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Santiago López Editor

Socio-Environmental Research in Latin America

Interdisciplinary Approaches Using GIS and Remote Sensing Frameworks



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Santiago López Editors

Socio-Environmental Research in Latin America

Interdisciplinary Approaches Using GIS and Remote Sensing Frameworks



Editor Santiago López University of Washington Bothell Bothell, WA, USA

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Preface

Socio-environmental (SE) research is one of the most vibrant areas of inquiry and knowledge production ascribed to current scientific agendas across the globe. It is also well understood that SE problems, by definition, reach across a diversity of disciplines and require different modes of analysis that could enable not only digging deeper into the unique features of place, societies, and individuals but also identifying general spatio-temporal patterns and trends that allow studying humanenvironment interactions over time.

GIScience (the science behind geotechnologies like geographic information systems and remote sensing and the processes of generating geographic knowledge) has allowed bridging the divide between the conceptual work of scholars and the empirical work of those who attempt to apply geographical principles and theories to changing and ever-evolving SE conditions. Thus, GIScience needs and continues to engage with a variety of actors and research practices, both remote and participatory, while expanding and diversifying its epistemological frameworks to respond to legitimate citizens' concerns about knowledge generation, data ownership, and information access.

This book presents relevant examples of SE research that highlight the challenges and opportunities of using geotechnologies in interdisciplinary settings across the vast, culturally and environmentally mega-diverse region known as Latin America. This is not a complete compilation, and it does not try to be. Each chapter prods deeply into relevant SE issues identified by researchers from Latin America and elsewhere doing applied empirical work in the region. In highlighting depth over breadth, some thematic content, applications, and locales were sacrificed. However, the intention is that students, academics, professionals, policy makers, and general audiences will not only learn about Latin American SE issues and GIScience applications but, in doing so, will also develop an interest in geographic exploration either through geotechnologies and *in situ* field work or through a combination of approaches that will continue beyond the themes, locations, and methods presented in this book. Geography is indeed an open discipline and GIScience an inclusive interdisciplinary framework. We hope that this book will inspire not only those who have profound knowledge of the themes, technologies, methods, and geographic locations covered in this compilation but also those who are just starting their career paths and geographic exploration of Latin American landscapes.

Bothell, WA, USA

Santiago López

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Chapter 1 Introduction: Interdisciplinarity, GIScience, and Socio-Environmental Research in Latin America



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Abstract Accelerated environmental change worldwide threatens the sustainability of the Earth system. Calls for research that involves community outreach and solutions to raising environmental concerns have triggered integrative research approaches to assess the myriad of factors affecting human-environment interactions. Some of the proposed solutions have required a re-thinking of humanenvironment relationships and the roles that science, policy makers, governmental and non-governmental organizations, communities, and individuals play in achieving local or regional sustainability. Interdisciplinary applied research in Latin America, the main regional focus of this book, has advanced in the past three decades to address issues of land degradation, forest loss, conservation of biodiversity, economic development, and more. Some of the solutions have been technoscientific and embedded in geographic information science, which has allowed the identification of not only locations threatened by environmental degradation, but the factors, geographic patterns, and spatio-temporal trends of socio-environmental change. The contribution of geographic information science toward the advancement of socio-environmental knowledge in Latin America is undeniable. Drawing on research from various countries and biogeographical regions across Latin America, the chapters in this book bring new interdisciplinary insights, deeply rooted in geographic information science and technologies, on the complex socioenvironmental dynamics that characterizes this diverse region, thus contributing to a vibrant research area within human-environment geography.

Keywords Interdisciplinary \cdot Socio-environmental interactions \cdot GIScience \cdot Latin America

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1 Interdisciplinary Socio-Environmental Research

The past two decades have been characterized by increasing calls for socioenvironmental (SE) research that involve outreach and pragmatic solutions to raising environmental issues and concerns (Turner II et al. 2016). These calls have been triggered by accelerated SE change worldwide that threatens the sustainability of the Earth system and its human and non-human elements. Further, SE systems (SES) (i.e., closely connected social and biophysical subsystems that affect each other) have experienced accelerated transformations that test their capacity to respond and adapt to endogenous and exogenous pressures, ultimately affecting their resilience and long-term survival (Postigo 2014). Threats on climate dynamics, land cover, and nutrient cycling are of particular concern since they are intimately entwined with the health and functioning of the biosphere (Mahli et al. 2020). These requests have also challenged researchers to be more responsive to societal needs and set research priorities that are directly aligned with such demands. In this way, research approaches have become more integrative than in the past, implementing SES frameworks that have required a re-thinking of human-environment relationships and the roles that science, policy makers, governmental and non-governmental organizations, communities, and individuals play in reaching local or regional sustainability goals.

Since SE change is systemic and cumulative, its analysis requires a suite of approaches and frameworks to unravel the connections between its human and physical drivers and their consequences for local populations and the environments where they interact (Brown 2017; Turner II et al. 1990). Thus, the requests have also been for 'interdisciplinary' research with emphasis on long term, placebased monitoring, mapping, and analysis of SES. Although there is no widely accepted consensus about the meaning of interdisciplinarity, in this book we use Hicks et al.'s (2010) conceptualization, who defined it as the 'production of research which crosses disciplinary boundaries.' Interdisciplinarity is not new; academic disciplines have been frequently combined to form new disciplines to provide better answers to emerging questions. We could distinguish, for example, between narrow or small interdisciplinarity, which implies collaboration between similar disciplines (e.g., between the biological and ecological sciences), and wide or big interdisciplinarity which involves collaboration between distant disciplines (e.g., between the natural/physical sciences and social sciences/humanities) (Morillo et al. 2003). This latter type does not only involve academics, but also policy makers and other stakeholders (e.g., people who can not only help co-define research questions and develop models, but also actively participate in data collections, scientific experiments, or in-depth conversations about specific research components). Interdisciplinary approaches have helped develop not only top-bottom characterizations of SES dynamics, but also bottom-up solutions to specific public concerns (Nakashima et al. 2018; Nielsen and D'haen 2014; Valdivia et al. 2010) and better understandings of SE change patterns than single-disciplinary responses.

The emphasis on both humans and their environments recognizes the complexity of past and present conditions affecting nature and society at various spatio-temporal scales. Technoscientific responses to address these complexities are commonly embedded in wide interdisciplinarity and constructed around common theoretical frameworks and research questions (Pulver et al. 2018). SES research frameworks that have emerged in the past couple of decades include coupled human-environment systems (Liu et al. 2007a, b) resilience (Folke 2006; Carpenter et al. 2001; Gunderson and Holling 2001), human-ecosystem relationships (Machlis et al. 1997), vulnerability (Turner II et al. 2003), social-ecological systems (Ostrom 2009), and integrated assessment of ecosystem functions and services (de Groot et al. 2002). This body of research has helped to progressively contextualize SE interactions and embed them in historical, political, and economic contexts to inform vulnerability, hazards (including land degradation and deforestation), adaptation, and ecosystem management (Fig. 1.1). Similarly, all these frameworks draw some attention to the importance of scale and acknowledge multi-scalar connections among SE features and processes (Pulver et al. 2018). Thus, geospatial approaches have been critical not only to delimit the geographic scope of SES research, but also to ease the integration of general scientific knowledge (*nomothetic geography*) and the unique characteristics of places (idiographic geography). These kinds of approaches, for instance, have allowed the 'telecoupling' (or remote connection) of spatially distant ecosystems and local processes via a range of social (e.g., socio-economic or health outcomes) and biophysical processes (e.g., greenhouse emissions), or a range of



Fig. 1.1 Conceptualization of a social and environmental system and the traditional study domains of the social sciences/humanities and the natural/physical sciences. Geographic information science (GIScience) may serve as a bridging scientific framework that allows the integration of diverse disciplines

distal (e.g., institutional conditions) and proximate factors (e.g., agricultural expansion), deeming them critical to climate change adaptation, land use land cover (LULC) change, or spatial epidemiological concerns.

2 Geographic Information Science Epistemology and Interdisciplinarity

The integration of geospatial technologies and *in-situ* or field-based SE research has opened up opportunities for advancing our understanding of the causes, consequences, and processes of environmental degradation and social change. Nevertheless, this type of integration comes with its own difficulties. For instance, one of the challenges that remote sensing (RS) has faced in the past is the difficulty of its integration with the social sciences and humanities, although this situation has been slowly changing since the end of the twentieth century. The integration of these scientific approaches requires the synthesis not only of data but also of quite different epistemologies. While geographic information science (GIScience) has been traditionally embedded in logical positivism and structuralism that connect knowledge production with formal universal laws based on verifiable, valid, and replicable observations (Leszczynski 2017), the social sciences (including the geohumanities) on the other hand, have been shifting towards a post-structuralist epistemology, moving away from pre-established, socially-constructed structures and top-down models in the search for more nuanced, bottom-up, understandings of human and environmental dynamics (Warf and Sui 2010). These different views of knowledge production undeniably affect those who do interdisciplinary research since they commonly trigger a sense of insecurity and marginalization as the questions and issues central to their research are somewhat tangential to the specialized disciplines (Rindfuss and Stern 1998).

How can different views of knowledge production be integrated in both theory and praxis in current SE research? Some alternatives include collaborative research design approaches that include mixed methodologies in which data and methods are combined in different ways to put emphasis on the qualitative or quantitative data and/or analysis techniques. These approaches necessarily need a measure of sensitivity and open communication among researchers from different fields, which implies active listening, curiosity, and understanding of each other's perspectives and potential contributions to joint efforts (Bridle et al. 2013). This communicative attitude has been referred to as "appreciative inquiry" (Graybill et al. 2006) and has been key to successful interdisciplinary programs. Recent advances in participatory and qualitative geographic information systems (GIS) have enabled some of these communication lines for a more refined exploration of social and spatio/environmental phenomena with the goal of generating more robust and appropriate policy responses (Elwood 2006). Consequently, there is a continuous need to develop novel forms of inquiry and methodological approaches, capable of accounting for the hybrid character of SE change and across geographic scales. In this context,



Fig. 1.2 A hybrid epistemological conceptual framework depicting the connection between geographic scope, type of knowledge, and methods. (Source: Modified from Lópezet al. (2017)

hybrid epistemological frameworks could allow the integration of different types of knowledge, methods, and geographic scopes (Fig. 1.2). Such a framework allows us to create a middle ground space that delimits the boundary, process, and scope of SE knowledge by integrating different analytical approaches that are often not compatible (Watson-Verran and Turnbull 1995). GIScience has been directly incorporating such hybridities since the late 1990s, especially through its engagement with mixed method practices and the evolution of a more inclusive and flexible epistemology (Elwood et al. 2012).

3 Geographic Information Science and Socio-Environmental Research in Latin-America

Latin American landscapes are diverse, complex, and undergoing significant transformations with implications for the sustainability of SES in the region, currently threatened by accelerated forest cover reduction (Manners and Varela-Ortega 2017), the replacement of native forests with exotic woody species (Schwartz et al. 2020), and land degradation (Metternicht et al. 2010). Although there are intricate connections between proximate causes and underlying forces of such changes and their operation at different spatio-temporal scales, in Latin America, these entanglements have been often associated with global change dynamics engrained in national neoliberal economic reforms and neo-extractivist agendas (Bebbington et al. 2018). These processes are affecting the ways humans relate to their local and regional environments, with major consequences for climate dynamics (Kalnay and Cai 2003), biotic diversity and ecosystem services (Daily 2000), and the sustainability of SES (Turner II et al. 2003).

Many of the solutions developed to address SE concerns in Latin America have been technical and rooted in GIScience, comprising both quantitative and qualitative GIS approaches (including participatory mapping), RS, and global navigational satellite systems (GNSS). GIScience approaches to study SES have been facilitated by the enhancement of remote sensors and their resolutions, and the advancement of geotechnologies and computing systems from mobile devices to super computers, cloud-based services, and artificial intelligence algorithms to capture and process geolocated data. In addition, the incorporation of alternative data collection and analytical methods (e.g., volunteered geographic information or VGI) have allowed not only more comprehensive characterizations of SES than in the past, but more meaningful ones. At the core of this integration is the recognition that SE change is multifaceted and driven by social, political, economic, cultural, and biophysical factors that affect human decision making in unique and intricate ways. Thus, the implementation of new interdisciplinary GIScience-based practices has been key to environmental justice concerns, conservation, development, adaptation, and mitigation strategies.

These past few decades have also been characterized not only by the evolution of geotechnologies (software and hardware), geospatial approaches, and novel concepts oriented toward the advancement of GIScience, but by increased human capacity through rigorous undergraduate and post-graduate training at higher education institutions worldwide. In Latin America, bachelor's in science and engineering degrees together with master's and doctoral programs with a focus on GIScience have proliferated. Different forums have also emerged since the earlier applications of GIS, RS, and GNSS in the 1980s to serve as knowledge exchange spaces for interaction among Latin American and Latin Americanist professionals, academics, and students. Some of these forums include international partnerships such as the Pan-American Institute of Geography and History (IPGH), the Ibero-American Conference of Geographic Information Systems (CONFIBSIG), the Latin-American chapters of Geoscience and Remote Sensing Society (GRSS), the Society of Latin-American Specialists on Remote Sensing (SELPER), or nationally sponsored forums like the Brazilian Symposium on Remote Sensing (SBSR) or the French Institute of Research for Development (IRD, or ex-ORSTOM) to name a few. Space research institutes like National Institute of Space Research (INPE) in Brazil or the Mario Gulich Institute for Advanced Space Studies in Argentina are examples of long-term programs, deeply rooted in RS and GIS technologies since their creation in the 1970s and early 2000s respectively, designed to advance SE research in the region.

4 Applied Geospatial Research in Latin America

Remote sensing technologies and products are not new. Aerial photographs, for instance, have been used for more almost a century and satellite images for more than four decades. Since their introduction of analog remote sensing products (e.g., photographs) in Latin America in the 1900s, remote sensing applications have focused on natural resource management, urban planning, land development, risk-hazards assessments, and monitoring of surface-level lithosphere processes including volcanism, geomorphology, air and water quality changes, climate change, habitat fragmentation, floods, hurricanes, landslides, droughts, and forest fires (Chuvieco et al. 2008). In addition, since the early 1990s, there has been an increased emphasis on remote sensing applications in conservation (Aide et al. 2019; Boyle et al. 2014; Leisher et al. 2013), invasion ecology processes (Hoyos et al. 2010), ecosystem function monitoring (Abelleira-Martínez et al. 2016), forest assessments and agricultural expansion (Graesser et al. 2015), soil erosion and land degradation (Metternicht et al. 2010), and carbon loss and storage (Chadwick and Asner 2016, Harris et al. 2012). Sociogeological RS applications in mining and natural resource extraction assessments (Mazabanda et al. 2020; Alvarez-Berríos and Aide 2015; Swenson et al. 2011) have also increased in recent years. Most of this research comes from regions of Latin America where remote sensing has been critical for the development of environmental policy such as Brazil and Argentina (Villalón-Turrubiates et al. 2016) or areas that have been identified as hot spots or fronts of environmental degradation as in the case of areas in Mexico, Ecuador, Bolivia, or Peru.

GIS technology has experienced a sustained growth in research since its introduction in Latin America in the late 1980s (Buzai and Robinson 2010). GIS approaches have been more widespread and interdisciplinary than RS applications and incorporate RS and field-collected socio-economic data to some extent. In recent years, citizen science approaches have helped incorporate local voices into the research process in different areas of Latin America with successful results (Mena et al. 2019; Cunha et al. 2017), especially when adapted to specific cultural settings (Ceccaroni and Piera 2017). The successful integration of multiple sources of geographic information, including VGI, offers SE researchers an unprecedented opportunity to fine tune models, theory, and policy (Elwood et al. 2012). In general, while remote sensing has been mostly used for mapping, monitoring, and analyses of physical processes and geo-ecological features, the data fusion power of GIS that allows linking socio-economic surveys, in-situ measurements, and participatory research approaches that guarantee the incorporation of situated experiential knowledge, offer additional opportunities to address important geo-political and socioeconomic processes that affect people's livelihoods (Salisbury et al. 2012). Processes such as territorial organization, land rights adjudication, or social resistance against extractive industries are currently widespread and considerably shaping Latin American landscapes. GIScience is at the forefront of many regional initiatives that are helping address such actions.

In summary, the contribution of GIScience toward the advancement of SE knowledge in Latin America is undeniable. Work produced by several research teams by the end of the twentieth century and beginning of the twenty-first century established some key methodological and theoretical foundations when pursuing the integration of social and environmental data at scales consistent with regional and subregional SE analysis (cf. Caldas et al. 2007; Fox et al. 2003; Soares-Filho et al. 2002; Liverman et al. 1998; Sierra 1996, among others). Currently, the theoretical and practical approaches that lead to the coupling of SE features and processes have probably reached a mature state and sophisticated geospatial modeling frameworks such as spatially-explicit regression analysis and agent-based or individual-based modeling approaches have evolved to deal with the spatio-temporal complexities of SE interactions in Latin American urban and rural areas (cf. Santos et al. 2019; España et al. 2018; Arima 2016; López 2014; Barros 2012, among others). Further, recent continental-level analyses of land use and land cover change have also contributed to understand non-linear patterns of SES dynamics in a mega-diverse region threatened by continuous human pressures (Aide et al. 2013, 2019; Grau and Aide 2008).

5 Scope and Purpose of This Book

The purpose of this book is to present current application of GIScience research that aims to advance our interdisciplinary understanding of SES and SE interactions, past and present, in a region that has experienced accelerated environmental degradation in recent decades. Specifically, this book aims to address the following overarching questions:

- 1. How are interdisciplinary approaches using RS and GIS uniquely facilitating a dialog between the geophysical sciences, natural sciences, social sciences, and the humanities as conceived by researchers doing work in Latin America?
- 2. How can multiple narratives be introduced to change the ways in which RS and GIS are practiced in this region?

We attempt to answer these questions through a sample of current applications of geospatial technologies and analyses of literature that emerge from Latin American and Latin Americanist scholarship. The different chapters in this volume showcase the challenges and opportunities of connecting disciplinary expertise rooted in GIScience and interdisciplinary approaches to the practice of SE research. Many of the case studies in this volume are embedded in hybrid epistemological frameworks implemented through a range of mixed methods that span over multiple disciplines such as land change science, watershed science, political ecology, environmental history and archaeology, physical geography, ecology, health sciences, human geography, and others. The chapters presented here present ways of overcoming linear, deterministic, and representational explanations of SE change in favor of non-linear but historically and politically situated SE interactions. We are cognizant that this coverage is not complete, but it offers a robust sample of current SE research

Drawing on research from various countries and biogeographical regions across Latin America, the chapters in this book bring new insights on SE dynamics from an interdisciplinary perspective rooted in GIScience, thus contributing to a vibrant research area in human-environment geography.

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