

SPRINGER BRIEFS IN GEOGRAPHY

Qing Tian

**Rural  
Sustainability**  
A Complex  
Systems Approach  
to Policy Analysis



Springer

# SpringerBriefs in Geography

SpringerBriefs in Geography presents concise summaries of cutting-edge research and practical applications across the fields of physical, environmental and human geography. It publishes compact refereed monographs under the editorial supervision of an international advisory board with the aim to publish 8 to 12 weeks after acceptance. Volumes are compact, 50 to 125 pages, with a clear focus. The series covers a range of content from professional to academic such as: timely reports of state-of-the art analytical techniques, bridges between new research results, snapshots of hot and/or emerging topics, elaborated thesis, literature reviews, and in-depth case studies.

The scope of the series spans the entire field of geography, with a view to significantly advance research. The character of the series is international and multidisciplinary and will include research areas such as: GIS/cartography, remote sensing, geographical education, geospatial analysis, techniques and modeling, landscape/regional and urban planning, economic geography, housing and the built environment, and quantitative geography. Volumes in this series may analyze past, present and/or future trends, as well as their determinants and consequences. Both solicited and unsolicited manuscripts are considered for publication in this series. SpringerBriefs in Geography will be of interest to a wide range of individuals with interests in physical, environmental and human geography as well as for researchers from allied disciplines.

More information about this series at <http://www.springer.com/series/10050>

Qing Tian

# Rural Sustainability

A Complex Systems Approach  
to Policy Analysis

 Springer

Qing Tian  
Computational Social Science Program  
Department of Computational and Data Sciences  
College of Science  
George Mason University  
Fairfax, VA, USA

ISSN 2211-4165                      ISSN 2211-4173 (electronic)  
SpringerBriefs in Geography  
ISBN 978-3-319-52684-3              ISBN 978-3-319-52685-0 (eBook)  
DOI 10.1007/978-3-319-52685-0

Library of Congress Control Number: 2017931081

© The Author(s) 2017

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Printed on acid-free paper

This Springer imprint is published by Springer Nature  
The registered company is Springer International Publishing AG  
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

# Preface

Poyang Lake is the largest freshwater lake in China. The area around Poyang Lake has such a rich tradition of rice cultivation and aquaculture that it is said to be 鱼米之乡. The Chinese 鱼 translates to *fish* and 米 means *rice*; the words together mean *land of fish and rice*. But one cannot fully appreciate its meanings and the subtlety of feeling it evokes, unless one understands the significance of rice in China's development history and has seen those rice paddies, with countless streams and irrigation canals meandering among them. It is a way of life so central and dear to generations of farmers in southern China. It is a culture, representing the wellspring of human civilization.

I did not know all these meanings growing up in northern China. But in the past ten years, I have gotten to know and grow fond of Poyang Lake and farmers in the area. It all started when I moved to Ann Arbor to pursue a PhD at the University of Michigan. I was working as a research assistant for my advisor, Dr. Daniel Brown, on a research project about land use and flood vulnerability around Poyang Lake. In the summer of 2006, we traveled around the entire lake to collect land-use data on crop and vegetation types. That was my first exposure to rural areas in southern China.

For my own dissertation research, I returned to visit nine villages around Poyang Lake in the summer of 2008. I stayed with farmer households and had the privilege of observing their daily lives. If that first visit in 2006 left me with pleasant but brief impressions on the rural south that had fascinated the mind, this field trip allowed me to learn much more about the rice culture and the rural livelihoods that had long depended on it.

Yet one didn't need to be a keen observer to see that the traditional lifestyle in 鱼米之乡, which meant working and living in harmony with nature, has been changing amid development transitions. In my more recent field trips to the area in 2014 and 2015, I noticed other dramatic changes, such as the rise of "landlords" who manage large farms, and an increasingly rural and urban mix in the cities.

During my visits to the villages, I was greatly impressed by the development progress I witnessed: newly built two- or three-story houses, solar panels on the roofs, children's playgrounds and senior activity centers, concrete roads leading to

every village, and in a village that had made its name for pearl growing and jewelry making, many new cars. Some of these advancements were direct outcomes of a national development initiative called “Build a New Countryside.”

What moved me most, however, were the farmers who still planted, tilled, and harvested by hand, the fishermen with tanned, weather-worn faces, and a hillside village on the lake that had developed a self-sufficient economy and maintained cultivation of many minor crops like peanut, sesame, and sweet potato, even now when it relied mainly on nonfarm income. There was a charm in them, and it was from them that I began to understand the culture of 鱼米之乡.

I was much taken with a young man who grew mushrooms in Anhui Province and wanted to farm in his own village if he could only secure a large enough farmland area; a young woman who came back to visit her parents and lamented that village girls got married too early; and a curious fisherman who came to see us while we were having dinner at the village leader’s home.

I still remember vividly a dark-faced woman who was tending both her sick husband and mother-in-law and made a living catching crayfish in the lake, and the village leader’s wife in that hillside village who always had a smile, whether she was cooking a simple winter squash dish or cutting sweet potato leaves to feed their pigs. Nor can I forget the accountant who welcomed us into his home and served our meals and refused to accept even a token payment, saying, “Let’s be friends.”

And those children in the villages—they are as lovely and intelligent as children anywhere. They give a real purpose to this work. After all, rural sustainability is all about them and their children and their children’s children. They have never left my thoughts since then.

I of course also recognized some of the rural development issues. For example, the insufficient education of children left behind by parents working far away in cities; the unoccupied new houses owned by migrant workers; and some uncultivated plots. I also learned about the pollution of rural industry, and the appropriation of farmland for industrial development, which left farmers worried about their livelihoods. Most of all, I felt the helplessness that many farmers expressed, not on account of flood hazards from Poyang Lake, but because they did not know what else, or more, they could do to improve their living conditions.

Traveling south (against the current) on the Gan River, one of the five major rivers that drain into Poyang Lake, one arrives at Nanchang, the capital of Jiangxi Province. The contrast between the villages and the city in all aspects of social, economic, and cultural development is immediately apparent.

Right on the river’s eastern bank, in the north west of the city, stands滕王阁, the Pavilion of Prince Teng. 滕王阁 is one of the three greatest pavilions in southern China. Since its construction in 653 AD, during the Tang dynasty, numerous poets have visited and enshrined the historical architecture in their famous works.

The view from the Pavilion of Prince Teng is indeed impressive. To the east, new buildings spread out wide and far in a multilayered pattern imbued with rhythms. On the other side, the river, dotted with small fishing boats, looks serene at sunset; it seems as if the whole history of Jiangxi has sunk into the river flow, and it feels

heavier as the river reaches the countryside. The past and the future come together, and the city and villages are connected, right now, right here, at this vantage point.

It is a place for contemplation. How will urban culture diffuse to influence life in villages? What will the countryside look like a few decades from now? Can urban life, and the economy as a whole, prosper without healthy, strong agriculture? What kind of world will those children I met in the villages face when they grow up, and how will their lives be different from their parents'?

The work presented in this book is an attempt to make sense of what I saw and heard in the field. The reality I was exposed to was complex, and I have tried to untangle that complexity. I was fortunate because the University of Michigan's Center for the Study of Complex Systems has an array of stellar scholars, whose pioneer work significantly influenced my approach to examine rural development. And I felt an instant click with "complexity thinking."

The Poyang Lake area is a miniature of rural China. It is also a window through which to examine the larger issues of development in the developing world, where rural households struggle to improve their economic situations and are also disproportionately affected by climate variability and change. While I am clear-headed about the limitations of one case study, I cannot help wondering what the villages around Poyang Lake share with other less developed rural areas, and it is granted that at times such questions run the risk of overgeneralization.

But I do believe that government policy is essential for guiding development to facilitate rural households in their efforts to build robust livelihoods. Increasing the well-being of rural households, promoting agriculture, and reducing climate impacts are not separate goals; they should and can be addressed together. To achieve these goals, policy will have to foster healthy rural-urban development dynamics, adapt over time to suit ongoing social and environment changes, and attend to local variations as well.

Every time I visit China, I am amazed by how fast things move. I have to apologize here if any of the analyses in this book fall behind the swift steps of development. In fact, China has been constantly adjusting its development policy and is an exemplar for adaptive policymaking. Its recent plans increasingly emphasize harmonious development with local natural environments. In the field, I also saw government-supported agricultural research projects, trying different approaches in different places. In general, I feel confident about the development policy and am optimistic about the future of rural development.

Washington, DC, USA  
October 2016

Qing Tian



The view of Nanchang, the capital of Jiangxi Province, from the Pavilion of Prince Teng on the eastern edge of the Gan River



The view of the Gan River at sunset from the Pavilion of Prince. In the background is new development of Nanchang along the Gan River's western bank



Children in a village alongside the Gan River, where the river flows into Poyang Lake

# Introduction

## Rural Development in the Context of Climate Variability (and Change)

The challenges confronting rural development in less developed areas that are affected by climate impacts are many and daunting. Improving rural livelihoods in the developing world has generally been challenging (World Bank 2008; UNDP 1990–2014); extreme climatic events impose an additional constraint (Kates 2000; Adger et al. 2006; Kates and Dasgupta 2007; Takeuchi and Aginam 2011). Persistently low development contributes to low levels of human well-being and limits the capacity of rural households to cope with and adapt to climate impacts as well (Ribot et al. 1996; Adger et al. 2003; O’Brien et al. 2004; Lemos et al. 2007; Eakin et al. 2014; McCubbin et al. 2015; Agrawal and Lemos 2015; Warner et al. 2015).

Furthermore, as rural households across developing countries continue to participate in larger economies, their livelihoods are increasingly affected by new dynamics beyond their local contexts (DeFries et al. 2010; Seto et al. 2012; Liu et al. 2013a; Meyfroidt et al. 2013; Verburg et al. 2013; Seto and Reenberg 2014). Rapid urbanization, in particular, and the broad development dynamics associated with urbanization all influence the land-use and livelihood decisions of rural households, affecting their well-being and overall agricultural development (Rigg 2006; Satterthwaite et al. 2010; Rigg et al. 2012; Henley 2012; Hazell and Rahman 2014; Dercon 2013; Wilson and Burton 2015; Tian et al. 2015).

Nonfarm work is generally seen as a complement to agricultural income and is often examined from the perspective of income diversification. Remittances from nonfarm work have helped to finance innovation and intensification of farming (Tiffen 2003; Hoang et al. 2005, 2008). Participation in urban economies has contributed to a reduction in rural poverty (Deshingkar 2006; De Janvry et al. 2005; Glauben et al. 2012). Rural households near urban centers have also benefited from nonfarm opportunities and access to markets (Hoang et al. 2008; Tian et al. 2016).

However, some new empirical evidence suggests that the diversification of rural livelihoods may be short-lived because migrant workers lack professional skills, and the instability of their work is actually associated with a welfare cost for rural households (Dzanku 2015). Additionally, greater livelihood diversity may not be associated with higher levels of household well-being (Gautam and Andersen 2016). It is not diversity per se but the types of activities that are important and affect the well-being of rural households (Martin and Lorenzen 2016).

Rapid urbanization in China, for example, has profoundly transformed the livelihoods of rural households. Participation in the urban economy and the wider, overall economic growth have contributed to improved rural living standards. However, rural income has consistently lagged behind urban income, and a broader prosperity gap persists between urban and rural areas (Long et al. 2010; Liu et al. 2013a; Li et al. 2015). The average net income for rural residents was 134CNY, 2,253CNY, and 9,892CNY in 1978, 2000, and 2014, respectively, compared to 343CNY, 6,280CNY, and 29,381CNY for urban residents (NSBC 2015). The average expenditure of rural and urban households in 2014 was 8,744CNY and 25,449CNY, respectively (NSBC 2015).

Meanwhile, increasing nonfarm income is associated with the decline of agriculture, especially in those regions with relatively high industrial development, because nonfarm work in general brings higher economic returns than does crop cultivation (Liu et al. 2005; Deng et al. 2006; You et al. 2011; Jiang et al. 2013; Tian et al. 2015). Further improving rural income, reducing the rural-urban gap, and promoting agriculture have remained major challenges for the Chinese government.

This book addresses the complex social and environmental processes that shape the livelihoods of rural households, and attempts to provide scientific support for government policy to improve human development and mitigate climate impacts in less developed areas. It integrates useful ideas from the research in natural hazards and climate change into a larger framework of sustainability, and tries to operationalize the concept of sustainability, from the perspective of coupled human-environment systems (CHES).

A CHES perspective allows us to examine an array of social, economic, and environmental factors, including climate, which affect human development in a place, and to consider both local environments and broad development context (Levin 1999; Holling 2001; Folke et al. 2002; Gunderson and Holling 2002; Turner et al. 2003, 2007; Clark 2007; Liu et al. 2007; Ostrom 2009; Levin and Clark 2010; Moran 2010; Cioffi-Revilla 2016). Sustainability is essentially about human well-being over a long time horizon (Holdren 2008), but we must address human well-being and environmental well-being together because they are interdependent.

The book uses a complex adaptive systems (CAS) approach to analyze human-environment systems. In complex adaptive systems, networks of heterogeneous agents act and interact with one another and with the environment, giving rise to system-level properties or patterns (Gell-Mann 1994; Holland 1995, 1998, 2012; Kauffman 1995; Arthur et al. 1997; Axelrod and Cohen, 2000). Human agents, however, are embedded within large social, economic, institutional, and development contexts, and these can constrain individual options and decisions. An important role of policy is to improve these macro-level processes to create opportunities for individuals and facilitate better individual decision making.

On the other hand, while the actions and interactions of agents are the major forces shaping the state of a CAS, individual decisions and actions do not necessarily result in optimal system-level outcomes. The Prisoner's Dilemma and the Tragedy of Commons are cases in point. Another important role of policy could be setting up "smart" incentives to influence individual decisions and induce individual actions such that they collectively lead to desired system-level outcomes.

When we apply a CAS lens to examine CHES, we can understand that sustainability is an emergent property of human-environment systems. We can investigate the decision making of human agents, and the interactions among human agents and between the social and natural components in a CHES, to understand the micro- and macro-level processes underlying sustainability or unsustainability. Such understanding is important for improving macro-level processes to help individual agents increase their well-being and for designing "smart" policy to influence agent behavior, steering a CHES onto a sustainable path. These are the basic ideas of the sustainability framework.

The framework has been applied to the study of rural development in the Poyang Lake Region of China amid flood hazards. The case study shows that multiple analyses can be combined to acquire a deeper understanding of human-environment systems and provide useful insights for government policy to promote household well-being and sustainable rural development. It is the author's modest hope that this study may have taken one small step toward "solution-oriented research to provide realistic, context-specific pathways to a sustainable future" (DeFries et al. 2012).

## References

- Adger, W. N., Huq, S., Brown, K., Conway, D., & Hulme, M. (2003). Adaptation to climate change in the developing world. *Progress in Development Studies*, 3(3), 179–195.
- Adger, W. N., Paavola, J., Huq, S., & Mace, M. J. (Eds.). (2006). *Fairness in adaptation to climate change*. Cambridge: MIT Press.
- Agrawal, A., & Lemos, M. C. (2015). Adaptive development. *Nature Climate Change*, 5(3), 185–187.
- Arthur, W. B., Durlauf, S. N., & Lane, D. A. (Eds.). (1997). *The economy as an evolving complex system II*. Reading: Addison-Wesley.
- Axelrod, R., & Cohen, M. D. (2000). *Harnessing complexity: Organizational implications of a scientific frontier*. New York: Basic Books.
- Cioffi-Revilla, C. (2016). Social-ecological systems. In W. S. Bainbridge & M. C. Roco (Eds.), *Handbook of science and technology convergence*. Switzerland: Springer.
- Clark, W. C. (2007). Sustainability science: A room of its own. *Proceedings of the National Academy of Sciences of the United States of America*, 104(6), 1737.
- De Janvry, A., Sadoulet, E., & Zhu, N. (2005). *The role of non-farm incomes in reducing rural poverty and inequality in China*. CUDARE Working Papers, Department of Agricultural and Resource Economics, University of California, Berkeley. Retrieved from <http://escholarship.org/uc/item/7ts2z766>
- DeFries, R. S., Ellis, E. C., Chapin, F. S., Matson, P. A., Turner, B. L., Agrawal, A., et al. (2012). Planetary opportunities: A social contract for global change science to contribute to a sustainable future. *BioScience*, 62(6), 603–606.

- DeFries, R. S., Rudel, T., Uriarte, M., & Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience*, 3(3), 178–181.
- Deng, X., Huang, J., Rozelle, S., & Uchida, E. (2006). Cultivated land conversion and potential agricultural productivity in China. *Land Use Policy*, 23(4), 372–384.
- Dercon, S. (2013). Agriculture and development: Revisiting the policy narratives. *Agricultural Economics* 44(s1), 183–187.
- Deshingkar, P. (2006). *Internal migration, poverty and development in Asia*. ODI Briefing Paper 11. London: Overseas Development Institute.
- Dzanku, F. M. (2015). Transient rural livelihoods and poverty in Ghana. *Journal of Rural Studies*, 40, 102–110.
- Eakin, H. C., Lemos, M. C., & Nelson, D. R. (2014). Differentiating capacities as a means to sustainable climate change adaptation. *Global Environmental Change*, 27, 1–8.
- Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C. S., & Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. *AMBIO: A Journal of the Human Environment*, 31(5), 437–440.
- Gautam, Y., & Andersen, P. (2016). Rural livelihood diversification and household well-being: Insights from Humla, Nepal. *Journal of Rural Studies*, 44, 239–249.
- Gell-Mann, M. (1994). *The Quark and the Jaguar: Adventures in the simple and the complex*. New York: Freeman.
- Glauben, T., Herzfeld, T., Rozelle, S., & Wang, X. (2012). Persistent poverty in rural China: Where, why, and how to escape? *World Development*, 40(4), 784–795.
- Gunderson, L. H., & Holling, C. S. (Eds.). (2002). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.
- Hazell, P., & Rahman, A. (Eds.). (2014). *New directions for smallholder agriculture*. Oxford: Oxford University Press.
- Henley, D. (2012). The agrarian roots of industrial growth: Rural development in South-East Asia and sub-Saharan Africa. *Development Policy Review*, 30, 25–47.
- Hoang, X., Dang, N., & Tacoli, C. (2005). *Livelihood diversification and rural–urban linkages in Vietnam’s Red River Delta*. London: IIED.
- Hoang, X. T., Dinh, T. T. P., & Nguyen, T. H. (2008). *Urbanization, fruit production and rural livelihood transformations in the Mekong Delta*. London: IIED.
- Holdren, J. P. (2008). Presidential Address: Science and technology for sustainable well-Being. *Science*, 25, 424–434.
- Holland, J. H. (1995). *Hidden order: How adaptation builds complexity*. New York: Basic Books.
- Holland, J. H. (1998). *Emergence: From chaos to order*. New York: Perseus Books.
- Holling, C. S. (2001). Understanding the complexity of economic, ecological, and social systems. *Ecosystems*, 4(5), 390–405.
- Holland, J. H. (2012). *Signals and boundaries: Building blocks for complex adaptive systems*. Cambridge: MIT Press.
- Jiang, L., Deng, X., & Seto, K. C. (2013). The impact of urban expansion on agricultural land use intensity in China. *Land Use Policy*, 35, 33–39.
- Kates, R. W. (2000). Cautionary tales: Adaptation and the global poor. In *Societal adaptation to climate variability and change* (pp. 5–17). Dordrecht: Springer.
- Kates, R. W., & Dasgupta, P. (2007). African poverty: A grand challenge for sustainability science. *Proceedings of the National Academy of Sciences*, 104(43), 16747–16750.
- Kauffman, S. (1995). *At home in the universe: The search for the laws of self-organization and complexity*. New York: Oxford University Press.
- Lemos, M. C., Boyd, E., Tompkins, E. L., Osbahr, H., & Liverman, D. (2007). Developing adaptation and adapting development. *Ecology and Society*, 12(2), 26.
- Levin, S. A. (1999). *Fragile dominion: Complexity and the commons*. New York: Basic Books.
- Levin, S. A., & Clark, W. C. (2010). *Toward a science of sustainability* (CID working paper No. 196). Cambridge: Center for International Development, Harvard University.

- Li, Y., Long, H., & Liu, Y. (2015). Spatio-temporal pattern of China's rural development: A rurality index perspective. *Journal of Rural Studies*, 38, 12–26.
- Liu, J., Dietz, T., Carpenter, S. R., Alberti, M., Folke, C., Moran, E., et al. (2007). Complexity of coupled human and natural systems. *Science*, 317(5844), 1513–1516.
- Liu, J., Hull, V., Batistella, M., DeFries, R., Dietz, T., Fu, F., et al. (2013a). Framing sustainability in a telecoupled world. *Ecology and Society*, 18(2), 26.
- Liu, J., Liu, M., Tian, H., Zhuang, D., Zhang, Z., Zhang, W., & Deng, X. (2005). Spatial and temporal patterns of China's cropland during 1990–2000: An analysis based on Landsat TM data. *Remote Sensing of Environment*, 98(4), 442–456.
- Liu, Y., Lu, S., & Chen, Y. (2013b). Spatio-temporal change of urban–rural equalized development patterns in China and its driving factors. *Journal of Rural Studies*, 32, 320–330.
- Long, H. L., Liu, Y. S., Li, X. B., & Chen, Y. F. (2010). Building new countryside in China: A geographical perspective. *Land Use Policy* 27, 457–470.
- Martin, S. M., & Lorenzen, K. (2016). Livelihood diversification in rural Laos. *World Development*, 83, 231–243.
- McCubbin, S., Smit, B., & Pearce, T. (2015). Where does climate fit? Vulnerability to climate change in the context of multiple stressors in Funafuti, Tuvalu. *Global Environmental Change*, 30, 43–55.
- Meyfroidt, P., Lambin, E. F., Erb, K. H., & Hertel, T. W. (2013). Globalization of land use: Distant drivers of land change and geographic displacement of land use. *Current Opinion in Environmental Sustainability*, 5(5), 438–444.
- Moran, E. F. (2010). *Environmental social science: Human-environment interactions and sustainability*. Hoboken: Wiley-Blackwell.
- NSBC. (2015). *China statistical yearbook*. National Bureau of Statistics of China. Retrieved from <http://www.stats.gov.cn/tjsj/ndsj/2015/indexch.htm>
- O'Brien, K., Leichenko, R., Kelkar, U., Venema, H., Aandahl, G., Tompkins, H., et al. (2004). Mapping vulnerability to multiple stressors: Climate change and globalization in India. *Global Environmental Change*, 14(4), 303–313.
- Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939), 419–422.
- Ribot, J. C., Najam, A., & Watson, G. (Eds.). (1996). Climate variation, vulnerability and sustainable development in the semi-arid tropics. In *Climate variability, climate change and social vulnerability in the semi-arid tropics* (pp. 13–54). Cambridge: Cambridge University Press.
- Rigg, J. (2006). Land, farming, livelihoods and poverty: Rethinking the links in the rural South. *World Development*, 34(1), 180–202.
- Rigg, J., Salamanca, A., & Parnwell, M. J. G. (2012). Joining the dots of agrarian change in Asia: A 25 year view from Thailand. *World Development* 40(7), 1469–1481.
- Satterthwaite, D., McGranahan, G., & Tacoli, C. (2010). Urbanization and its implications for food and farming. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1554), 2809–2820.
- Seto, K. C., & Reenberg, A. (2014). *Rethinking global land use in an urban era*. Cambridge: MIT Press.
- Seto, K. C., Reenberg, A., Boone, C. G., Fragkias, M., Haase, D., Langanke, T., et al. (2012). Urban land teleconnections and sustainability. *Proceedings of the National Academy of Sciences*, 109(20), 7687–7692.
- Takeuchi, K., & Aginam, O. (2011). Sustainability challenges and opportunities in Africa. *Sustainability Science*, 6(1), 3–5.
- Tian, Q., Brown, D. G., Zheng, L., Qi, S., Liu, Y., & Jiang, L. (2015). The role of cross-scale social and environmental contexts in household-level land-use decisions, Poyang Lake Region. *Annals of Association of American Geographers*, 105(6), 1240–1259.
- Tian, Q., Guo, L., and Zheng, L. (2016). Urbanization and rural livelihoods: A case study from Jiangxi Province, China. *Journal of Rural Studies*.
- Tiffen, M. (2003). Transitions in sub-Saharan Africa: Agriculture, urbanization and income growth. *World Development* 31, 1343–1366.

- Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., et al. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, 100(14), 8074–8079.
- Turner, B. L., Lambin, E. F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Sciences*, 104(52), 20666–20671.
- UNDP. (1990–2014). Human development reports. Retrieved from <http://hdr.undp.org/en/global-reports>
- Verburg, P. H., Mertz, O., Erb, K. H., Haberl, H., & Wu, W. (2013). Land system change and food security: Towards multi-scale land system solutions. *Current Opinion in Environmental Sustainability*, 5(5), 494–502.
- Warner, B. P., Kuzdas, C., Yglesias, M. G., & Childers, D. L. (2015). Limits to adaptation to interacting global change risks among smallholder rice farmers in Northwest Costa Rica. *Global Environmental Change*, 30, 101–112.
- Wilson, G. A., & Burton, R. J. (2015). ‘Neo-productivist’ agriculture: Spatio-temporal versus structuralist perspectives. *Journal of Rural Studies*, 38, 52–64.
- World Bank. (2008). *World development report 2008: Agriculture for development*. Washington, DC: The World Bank.
- You, L., Spoor, M., Ulimwengu, J., & Zhang, S. (2011). Land use change and environmental stress of wheat, rice and corn production in China. *China Economic Review*, 22(4), 461–473.

# Abstract

Less developed rural areas that are affected by climate impacts face great challenges for development. This book addresses the complex social and environmental processes underlying rural livelihoods, and attempts to provide scientific support for government policy to promote sustainable development in such areas. It uses a complex adaptive systems (CAS) approach to analyze coupled human-environment systems (CHES), and treats climate as one of many factors affecting human development in a CHES. Additionally, it examines rural livelihoods within local environments, as well as the broad development context of urbanization, emphasizing variations across local contexts and rural-urban connections.

The book first presents a sustainability framework for policy analysis. The framework uses two concepts to characterize and quantify sustainability of human-environment systems. Well-being describes the state of a CHES at a given time, while resilience describes how the system's state changes over time. The bulk of the book presents a case study that examines rural development in the Poyang Lake Region (PLR). The PLR is an important agricultural area in south-central China and part of the Yangtze River Basin. The region has been historically subjected to flooding from Poyang Lake, China's largest freshwater lake. As with other rural areas in China, rural livelihoods in the PLR are deeply integrated with urban economies, and rural development faces a number of difficult issues, central to which are agricultural decline associated with increasing nonfarm work and slow growth of rural income.

The case study includes three major analyses: (1) a regional assessment of human well-being, (2) an empirical analysis of rural livelihoods, and (3) an agent-based computer model used to explore future rural development. These analyses provide a meaningful view of human development in the PLR and illustrate some of the complex local- and macro-level processes that shape the livelihoods of rural households, in the dynamic process of urbanization. They generate rich insights about how government policy might effectively improve the well-being of rural households and promote sustainable development amid social, economic, and environmental changes. The final chapters of the book discuss possible implications for other less developed rural areas and the complex systems approach to policy analysis broadly.

# Contents

<b>1</b>	<b>Complex Adaptive Systems and a Sustainability Framework</b>	<b>1</b>
1.1	The Science of Complexity and Sustainability of Human-Environment Systems	1
1.2	A Sustainability Framework for Policy Analysis	3
1.3	Potential Usefulness of the Sustainability Framework	5
1.4	Implementation of the Sustainability Framework	7
1.4.1	Assessing Well-Being	7
1.4.2	Analyzing the Complex Processes Underlying Well-Being	8
1.4.3	Exploring Future Paths of the System	9
1.5	Looking Ahead	10
	References	11
<b>2</b>	<b>Rural Development in the Poyang Lake Region amid Floods</b>	<b>15</b>
2.1	The Dynamic Human-Environment System around Poyang Lake	15
2.2	Broader Development and Policy Context in China	21
	References	25
<b>3</b>	<b>Assessing Human Well-Being in the Poyang Lake Region</b>	<b>29</b>
3.1	Mapping Flood Risk	29
3.2	Measuring Well-Being at the Township Level	31
3.3	Assessment Results	35
3.4	Implications for Future Development and Policy Interventions	39
3.5	Conclusions	41
	References	41
<b>4</b>	<b>Understanding the Complex Processes Underlying Well-Being of Rural Households</b>	<b>43</b>
4.1	Micro- and Macro-level Processes Affecting Rural Livelihoods	43
4.2	Measuring Well-Being of Rural Households	44
4.3	Household Surveys and Interviews	45
4.4	The Use of Quantitative and Qualitative Analyses	50

- 4.5 Results . . . . . 52
  - 4.5.1 Differences among Villages and Local Social, Environmental Factors . . . . . 52
  - 4.5.2 Low-Income Households . . . . . 53
  - 4.5.3 High-Income Households and Successful Livelihood Strategies . . . . . 54
  - 4.5.4 Most Households and Constraints on Rural Livelihoods. . . . . 58
  - 4.5.5 Sensitivity to Flooding and Inequality in Flood Impacts. . . . . 61
- 4.6 Reflections on Policy . . . . . 62
  - 4.6.1 Urbanization and Rural Development . . . . . 62
  - 4.6.2 Flood Impacts and Equitable, Sustainable Development. . . . . 66
- 4.7 Conclusions . . . . . 66
- References. . . . . 68
- 5 Exploring Future Rural Development in the Poyang Lake Region . . . . . 71**
  - 5.1 Modeling Future Rural Development . . . . . 71
    - 5.1.1 Shaping the Future: Three Different Subsidy Policies. . . . . 71
    - 5.1.2 Plausible Economic and Environmental Shocks and Resilience of Rural Development . . . . . 72
  - 5.2 Model Conceptualization: Entities, Interactions, and Feedbacks . . . . . 72
  - 5.3 Empirical Data Used in the Model. . . . . 74
  - 5.4 Model Design and Implementation . . . . . 76
    - 5.4.1 Agents: Farmer Households. . . . . 76
    - 5.4.2 Land Rental Market . . . . . 76
    - 5.4.3 Migratory Work Efficiency Function. . . . . 78
    - 5.4.4 Rice Yield Functions . . . . . 79
    - 5.4.5 Major Model Parameters and Model Initialization . . . . . 80
  - 5.5 Model Verification and Validation . . . . . 80
  - 5.6 Effects of Subsidy Policies at Different Stages of Development. . . . . 83
    - 5.6.1 Model Experiments for Exploring the Effects of Policies . . . . . 83
    - 5.6.2 Future Development in Villages with Poor, Average, and Good Farmland . . . . . 85
    - 5.6.3 Policy Effects in Villages with Poor, Average, and Good Farmland . . . . . 90
    - 5.6.4 Differentiating Policy Interventions across Villages and Adaptive Policy. . . . . 92
  - 5.7 Resilience of Rural Development . . . . . 95
    - 5.7.1 Potential Effects of Severe Floods. . . . . 95
    - 5.7.2 Modeling Potential Effects of Economic Shocks . . . . . 96
    - 5.7.3 Rural Development under Economic Shocks . . . . . 97
    - 5.7.4 Enhancing Resilience amid Social and Environmental Changes . . . . . 102

5.8 Robustness Analysis. . . . . 104

5.9 Limitations of the Model . . . . . 104

5.10 Conclusions . . . . . 105

References. . . . . 107

**6 Sustainability of Human-Environment Systems . . . . . 109**

6.1 Sustainable Development in the Poyang Lake Region . . . . . 109

6.1.1 Major Findings from the Study . . . . . 109

6.1.2 Implications for Future Development and Policy  
Recommendations . . . . . 111

6.2 Implications for Sustainable Development in Other Rural Areas . . . 113

6.3 From Vulnerability to Sustainability . . . . . 115

6.4 A General Framework for Analyzing Global Sustainability . . . . . 116

6.4.1 Definitions and System Properties. . . . . 116

6.4.2 Broad Research Questions and Approaches . . . . . 118

References. . . . . 120

**7 The Complex Systems Approach to Policy Analysis . . . . . 123**

7.1 The Sustainability Framework and Complex Systems Approach  
to Policy Analysis . . . . . 123

7.2 Agent-Based Modeling for Policy Analysis . . . . . 124

7.2.1 Design Useful Models and Ask Meaningful Questions. . . . . 124

7.2.2 Meet the Challenge of Conceptualization . . . . . 125

7.2.3 Strengthen a Model’s Credibility. . . . . 132

7.2.4 Models as Projection Systems . . . . . 135

7.2.5 Unlock the Modeling Potential for Policy Analysis . . . . . 137

7.3 An Unfolding End . . . . . 138

References. . . . . 139

**Acknowledgments . . . . . 143**

**About the Author . . . . . 145**

**Index. . . . . 147**