façon d'appliquer la GPC.

Mots clés : géographie physique, géographie humaine critique, transdisciplinarité, anthropocène

Introduction

In a recent column in *Geolog*, Stephen Johnston, a geologist at the University of Victoria, proposed the disbanding of geography departments in order to end the "entirely arbitrary" combination of physical and human geographers and reunite them with their respective physical and social science kin (2012, 6). Johnston's piece catalyzed a fierce debate on a number of online fora. The bulk of responses rejected his argument, but the belief that physical and human geographers are joined by historical inertia rather than any potential or actual intellectual synergy remains common both inside and outside the discipline, and is important to refute.

We argue here that there are great mutual benefits from active integration of physical and critical human geography, as demonstrated in the work of geographers who combine critical attention to relations of social power with deep knowledge of a

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particular field of biophysical science or technology in the service of social and environmental transformation. We term this integrative intellectual practice *critical physical geography (CPG)*. Its central precept is that we cannot rely on explanations grounded in physical or critical human geography alone because socio-biophysical landscapes are as much the product of unequal power relations, histories of colonialism, and racial and gender disparities as they are of hydrology, ecology, and climate change. CPG is thus based in the careful integrative work necessary to render this co-production legible.

Naming has material impacts, demanding particular forms of intellectual practice and marking out particular objects of inquiry. Critical physical geography calls forth a distinctive combination of research that may appear oxymoronic to human geographers who oversimplify contemporary research in physical geography as naively positivist (a position that ignores the range of epistemological approaches within it, as Gregory 2000, Rhoads and Thorn 1996, Trudgill and Roy 2003, and many others have pointed out), or offensive to physical geographers who interpret it as a renewed critique *of* physical geography. Despite these potential hazards, we believe that the term raises important questions: what are the opportunities for a more critical physical geography and a more physical critical human geography? What new research, teaching, and political practices can we build on a foundation of subaltern studies, biogeography, political-economy, geomorphology, social studies of science, and climate science?

Antecedents and existing work

We begin by acknowledging that the synthesis we espouse has clear precedents. There is a long history of critical work within physical geography. Biogeographers, for instance, have debated the epistemology of human disturbance as well as the ontology of biogeographic features, even if not in these philosophical terms (Duvall 2011a). Thomas Vale argued that "human values, not the ecological effects *per se*, determine the 'goodness' or 'badness' of human alteration of [vegetation]" (Vale 1982, 67), and William Denevan critically re-read source literature to explode "the pristine myth" of American wilderness in 1492 (Denevan 1992). This tradition continues in current physical geography research. For example, Clark and Richards (2002), Fryirs and Brierley (2009), Phillips (2010, 2011), Rhoads et al. (1999), and Wohl and Merritts (2007) demonstrate how apparently objective reference frames in fluvial geomorphology are imbued with value-based assumptions about the relevant human scales in environmental change. Such notions of river channel "naturalness" are as much normative and contextual as "scientific," and shape environmental management in particular ways. As these and other physical geographers have pointed out, research does not merely describe, but also produces the environments in which we live.[1]

Similarly, CPG is foreshadowed by three decades of work in political ecology and environmental history, which combine ethnographic work with attention to the specificity of nature's material features to explain environmental change and degradation (Blaikie 1985; Hecht 1985; Watts 1985; Blaikie and Brookfield 1987; Cronon 1995; Bakker and Bridge 2006; Huber and Emel 2009; Robbins 2012). This combination enabled political ecologists to explain, for example, African drought and pastoralist responses to it as regionally specific, variable, and impossible to characterize accurately from either satellites or UN Headquarters (Turner 1999), and soil erosion in rural Bolivia as a result of *de*population, contradicting widespread Malthusian assumptions (Zimmerer 1993). Yet, while political ecology has done a great deal to foreground our always-politicized interactions with the biophysical environment, it frequently privileges social processes/theories in the explanation of biophysical situations. The "ecology" is rarely an equal partner to the "political" (Walker 2005).[2]

[1] For some physical scientists, research termed "physical geography" already evokes multi- and trans-disciplinary intellectual practices and the hybridities of working across practice, analysis, and policy-making.

[2] Another important precedent is the vital ongoing work in sustainability science and land use/land cover change science. The work of W. Clark, B.L. Turner, and their colleagues is compatible with CPG in its interdisciplinarity, its attention to social-ecological interactions that are non-linear and path dependent, and in its aspiration to practical relevance and policy impact (Turner et al. 2007; Turner and Robbins 2008). Where CPG differs is in its emphasis on the co-production of socio-biophysical systems, its deep engagement with social theory and the material roots and consequences of unequal power relations, and its reflexive intellectual practice that acknowledges the social and political shaping of research agendas and practices, calling into question claims to universal and value neutral research findings.

CPG thus extends both political ecology and the tradition of critique within physical geography through a fresh integration of physical geography and critical human geography. The integrative holism of CPG requires critical human geographers to engage substantively with the physical sciences and the importance of the material environment in shaping social relations, while expanding physical geographers' exposure to and understanding of the power relations and human practices that shape physical systems and their own research practices. The intellectual project at CPG's core is not a matter of compiling different approaches in adjacent boxes, but of working synthetically to integrate those approaches through direct conversation and mutual interference (Demeritt 2009). With this deeply integrative approach, we believe that CPG can become an important subfield of geography that occupies a vital niche at the interface of critical human and physical geography.

A number of researchers have begun to demonstrate the reflexive and integrative epistemological spirit that motivates CPG, striving to produce critical biophysical and social explanations while also reflecting on the conditions under which those explanations are produced. For example, in "human bio-geography" (Head et al. 2012), scholars read plant ecology alongside political discourse to understand pattern and process in the postmodern biosphere. Chris Duvall's work explores how humans have affected plant distribution by drawing on historical data about where particular species were recorded (Duvall 2011a, 2011b). Yet the documentary sources for much of the Global South are loaded with dated, ethnocentric, colonialist, and racialized views of the world that affect how both people and plants are represented. Duvall draws on both Edward Said and soil science to demonstrate how definitions of geographic features in Africa have been intimately tied to colonial and neo-colonial goals of controlling natural resources and recalcitrant populations, thus strengthening our physical and social understanding of biogeographic relations (Duvall 2011a, 2011b).

Extending Stuart Lane's collaborative work on practicing flood science within a wider participatory framework (Lane et al. 2011), Rachel Pain's team of human and physical geographers and an English Rivers Trust group used Participatory Action Research, a collaborative approach that enables affected or interested people to take a leading role in research, thus unsettling scientists' and policymakers' monopoly on expertise. Trust members identified slurry getting into the river as an issue of particular concern, collected data, and conducted analysis with support from scientists, discussed the implications of their findings, and planned and implemented follow-up action. The result was a series of maps of land cover and risk across the catchment, and a model to identify farm vulnerability, allowing locally tailored and politically sensitive solutions to slurry pollution (Pain et al. 2011).

Bruce Rhoads, Michael Urban, and their collaborators have addressed the interplay between human agency and biophysical processes in the agricultural landscape of the Midwestern United States, where economic imperatives to sustain agricultural production in seasonally wet, poorly drained soils led farmers to channelize extant streams and extend drainage channels into previously unchanneled parts of the landscape (Rhoads and Herricks 1996; Urban 2005a). Humans thus became the dominant geomorphological agent of change in headwater streams (Urban and Rhoads 2003a), resulting in widespread simplification and homogenization of channel form that limits habitat complexity and affects the integrity of fish communities (Frothingham et al. 2001; Rhoads et al. 2003; Rhoads and Massey 2012). Addressing this anthropogenic damage would appear to be straightforward, but, over time, land drainage has taken on cultural and social significance, becoming a central part of farmers' sense of identity (Wilson et al. 2003; Urban 2005b). Rhoads, Urban, and their colleagues have demonstrated that alternative management solutions must engage social and cultural concerns if they are to succeed environmentally.

There are numerous other examples of CPG work, such as research on the ways in which institutional power is coded into land-cover classification (Robbins 2001), the interrelated neoliberalization of environmental science and management in stream restoration (Lave et al. 2010; Lave 2012a, 2012b), the effects of socio-economic conflicts on water management and climate change adaptation (Carey 2010; Carey et al. 2012), and the ways in which existing hydrological models entrench certain tradeoffs about who is at risk from flooding and who loses and gains from it (S. Lane et al. 2011), among many others (Proctor 1998; Robertson 2006; Crifasi 2007; Sutter 2007; Sayre 2008; Hird 2009; Linton 2010; Lorimer 2010, 2012; Mansfield et al. 2010; Clark

2011; K.M. Lane 2011; Grabbatin and Rossi 2012; Mahoney and Hulme 2012; Simon 2012; Tadaki et al. 2012; Wainwright 2012; Doyle et al. 2013; Barron et al. in review). Although this work spans a wide range of topics and fields within geography, its common characteristic is deep engagement with both theories of power and physical science, using integrative explanatory frameworks to better illuminate the co-production of socio-biophysical systems.

Potential benefits: Why bother?

This growing body of CPG work is difficult to dismiss because it is so deeply *necessary*, intellectually and practically. Scholars in a wide and growing array of biophysical disciplines have concluded that many of Earth's most fundamental processes are now *dominated* by human activities (Vitousek et al. 1997; Lubchenco 1998; Haff 2010). Geologists and chemists have gone so far as to propose a new geological epoch—the Anthropocene—for the current period of Earth's history, recognizing that broad areas of inquiry are simply unintelligible if human and physical considerations are addressed in isolation (Crutzen and Stoermer 2000; Zalasiewicz et al. 2010; Biermann et al. 2012; Lorimer 2012; Sayre 2012; Proctor 2013). But the complexity of these socio-biophysical systems—as embodied in issues such as natural hazards, biodiversity loss, epidemiology, and food security—often falls victim to "the violence of abstraction" (Sayer 1989) when isolated within (sub)disciplinary silos that reduce human/social factors and processes to a simple variable or that, conversely, view natural factors as mere politically motivated constructs.

To dissolve the human/nature dualism our concepts have to change, as do our explanatory frameworks. For example, are existing classifications of species and even biomes, such as savannas or rainforests, still useful with the ongoing anthropogenic changes in climate and species distribution (Ellis et al. 2010; Duvall 2011a)? The acceleration of change and interconnectedness among these systems is inarguable, yet once used in policy, these ecological boundaries become materially instantiated through management provisions, thus effectively transitioning "from a socially constructed line, to a line actively constructing society" (Simon 2011, 97). Because governance and conservation frameworks are organized around these shifting distinctions, new points of collaboration are necessary to reassess a wide variety of boundaries, their (mis)use in the policy realm, and their consequences for social justice and ecological health.

Similarly, to better understand current forms of environmental degradation, vulnerability to natural hazards, and the dynamics of food insecurity, we need to address the different stages of capitalism and their accompanying landscape signatures. Resource use and landscape management practices have changed in concert with capitalism's transitions from mercantilism to colonial extraction, through Fordism and into its current neoliberal phase (Arrighi 1994; Moore 2000, 2008). New forms of government and civil regulation have emerged at each stage, dictating how these new modes of production interact with the environment (Polanyi 1944; Jessop 1997; Agrawal 2005). The rescaling of both production and regulation has generated qualitatively different forms of nature (Gibbs and Jonas 2000; Swyngedouw and Heynen 2003; McCarthy 2005), fundamentally altering both human and physical geographers' field sites.

For instance, to understand the dynamics of food insecurity, it is now necessary to consider the "rediscovery" of grains as speculative financial commodities, which has had serious consequences for both food security and cultivation patterns. Similarly, to explain losses of soil organic matter or of particular soil microorganisms it is increasingly necessary to address management practices that respond to particular political economic drivers—such as the slashing of government subsidies for agricultural inputs, credit, and extension under neoliberal structural adjustment programs—and the consequent shift towards export production.

We advocate for this new subfield because we believe it will benefit a wide range of geographers. CPG foregrounds the material bases of issues such as resource availability, vulnerability, and resilience, enabling *critical human geographers* to develop a deep knowledge of the biophysical processes at work in their field sites, and the influence of these processes on human agency and inequality. Julie Guthman's (2011) recent work, for example, centres on the processes by which environmental toxins might contribute to obesity. Guthman's claim that obesity should be addressed as a product of capitalist-driven industrial processes rather than as a moral failing of individuals relies heavily on physical science data on the production and

proliferation of endocrine-disrupting chemicals. Further, critical human geographers may find that engaging in CPG research, individually or collaboratively, gains them greater access to policy audiences in order to expand the social justice impacts of their research.

At the same time, CPG enables *physical geographers* to understand and recognize the politics that shape both their own research and the systems they study. To understand the impacts of climate change in the Peruvian Andes, for example, demonstrating that glacier-fed rivers are drying up is very important (Chevallier et al. 2011; Baraer et al. 2012). However, recognizing who manages that water, how stakeholders' objectives and power vary, and how hydrological research to date has benefitted hydroelectric companies more than peasants (Vergara 2007; Carey et al. 2012) is also a crucial step toward producing more accurate, practical, and relevant knowledge. CPG thus enables physical geographers to improve their understanding of the socio-ecological roots of environmental processes, and to present findings more likely to produce socially and environmentally resilient policy outcomes (Berkes and Folke 1998). CPG also offers physical geographers the resources to examine the connections between their research and its social, economic, and political context, deepening their understanding of the ways that their own knowledge is situated in time and space (Livingstone 2003; Raj 2007; Tadaki et al. 2012).

Put bluntly, to understand the Anthropocene we must attend to the co-production of socio-biophysical systems. Integrating the power relations and social processes at the heart of critical human geographic inquiry and the material processes at the heart of physical geographic inquiry is increasingly important for both the analytical strength and political impact of our work.

Critical physical geography in practice: Making this work

Conducting CPG research is challenging because it integrates substantively different epistemologies. Despite this, we have found CPG surprisingly doable in practice because of the shared emphasis on complexity, particularity, and processes across critical human and physical geography. The biophysical sciences' turn away from equilibrium theories about how nature works in favor of emphases on nonlinearities, multi-scalar phenomena, complexity, path dependencies, thresholds of change, and historical legacies is very compatible with critical social scientific ideas about agency, change, contingency, and causality (Zimmerer 1994; Urban and Rhoads 2003b; Proctor and Larson 2005; Rhoads 2006; Harrison et al. 2008). This turn towards process, stochasticity, and observer-dependence in physical geography is directly cognate with what is known as the "post-structural turn" in critical human geography. Thus for both individual CPG researchers and transdisciplinary teams, issues of epistemological compatibility are less severe than many would expect. There are other barriers to CPG research, however, that we wish to highlight; our recommendations to address them underline the importance of integration, cross-training, and collaboration.

A first issue is building shared, or at least compatible, research methodologies to expand the pool of CPG research and researchers; each of us has discovered that making critical physical geography work *in practice* requires some methodological retooling. It is a tall order to master methods that may range from historical materialist dialectics to calculus. Some researchers will embrace the extra training required to conduct CPG research solo, while others will prefer to pursue disciplinary excellence as part of a team. In the latter case, a basic competence in—and mutual respect for—the methodological frameworks of CPG collaborators should be a minimum requirement.

In addition to methodological work, expanding CPG will require attention to pedagogy as we develop the institutional frameworks to create and encourage new cultures of epistemic pluralism (Castree 2012). CPG needs to encompass and engage a diversity of teaching, learning, and research styles. As Nick Clifford (2002) argues:

> One of the messages from the study of the sciences is the power of culturing: if we do not expect (or even want) students to integrate in circumstances where we have complete control, then how much less so can we expect a unitary discipline to survive, let alone thrive, when these students progress as the next generation? Which is worse: near fainting at the sight of an equation in a lecture, or derision of "imagined" or "mystic" geographies? The truth is, neither should ever have been indulged! (435)

Clearly, we need to strengthen institutional spaces for cross-training so that students become familiar

with, or even master, multiple methods and academic languages. A central part of this will be bringing the concepts and categories through which critical human and physical geographers "see" the world into conversation through concept orientations that detail the origin and context of key ideas, perspectives, and theories. In our experience, such conversations can create discomfort, but they are critical to the development of integrative research, and to shared intellectual growth.

Another key element will be strengthening or reinstating requirements for coursework cross-training, which at many universities have been a casualty of the competitive struggle for funding, university auditing of time-to-completion, and the demands of specialization. This is a major challenge to the ongoing survival of geography as a discipline (as evidenced by Johnston 2012), and demands a commensurate rethinking of both how we train students and how we explain and justify this training. We thus suggest that students participate in classes that are themselves an integration of critical human and physical geography approaches, to demonstrate how such integration can generate innovative research questions and findings that advance our understanding of complex socio-biophysical issues.

Finally, enabling integrative CPG work requires some logistical effort. Funding is certainly a key issue, as many existing grant programs are closed to CPG proposals. In Canada, for example, national funding is divided between social and physical science, so it is not possible to apply for a grant to do CPG work. But even in countries with programs that accept CPG proposals, it is critical for program officers to select reviewers open to, and capable of evaluating, both physical and critical human work. Thus, although the funding situation for CPG research in the United States. appears more promising, inappropriate reviewer pools mean that such research is difficult to fund in practice. There is a similar situation for publication. In our experience, it can be very hard to publish work that combines physical science and critical engagement with social theory and power relations. New journals are one possibility, but a better solution would be for editors and associate editors of existing journals to change the ways in which they select and recruit reviewers.

The emergence of the GIS & Society movement within geography provides an example of a similar effort to bridge subfields that has been quite successful. After the disruptive "GIS Wars" of the early 1990s, critical human geographers and GIScientists worked together to design and agree upon a shared research agenda focused on the social implications of mapping technologies (Schuurman 2000; Sheppard 1995, 2005). Today, some graduate (and even undergraduate) programs have incorporated these perspectives on GIS into their training. New generations of critical human geographers are finding ways to both incorporate GIS techniques as part of radical praxis and provide an informed critique of the technologies, and new cohorts of GIScientists are increasingly interested in enrolling the theories and methodologies of critical human geography to iteratively construct alternative mapping technologies (Elwood 2009). This does not mean that the differences between them have collapsed; indeed, there remain real challenges in bridging geo-technical scholarship with critical theory. However, the last 20 years of GIS & Society work has enabled a more reasoned debate about these challenges, creating opportunities for engagement and experimentation and providing a striking precedent for critical physical geography.

Conclusions

Critical physical geography embraces the unity of social and physical landscape change, a claim that Carl Sauer and geographers of his generation accepted as fundamental. But the modern context demands that we engage beyond generalized concepts of "culture" or "society" interacting with stable earth systems and ecologies. Specific modes, strategies, and institutions of governance and development interact with stochastic, contingent physical processes to shape the earth; racism, the movement of global capital, and the history of colonialism are as fundamental as the hydrologic cycle, atmospheric circulation, and plate tectonics. We have defined CPG as work that combines critical attention to relations of social power with deep knowledge of biophysical science or technology in the service of social and environmental transformation. Eliding the diversity of either social or physical processes is not just misleading, but actively unhelpful in contributing to that transformation.

We hope the discussion above will spark conversation about the possibility for more integrative scholarship and more collaborative practices. Read

in a different light, Stephen Johnston's *Geolog* column (2012) points to a broader problem of lost opportunities. CPG is our response.

References

Agrawal, A. 2005. *Environmentality: Technologies of government and the making of subjects*. Chapel Hill, NC: Duke University Press.

Arrighi, G. 1994. *The long twentieth century: Money, power and the origins of our times*. London: Verso.

Bakker, K., and G. Bridge. 2006. Material worlds? Resource geographies and the "matter of nature." *Progress in Human Geography* 30(1): 5–27.

Baraer, M., B. G. Mark, J. McKenzie, T. Condom, J. Bury, K. I. Huh, C. Portocarrero, J. Gómez, and S. Rathay. 2012. Glacier recession and water resources in Peru's Cordillera Blanca. *Journal of Glaciology* 58(207): 134–150.

Barron, E. S., C. Shultz, D. Hurley, and A. Pringle. Forthcoming. Practicing epistemological pluralism: Transdisciplinary research for adaptive co-management and conservation of fungal resources. *Conservation Biology*.

Berkes, F., and C. Folke, eds. 1998. *Linking social and ecological systems: Management practices and social mechanisms for building resilience*. New York: Cambridge University Press.

Biermann, F., K. Abbott, S. Andresen, K. Bäckstrand, S. Bernstein, M. M. Betsill, H. Bulkeley, B. Cashore, J. Clapp, C. Folke, A. Gupta, J. Gupta, P. M. Haas, A. Jordan, N. Kanie, T. Kluvánkováa-Oravská Lebel, D. Liverman, J. Meadowcroft, R. B. Mitchell, and P. Newell. 2012. Navigating the anthropocene: Improving earth system governance. *Science* 335(6074): 1306–1307.

Blaikie, P. 1985. *The political economy of soil erosion in developing countries*. New York: Longman Scientific & Technical.

Blaikie, P., and H. Brookfield. 1987. *Land degradation and society*. New York: Routledge.

Carey, M. A. 2010. *In the shadow of melting glaciers: Climate change and Andean society*. New York: Oxford University Press.

Carey, M., A. French, and E. O'Brien. 2012. Unintended effects of technology on climate change adaptation: An historical analysis of water conflicts below Andean glaciers. *Journal of Historical Geography* 38(2): 181–191.

Castree, N. 2012. Progressing physical geography. *Progress in Physical Geography* 36: 298–304.

Chevallier, P., B. Pouyaud, W. Suarez, and T. Condom. 2011. Climate change threats to environment in the tropical Andes: Glaciers and water resources. *Regional Environmental Change* 11 (Suppl no 1): S179–S187.

Clark, M. J., and K. J. Richards. 2002. Supporting complex decisions for sustainable river management in England and Wales. *Aquatic Conservation: Marine and Freshwater Ecosystems* 12(4): 471–483.

Clark, N. 2011. *Inhuman nature*. London: Sage.

Clifford, N. J. 2002. The future of geography: When the whole is less than the sum of its parts. *Geoforum* 33(4): 431–436.

Crifasi, R. R. 2007. A subspecies no more? A mouse, its unstable taxonomy, and western riparian resource conflict. *Cultural Geographies* 14(4): 511–535.

Cronon, W. 1995. The trouble with wilderness; Or, getting back to the wrong nature. In *Uncommon ground: Rethinking the human place in nature*, ed. W. Cronon. New York: W.H. Norton & Company, 69–90.

Crutzen, P. J., and E. F. Stoermer. 2000. The "anthropocene." *IGBP Global Change Newsletter* 41: 17–18.

Demeritt, D. 2009. From externality to inputs and interference: Framing environmental research in geography. *Transactions of the Institute of British Geographers* 34(1): 3–11.

Denevan, W. M. 1992. The pristine myth: the landscape of the Americas in 1492. *Annals of the Association of American Geographers* 82(3): 369–385.

Doyle, M. W., R. Lave, and M. M. Robertson. 2013. River federalism and individualism. *Annals of the Association of American Geographers* 103(2): 290–98.

Duvall, C. S. 2011a. Biocomplexity from the ground up: Vegetation patterns in a West African savanna landscape. *Annals of the Association of American Geographers* 101: 497–522.

———. 2011b. Ferricrete, forests, and temporal scale in the production of colonial science in Africa. In *Knowing nature: Conversations at the border of Political Ecology and Science Studies*, eds. M. Goldman, P. Nadasdy, and M. Turner. Chicago: University of Chicago Press, 113–127.

Ellis, E. C., K. K. 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.

Elwood, S. A. 2009. Integrating participatory action research and GIS education: Negotiating methodologies, politics and technologies. *Journal of Geography in Higher Education* 33(1): 51–65.

Frothingham, K. M., B. L. Rhoads, and E. E. Herricks. 2001. Stream geomorphology and fisheries in channelized and meandering reaches of an agricultural stream. In *Geomorphic processes and riverine habitat*, eds. J. M. Dorava, D. R. Montgomery, B. B. Palcsak, and F. A. Fitzpatrick. Washington, DC: American Geophysical Union, 105–117.

Fryirs, K., and G. J. Brierley. 2009. Naturalness and place in river rehabilitation. *Ecology and Society* 14(1): 20.

Gibbs, D., and A. E. G. Jonas. 2000. Governance and regulation in local environmental policy: The utility of a regime approach. *Geoforum* 31(3): 299–313.

Grabbatin, B., and J. Rossi. 2012. Political ecology: Noequilibrium science and nature-society research. *Geography Compass* 6(5): 275–289.

Gregory, K. J. 2000. *The changing nature of physical geography*. London: Arnold.

Guthman, J. 2011. *Weighing in: Obesity, food justice, and the limits of capitalism*. Berkeley: University of California Press.

Haff, P. K. 2010. Hillslopes, rivers, plows, and trucks: mass transport on Earth's surface by natural and technological processes. *Earth Surface Processes and Landforms* 35(10): 1157–66.

Harrison, S., D. Massey, and K. Richards. 2008. Conversations across the divide. *Geoforum* 39: 549–551.

Head, L., J. Atchison, and A. Gates. 2012. *Ingrained: A human bio-geography of wheat*. Surrey, UK: Ashgate.

Hecht, S. 1985. Environment, development and politics: Capital accumulation and the livestock sector in Eastern Amazonia. *World Development* 13(6): 663–684.

Hird, M. 2009. *The origins of social life: Evolution after science studies*. Basingstoke, UK: Palgrave Macmillan.

Huber, M. T., and J. Emel. 2009. Fixed minerals, scalar politics: The weight of scale in conflicts over the "1872 mining law" in the United States. *Environment and Planning A* 41(2): 371–388.
Jessop, B. 1997. Capitalism and its future: remarks on regulation, government and governance. *Review of International Political Economy* 4(3): 561–581.
Johnston, S. 2012. Get rid of geography departments. *Geolog* 41(1): 6–7.
Lane, K. M. D. 2011. Water, technology, and the courtroom: Negotiating reclamation policy in territorial New Mexico. *Journal of Historical Geography* 37: 300–311.
Lane, S. N. 2001. Constructive comments on D Massey—Space-time, "science" and the relationship between physical geography and human geography. *Transactions of the Institute of British Geographers* 26(2): 243–256.
Lane, S. N., N. Odoni, C. Landstroem, S. J. Whatmore, N. Ward, and S. Bradley. 2011. Doing flood risk science differently: An experiment in radical scientific method. *Transactions of the Institute of British Geographers* 36(1): 15–36.
Lave, R. 2012a. Bridging political ecology and STS: A field analysis of the Rosgen Wars. *Annals of the Association of American Geographers* 102(2): 366–382.
———. 2012b. *Fields and streams: Stream restoration, neoliberalism, and the future of environmental science.* Athens: University of Georgia Press.
Lave, R., M. Doyle, and M. Robertson. 2010. Privatizing stream restoration in the US. *Social Studies of Science* 40(5): 677–703.
Linton, J. 2010. *What is water?: The history of a modern abstraction.* Vancouver: UBC Press.
Livingstone, D. N. 2003. *Putting science in its place: Geographies of scientific knowledge.* Chicago: University of Chicago Press.
Lorimer, J. 2010. Elephants as companion species: The lively biogeographies of Asian elephant conservation in Sri Lanka. *Transactions of the Institute of British Geographers* 35(4): 491–506.
———. 2012. Multinatural geographies for the Anthropocene. *Progress in Human Geography* doi: 10.1177/0309132511435352
Lubchenco, J. 1998. Entering the century of the environment: A new social contract for science. *Science* 279(5350): 491–97.
Mahony, M., and M. Hulme. 2012. Model migrations: Mobility and boundary crossings in regional climate prediction. *Transactions of the Institute of British Geographers* 37(2): 197–211.
Mansfield, B., D. Munroe, and K. McSweeney. 2010. Does economic growth cause forest recovery? Geographical explanations of forest regrowth. *Geography Compass* 4(5): 416–427.
McCarthy, J. 2005. Scale, sovereignty, and strategy in environmental governance. *Antipode* 37(4): 731–753.
Moore, J. W. 2000. Environmental crises and the metabolic rift in world-historical perspective. *Organization & Environment* 13(2): 123–157.
———. 2008. Ecological crisis and the agrarian question in world-historical perspective. *Monthly Review* 60(6): 54–62.
Pain, R., G. Whitman, D. Milledge, and Lune Rivers Trust. 2011. *Participatory action research toolkit: An introduction to using PAR as an approach to learning, research and action.* Durham, UK: Durham University, http://www.dur.ac.uk/resources/beacon/PARtoolkit.pdf
———. 2010. The job of the river. *Earth Surface Processes and Landforms* 35: 305–313.
———. 2011. Emergence and pseudo-equilibrium in geomorphology. *Geomorphology* 132: 319–326.
Polanyi, K. 1944. *The great transformation: The political and economic origins of our time.* Boston: Beacon Press.
Proctor, J. D. 1998. The meaning of global environmental change: Rethinking culture in human dimensions research. *Global Environmental Change: Human and Policy Dimensions* 8(3): 227–248.
———. 2013. Saving nature in the Anthropocene. *Journal of Environmental Studies and Sciences* 3(1): 83–92.
Proctor, J. D., and B. M. H. Larson. 2005. Ecology, complexity, and metaphor (introduction). *BioScience* 55(12): 1065–68.
Raj, K. 2007. *Relocating modern science: Circulation and the construction of knowledge in South Asia and Europe, 1650–1900.* New York: Palgrave Macmillan.
Rhoads, B. L. 2006. The dynamic basis of geomorphology reenvisioned. *Annals of the Association of American Geographers* 96: 14–30.
Rhoads, B. L., and E. E. Herricks. 1996. Naturalization of headwater agricultural streams in Illinois: Challenges and possibilities. In *River Channel Restoration*, eds. A. Brookes and D. Shields. Chichester, UK: Wiley, 331–367.
Rhoads, B. L., and K. Massey. 2012. Flow structure and channel change in a sinuous grass-lined stream within an agricultural drainage ditch: Implications for ditch stability and aquatic habitat. *River Research and Applications* 28(1): 39–52.
Rhoads, B. L., J. S. Schwartz, and S. A. Porter. 2003. Stream geomorphology and variability of hydraulic habitat for fish in four Midwestern agricultural streams. *Water Resources Research* 39(8): 1–13.
Rhoads, B. L., and C. E. Thorn, eds. 1996. *The scientific nature of geomorphology.* Chichester, UK: Wiley.
Rhoads, B. L., D. Wilson, M. Urban, and E. E. Herricks. 1999. Interaction between scientists and nonscientists in community-based watershed management: Emergence of the concept of stream naturalization. *Environmental Management* 24(3): 297–308.
Robbins, P. 2001. Fixed categories in a portable landscape: The causes and consequences of land-cover categorization. *Environment and Planning A* 33(1): 161–179.
———. 2012. *Political ecology: A critical introduction.* Chichester: Wiley-Blackwell.
Robertson, M. M. 2006. The nature that capital can see: Science, state and market in the commodification of ecosystem services. *Environment and Planning D: Society and Space* 24(3): 367–387.
Sayer, D. 1989. *The violence of abstraction: The analytic foundations of historical materialism.* Oxford: Basil Blackwell.
Sayre, N. F. 2008. The genesis, history, and limits of carrying capacity. *Annals of the Association of American Geographers* 98(1): 120–134.
———. 2012. The politics of the anthropogenic. *Annual Review of Anthropology* 41: 57–70.
Schuurman, N. 2000. Trouble in the heartland: GIS and its critics in the 1990s. *Progress in Human Geography* 24(4): 569–590.
Sheppard, E. 1995. GIS and Society: Towards a research agenda. *Cartography and Geographic Information Systems* 22(1): 5–16.
———. 2005. Knowledge production through Critical GIS: Genealogy and prospects. *Cartographica* 40(4): 5–21.
Simon, G. 2011. The 100th meridian, ecological boundaries and the problem of reification. *Society and Natural Resources* 24(1): 95–101.
———. 2012. Development, risk momentum and the ecology of vulnerability: A historical-relational analysis of the 1991

Oakland Hills firestorm. In *Cities, nature, development: The politics and production of urban vulnerabilities*, eds. S. Dooling and G. Simon. Aldershot, UK: Ashgate, 23–48.

Sutter, P. S. 2007. Nature's agents or agents of empire? Entomological workers and environmental change during the construction of the Panama Canal. *Isis* 98(4): 724–754.

Swyngedouw, E., and N. Heynen. 2003. Urban political ecology, justice and the politics of scale. *Antipode* 35(5): 898–918.

Tadaki, M., J. Salmond, R. L. Heron, and G. Brierley. 2012. Nature, culture, and the work of physical geography. *Transactions of the Institute of British Geographers* 34(4): 547–562.

Trudgill, S., and A. Roy, eds. 2003. *Contemporary meanings in physical geography: From what to why?* London: Arnold.

Turner, B. L., II, and P. Robbins. 2008. Land-change science and political ecology: similarities, differences, and implications for sustainability science. *Annual Review of Environment and Resources* 33: 295–316.

Turner, B. L., II, E. Lambin, and A. Reenberg. 2007. The emergence of landchange science for global environmental change and sustainability. *PNAS: Proceedings of the National Academy of Sciences of the United States of America* 104(52): 20666–20671.

Turner, M. D. 1999. Merging local and regional analyses of land-use change: The case of livestock in the Sahel. *Annals of the Association of American Geographers* 89(2): 191–219.

Urban, M. A. 2005a. An uninhabited waste: Transforming the grand prairie in nineteenth century Illinois, USA. *Journal of Historical Geography* 31(4): 647–665.

———. 2005b. Values and ethical beliefs regarding agricultural drainage in central Illinois, USA. *Society and Natural Resources* 18(2): 173–189.

Urban, M. A., and B. L. Rhoads. 2003a. Catastrophic human-induced change in stream-channel planform and geometry in an agricultural watershed, Illinois, USA. *Annals of the Association of American Geographers* 93(4): 783–796.

———. 2003b. Conceptions of nature. In *Meaning in Physical Geography*, eds. S. Trudgill and A. Roy, London: Arnold, 211–231.

Vale, T. R. 1982. *Plants and people: Vegetation change in North America.* Washington, DC: Association of American Geographers.

Vergara, W. 2007. Economic impacts of rapid glacier retreat in the Andes. *EOS, Transactions, American Geophysical Union* 88(25): 261–268.

Vitousek, P. M., H. A. Mooney, J. Lubchenco, and J. M. Melillo. 1997. Human domination of Earth's ecosystems. *Science* 277: 494–99.

Wainwright, S. 2012. Science studies in physical geography: Anidea whose time has come? *Progress in Physical Geography* 36(6): 786–812.

Walker, P. A. 2005. Political ecology: Where is the ecology? *Progress in Human Geography* 29(1): 73–82.

Watts, M. J. 1985. Social theory and environmental degradation: The case of Sudano-Sahelian West Africa. In *Desert development: Man and technology in sparselands*, ed. Y. Gradus. Dordrecht: Reidel, 14–32.

Wilson, D., M. A. Urban, M. Graves, and D. Morrison. 2003. Beyond the economic: Farmer practices and identities in Central Illinois, USA. *The Great Lakes Geographer* 10(1): 21–33.

Wohl, E., and D. J. Merritts. 2007. What is a natural river? *Geography Compass* 1(4): 871–900.

Zalasiewicz, J., M. Williams, W. Steffen, and P. J. Crutzen. 2010. The new world of the Anthropocene. *Environmental Science and Technology* 44(7): 2228–2231.

Zimmerer, K. S. 1993. Soil erosion and labor shortages in the Andes with special reference to Bolivia, 1953-91: Implications for "conservation-with-development." *World Development* 21(10): 1659–1674.

———. 1994. Human geography and the "new ecology": The prospect and promise of integration. *Annals of the Association of American Geographers* 84(1): 108–125.