13 Interactions of Geography with Other Natural and Social Sciences and the Humanities

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Abstract

Geography has historically enjoyed strong interactions with other disciplines in addressing major challenges related to social, economic, and environmental issues and in contributing overall to sustainability. More especially in the Anthropocene, issues such as climate change, biodiversity loss, terrorism, poverty, refugees, environmental hazards, and pandemics have emerged that require an improved understanding of spatial and temporal patterns, processes, and impacts. Consideration of scale and place-based perspectives are essential in helping to resolve such complex issues. The chapter highlight five arenas of interaction between geography and other disciplines, viz. the natural sciences, socioeconomic sciences, humanities, human-environment relationships, and sustainability science. The International Geographic Union (IGU) provides a platform to unite geographers globally to share ideas, promote communication, and advance the interaction of geography with other disciplines, and also with different stakeholders from NGOs, governmental agencies, and international organizations. At this critical juncture, Geography must continue to develop through its vibrant connections with other fields and geographers should continue to exhibit interdisciplinary leadership by embracing different perspectives, by supporting institutional arrangements that foster interdisciplinary activity, and by seeking the knowledge and techniques that other fields can contribute to geographic perspectives, approaches, and insights to the collective effort. The IGU continues to play an important role in facilitating knowledge development and sharing, and in encouraging transformational actions that promote a just, peaceful, and sustainable planet.

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13.1 Introduction

Social, economic, environmental, and related health issues are receiving increased attention globally and have been brought into particularly sharp focus by the coronavirus pandemic. The continued spread of COVID-19 is an illustration of the increasingly interconnected nature of the world. At the same time, the pandemic is a timely reminder, not only of the importance of distance and geographic space but also of our vulnerability as a species. From its 'rediscovery' (National Research Council 1997) to its 'secret powers to save the world' (Bednarz 2019), there has never been a more relevant, or important, time for the discipline of geography, sitting astride—as indeed it does—the social and natural sciences.

The origin and evolution of geography have been shaped by its interactions with other disciplines, and its response to emerging global issues. In early times, astronomy, geometry, physics, anthropology, and history, among others, provided questions, perspectives, methods, and tools for geography as geographers accumulated knowledge of different places and countries in what was essentially exploration, discovery, and cartography (Baker 1931). The development of an identifiable academic discipline (Stoddart 1986) and its broader subdisciplines of physical geography and human geography in the last century benefited from interaction with other disciplines. Geographers have played active roles in multi-disciplinary, cross-disciplinary, interdisciplinary, and transdisciplinary research because the subject is itself inherently interdisciplinary. As Baerwald (2010) claims, geography has built on its fundamental element of spatial analysis to explore human-environment interactions and place-based and regional analyses to encourage communication and interaction with a myriad of other disciplines. The active pursuit of inquiry related to space and place, and to the dynamic interactions within and between spaces and places, has encouraged geographers to range far from its traditional core and explore the peripheral realms where geographic perspectives and insights intersect with those from other fields (Baerwald 2010). The International Geographical Union itself has a record of fostering such interactions, not least in the number of its Commissions that are interdisciplinary in nature (e.g., Geography for Future Earth, Sustainability of Rural Systems). Indeed two IGU Commissions are formally co-hosted with other major scientific organizations (Geomorphology and Society, with the International Association of Geomorphologists, and Toponymy, with the International Association of Cartography).

As a discipline, geography endured a particularly difficult time in the second half of the twentieth-century, as many universities in the United States, notably including Harvard, Columbia, and Michigan closed their geography departments (Fink 1979). Such challenges were not confined to the US and became further intensified as geography, even in the universities where it did survive, began to lose its identity as departmental names changed and incorporated other disciplinary labels (see Hall et al. 2015). More recently, the development of Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning System (GPS) has reinvigorated, perhaps even revolutionized, geography. Several IGU Commissions, most notably the Commission on Geographical Information Science and Geography of Information, Innovation and Technology, have been established in response. The COVID-19 maps developed by Johns Hopkins University (https://gisanddata.maps.arcgis.com/apps/opsdashboard/index) are universally consulted and have certainly assisted in tracking the spread of the virus such that the significance of spatial analysis has been brought into the global spotlight. What this serves to emphasize is the importance of geography in its relationships with other disciplines. The history of the discipline is a mirror for the

future in highlighting that geography has to be flexible and responsive, not only to developments in technology but also to the needs of society at large.

Currently, the study of high profile global issues such as climate change, loss of biodiversity, human migration, land degradation, refugees, poverty, terrorism, and pandemics all enjoy a legitimate place in the field of geography, but it is only through the relationship of geography with other disciplines, including atmospheric science, ecology, demography, political science, psychology, and medical science among others, that these complex issues can be comprehensively understood and addressed. Therefore, the interactions with other sciences, natural, social, human, and economic, have played their part in shaping the modern discipline and it is through such relationships that the future of geography will take shape. In this chapter, therefore, we highlight five arenas of interaction between geography and other disciplines, viz. the natural sciences, socioeconomic sciences, humanities, human-environment relationships, and sustainability science.

13.2 Geography and the Natural Sciences

Geography has deep roots as a natural science and, in the form of the sub-discipline of physical geography, typically uses many methods that evolved within the natural and physical sciences. The sciences, in general, have been, and remain, highly influential, although two concepts, in particular, have played an enormous role in the development of physical geography, viz. Hutton's 1795 uniformitarianism and Darwin's theory of evolution (Gregory 2000). Uniformitarianism, amplified notably by the geologist Charles Lyell as its 'high priest' (Chorley et al. 1964), was a counter to both scientific catastrophism and biblical fundamentalism and led to the prospect of using 'the present as a key to the past' to explain landscape formation. How can we imagine the contemporary science of geomorphology, in its various manifestations, without recourse to this seminal principle that allows us to interpret past features in terms of contemporary patterns and processes? The influence of Charles Darwin has been similarly pervasive and, as Stoddart (1966) argues, the idea of change through time strongly impacted the development of physical geography.

Physical geography has obvious and important relationships with the fundamental sciences, including Mathematics, Physics, Chemistry, Biology, and Geology. Indeed, for many students of physical geography to this day, these disciplines are essential (and often compulsory) building blocks for their curriculum. The physical sciences offer what Richards (2008) refers to as a 'role model' for physical geography which has borrowed from them the basic idea of testing theory through experimentation to develop systematic and formulated knowledge. Ultimately, these foundations led to the development of the recognizable branches of the subject, perhaps the earliest example of which is Huxley's (1877) *Physiography*, but which diversified through the first part of the twentieth-century into soil science, biogeography, climatology, hydrology and, of course, geomorphology. In respect of the latter, the work of W. M. Davis has been enormously influential, as the 'cycle of erosion' concept, rooted strongly in the concept of evolution and change over time, characterized physical geography up to 1950 (Gregory 2000). The cycle of erosion concept is at once elegant in its simplicity and convincing due to its perceived widespread applicability. Chorley (1973) went so far as to suggest that this notion essentially established geomorphology as a mature science and as an academic discipline (albeit one that is usually taught in US universities in geology departments). The second half of the twentieth-century witnessed a number of developments, among them a shift from a focus on longer-term landscape evolutionary processes to a consideration of shorter time scales. The Quaternary, with its dramatic shifts from glacial to interglacial conditions, proved an attractive line of inquiry for physical geographers that strengthened the linkages in particular with geology and biology, among other sciences. Studies of contemporary

physical environmental processes were also to become a prominent theme. Before 2000, for example, physical geography research in China was dominated by the study of sediment sequences on the loess plateau, ice cores on the Qinghai-Tibet plateau, and speleothems in karst caves that record changes during the Quaternary through to the late Holocene, including the historical period. There has, however, been a broadening of emphasis to include landscape processes and the effects of recent climate change.

Physical processes are fundamental to all features of the earth system, but there is more to physical geography than this since it is concerned with 'phenomena that unfold in an unconstrained social and environmental space, across a wide range of scales' (Richards 2008: 24). Moreover, the methods by which such complex processes are observed, measured, and interpreted have also changed. Thus, physical geography engaged not only with the trend toward quantification and positivism, but ultimately also modeling, detailed investigations of processes, and a concern with human impact on the environment including, for example, studies of global climate change, land degradation, hazards, and risks, among others—themes that are the focus of several IGU Commissions. Developments were also prompted by novel techniques and technologies. Advances in remote sensing, geographical information systems, and information technology have at once prompted highly detailed small-scale analyses but also facilitated global-scale analysis. A fresh impetus has been given by the emergence of a more culturally-based approach throughout many branches of physical geography. A series of issues can be identified including the increasingly holistic trend prompted by a greater awareness of global environmental problems, the development of earth system science, and of the timely opportunities which can arise from closer links with human geography and with other disciplines. Extrapolating present trends suggests a bright future for physical geography involving a more integrated approach, even greater concern for environmental futures, and closer links to human geography, along with other disciplines. As physical geography evolves and reflects these trends, it seems likely that pluralist approaches will increasingly feature and that university departments may take on distinctive flavors according to the expertise of their staff and the nature of the research relationships they develop with other disciplines.

13.3 Geography and the Social and Economic Sciences

As Johnston (2009: 58) puts it: 'Geography came late to the social sciences' and its relationship with economics, political science, and sociology, the 'core' social science disciplines, is essentially a post-World War Two phenomenon. Prior to this time, geographers' concern with regions, distinctive areas with characteristic landscape features that were different from neighboring areas, meant that there was little, if any, orientation toward the social sciences. Johnston argues that while geographers were concerned with mapping economic activity and relating this to particular environments, they appear to have made few connections with economists prior to the 1950s and other social sciences were connected only very tangentially at best. This was to change, however, as human geography successfully remodeled itself and gained recognition as a social science by the 1970s, drawing on a wide range of additional traditions, such as Marxism, feminism, and postmodernism (Johnston and Sidaway 2004). The ideas of key social theorists, in particular, Anthony Giddens in revolutionizing social theory and Manuel Castells in considering the nature of 'the network society' were certainly instrumental in reshaping human geography (Giddens 1971; Castells 1996). Although, as Johnston (2009) suggests, geographers have been largely 'net importers' from the social sciences, we focus here on developments in economic geography by way of illustrating that interactions between disciplines may lead to mutual strengthening of both theory and practice.

In recent decades, intellectual exchange and collaboration between economic geography and economics and management have been

flourishing, a trend that has been given further impetus due to the rise of globalization. Economic geographers adopt a spatial perspective to analyze activities, such as entrepreneurship, manufacturing, and innovation, which exhibit a highly uneven pattern, and try to answer questions such as why do some industries agglomerate in specific areas, e.g., high-tech in Silicon Valley, cellphones in Shenzhen, and finance in Wall Street? Why do some regions develop steadily while others decline rapidly, for example, Detroit? These questions attract geographers as well as economists and management scholars. Trained in their own disciplines, economic geographers, economists and management scholars tackle the same phenomenon from different perspectives using different methods. However, given that any economy, at whatever scale, is multifaceted, a single disciplinary investigation often neglects other important dimensions of the research subject, generating a biased understanding. For example, the assumption of firms with the same preference to maximize profits in economics rules out their heterogeneity in managerial practices and choices, which can be place-specific (Clark 2018; Storper 2013).

The significance of location to economic theory, previously largely neglected by economists, was emphasized by Paul Krugman (1991). In economics, economy was traditionally modeled in an abstract location-free market, an assumption challenged by Krugman who argued for the formal integration of location into economic models (see Krugman 1993). Together with others, Krugman introduced geography into mainstream economics and was indeed awarded a Nobel prize in 2009 for his contribution (see also Fujita et al. 1999). Although critiqued by geographers, his original contribution laid out the intellectual basis for dialogue between the two disciplines (Martin and Sunley 1996). A formal marriage between geography and economics was signified by the establishment of the *Journal of Economic Geography* in 2001 by Oxford University Press, edited by leading scholars split equally across geography and economics, with the aim 'to redefine and reinvigorate the intersection between economics and geography.' Geographers and economists have been prompted to discuss the strengths and weaknesses of their research methods and explore how one can learn from the other (Overman 2004; Storper 2013). The mathematical modeling approaches deployed by economists to identify and quantify mechanisms and geographers' more qualitative analysis to identify patterns and processes complement each other and deepen our understanding of spatial economies. Interestingly, related to their different preferences of research methods, geographers and economists implicitly developed a division of labor when examining the same phenomenon. For example, in relation to industrial agglomeration, economists prefer to detect the effects of supplier sharing and local labor markets (Combes and Gobillon 2015), while geographers are interested in understanding the social structure of knowledge sharing (Li et al. 2012).

In relation to management, the engagement of geography was given huge impetus through the work of Michael Porter who highlighted the significance of location and industrial clusters for business strategy (see, for example, Porter 2000). Unlike economists who discovered geography at the macroeconomic level, management scholars recognized the importance of location in the micro-processes of individual firms. Strategy and management studies build on observations of actions and choices made by firms using a diverse range of research methods. Compared to deductive reasoning of economists, this empiricism by management scholars is more in line with geographers' research practices. As a result, research collaboration and cross-fertilization between geography and management scientists have been relatively smooth. For example, in the past several years, several major journals have published special issues to bridge the two fields, including *Regional Studies* (Knight et al. 2020), *Journal of Economic Geography* (Bathelt et al. 2018), and *Journal of International Business Studies* (Mudambi et al. 2018). Overlapping themes range from innovation strategies and industrial clustering to international investment and global knowledge flows. The advantage of

management studies lies in a deep understanding of what happens inside the firm, while geographer's work tends to emphasize how the firm's business environment shapes its competitive advantages or disadvantages. Geographers benefit from the research exchange with management studies since the firm-centered approach addresses the concern that many regional development theories lack a solid foundation of microeconomic processes (Li and Bathelt 2018).

Recent decades have witnessed increasingly prominent interactions between economic geography and economics and management. Looking back, economic geography has benefited greatly from this interdisciplinary knowledge exchange that has broadened its frontiers, tightened research rigor, and enriched the understanding of the spatial dimension of economies. Looking forward, it seems likely that this endeavor will continue to bear fruit.

13.4 Geography, Critical Theory and the Humanities

Within the field of human geography, there has been a strong social science emphasis, as discussed above. Yet, also during this time, human geography has adopted more critical approaches that have widened and enriched the field. These more critical approaches look beyond the scientific pursuit of collecting more data and knowledge about the world and instead critically reflect on how social, political, economic, and cultural factors shape knowledge production, society, and space in ways that earlier approaches tended to ignore. This happened first with the sub-field of cultural geography beginning in the 1920s, and much more forcefully with the related sub-field of critical geography in the 1970s. To this day, engagement with critical theory and the humanities continues to reinvigorate the field of geography well beyond its classical borders. The analytical rigor of these approaches is not in big data or modeling, but rather in challenging key assumptions about space and power that more conventional geographic analyses leave unquestioned and unexplored.

13.4.1 Cultural and Humanistic Geography

Cultural geography represents one of the first major shifts away from the positivism and determinism that dominated early twentieth-century geographic thought. Rather than emphasizing how landscapes and available resources influence or determine the development of societies, cultural geography instead acknowledges that people affect their environments as much as their environments affect them. Starting in the 1920s, cultural geography began exploring these interconnections between societies and their wider landscape. The field posited that the constitution of a society—its tools, shelters, cuisine, and other elements typically associated with culture—is not determined by environmental factors, but in many ways the reverse. Culture influences how the world is understood and how societies interact with their environments, resulting in 'cultural landscapes' created as much by human culture as environmental constraints (Sauer 1925). Culture, in short, is not passively determined but is an active agent of environmental change.

In the 1970s and 80s, developments in the humanities and critical theory began to influence the field of geography even more profoundly. Humanistic geography, 'new humanism,' and 'new cultural geography' took the wider discipline of geography even further from its historical roots in positivism, determinism, and quantitative analysis (Tuan 1976; Relph 1976; Buttimer and Seamon 1980; Ley 1981; Cosgrove and Jackson 1987; Ley 1985). The focus on the particularities of human intention, meaning, and culture in these analyses became even stronger, shifting further away from the determinism associated with environmental context.

13.4.2 Critical Geography

From the 1960s onward, alongside developments in cultural and humanistic geography, the subfield of 'critical geography' emerged. Similar in its rejection of positivism, critical geography

builds heavily on key themes in critical theory, in particular Marxism and post-structuralism. Critical geography moves beyond an emphasis on culture or the humanities, to consider questions of power more directly. As diverse as this subfield is, it is nonetheless united in its commitment to reflect critically on how power shapes space and society in ways previously overlooked.

Critical geography has its roots most firmly in Marxist critique, which was experiencing a revival in the 1970s. At this time, heightened awareness of the geographic impacts of capitalism in terms of 'unequal exchange' (Emmanuel 1972), 'underdevelopment' (Frank 1966), and 'regionalism' (Massey 1978) began to infiltrate the field. Building on these early critiques, Harvey (1981) and Smith (1984) advanced the concepts of 'spatial fix' and 'uneven development' that have since become seminal in the field. Harvey uses the concept of a spatial fix to show how capitalism's inherent push for continued expansion manifests spatially. Once the accumulation of surplus-value is saturated in a given terrain, capital must continue expansion beyond its borders. This geographic expansion provides a temporary 'fix' to crises of capital overaccumulation, forging new outlets for the accumulation of surplus-value. Through the concept of 'uneven development', Smith further extended this work, applying it to the realm of nature and the natural. These ideas remain highly influential at the beginning of the 21st Century, with a new generation of critical geographers advancing various 'fixes' beyond the spatial: 'regulatory', 'environmental', 'biophysical', hydro-social', socioecological', and 'cultural' fixes all open new sites of accumulation to capitalist dynamics (Swyngedouw 2013; Cohen and Bakker 2014; Castree and Christophers 2015; Ekers and Prudham 2017; Zhu 2020).

In addition to the Marxist critique, critical geography increasingly relies on other strains of critical theory, including postmodernism, constructivism, and post-humanism. While there is no clear term that unites these diverse approaches, they are sometimes grouped together under the broad label of 'post-structuralism', given their mutual aversion to analyzing society in terms of its underlying structures (capitalist vs. proletariat, sign vs. signified, and so forth). Post-structural approaches reject the 'grand narratives' associated with Marxist critiques of capitalism (e.g., the singular logic of capital accumulation that drives its exploitative relations) and further maintain that there is no vantage through which one can objectively analyze the world to reveal its deeper truths. Indeed, for the post-structuralist, there is no deeper truth to speak of, but rather many truth statements that only make sense as such within a given discourse. Key post-structural thinkers include Michel Foucault on discourse and power/knowledge (Foucault 1984), Gilles Deleuze and Felix Guattari on assemblage (Deleuze and Guattari 1987), Donna Haraway on situated knowledges (Haraway 1988), and Bruno Latour on actor-network-theory (Latour 2005). While these scholars are not themselves geographers, their work has inspired a new turn in critical geography toward the post-structural, postmodern, and posthuman (Soja 1989; Minca 2001; Murdoch 2006; Castree and Nash 2006; Soja 2011).

Despite differences between post-structural and Marxist geographies, most contemporary critical geographers engage with both approaches. More than choosing one side or another, strains of critical geography such as feminism, post-colonialism, and political ecology draw from both Marxist and post-structural thought (Rose 1993; Peet and Watts 1996; Ashcroft et al. 1998; Robbins 2012; McDowell and Sharp 2016). This has resulted in a focus not only on the political-economic and material production of nature and space but also on their production through more intangible, discursive means. Critical geographers contend with a range of power structures from the material to the discursive, with no clear line distinguishing the two. This scholarship is at the forefront of critical geography today and is certainly a key research theme within the IGU Commission on Political Geography. United in its firm rejection of positivism and determinism, the emergence of critical geography represents a profound shift in the spirit and commitment of the field of geography.

13.5 Geography and Human-Environment Relationships

13.5.1 Evolution of Ideas on Human-Environment Interactions

Human-environment relationships can be partly reflected by the multiple conceptualizations of nature in different languages and countries (Coscoeme et al. 2020). Traditionally China views humans as part of nature and thought (天人合一), which seeks a harmony between people and nature. The conceptualization has also affected human behaviors and designing landscape architecture. Research on human-environment interactions (HEI) is not only a reflection on the history of societal development but also a reflection on the evolving human epistemology regarding the relationship between people and nature. The nature of the relationship between humans and their environment has changed since behaviorally modern humans, *Homo sapiens* first emerged. A reliance on natural systems for food and other resources evolved, in particular through advances in technology, that ultimately enabled the establishment of our modern substantially industrialized, and urbanized society. Just as the nature of the relationship itself has changed, so has the *interpretation* of the nature of that relationship.

According to Moran (2005), three main themes can be identified in Western intellectual history to explain human interactions with nature: (1) environmental determinism, which emphasizes the dominance of nature, (2) possibilism, which emphasizes the dominance of human culture, and (3) adaptationism, which bridges the gap between these two and emphasizes the mutual interactions of people with nature. Harden (2012) identifies five categories of HEI, among which both environmental determinism and natural hazards approaches portray humans as essentially passive agents that lie at the mercy of environmental change (Fig. 13.1). The 'human impact' perspective on the other hand recognizes the significant role of people in changing their environment (Marsh 1864; Carson 1962). The sustainability framework considers that interactions between the human and natural systems may be mutually supportive.

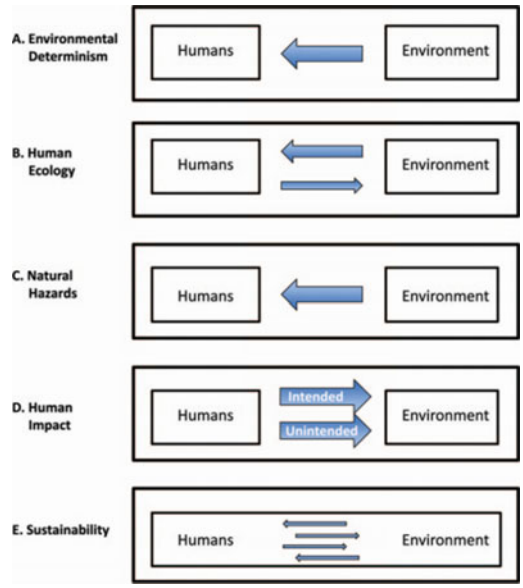

Fig. 13.1 Ways of framing human-environment interactions. The arrows represent the direction(s) of causation. *Source* After Harden 2012

13.5.2 Population, Resources, and Environment

Consideration of human-environment interactions initially focused largely on the relations between population and resources. Malthus (1798) envisaged that population growth would outstrip the ability of the environment to support it and that the lack of sufficient resources would result in population collapse. The Malthusian influence on theory was prominent for some time but in due course, counter-arguments prevailed, among others that improvements in agricultural productivity and efficiency through technology facilitate ongoing population growth. Von Thünen's model of agricultural land use also provided an important impetus for geographers in their attempts to understand resource-related spatial elements of the human-environment nexus

(O'Kelly and Bryan 1996; Van Wey et al. 2005). Public attention on resource constraints resurfaced in the 1960s and 70s with the publication of *The Population Bomb* (Ehrlich 1968) and *The Limits to Growth* (Meadows et al. 1972) prompted by emerging environmental problems and encapsulated in Rachel Carson's (1962) *Silent Spring*. Concerns around global environmental problems such as deforestation, pollution, biodiversity loss, greenhouse gas emissions, and land degradation were growing and from the 1980s onwards; these issues provided fertile ground for the boom in global environmental change approaches that geographers were quick to adopt (Mannion 1991) and in which the IGU community has made substantial contributions through the work of, for example, the Commissions on Population, Land Degradation, and Land Use and Land-Cover Change to name but three.

13.5.3 Integrated Research Initiatives

In the late 1980s, studies under the International Geosphere-Biosphere Program (IGBP) were led by largely natural science disciplines, not least geology, climatology, and biology. However, with growing evidence that socioeconomic uncertainties exacerbate physical environmental problems, the International Human Dimensions Program (IHDP) was created in parallel. Several influential reports, such as *Grand Challenges in Environmental Sciences* (National Research Council 2001), released in the following years greatly facilitated more integrated research in identified priorities such as energy, industrial metabolism, health, environmental security, and land-use/land-cover change) and to which geographers could make strong contributions (e.g., Moran 2005, 2010). The UN Sustainable Development Goals (UNSDGs have, of course, been driving the research agenda in many disciplines, including Geography (see below). Understanding cross-scale interactions is a rising challenge in sustainability science and transdisciplinary research in general, especially where solutions need to arise from the intersection of top-down and bottom-up activity (Smith et al. 2018). Physical geographers especially have made contributions to global environmental change and what is broadly termed earth system science, while—increasingly of late—they have turned to the Anthropocene (Meadows 2022) as a lens through which to view their subject, the concept itself spawned out of a realization of the sheer magnitude of human impact on the global environment.

Geography has long had a concern with the relationship between people and land and, using tools such as remote sensing and Geographic Information System (GIS), geographers combine both field observation and large-scale satellite observation to understand the human-environment interactions across scales. The advantage of these tools, coupled with increasing computational power, is that they enable analyses of a much wider range of factors to explain geographic processes and patterns. For example, it is possible to include household attributes, such as demographic information and decision-making, to develop spatially explicit maps (Evans et al. 2005; Moran and Brondizio 1998) and understand more completely the driving forces underlying land-use and the influence of socioeconomic and cultural dynamics.

In addition to understanding the patterns of changes in human-environment interactions, it is also critical to understand processes and to know more about how (and why) humans make decisions, and how they induce collective actions that may have deleterious consequences. The depletion of public goods/resources (such as fisheries, forests, and water resources) is a major global challenge and, as Hardin (1968) argues in *The Tragedy of the Commons*, individual users in a shared resource system acting independently according to their own self-interest may behave contrary to the common good and invoke resource depletion. To tackle this problem, Ostrom developed a framework for analyzing the sustainability of Social-Ecological Systems (SES) (Ostrom 2009, 1990). The basic structure

of Ostrom's SES framework is organized into four main domains of analysis (resource systems, resource services and units, governance systems, and actors), each of which has a nested set of tiers of level-specific variables that affect the likelihood of self-organization in efforts to achieve a sustainable SES. In fact, multiple economic theories are also applied to human-environmental interaction research. For example, the management of the commons often builds on the assumption of 'economic man' which envisages humans as consistently rational, narrowly self-interested agents. Economics that examines production, consumption, and exchange, provides important theory and methodology (e.g., general equilibrium models) for analyzing international trade and its impacts on telecoupled human-environment systems (Andrew and Peters 2013; Hertel and Tsigas 2000; Lenzen et al. 2013).

In the meantime, with the development of human ecology, cultural ecology, political ecology, and ecosystem ecology at the interfaces of geography, anthropology, and ecology, research on human-environment interactions has evolved to be interdisciplinary and transdisciplinary. In 1995, the U.S. National Science Foundation announced a competition for national centers of excellence on the human dimensions of global environmental change. Carnegie Mellon and Indiana Universities received center-level awards. Of the two centers, Indiana University focused more on land-use/land-cover change and on forest ecosystems in particular, while the Carnegie Mellon center focused on integrated assessment issues. In 2007 a formal standing program in 'Dynamics of Coupled Natural and Human Systems' was created (National Science Foundation 2014) that supports research projects that advance basic scientific understanding about the complex interactions among natural physical and/or biological systems and human social and behavioral systems. Several other programs or initiatives on the studies of HEI have emerged globally (Table 13.1). These initiatives and funding support have greatly facilitated HEI research and a number of these have been taken up by IGU Commissions.

13.5.4 Frameworks for Studying Human-Environment Interactions

A framework approach is helpful in understanding complex research questions and can provide the basic vocabulary of concepts and terms for constructing causal explanations, thereby assisting in identifying the universal elements of a theory (McGinnis and Ostrom 2014). A number of such frameworks have been developed in relation to human-environment interactions (Binder et al. 2013; Liu et al. 2007a; Fishcher-Kowalski and Weisz 2016) which, despite the shared goal of understanding the complex relationships toward the goal of sustainability, differ in their disciplinary roots, applicability, and spatio-temporal scale. The 'human-earth' system was proposed in the 1970s by Chuanjun Wu, a former IGU Vice-President from China, which stresses that the human-earth relationship is core to geographical study in all developmental stages of the discipline (Lu and Guo 1998). The social-economic-natural complex ecosystem theory was also put forward by a Chinese ecologist and geographer in 1984 (Ma and Wang 1984), which represents an early attempt to understand the complex interaction between humans and environmental systems. Three of the most commonly applied frameworks are briefly reviewed here, viz. socioecological systems (SES), coupled human and natural systems (CHANS), and telecoupling/metacoupling.

SES, as noted above, is a widely applied general framework for analyzing sustainability (Ostrom 2009). Prominent applications of SES are those that focus on resilience, vulnerability, and adaptability (Folke 2006; Folke et al. 2005; Walker et al. 2004; Young et al. 2006). Specifically, this field investigates the nested cycles of adaptive change in SESs in which persistence and novelty are intertwined, leading finally to transformations. The CHANS framework (Turner et al. 2003b, 2003a) is similar in dealing with vulnerability (exposure, sensitivity, and resilience) to environmental hazards. Liu et al. (2007a, 2007b) show how CHANS characterizes the dynamical two-way interactions between

Table 13.1 Representative programs on the studies of coupled human and natural systems

Program name	Dynamics of coupled natural and human systems	Beijer Institute of Ecological Economics	Resilience alliance	Intergovernmental panel on climate change	Millennium ecosystem assessment	Intergovernmental science-policy platform on biodiversity and ecosystem services
Focus	Complex interactions among human and natural systems at diverse spatial, temporal and organizational scales	Ecological economics	Research on the dynamic of complex adaptive systems in order to discover foundations for sustainability	Assessment of scientific, technical, and socioeconomic information to understand climate change, its impacts, and choices for adaptation, and mitigation	An international program assessing conditions and consequences of ecosystem change for human well-being and options for responding to those changes	IPBES performs regular and timely assessments of knowledge on biodiversity and ecosystem services and their interlinkages
Major funding source	U.S. National Science Foundation	Kjell & Marta Beijers Foundation	Diverse grants from private foundations	World Meteorological Organization and United Nations Environment Program	Multiple sources	National governments, United Nations
Duration	2000–present	1991–present	1999–present	1988–present	2001–2005	2012–present
Web address	https://www.nsf.gov/pubs/2006/nsf06587/nsf06587.htm	http://www.beijer.kva.se/	http://www.resalliance.org	http://www.ipcc.ch/	https://www.millenniumassessment.org/en/index.html	https://www.ipbes.net

Updated after Liu et al. (2007b)

human systems (e.g., economic, social) and natural (e.g., hydrologic, atmospheric, biological, geological) systems. Of particular interest in studying these interactions is the understanding of feedbacks, surprises, nonlinearities, thresholds, time lags, legacy effects, path dependence, and emergence across multiple spatial, temporal and organizational scales (Liu et al. 2007a). Telecoupling (telecoupled human and natural systems) (Liu et al. 2015, 2013) builds on the key elements of CHANS but extends the spatial scope and scale of connections, while metacoupling is a more integrated framework that deals with socioeconomic and environmental interactions within a coupled human-natural system (intracoupling), between adjacent systems (pericoupling), and between distant systems (telecoupling) (Liu 2017). In all these frameworks, the selection of appropriate scale of analysis is important (Dietz 2017). The SES framework emphasizes individual scale, while many applications of CHANS emphasize the household scale (Liu et al. 2016). Compared to SES and CHANS, the metacoupling framework is more inclusive and has the capacity of analyzing HEI across different scales.

13.6 Geography and Sustainability Science

Sustainability science has emerged rapidly during the last four decades and focuses on the interactions between natural and social systems and how, without threatening the planet's life support systems, these systems impact on the dual challenge of meeting the needs of the world's population while substantially reducing poverty (Fig. 13.2; Kates 2011). Sustainability science focuses on the dynamic interactions between nature and society, which echoes the identity of geography: human-environment (nature) interaction (Turner 2002), or geography as human ecology (Barrows 1923). In the past several decades, geography and sustainability science have enriched each other and this has reshaped the dimensions and direction of geography.

The concept of sustainable development has experienced extraordinary success since its advent in the 1980s. Sustainability is often these days an integral part of the agenda of governments and corporations and has become central to the mission of research laboratories and universities worldwide (Bettencourt and Kaur 2011). Although the term sustainable development was promoted by the Brundtland Commission's report in 1987 (Brundtland 1987), the concept emerged much earlier. In the early 1970s, Paul Ehrlich raised the issue of a sustainable civilization in several of his influential works (for example, Ehrlich and Ehrlich 1970). The term sustainable development is enshrined in the Agenda 21 action plan that emerged from the United Nations Conference on Environment and Development in 1992 (Piel 1992) and soon became a major focus. The US National Research Council of the National Academies of Sciences, Engineering, Medicine issued a major report about transitioning to sustainability in 1999, which aimed at building a foundation for the development of science and technology for the new century (National Research Council 1999). Geographer Robert Kates' ideas on sustainability science (Kates et al. 2001) were influential and followed up by many. In 2004, the journal *Proceedings of the National Academy of Sciences* (PNAS) initiated a special section devoted to sustainability science, and this greatly promoted the field (https://www.pnas.org/portal/sustainability). Then, in 2015, the United Nations adopted the Sustainable Development Goals (SDGs) as a universal call to action to end poverty, protect the planet and ensure that all people enjoy peace and prosperity by 2030 (https://sdgs.un.org/goals) which has proved to be a milestone in promoting the development of sustainability science. All these efforts are aimed at transitioning from an economy-centered to an environment-centered world (see also Messerli et al. 2019) and the Sustainable Development Report (Independent Group of Scientists 2019).

Geographers have proved to be major players in the field of sustainability science. The 1994 and 1995 presidential addresses of the American Association of Geographers (AAG) were all

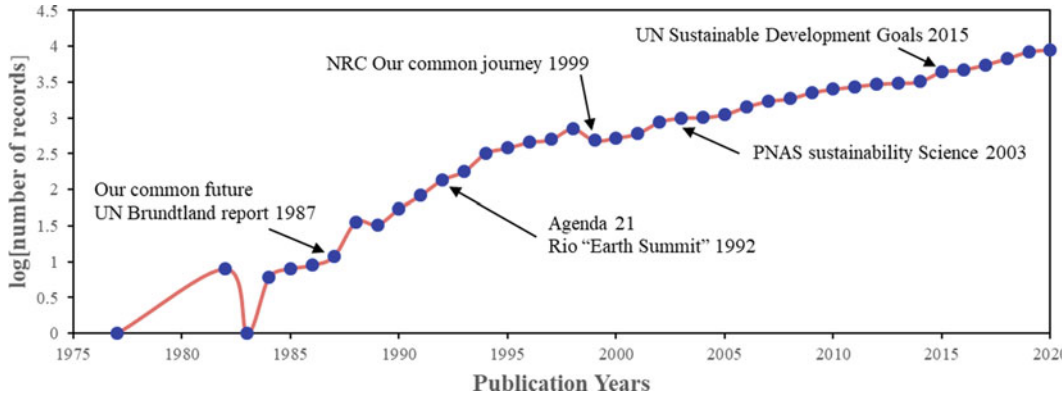

Fig. 13.2 Research publications with the terms 'sustainability' or 'sustainable development' in the title, 1977–2020. *Source* Web of Science: https://www.webofknowledge.com/

directly focused on sustainable development. Thomas Wilbanks spoke of 'sustainable development in geographic perspective' in 1994 (Wilbanks 1994), while Kates entitled his address 'Lab notes from the Jeremiah Experiment: hope for a sustainable transition' (Kates 1995). The International Geographical Union (IGU) has also promoted many kinds of activities related to sustainability and established a Study Group on Rural Sustainability as early as 1992, which was ultimately to be accepted as a Commission (Ehlers 1993). The IGU Commission on Geographical Education (CGE) published the Lucerne Declaration on Education for Sustainable Development in July 2007 (Reinfried 2009). The recently established Commission on Geography for Future Earth: Coupled Human-Earth Systems for Sustainability clearly addresses such issues head-on. As 'the science for sustainability', Geography has an increasingly important role to play in developing the knowledge and the skills to equip future generations with the tools to adapt to and mitigate potentially catastrophic global environmental change (Meadows 2020).

The challenge of sustainable development is achieving society's development goals within the planet's environmental limits over the long term. In seeking to help meet this sustainability challenge, geographers and researchers from other disciplines are focusing on the dynamic interactions between nature and society, with equal attention to how social change shapes the environment and how environmental change shapes society. These questions are problem-driven, with the goal of creating and applying knowledge in support of decision-making for sustainable development (Clark and Dickson 2003). To address the most important challenges we face today, geography and sustainability science must continue to support each other mutually with a view to achieving the SDGs and, perhaps, even the global 'prosperity' that Moore (2015) calls for.

13.7 Conclusions: Geography as a Bridge

In pondering the discipline of Geography in the context of the other sciences and social sciences, it becomes evident that, while geography indeed has enormous integrative potential, many academic departments have diverged, resulting in the separation of 'human' from 'physical' geography. This has been expressed by the observation that many university geography departments have changed their names or split altogether, as physical geographers joined their earth science partners and human geographers teamed up with, among others, anthropologists and sociologists (Meadows 2018). So, is the integrating capacity of geography a 'historical relic' and '…more rhetoric than reality' (Sharpe 2009)?

The world is changing more rapidly and more profoundly than ever before, all the more obviously so given the rampant spread of the COVID-19 pandemic. The unprecedented dispersal of the virus has led to disruption of global supply chains, the closing of national borders, and widely imposed lockdown restrictions with diverse implications for the economy, livelihoods and – all of which demonstrate the imperative of geography which deals with the interconnectedness of people and places among all the components of the earth system, and also among remote places in the telecoupled world systems. Issues ranging from the local to global scales that relate to, for example, poverty, environmental hazards, migration, refugees, border walls, trade wars, climate change, biodiversity loss – all have a geographic component. In the post-pandemic world, a green transition is already on the horizon, COP 15 of the UN Convention on Biological Diversity and COP 26 of UN Climate Change Conference have called for a sustainable transition. Carbon neutrality and sustainable development need to be embraced, not only by scholars and researchers from diverse disciplines but also the politicians, decision-makers, and the global population at large. Against this background, geography is likely to be regarded by other disciplines as increasingly indispensable.

As global actions are converging to integrative, interdisciplinary, and future-oriented research, this is a good time for geography. Future earth, the world's largest community of sustainability scientists—is transforming its governance and management structures in pursuit of deeper efficiency, inclusivity, and impact. This shift will broaden its reach and open new inroads for transformative sustainability science around the world. The National Science Foundation of the United States has supported convergence research which integrates knowledge, methods, and expertise from different disciplines, thus forming novel frameworks to catalyze scientific discovery and innovation. The IGU is moving into its second century and we find ourselves at a turning point for humanity. We have entered a decade of action to transform the world and achieve the SDGs outlined in Agenda 2030. IGU should build on its heritage, and its voices must be heard on the many critical global challenges; joining hands with other disciplines is an important step toward addressing the current crises.

The challenges posed by the range of human-environmental problems that characterize the Anthropocene should be a 'call to arms' for geographers, soliciting the rediscovery of the importance of the diverse and complex connections between nature and society and the recognition that explanations rooted in both the physical and the human (social, economic, political, cultural) domains are essential. However, this should entail more than simply collaborating on problems of common interest but rather a fundamental recognition of the concept that environments 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' (Lave et al. 2014: 2). Geography continues to develop through its vibrant connections with other fields and geographers should continue to show interdisciplinary leadership by embracing different perspectives, by supporting institutional arrangements that foster interdisciplinary activity, and by seeking the knowledge and techniques that other fields can contribute to geographic perspectives, approaches, and insights to the collective effort. Indeed, we still have much to learn from (and to teach) each other.

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