

Sustainability Science and Geography

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Abstract

Sustainability science has been growing explosively thanks to contributions from multiple disciplines and intense debates over sustainability issues and relevant policies. This paper provides a close look of geography's contributions to sustainability science. It explores the relationship between geography and sustainability science, major geographic contributions to sustainability science, sustainability science topics for further geography research, and benefits to geography. The paper also examined main articles published in major comprehensive geography journals. It may be argued that contributions and benefits have been mutual. As geography is a core area of sustainability, sustainability has also become a common theme in geography. The paper calls for significant contributions to continue to be made by exploring the spatialities of sustainability. In particular, geography needs to get more involved in the current debates on sustainability definitions, sustainability indicators, environmental justice, and paths to sustainability.

Keywords: Sustainability, geography, sustainability science, environment, environmental justice, paths to sustainability.

Introduction

The debate over sustainability has resulted in new journals specializing in sustainability and new sections on sustainability in established journals, such as the *Proceedings of National Academy of Science (PNAS)*. *PNAS* (2012) seeks original research contributions on both the fundamental character of interactions among humans, their technologies, and the environment, and on the use of such knowledge to advance sustainability goals relevant to water, food, energy, health, habitation, mobility, and ecosystem services. Over the past seven years, *PNAS* has published over 300 papers in its sustainability science section (Kates 2011). A recent *PNAS* article, by Bettencourt and Kaur (2011) on the evolution and structure of sustainability science, confirms that sustainability science has been growing explosively and there exists a growing scientific field of sustainability science as an unusual, inclusive and ubiquitous scientific practice and bode well for its continued impact and longevity. According to the article, the sustainability science literature emphasizes the management of human, social, and ecological systems seen primarily from an engineering and policy perspective, dominated by contributions from the social sciences, biology, and engineering, while the social sciences publications are mainly from environmental policy, environmental

management, regional studies, human resource management, political geography, rural studies, urban studies, and econometrics (Bettencourt and Kaur 2011). A momentous publication as it is (Kates 2011), the *PNAS* article hardly reveals the significance of geography's contributions to sustainability science, which has so far barely been systematically examined in any academic publication.

This paper attempts to fill in that gap by addressing the following questions. 1. How is sustainability science related to geography? 2. How much has geography contributed to sustainability science? 3. How different sub-fields of geography have contributed? 4. Where have productive contributions occurred and should continue? 5. Have the contributions brought benefits? The paper argues that not only that sustainability science is very geographical, but also geography is very sustainability-oriented. Geography has made significant contributions to sustainability science and should continue to do so by exploring the spatialities of sustainability. Further geographic research can advance sustainability science in many areas, particularly in sustainability definitions, sustainability indicators, environmental justice, and sustainability transition and paths to sustainability.

How is sustainability science related to geography?

The question how sustainability science is related to geography may be answered by looking into what sustainability science is about. Consensual definition of sustainability science is as elusive as the definition of sustainability (O'Riordan 2004), however, there are generally recognized core elements. In a *Science* article "Sustainability Science," Kates et al (2001, 641) introduces to the science and technology community that sustainability science seeks to understand the fundamental character of interactions between nature and society and integrate the effects of key processes across the full range of scales from local to global. The *PNAS* (2012) describes sustainability science as "an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems." There are also many definitions of sustainability but the core idea is the same. According to the United Nations (2012a), sustainability calls for a decent standard of living for everyone today without compromising the needs of future generations. It is still being debated as what differentiates sustainability science from established fields such as environmental science (FORUM 2009), to which geography has made tremendous contributions. To me, one of the differences is the scope of study. Sustainability includes environmental, social, economic, and cultural sustainability, while environmental science focuses on the environment. Sustainability science is broader and more human-centered than environmental science. Sustainability science, as a newly established discipline, is also different from "sustainability studies," which tends to refer to an interdisciplinary research in sustainability issues or an interdisciplinary academic program.

The definition of sustainability science demonstrates that it is profoundly geographical, as such integrative endeavours must be situated in place, where the complex interactions become 'tractable, understandable and manageable' (Kates 2000, 2). As the study of sustainability deepens, the newest approach to understanding the causes of sustainability has involved the rediscovery of geography and attention to a place's physical and human geographic features (National Research Council 1997; Kates and Dasgupta 2007). Geographers have been key players in the development of sustainability science. Leading geographer Gilbert F. White and his students laid much of the groundwork in the twentieth century for geography's contributions to what has been called sustainability research in recent decades (Clark 2009). Five of the 23 eminent scientists and policy analysts who coauthored that *Science* article mentioned earlier are geographers, including lead author Robert W. Kates, Jill Jäger, Roger E. Kasperson, Akin Mabogunje, and Timothy O'Riordan (Clark 2009). The concept of sustainability science includes many "geographical"

themes such as nature-society interactions, scale, regional studies, vulnerability from multiple stresses, and multiple ways of knowing and learning (Kates 2002). Kates and Parris (2003) deem that it is the responsibility of sustainability science to map the broad, inclusive, and contradictory currents that humankind will need to navigate toward a just and sustainable future.

Similar geographic themes are recognized by others. Komiyama and Takeuchi (2006) propose that sustainability science must adopt a comprehensive, holistic approach to identification of problems and perspectives involving the sustainability of the global, social, and human systems, and the ultimate purpose of sustainability science is to contribute to the preservation and improvement of the sustainability of these three systems. Geography's focus on scale, both spatial and temporal, is also one of the key challenges of sustainability science (Blackstock and Carter 2007). Indeed geography and sustainability science are closely related in that both study human-environment interactions at the global and local levels (Wolch 2007; Whitehead 2006; Zimmerer 2006a; Yarnaland Neff 2004, 29; Turner 2002).

Sneddon (2000) pointed out that the breadth and specific character of work in human-environment geography could and should represent prominent themes in debates over sustainability, which had become its dominant trope, and geographers examining human-environment interactions through the analytical frames of nature-society relations and a broadly construed political ecology stand to reorientate debates over sustainability in several ways. Geography has particularly contributed to sustainability science through discourses in human-environment geography (Yarnaland Neff 2004; Turner 2002; Kates 1987), political ecology (Staddon 2009; Neumann 2009; Turner II and Robbins 2008; Klooster 2006; Robbins 2004; Zimmerer and Bassett 2003; Zimmerer 2000), and environmental geography (Reed and Christie 2009; Demeritt 2009; Braun 2008), despite epistemological and ontological differences between these areas of study and sustainability science. Clark (2009) argues that sustainability science reaches across many different disciplines, encompassing natural sciences, social sciences, and policy research—but the discipline of geography comes closest to tying it all together; it is a core of sustainability science.

How much has geography contributed to sustainability science?

If the two are so closely related, it would be interesting to find out how much geography have contributed to sustainability science. However, that appeared to be too much work for me to handle quantitatively. Instead, I examined how much geography journals have published sustainability science articles. It may be reasonable to use the result as an indication of geography's contributions. To achieve such a result, I considered the top 20 journals in the Subject Category Listing for Geography in the 2011 Journal Citation Reports Social Science Edition (Thomson Reuters, 2012). I use the four journals that intend to carry articles ranging across the entire subject of Geography; the other journals intend to be more focused on certain areas. The journals are *Annals of the Association of American Geographers (Annals)*, *The Professional Geographer (PG)*, *Transactions of the Institute of British Geographers (TIBG)*, and *The Geographical Journal (GJ)*. I surveyed main articles (or papers) published from January 2010 to December 2012 in the journals to provide an overview of present situation. The articles were chosen based on the contents in their titles, keywords, and abstracts, while the entire articles were sometimes examined to make sure of the selection. The selection was not easy as there are no agreed upon definitions of sustainability science or criteria for sustainability science articles. The articles were selected depending on whether they address nature and society interactions at the global or local levels and the needs of present and future generations, based on the definitions of sustainability science discussed above. Definitions of "the needs" may be different but generally include environmental quality, social justice, and economic well-being. Sustainability science includes research on sustainability and geography articles on sustainability automatically fall into this category. The sustainability articles are those dealing with social, cultural,

environmental, and economic sustainability or social, cultural, environmental, and economic issues from a sustainability point of view, as geography covers many issues from the geographic point of view.

The results show that, from January 2010 to December 2012, the four journals published a total of 453 articles, of which 215, or 47 percent, were on sustainability science. The percentage varies among the journals, ranging from about two thirds in *Annals* and *GJ* to one quarter in the *PG* and the *TIBG* (Table 1). Sustainability science is covered in one third to all of the articles in any issue of the *GJ*, from 30 to 100 percent in any issue of *Annals*, while the ranges are from 0 to 83 percent in the *PG* and 0 to 57 percent in the *TIBG*. *Annals*' 100 percent coverage happened in the two special issues: one on climate change and the other on energy. High percentage (68%) is also found in a third special issue on geographies of health (Table 1).

The above discussion is based on quantity: the number of articles. Quantity does not equal to quality, however, the numbers provide indications of the scope of geography's contributions. And the scope of contributions is an indication that geography has made substantial contributions to sustainability science. The next section goes further to investigate how different sub-fields of geography have done.

How have different sub-fields of geography contributed?

In addition to the difference between geography journals, it is reasonable to assume that different sub-fields of geography have done differently in terms of coverage in sustainability topics. To test this assumption, the paper uses *Annals* as a case study, because the journal divides geography into four sections: "Environmental Sciences," "Methods, Models, and GIS," "Nature and Society," and "People, Place, and Region." I use the four sections to represent different sub-fields of geography, an approach that may be controversial but seems handy for this research. Theoretically, all articles in "Environmental Sciences" and "Nature and Society" should be on sustainability and I decided to do so after repeated considerations (Table 2). Contributions by "Methods, Models, and GIS" are significant with 24 percent of the articles in this section related to sustainability issues. Recent examples include "Citizen science in the age of neogeography: Utilizing volunteered geographic information for environmental monitoring" (Connor *et al.* 2012) and "Mapping spaces of environmental dispute: GIS, mining, and surveillance in the Amazon" (Spiegel *et al.* 2012).

I had expected to find a higher ratio; however, only a quarter of all articles in "People, Place, and Region" are on sustainability. Three of the 14 issues carried no sustainability articles in this section. Recent sustainability articles include "The uneven geography of racial and ethnic wage inequality: Specifying local labor market effects" (Parks 2012) and "Making a living the Hmong way: An actor-oriented livelihoods approach to everyday politics and resistance in upland Vietnam" (Turner 2012).

While "Nature and Society" and "Environmental Sciences" have full coverage over sustainability, I expect the coverage in other sections to increase in the future along with growing interests in sustainability. For example, the "People, Place, and Regions" section is well suited to address sustainability issues, because sustainability is people-centered and place specific, while covering over many scales of space, ranging from global to local. The National Research Council (1999) believes that a priority for sustainability research is to develop a research framework that integrates global and local perspectives to shape a "place-based" understanding of the interactions between environment and society. Geography has the opportunity to make an important contribution by assessing the critical importance of space and geographical scale in understanding sustainability (Bowler *et al.* 2002). A diversity of solutions should be sought in accordance with the particular environmental and cultural conditions of each nation or region, and any attempt to impose uniform solutions of global environmental problems will threaten the diversity of the earth's regions and cultures (Komiya and Takeuchi 2006). Geography should examine how the contested nature of sustainability plays out between and within specific countries and at competing scales (Biles 2007).

According to Sultana (2009), scholars studying community and participation need to pay greater attention not only to gender and spatial power relations, but also to the importance of spatial locations and the agency of heterogeneous nature in the ways water management and development interventions fail and succeed, as relational conceptions of space and engagement with space is a representational media and medium of power.

Where have productive contributions occurred and should continue?

The above discussion shows the large variety of topics where geography has contributed to sustainability science. However, I argue that the most important productive contributions have occurred and should continue in the area of spatialities of sustainability. The following are some examples. Geography is found to be an important factor in understanding spatial variations in agricultural conservation (Liu 1999) and nature reserve sustainability in China (Zhang *et al.* 2009). Eden (2000) argues that geographical perspectives help the understanding of the multifaceted sustainability agenda, including analysis of the theoretical and ideological questions and practical problems that sustainability posed. Pini *et al.* (2007) use data from 15 case studies of rural local governments in Australia to identify the main factors that inhibit natural resource management by rural councils. They argue that the geographic location of the areas under investigation aggravates barriers to engaging sustainability initiatives. Fan and Qi (2010) assess the sustainability of major cities in China and highlight socioeconomic driving forces for spatial restructuring and land-use change. Examining how gender and mobility interact in the context of sustainability goals, Hanson (2010) argues that the kinds of changes that will be required to move toward sustainability will be different for different places and times. Pickerill and Maxey (2009) argue for greater attention to be paid to the geographies of sustainability, in order to tackle “actually existing sustainabilities,” find radical solutions, regard sustainability as holistic, integrating social, economic and environmental factors, be more assertively political, and include a clearer consideration of scale. The following discussions focus on specific topics including sustainability definitions, sustainability indicators, environmental justice, and sustainability transition and paths to sustainability, some of which may not have been generally regarded by all geographers as geographic topics. I will show that they can be.

The Definition of Sustainability

Kajikawa (2008) claims that the introduction of a spatial perspective is a contribution to the definition of sustainability, which emphasizes intragenerational equity, including economic disparity, particularly among nations. Conventional definitions of sustainability support economic growth with reduced impact on the environment. It also assumes that the Earth is able to provide enough resources for humankind to meet both present and future needs. However, that assumption is questionable as the Earth's resources are finite and are being depleted and degraded. Distribution of resources has always been and will always be unequal between and within countries, and sustainability may be achieved if one lives within one's own ecological means (Liu 2009).

The current definitions of sustainability do not adequately address the dilemma that many developing countries can neither meet their needs of the present or the future. Through an examination of sustainability of rural places in developed countries (Bowler *et al.* 2002), researchers at the International Geographical Union's Commission on the Sustainability of Rural Systems took sustainability definition to a higher level by exploring how conflicting environmental, social, cultural, and political values inherent in the development process can be addressed within the contexts of particular places (Pyle 2003). Geography should continue with the work in advancing sustainability definition, focusing on the spatialities of sustainability.

Sustainability Indicators

Parris and Kates (2003) point out that defining sustainability is ultimately a social choice about what to develop, what to sustain, and for how long. They explicitly distinguished between goals, indicators, targets, trends, and driving forces. In their framework, indicators are quantitative measures selected to assess progress toward or away from a stated goal, and targets are quantitative values of indicators for attaining the goal at a specific time or within a certain timeframe. There are no globally agreeable indicators of sustainability, however, Ecological Footprint (EF) has been often used as an indicator for environmental sustainability. According to the Global Footprint Network (2010), EF is a measure of how much biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates using prevailing technology and resource management practices. The EF has strengths and weaknesses as a sustainability indicator. One problem is that it uses country averages at the global scale, while there are considerable spatial variations within large countries such as Russia, China, Canada, the United States, and India. Measurement at local scales is desirable for better understanding of sustainability of places.

Sustainability will be better understood when we examine the spatial pattern of ecological creditor and debtor countries (Global Footprint Network 2010). The ecological debtor countries, mostly found in the temperate and sub-tropical zones in the northern hemisphere, are living beyond their ecological means (Environmental News Network 2007), meeting their present needs in an unsustainably way while compromising the ability of future generations to meet their needs. Many developing countries, such as China, India, and Bangladesh, are not meeting their present needs while degrading their environment and compromising the ability of future generations to meet their needs. Further research should examine sustainability indicators that take consideration of the vast differences among different countries.

Kajikawa (2008) states that to advance sustainability as a science we must develop new, efficient, and effective indicators that are optimally suited to our purposes. New indicators need to be proposed that possess a geographic dimension and undermine the importance of space and scale. There is a wonderful scope for geographers to combine their experience of the physical and the human to devise indicators for sustainability that are relevant to the eco-social circumstances, measurable and communicable to all, which will be a real test of the unity of Geography (O'Riordan 2004). For example, Kropp and Lein (2012) integrate a spatial multicriteria decision analysis model for sustainable development with scenario planning which resulted in an interpretation of sustainability that is more appropriate for local conditions and useful when exploring sustainability's semantic uncertainties, particularly those alternate perspectives that influence future environments.

Environmental Justice

Agyeman (2008) argues that human inequality is bad for environmental quality, from global to local, and justice and equity must move center stage in sustainability discourses. When harm or diminished wellbeing is experienced by already marginalized groups as a direct consequence of the actions of those that are more advantaged, then claims of injustice become particularly powerful (Walker 2009). Geography has made important contributions to research in environmental justice. This is because justice and geography matter together; they interrelate and are co-constructed as claims of inequality and injustice are put forward (Harvey 1996). Geographers are uniquely poised to understand human-environment relations, spatial and social distributions of environmental goods and bads, and to theorize the origins and perpetuation of inequality and injustice (Walker and Bulkeley 2006).

Another reason may be that spatial environmental justice has been an important environmental justice topic that interests geographers as well as non-geographers. Among many reports, spatial environmental

justice has been examined for the United States (Ueland and Warf 2006; Kurtz 2003), United Kingdom (Fairburn *et al.* 2009), Iraq (Loyd 2009), Thailand (Sajor and Ongsakul 2007), and Mexico (Grineski and Collins 2008). Early and ongoing research focusing on the spatial and social patterns of environmental hazards and associated activism demonstrates the power of a geographic perspective, and in recent years, scholars have noted a broadening of environmental justice research, both geographically and conceptually, to include global issues that expand beyond the spatial distributions of environmental 'goods' and 'bads' to include other dimensions including recognition, participation, and capabilities (Reed and George 2011). Geographic research on environmental justice and risk is moving beyond its conventional focus on proximity and spatial distribution, increasingly recognizing multiple spatialities entailed in other dimensions of environmental justice --including recognition and participation -- and in risk itself (Holifield 2012).

However, further contributions from geography are badly needed. As multiple forms of spatiality are entering our understanding of environmental injustice in different contexts, Walker (2009) argues for a richer, multidimensional understanding of the different ways in which environmental justice and space are co-constituted, within a framework of three different notions of justice—as distribution, recognition and procedure (or participation). Procedural justice means that those who are most affected by decisions should have particular rights to be involved and have their voices heard on a fully informed basis (Hampton 1999). For example, Through an investigation of the intersections between spatialities of risk and spatialities of environmental justice as participation and recognition, Holifield (2012) finds that the historical production of the Indian reservation as place, territory, and scale lies at the origin not only of distributive injustices but also of injustices of misrecognition and marginalized participation in the assessment and management of risk.

Contradicting previous claims that environmental justice research has greatly expanded conceptually or geographically beyond its traditional origins, Reed and George (2011) show that the research remains firmly rooted in the United States, focusing on the distributional aspects of environmental harms, while academic contributions from developing countries (or from marginalized populations within industrialized countries) are still at the margins and the voices of these scholars are still muted. Geographers need to get involved in environmental justice research in developing countries and marginalized populations within industrialized countries. Compared to the United States, developing countries tend to have worse environmental justice problems due to lack of human rights and democracy and rising industrial pollution. Without an independent media and information freedom, victims of environmental hazards in developing countries have not been able to have their voices heard (Liu 2010, 2012). Referring to China, Ma (2007) argues that geographers have the moral and disciplinary obligation to widen the scope of their scholarship to include work that would critically analyze and expose important issues of social and environmental injustice, which have negatively affected the lives of a large number of the socially excluded, marginalized, and disadvantaged groups.

Paths to sustainability

Geographers have contributed to the concept of sustainability transition (Kates and Parris 2003; Lee 2001; Kates 2000; O'Riordan and Voisey 1998; Pretty 1997). Associated with the concept of sustainability transition, the best paths to environmental recovery or a sustainable future have been debated, but contributions from geography has been lacking. Conventional thinking of environment-development relations tends to regard income as the dominant explanation for variations in environmental success (Esty *et al.* 2008; The Economist 2008). The notion of the environmental Kuznets curve (EKC) argues that the initial stages of economic growth are accompanied by increasing environmental degradation, once income exceeds a given threshold, not only does the structure of the economy change, but people can also afford to demand a better environment (Shafik 1994; Beckerman 1992). There has been an intense debate on the applicability of

the EKC. Some have regarded the EKC as the optimal growth path (Chimeli and Braden 2002), in the belief that high income is a precondition for environmental recovery. Consequently the “grow first and clean up later” approach has often been viewed as practical and desirable for developing economies (Rock and Angel 2007) or even optimal to sustainability (Azadi *et al.* 2011).

A geographic perspective suggests that low levels of development should not prevent countries from having effective environmental institutions and policies (Liu 2008, 2011; Dasgupta *et al.* 2006). The geographic approach undermines that fact that place matters in understanding the applicability of the EKC: only some places are able to follow the EKC or the “grow first, clean up later” approach before irreversible environmental degradation occurs. Severe social and economic inequalities plus environmental degradation in the early stages of development can cause such irreversible damage to the environment and society that the places will experience economic decline and the environmental conditions will not improve. Realizing an EKC is not the optimal growth path to environmental recovery, even if it may be applicable in certain cases (Liu 2008). Developing areas need to consider the environmental damage caused by the “grow first and clean up later” approach before moving to later stages of the EKC. Studies have shown that some places improve their environmental conditions or achieve environmental recovery at the environmental expenses of other places and the EKC or “grow first, clean up later” approach is not a sustainable practice (Liu 2012). Further research should incorporate the concept of environmental justice and spatialities of sustainability to examine place-specific paths to sustainability.

Have the contributions brought benefits?

The above discussion has confirmed the significance of geography’s contributions to sustainability science, which is the focus of the paper. By reviewing the publications, however, I see indications that sustainability science has also contributed to geography; contributions and benefits have been mutual. Many of the geography articles benefit greatly from the development of the concept of sustainability science. They would not have been written without drawing new ideas from sustainability science. It appears that geography articles on sustainability are also well-cited by geographers and non-geographers. As of September 4, 2012, 13 (65%) of the top 20 most cited articles in *Annals* addressed sustainability topics (Taylor & Francis Online, 2012). The top three are all on sustainability. They are “Ecoregions of the conterminous United States” (Omernik 1987) with 194 citations, “Multi-agent systems for the simulation of land-use and land-cover change: A review” (Parker *et al.* 2003) with 138 citations, and “Revealing the vulnerability of people and places: A case study of Georgetown County, South Carolina” (Cutter *et al.* 2000) with 88 citations. I argue that sustainability research helps geography to grow.

Furthermore, non-geographers working on sustainability issues have also contributed to geographic topics such as location and place characteristics. Here are two examples. In examining environmental justice implications of brownfield redevelopment in the United States, Lee and Mohai (2012) pay special attention to geographic features such as: who lives near brownfield sites and which sites are cleaned up first, and whether brownfield development can provide economic benefits without any adverse consequences of development to local residents. Owen *et al.* (2011) discover that geography matters for civil engineering solutions, because they are routinely responsive to the places where those solutions are going to be built and the physical aspects of places are integral to good design. They show that characteristics of a place, in particular its social or economic geography, will affect the design, implementation and impact of many civil engineering projects (Owen *et al.* 2011). This kind of publications contributes to geography as well as sustainability science.

Many sustainability topics are very “geographic” and geography should strive to make further contributions. For example, the following fundamental questions, raised in *Toward a Science of*

Sustainability (Levin and Clark 2010), may well suit geographers: (1) What are the principal tradeoffs between human well-being and the natural environment? (2) How are those tradeoffs mediated by the ways in which people use nature? (3) How can less-developed places most effectively guide or manage human-environment systems toward a sustainability transition? As sustainability science sustains its rapid growth, we should expect to see growing opportunities for geography's further contributions. Geographers should not miss the boat. O'Riordan (2004) argues that geographers have evolved the methodologies to cope with sustainability science and the scope for a successful Geography around sustainability is a real possibility, and an option that should not be denied current or future geographers. Showing insights from geographers can help address limitations of the socio-technical transition approach, Lawhon and Murphy(2012) state that sustainability is increasingly becoming a core focus of geography.

This paper demonstrates that sustainability has become a core focus in different sub-fields of geography. I would like to call for geographers to consider using the term 'sustainability geography' to integrate sustainability science and geography. Further research in sustainability geography may address the question of the sustainability of places: why some places are more sustainable than other places. This has the potential to make further contributions to both sustainability science and geography. With or without the label "sustainability geography," geographic contributions to sustainability science should be further examined and expanded to enhance the growth of geography and sustainability science. There are indications that policy makers/stakeholders are recognizing the geographies of sustainability. For example, the United Nations (2012b) Global Compact LEAD launched a series of *New Geographies of Corporate Sustainability* workshops to explore how corporate sustainability is impacted by local contexts and key emerging sustainability trends, to inform Rio+20 Corporate Sustainability Forum. Business for Social Responsibility (BSR, 2012) also initiated the New Geographies of Sustainability workshop series and research initiative to harvest and bring to the forefront the perspectives of key opinion formers in Brazil, China, and India, in order to balance Western perspectives about corporate sustainability.

Conclusions

This paper has examined geography's contributions to sustainability science, through a literature review and an examination of sustainability science articles in four leading geography journals. It demonstrates that geography and sustainability science are closely related. Geography has become very sustainability-oriented, with sustainability as a major theme in different sub-fields of geography. While the nature-society and environment sub-fields are heavily sustainability focused, other sub-fields including GIS and methods have also contributed substantially. Productive contributions have occurred and should continue in many areas of geography, with a focus on spatialities of sustainability.

Growth in sustainability science and geography has benefited from revealing spatialities of sustainability in the current debates on sustainability definitions, sustainability indicators, environmental justice, and paths to sustainability. New definitions of sustainability need to consider the problem that many developing countries can neither meet their needs of the present or the future. New sustainability indicators need to possess a geographic dimension and undermine the importance of space and scale. Geography has already made important contributions to research in environmental justice, with current research emphasizing the geographical disparities within a framework of three different notions of justice: distribution, recognition and participation. Regional geography may contribute to the need to expand the research beyond the United States to reveal environmental injustice in developing countries. Geography enhances the academic and policy debates over the paths to sustainability. A geographic perspective reveals that conventional thinking of the "grow first and clean up later" approach is not applicable to the paths to sustainability for developing countries, as some places are more sustainable than others, and some places

may improve their environmental conditions at the environmental expenses of other places. Further geographic contributions should incorporate the concept of environmental justice and spatialities of sustainability to examine place-specific paths to sustainability.

Geography has been a core area of sustainability science, which in turn has become a major theme in geography. Contributions and benefits have been mutual. As sustainability science continues to grow, geography's contributions are expected increase. I call for using the term "sustainability geography" to integrate sustainability science and geography, to especially address the questions why some places are more sustainable than other places, and why some places improve their environmental conditions at the environmental expenses of other places. Many sustainability topics are very geographic and suit future geographic research, including tradeoffs between human well-being and the natural environment, tradeoffs meditations, and sustainability transition in less-developed places. Important public debates and policy making in sustainability cannot be relevant to local communities without understanding spatialities of sustainability, which is critical in terms of generating more nuanced public and policy relevant debates.

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Table 1 Sustainability science(SS) articles in four geography journals published from January 2010 to September 2012

Journal	Annals		PG		TIBG		GJ	
	SS/All	%	SS/All	%	SS/All	%	SS/All	%
2012.6	5/15	33						
2012.5	23/34*	68						
2012.4	3/7	43	1/9	11	3/10	33	1/2	50
2012.3	6/11	55	2/9	22	4/7	57	2/4	50
2012.2	7/12	58	2/11	18	0/9	0	4/6	67
2012.1	6/11	55	3/6	50	0/11	0	4/6	67
2011.6	4/10	40						
2011.5	6/11	55						
2011.4	22/22*	100	1/3	33	2/7	29	6/7	86
2011.3	5/10	50	3/4	75	2/8	25	1/2	50
2011.2	4/10	40	0/2	0	2/8	25	2/2	100
2011.1	5/10	50	0/8	0	2/9	22	2/6	33
2010.5	3/5	60						
2010.4	26/26*	100	0/1	0	4/9	44	3/6	50
2010.3	3/10	30	0/2	0	2/8	25	3/5	60
2010.2	6/11	55	0/8	0	2/8	25	2/4	50
2010.1	6/10	60	5/6	83	2/8	25	3/6	50
Total	140/226	62	17/69	25	25/102	25	33/56	59

Notes: * Special Issue

Source: Own research

Table 2 Distribution of sustainability science (SS) articles in the four sections of *Annals of the Association of American Geographers*, Issue 1, 2010 - Issue 6, 2012

Sections	Environmental Sciences		Methods, Models, and GIS		Nature and Society		People, Place, and Region	
	SS/All	%	SS/All	%	SS/All	%	SS/All	%
2012.6	1/1	100	2/6	33	2/2	100	0/6	0
2012.4	1/1	100	0/1	0	1/1	100	1/4	25
2012.3	2/2	100	1/2	50	2/2	100	1/5	20
2012.2	2/2	100	1/3	33	2/2	100	2/5	40
2012.1	2/2	100	0/3	0	1/1	100	3/5	60
2011.6	2/2	100	0/2	0	2/2	100	0/4	0
2011.5	2/2	100	1/3	33	2/2	100	1/4	25
2011.3	2/2	100	0/3	0	2/2	100	1/3	33
2011.2	2/2	100	0/2	0	2/2	100	0/4	0
2011.1	2/2	100	1/2	50	1/1	100	1/5	20
2010.5	1/1	100	0/1	0	1/1	100	1/2	50
2010.3	1/1	100	0/3	0	1/1	100	1/5	20
2010.2	1/1	100	1/3	33	3/3	100	1/4	25
2010.1	1/1	100	2/3	67	1/1	100	2/5	40
Total	22/22	100	9/37	24	23/23	100	15/61	25

Source: Own research

Notes: *The three Special Issues in Table 1 are excluded because they are not divided into sections. Without the Special Issues, *Annals* published 143 articles, of which 69 articles, or 48 percent is related to sustainability

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