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ORIGINAL PAPER

Urbanization, urban land expansion and environmental change in China

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Abstract China's economic reforms and unprecedented growth have generated many fascinating issues for scholarly research. An understanding of urbanization and land use change in China is required for appropriate strategies and policies to facilitate future sustainable development. This paper reviews the literature on urbanization, land use and sustainable development in China with a focus on land use change. We argue that land use and environmental research are embedded in the complex economic-geographical processes and multiple trajectories of development and urbanization in China. This paper highlights the important role of space–time modeling in a multi-disciplinary setting in the study of urbanization, land use and sustainable development. It also points out potential areas for future research.

Keywords Urbanization · Land use · Sustainable development · Space–time modeling · China

1 Introduction

China has experienced unprecedented economic growth and urbanization since the launch of economic reforms in the late 1970s. While urbanization has long been the subject of academic inquiry, urbanization on such a massive scale as that of China's has hardly ever been seen in human history. The velocity and complexity of China's transition and urbanization, in terms of the economic, social, and environmental dimensions, are unprecedented and merit further investigation (Ma 2002; Wei and Liefner 2012). China's rapid growth and structural change have raised many intriguing issues, and scholars have been debating the extent, process and consequences of urbanization and land use change in China.

Since 2012, more than half of people in China have been living in cities, and more people will become urban, generating severe challenges for housing, food, jobs, social services, and environmental sustainability. The efforts to understand urbanization and land use change in China have been heightened recently, due to the intensified unequal opportunities, social conflicts and negative consequences of human activities on resources, land spaces, and environment (Yeh and Li 1998; Xie et al. 2005). The new leadership of China has placed urbanization as one of its core subjects in its policy agenda.

China's transition from state socialism to market economy is accompanied by urban sprawl and environmental deterioration (He et al. 2014). The dramatic urban expansion in Chinese cities is a burning issue, attracting considerable scholarly attention. Researchers have documented the extent and spatial forms of urban growth (e.g., Yeh and Li 1998; Yue et al. 2010), and explored underlying driving forces of urban land expansion, as well as the relationship between urban expansion and environmental change (e.g., Liu et al. 2011a, b; Luo and Wei 2009; Wang et al. 2012). Aerial photos and remote sensing data have been accepted as reliable data sources that offer accurate estimation of urban land expansion in Chinese cities (e.g. Seto and Kaufmann 2003). The issue of land

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development is complicated since land has become a key instrument for local governments to promote economic growth, subsidize infrastructure development and compete for external investment. Hence, we feel an urgent need to further the study of urbanization and land use change in China through more systematic and organized efforts.

2 China: globalization, development and land urbanization

China offers a great opportunity to test existing theories and develop context-sensitive theories which are capable of explaining the dramatic change taking place in China. Urban expansion and sprawl in China are related to many institutional and economic factors, such as globalization, rural industrialization, improvements in transportation, and land management systems. Urban growth might also escalate regional inequality with outflows of resources from poorer places, along with regional conflicts and protectionism.

China has recorded significant economic growth since the initiation of economic reforms and open-door policies in the late 1970s. The post-Mao restructuring of the Chinese economy was initiated in 1978 with the launch of the rural reform. The reform allowed the privatization and de-collectivization of agricultural activities, leading to reduced poverty while stimulating rural agriculture and industry. This reform was followed by comprehensive urban reforms, and gradually, collective and private businesses began to outpace state-owned enterprises. China's open door strategy witnessed the introduction of special economic zones and open coastal cities that provided preferential policies for foreign investment and trade, allowing coastal provinces to use global resources and facilitate their integration into the global economy (Brandt and Rawski 2008). China's reforms were accelerated in the early 1990s after Deng Xiaoping's Southern Tour pushing for more radical economic reforms. Its entrance into World Trade Organization (WTO) in 2001 was another milestone in China's reform.

Former socialist countries, under the influence of socialist ideology, intended to control urbanization and the growth of large cities, as evidenced by the notion of "under-urbanization" influence of socialist ideology, China implemented a policy of controlling migration and urbanization while promoting industrialization (Zhou and Ma 2000). However, cities are the centers of economic growth, political power, and cultural activities. With the liberalization and globalization of the Chinese economy, China's urbanization has accelerated since the economic reform. Chinese cities have been undergoing unprecedented growth and restructuring, and millions of rural migrants have flooded into both large and small cities (Shen et al. 2002). More people are living in cities than in the countryside. The official statistics also indicate that between 1978 and 2008, the total cultivated land in China shrank from 134.4 million hectares to 121.72 million hectares, while the level of urbanization increased from 17.9 % in 1978 to 29 % in 1995 and 51.3 % in 2011.

Since the late 1970s, foreign investment and trade in China have risen dramatically. China's entrance into the WTO has pushed domestic manufacturers to compete globally. Economic reforms have liberalized and globalized the Chinese economy, placing China's urbanization in the global context. The orthodox work on the location of foreign direct investment (FDI) focuses on traditional locational factors, such as labor cost, market size, union membership, and transportation, while more recent work has uncovered the significance of globalization, nation states, and interfirm networks. Research points to the indisputable role of the state in the globalization and transformation of Chinese cities, with notions such as embedded globalization, transitional institutions, transitional cities, globalizing cities, expo-urbanization and dual-track urbanization (e.g., Sit and Yang 1997; Shen et al. 2002; Wei 2005).

The literature, however, has paid little attention to the significant role of land in FDI location and economic development in China. FDI zones often provided foreign firms cheap (sometimes free) land or office space, as evidenced by Liao and Wei (2014) and Yue et al. (2014). Foreign investment zones and districts are the most globalized places in Chinese cities and function as critical nodes of globalization and global–local interface, and are therefore experiencing dramatic land use change (Wei 2012). FDI zones and CBDs also contrast sharply with traditional urban spaces and urban villages, creating a dualistic urban land use structure (Wei et al. 2013). Scholars have also studied high-tech parks as they showcase agglomeration effects and the development of the high-tech industry in China (Zhou et al. 2011). Moreover, since a city's FDI inflow increases with the FDI inflow of neighboring cities (He and Wang 2008), cities also compete for FDI by providing even larger and cheaper land spaces, and increasingly, such spatial competition has shifted from coastal cities to interior cities.

Globalization, development and urbanization all have spatial dimensions, and spatial inequality is a common phenomenon among them. Research on China has unfolded the substantial regional inequality and multiple pathways of regional development (Ye and Wei 2005; Wei 2007; Wei and Ye 2009). The coalescence of state policy, local agents, and foreign investment has accelerated disparity between the coastal and inland provinces. FDI acts as the most important agent of regional inequality in China, both

at interregional and interprovincial scales (Li and Wei 2010). Besides differences in regional policy, location and infrastructure account significantly for spatial variation of growth. Enhancing infrastructure and human capital formation (education and medical care) to overcome geographic barriers is crucial to solve such unbalanced growth and urbanization (Démurger 2001).

Globalization and rapid economic growth have also stimulated urbanization in China. Rapid urbanization has challenged the dualism of Chinese economy and society (Shen et al. 2002), especially the orthodox socialist institutions creating uneven opportunities and dualism, including the household registration system, family planning, public resource allocation and land systems. Land has also contributed to the uneven process of globalization and economic growth. Land urbanization and regional development are mutually reinforcing, and urban land expansion is both the driver and consequence of economic growth in cities (Bai et al. 2012). Land availability has more significant impact on economic growth than domestic and foreign investment, labor supply, and government spending (Ding and Lichtenberg 2011). However, existing research on the relationship between globalization, development, urbanization and land use change remains weak. The causal effects have not been fully investigated.

Shanghai has quickly surged as the subject of a burgeoning literature on globalization and development in China, and research on the rest of the Yangtze Delta has also been increasing over the years (Xie et al. 2005; Wei et al. 2006; Yue et al. 2010). The miraculous resurgence of Shanghai as an emerging global city has attracted considerable scholarly attention. It is also the subject of inquiry for Yue et al.'s (2014), which makes a modest contribution to the study of urban land expansion and environmental change in Shanghai incorporating spatial modeling and institutional analysis. However, such a city-level comprehensive study should be followed by more detailed analysis of different types of land use, the varied districts and development zones, and the complicated interaction between different forces of globalization, development, and urbanization.

3 Urban expansion, sprawl and land use change

Rapid urban growth and land use change in developing countries, especially in Asia, have generated considerable governmental concerns and scholarly attention. These issues are important to governments, as they are associated with economic growth, resource allocation, inequality, social unrest, and sustainability. Efforts to understand the complexity of urbanization and land development have been heightened recently due to the consequences of intensified human activity upon resources, open spaces, and the natural environment. The importance of monitoring and modeling land use change is even drawing the attention of premiere scientific journals such as *Nature* and *Science* (e.g., Makse et al. 1995).

China land use/land cover mainly takes the forms of urban expansion and cultivated land reduction in urban regions. China's population is unevenly distributed, with unequal ecological carrying capacities ranging from overloading to richness (Liu et al. 2011a, b). Although the loss of cultivated land is partially attributed to the structural transformation within agriculture (for example, the conversion of cultivated land to pasture, forest and fishponds), a crucial driver has been the conversion of agricultural lands to lands supporting urban activities (Lin 2007). In most of the Chinese cities, urban built-up areas have been more than doubled—sometimes more than tripled—since the economic reform, as revealed by the literature, especially in coastal large cities (e.g., Yue et al. 2010; Wei 2012; Liao and Wei 2014). Infilling, extension, sprawl or enclave and linear development are four major types of urban land expansion and have been found common among Chinese cities. Yue et al. (2010) have found that edge growth and spontaneous growth accounted for 40–50 % and 30–40 % of urban growth respectively, while infill growth was responsible for only a small proportion of urban growth. Large Chinese cities have increasingly become polycentric. Rapid urban expansion and the disappearance of cultivated land impose serious challenges for food security, social management and economic polarization in China (Long et al. 2011).

Urban land expansion is more intensive when compared with urban population growth in Chinese cities. Our research has found that between 1993 and 2009, the total population living in prefectural cities increased by seventy-five percent, from 126.57 million to 219.82 million. On the other hand, built-up urban area more than doubled over the same period, from 10,549 sq. km in 1993 to 26,100 sq. km in 2009. This indicates that land has become a pioneer driver of economic growth and population change (Lin 2007). Urban expansion in China is also a geographically uneven process led by coastal cities. Official urban statistics show that urban populations in eastern provinces have increased at a faster pace than in western provinces, with a threefold increase from 69.25 million in 1993–130.71 million in 2009 among the cities in our study. With a massive migration from west to east, urban land expansion in the eastern area is also evident where the total area of urban land has nearly tripled.

Land use patterns have been diversified as a response to the increased urban land demand. It is puzzling that while a larger amount of rural land has been lost to urban use, Chinese cities' demand for rural land remain insatiable and

housing prices continue to skyrocket, making China one of the least affordable countries in the world in terms of housing. While many forces are underlying urban land shortage, a large percentage of urban land is for industrial and governmental use. The national land use surveys reported that the urban land in China increased by 51.68 % between 1996 and 2008 while rural residential land only rose by 1.44 % in the same period (Wang et al. 2012: p. 744). Based on the land use data published by China Ministry of Housing and Urban–Rural Development, we have found that industrial land expansion is the major contributor to urban expansion in the Yangtze River Delta (YRD). Even as the total amount of residential land has increased, the share of residential land declined by 2.37 %, while the share of industrial land increased from 25.28 % in 1999 to 26.66 % in 2009. In other words, urban land expansion is structurally focused on the expansion of industrial land. Moreover, the share of industrial land outside Shanghai has increased by 3.51 % over the period from 1999 to 2009. In other words, the expansion of industrial land in the second-tier cities in the YRD is more evident. Meanwhile, a substantial increase in the land used for local roads, plazas and public facilities, implies that the local governments in the YRD have invested heavily in the infrastructure to support the industrial development. In fact, since the late 1990s, YRD cities have mainly undertaken a top-down approach of building up large-scale development zones, so as to compete for foreign investment in the high-tech sector.

Two broadly defined groups of scholars have been working on urban growth and land use expansion in China. The first group is more interested in the process, mechanisms and consequences of urban growth and land use restructuring, with institutional and political economy perspectives, although from time to time modeling and GIS have also been used. They have adopted the concepts of development/entrepreneur states, transitional institutions, growth machines, and externally-driven development and urbanization to account for rapid urbanization and urban expansion in China (Sit and Yang 1997; Ma 2002; Wei 2007). They have studied particularly the processes of economic and land reforms, the role of state institutions and their rent-seeking behaviors, and the effects of reforms and globalization on urban growth, and view urban growth and land expansion as processes unleashed by the economic reform and led by the state and TNCs (e.g., Shen et al. 2002; Lin 2007; Wei 2012).

From the perspective of political economy, the research has found that economic reforms have empowered growth-oriented local governments and that urban land has become a central concern for government officials. Skyrocketing land prices and values have triggered the "profitable" conversion from cultivated land to urban land, making land the frontier of social conflict in urban China (Lin 2007). Researchers have documented the dramatic change in ownership structure and land systems, and have also investigated the role of property rights in urban land expansion and adopted institutional approaches to explain urban expansion and land use problems (Li and Li 2007; Tan et al. 2009; Xu et al. 2009; Wang et al. 2012). The control of urban expansion and protection of cultivated land have become a priority issue for the State Council, prompting the central government to implement the 'Equilibrium of Requisition-Compensation of Cultivated Land policy' in 1999, which requires any loss of cultivated land to be compensated by the reclamation of a similar area of cultivated land from other land-use types (Wang et al. 2012).

The second group of scholars is more interested in modeling the patterns, mechanisms, and effects of urban growth and land use expansion in China, following the neoclassical perspectives and relying heavily on modeling, GIS, and remote sensing techniques. GIS and remote sensing technologies have been used extensively to track urban expansion in China. Most of the work analyzes patterns and determinants of urban land development, whether they study agriculture land loss, multiscalar urban growth patterns, or changing determinants, and many have used GIS, remote sensing, and landscape metrics (e.g. Yeh and Li 1998; Xie et al. 2005; Luo and Wei 2009; Yue et al. 2010).

First, various models have been developed to analyze and simulate urban expansion and land use patterns in China (e.g., Xie et al. 2005; Wu et al. 2010; Liu et al. 2011a, b). The advance of the research is therefore tied heavily with the development and application of new models and methods in GIS and remote sensing. Landsat imagery has been used in conjecture with baseline economic data to model rapid urban growth along transportation networks in China. Scholars have increasingly used a mix of models and methods to analyze land use change, although many of the researches tend to deemphasize theoretical foundations for the mechanisms of land use change.

Second, scholars have also localized statistical models by using local indicators of spatial analysis, spatial regression and geographically weighted regression (e.g., Cheng and Masser 2003; Luo and Wei 2009). In association with the critique of grand theories and macro models, local and spatial variations in urban growth have recently attracted scholarly attention, which has been made possible by the development in GIS and spatial analysis. While orthodox land use models only reveal urban growth patterns from a global or whole map view, the same set of underlying factors may yield various effects in different parts of a city. At the local level, urban land expansion is

more closely related to spatial variables such as proximity to roads and existing urban centers, and scholars have clarified the spatial variances of the influence of spatial variables on urban land development. Exploring the spatially varying relationships between land use change and influence factors helps to better understand the inherent spatial heterogeneity of urban growth patterns and make reasonable predictions. In the push towards localized understanding, however, macro processes and mechanisms have often been left behind.

Third, scholars have also attempted to include socio-economic and institutional factors in the models and develop integrated models with natural, ecological, and socio-economic factors. They even now integrate on-the-ground fieldwork experiences and incorporate institutional analysis and qualitative methods. While many of the urban growth models mainly include physical and proximity variables, urban growth is driven by human activities. The research on China also shows such attempts (e.g., Xie et al. 2005; Luo and Wei 2009). The challenges are that there is a lack of data and many social, economic, and institutional forces are difficult to quantify. Nevertheless, such efforts have the potential to bridge the quantitative and qualitative researches on urban land expansion in China and provide a more complete understanding of the complexity of urbanization and urban growth. A future direction for this line of enquiry is to introduce the perspectives and approaches of evolutionary economic geography, which may help the understanding of the process of urbanization and urban land expansion.

Lastly, most of the studies on urban growth in China have dealt with the most rapidly growing coastal cities and regions, such as the YRD (e.g., Xie et al. 2005; Luo and Wei 2009; Yue et al. 2010), the Pearl River Delta (e.g., Yeh and Li 1998; Weng 2002), and Beijing (e.g., Wu et al. 2006), and more recently, major interior cities such as Wuhan (e.g., Cheng and Masser 2003) and Chengdu (e.g., Schneider et al. 2005). There are very limited studies on the peripheral cities in both coastal and interior regions. Studies at the peripheral regions and small cities are therefore welcome to enrich our understanding the multi-dimensional urban growth and land use expansion in China.

Liao and Wei (2014) investigate the spatial patterns of urban growth and its underlying factors in Dongguan, a coastal city which has faced substantial challenges of environmental sustainability arising from the loss of agricultural land. They conclude that more governmental efforts have very limited effects towards a compact and sustainable urban development. Xie and Fan (2014) construct a multi-city agent-based model to explore possible trajectories of regional urban growth along the entire environmentally strained He-Xi Corridor, which has been constrained by water shortage and harsh natural environment because this region is located in arid and semi-arid climate zones. This model simultaneously considers the spatial variations of a system of cities in terms of population size, development history, water resource endowment and sustainable development potential. It also explores potential impacts of exogenous inter-city interactions on future urban growth on the basis of urban gravity model.

Li et al. (2014a, b) develop two multi-scale modeling approaches, the SD-CLUES and SDCA models, to examine the process of urban spatial dynamics of Daqing. The SD-CLUES connects the SD model, a macro-scale approach, with the CLUE-S model, a top-down micro-level method. The SD–CA model integrates the results of the SD model with the bottom-up CA modeling approach. Further, visual comparisons and validations indicate that the SD–CA model performs better when compared with the reference map. Finally, analysis of results also suggests that the stochastic factor in the CA model has significant impact on the modeling accuracy.

4 Urbanization, land use, and environmental change

Rapid urbanization in China had its profound environment impacts. Dramatic urban growth is usually accompanied by an increased burden on rural land and urban environment, due to growing energy use, aggravating air and water, noise pollution, and loss of agricultural and natural land to urban land. Restless and unchecked urbanization brings up an increasingly important and serious issue of arable land scarcity in China. Various opportunities in cities are fueling the massive migration from rural to urban areas. Fast urban development and population growth has led to a steadily shrinking land base for agricultural production, threatening grain self-sufficiency over the long run. Urbanization also leads to the destruction of sensitive ecosystems and alters the hydrology of urban area and their immediate vicinity. Hence, urbanization not only has local environmental impacts, but also makes large ecological footprints beyond, which are being felt around the globe. As argued by Seto and Satterthwaite (2010, p. 127). “Today we face a great challenge for sustainability at the planetary scale, brought about by the confluence of two global trends: the transition towards an increasingly urbanized world and global environmental change.”

The continued rapid urbanization of China will make ecological deficits become more severe as urban land expands and encroaches on arable land (Wang et al. 2009; Liu et al. 2011a, b). The ecological footprints of China and most provinces run a national or regional ecological deficit. Urban land expansion and arable land loss were closely related to economic development, household registration

systems, urban development policies, and land use policies (Wang et al. 2009). Informal housing and industrial developments in urban villages are also important parts of the urbanization process (Wang et al. 2009). The use of GIS and remote sensing to detect heat-island effects as an indicator of growth in the built environments of China is more easily observed (Weng 2002).

China's development priority is economic growth, which is needed to secure the authority of the government and the stability of Chinese society. China's phenomenal growth however has increased the demand for energy and resources, and environmental harms stem from widespread exploitation of natural resources. Environmental challenges are generated by an economy focusing single-mindedly on gross domestic product growth. China's rapidly economic growth has been accompanied by degradation of natural resources and pollution. In addition, the environmental impacts of rapid growth not only are concentrated in China, but increasingly affect stability of the global environment. China's urban growth impacts surrounding environments and contributes to broader environmental threats because of the tightly woven fortunes across communities and nations.

Concomitant with these demographic and urban changes, the overall environmental quality is worsening in China. In addition, environmental pollution has caused serious health issues and economic loss. It might jeopardize economic development and sustainability. The pro-growth and resource intensive strategy has certainly led to the environmental deterioration and thus have raised environmental awareness in the nation (Cao and Ye 2012). China's ecological balance between supply and demand has become a global concern (Liu et al. 2011a). Land use and land cover change, as a consequence of rapid growth and urbanization can have environmental impacts on hydrologic, climatic and socio-economic systems (LeBlanc et al. 1997; Zhao et al. 2001; Veldkamp and Verburg 2004). Rampant urban growth/sprawl and massive encroachment on agricultural land have led to severe environmental problems in China (Weng 2002).

As the number of city dwellers grows, China is also entering a more car-dependent society. Due to China's rapid growth toward fostering a private-car based economy, pressure is put on scarce and limited resources in the context of sprawling settlement patterns. As Davis (2002, p. 165) points out, "to raise consumption of energy and materials throughout the world to Western levels, given current population projections, would require the resources of four planet Earths by the year 2100. To do so with the one world we have would so severely compromise the biosphere that the Earth would be unrecognizable." China harbors sixteen of the world's twenty greatest polluted cities, with roughly 14,000 new cars emerging on China's roads per day (Davis 2002).

The vast and rapid development of urban areas has caught the growing attention both nationally and globally about energy security and greenhouse gas emissions. Heightened awareness of China's growth footprint on the global environment has promoted the discussion of environmental and climate issues in China while a dilemma exists between economic development and environmental/climate change mitigation. It is necessary to maintain dynamic and smarter urban development while mitigating damage to the environment. However, Local Chinese officials are in the hasty quest for economic growth as career promotion while there is a lack of incentives to make environmental protection a priority (Brajer et al. 2010).

Yue et al. (2014) argue that land use/cover characteristics have contributed significantly to spatial patterns of economic activity and environmental conditions in Shanghai, especially in terms of affecting the range and intensity of air pollution and UHI. In combination with other socioeconomic data, they analyze urban expansion patterns and explained the inter-relationship between economic development and environmental conditions. Xu et al. (2014) promote the integration of carbon sequestration into sustainable forest management and rural development plan with multi-stakeholder participation. A range of forest land use scenarios that address various aspects of the forest carbon sequestration rate and rural sustainability are evaluated against a sustainable development indicator system. The integrated assessment based on the AHP method provides an effective tool to help understand how economic, social and environmental factors are related to each other in affecting the nature of rural sustainability. Using The East River in South China as the case study, Niu and Sivakumar (2014) argue for the understanding of the hydrologic response to land use change is crucial to develop sustainable water resources in the region. They evaluate the possible impacts of land use change on hydrologic response using a numerical model and corresponding available vegetation datasets. The variable infiltration capacity model is applied to simulate runoff responses to several land use scenarios within the basin during 1952–2000.

Qi et al. (2014) analyzes land use dynamics, land fragmentation, variation of ecosystem service value (ESV), and the underlying driving forces in the context of rapid urbanization over the period of 1995–2010 in Taizhou. As a whole, significant change in key landscape, especially a net decrease in forest, and remarkable socioeconomic development should be responsible for the sharp decline of total ESV. He et al. (2014) apply the three-dimension framework of density, division and distance proposed by the World Bank to identify the spatial heterogeneity of development and pollution in urban China. An inverted U relationship is detected between density and industrial SO_2

emission, while a cubic relationship is found between density and industrial SO_2/soot emission intensity. The statistical significance of division indicates that the pollution haven hypothesis holds in the western region and cities in the periphery. The environmental implication of distance is that industrial pollution is largely concentrated in the national and regional cores. Li et al. (2014a, b) studies the emissions of SO_2 and COD in China using county-level data. Level of economic development, population density, and industrial structure are highly correlated with the level of SO_2 and COD emissions, though their impacts on SO_2 and COD vary. Based on the research results, they present some preliminary policy recommendations, especially for those cluster regions that face significant environmental degradation and challenge.

5 Conclusion

In the past three decades, China has gone through a dynamic urban transformation the world has hardly seen. China is changing from a socialist regime of planned economy to a more market-based profit-seeking entrepreneurial state (Ye and Xie 2012). These politically correct and economically rewarding entrepreneurial activities are encouraged, admired, and pursued by government agencies and individuals. China's transition has led to impressive economic growth rates, while the speed of urbanization and land use change has also been accelerated. As the fastest growing economy in the world, China is also faced with serious problems of environmental degradation.

The fast-growth, resource-intensive and export-oriented development strategy has contributed to environmental degradation in China. Changes to the physical landscapes reflect intersections of reform and modernization. Large-scale projects, including new sites for natural resource extraction and transportation infrastructure, illustrate how the physical environment continues to be transformed through the nexus of political, economic, and technological access and control. The dilemma still exists between uneven development and environmental change in this continued dynamic economic system (Ye and Wei 2012). Moreover, the burden of environmental and climate hazards (such as desertification, soil erosion and deforestation) has fallen disproportionately on poorer and less powerful individuals and regions. Evidences illustrate that people and regions in China do not benefit from the same level and degree of protection from hazards.

Broad developments, such as the rise of trade, the strengthening of regional interconnections through direct highways, railroads, and complex energy transport networks, and the intensifying pressures to expand natural resource extraction and transportation, present a mosaic of contrasting perspectives and expectations among diverse stakeholders and interested observers. Amidst the variety of development challenges and opportunities spanning China, citizens may find themselves located on the weaker side of asymmetrical local and national power hierarchies, governments may form alliances with corporate entities for the creation of "mega-projects," and international NGOs and local organizations may be required by government officials to identify themselves as "foreign agents."

The core of this new stage of urbanization is to improve the quality of urbanization and to take little count of urbanization quantity (Chen et al. 2013). A careful development and implementation of the notions of growth management and sustainable development may guide the urbanization process and the use of land resources. As a modified derivative of the concepts of the limit to growth and carrying capacity, sustainable development not only stresses the importance of resource in limiting economic growth, but also draws people's attention to the need of developing methods to grow in harmony with the environment (Yeh and Li 1998; Wu et al. 2012).

China's urban growth, population resettlement, surging popularity of private vehicles, and the associated demand for resources and energy have been transforming terrestrial ecosystems, along with a plague of city diseases. Unrestrained urbanization can lead to unplanned and poorly managed sprawl, which undermines the environment, the economy, and the society. Policymakers in China begin to be aware of the need to guide urbanization in a sustainable way. However, there is a general lack of operational models for implementing sustainable development in urbanization and land development processes. Additionally, more stochastic modeling methods in urbanization and land use change studies are needed.

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References

Bai XM, Chen J, Shi PJ (2012) Landscape urbanization and economic growth in China: positive feedbacks and sustainability dilemmas. Environ Sci Technol 46(1):132–139

Brajer V, Mead RW, Xiao F (2010) Adjusting Chinese income inequality for environmental equity. Environ Dev Econ 15(3):341–362

Brandt L, Rawski GT (2008) China's great transformation. Cambridge University Press, Cambridge

Cao K, Ye XY (2012) Coarse-grained parallel genetic algorithm applied to a vector based land use allocation optimization problem: the case study of Tongzhou Newtown, Beijing, China. Stoch Environ Res Risk Assess. doi:10.1007/s00477-012-0649-y

Chen MX, Liu WD, Tao XL (2013) Evolution and assessment on China's urbanization 1960–2010: under-urbanization or over-urbanization? Habitat Int 38(4):25–33

Cheng J, Masser I (2003) Urban growth pattern modeling: a case study of Wuhan City, China. Landsc Urban Plan 62(4):199–217
Davis W (2002) For a global declaration of interdependence. In: González RJ (ed) Anthropologists in the public sphere. University of Texas Press, Austin, pp 165–169
Démurger S (2001) Infrastructure development and economic growth: an explanation for regional disparities in China? J Comp Econ 29(1):95–117
Ding C, Lichtenberg E (2011) Land and urban economic growth in China. J Reg Sci 51(2):299–317
He XQ, Wang LX (2008) Empirical analysis on spatial linkages in FDI across China. Econ Res J 11:137–150
He CF, Huang ZJ, Ye XY (2014) Spatial heterogeneity of economic development and industrial pollution in urban China. Stoch Env Res Risk Assess. doi:10.1007/s00477-013-0736-8
LeBlanc RT, Brown RD, FitzGibbon JE (1997) Modeling the effects of land use change on the water temperature in unregulated urban streams. J Environ Manage 49(4):445–469
Li LH, Li X (2007) Land readjustment: an innovative urban experiment in China. Urban Stud 44(1):81–98
Li YR, Wei YHD (2010) The spatial-temporal hierarchy of regional inequality of China. Appl Geogr 30(3):303–316
Li Q, Song JP, Wang E, Hu H, Zhang JH, Wang YY (2014a) Economic growth and pollutant emissions in China: a spatial econometric analysis. Stoch Env Res Risk Assess. doi:10.1007/s00477-013-0762-6
Li WL, Wu CS, Zang SY (2014b) Modeling urban land use conversion of Daqing City, China. Stoch Environ Res Risk Assess. doi:10.1007/s00477-012-0671-0
Liao FHF, Wei YHD (2014) Modeling determinants of urban growth in Dongguan, China: a spatial logistic approach. Stoch Env Res Risk Assess. doi:10.1007/s00477-012-620-y
Lin GCS (2007) Reproducing spaces of Chinese urbanization. Urban Stud 44(9):1827–1855
Liu D, Feng ZM, Yan YZ, You Z (2011a) Spatial patterns of ecological carrying capacity supply-demand balance in China at county level. J Geogr Sci 21(5):833–844
Liu Y, Yue W, Fan P (2011b) Spatial determinants of urban land conversion in large Chinese cities: a case of Hangzhou. Environ Plan 38(4):706–725
Long H, Zou J, Pyket J, Li Y (2011) Analysis of rural transformation development in China since the turn of the new millennium. Appl Geogr 31(3):1094–1105
Luo J, Wei YHD (2009) Modeling spatial variations of urban growth patterns in Chinese cities. Landsc Urban Plan 91(2):51–64
Ma LJC (2002) Urban transformation in China, 1949–2000. Environ Plan A 34(9):1545–1569
Makse HA, Havlin S, Stanley HE (1995) Modelling urban growth pattern. Nature 377(6550):608–612
Niu J, Sivakumar B (2014) Study of runoff response to land use change in the East River basin in South China. Stoch Environ Res Risk Assess. doi:10.1007/s00477-013-0690-5
Qi ZF, Ye XY, Zhang H, Yu ZL (2014) Land fragmentation and variation of ecosystem services in the context of rapid urbanization: the case of Taizhou city, China. Stoch Environ Res Risk Assess. doi:10.1007/s00477-013-0721-2
Schneider A, Seto KC, Webster DR (2005) Urban growth in Chengdu, western China: application of remote sensing to assess planning and policy outcomes. Environ Plan Plan Des 32(3):323–345
Seto KC, Kaufmann RK (2003) Modeling the drivers of urban land use change in the Pearl River Delta, China: integrating remote sensing with socioeconomic data. Land Econ 79(1):106–121
Seto KC, Satterthwaite D (2010) Interactions between urbanization and global environmental change. Curr Opin Environ Sustain 2:127–128
Shen J, Wong K, Feng Z (2002) State-sponsored and spontaneous urbanization in the Pearl River Delta of South China, 1980–1998. Urban Geogr 23(7):674–694
Sit VFS, Yang C (1997) Foreign-investment-induced exo-urbanisation in the Pearl River Delta, China. Urban Stud 34(4):647–677
Tan R, Beckmann V, VandenBerg L, Qu F (2009) Governing farmland conversion. Land Use Policy 26(4):961–974
Veldkamp A, Verburg PH (2004) Modelling land use change and environmental impact. J Environ Manag 72(1–2):1–3
Wang YP, Wang YL, Wu JS (2009) Urbanization and informal development in China: urban villages in Shenzhen. Int J Urban Reg Res 33(4):957–973
Wang J, Chen Y, Shao X, Zhang Y, Cao Y (2012) Land-use changes and policy dimension driving forces in China: present, trend and future. Land Use Policy 29(4):737–749
Wei YHD (2005) Planning Chinese cities: the limits of transitional institutions. Urban Geogr 26(3):200–221
Wei YHD (2007) Regional development in China: transitional institutions, embedded globalization, and hybrid economies. Eurasian Geogr Econ 48(1):16–36
Wei YHD (2012) Restructuring for growth in urban China: transitional institutions, urban development, and spatial transformation. Habitat Int 36(3):396–405
Wei YHD, Liefner I (2012) Globalization, industrial restructuring, and regional development in China. Appl Geogr 32(1):102–105
Wei YHD, Ye XY (2009) Beyond convergence: space, scale, and regional inequality in China. Tijdschrift Voor Economische En Sociale Geografie 100(1):59–80
Wei YHD, Leung CK, Luo J (2006) Globalizing Shanghai: foreign investment and urban restructuring. Habitat Int 30(2):231–244
Wei YHD, Yuan F, Liao FH (2013) Spatial mismatch and determinants of foreign and domestic ICT firms in China. Prof Geogr 65(2):247–264
Weng QH (2002) Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modeling. J Environ Manag 64(3):273–284
Wu Q, Li HQ, Wang RS, Paulussen J, He Y, Wang M, Wang BH, Wang Z (2006) Monitoring and predicting land use change in Beijing using remote sensing and GIS. Landsc Urban Plan 78(4):322–333
Wu D, Liu J, Wang S, Wang R (2010) Simulating urban expansion by coupling a stochastic cellular automata model and socioeconomic indicators. Stoch Env Res Risk Assess 24(2):235–245
Wu K, Ye XY, Fang Z, Zhang H (2012) Impacts of land use/land cover change and socioeconomic development on regional ecosystem services: the case of the fast-growing Hangzhou metropolitan area, China. Cities 31:276–284
Xie YC, Fan SY (2014) Multi-city sustainable regional urban growth simulation-MSRUGS: a case study along the mid-section of Silk Road of China. Stoch Env Res Risk Assess. doi:10.1007/s00477-012-0680-z
Xie YC, Yu M, Tian GJ, Xing XR (2005) Socio-economic driving forces of arable land conversion: a case study of Wuxian city, China. Glob Environ Change 15(3):238–252
Xu J, Yeh A, Wu F (2009) Land commodification: new land development and politics in China since the late 1990s. Int J Urban Reg Res 33(4):890–913
Xu W, Khoshroo N, Bjornlund H, Yin YY (2014) Effects of "Grain for Green" reforestation program on rural sustainability in China. Stoch Env Res Risk Assess. doi:10.1007/s00477-012-0592-y
Ye XY, Wei YHD (2005) Geospatial analysis of regional development in China: the case of Zhejiang Province and the Wenzhou Model. Eurasian Geogr Econ 46(6):445–464
Ye XY, Wei YHD (2012) Regional development, disparities and polices in globalizing Asia. Reg Sci Policy Pract 4(3):179–182

Ye XY, Xie YC (2012) Re-examination of Zipf's Law and urban dynamic in China: a regional approach. Ann Reg Sci 49(1):135–156

Yeh AGO, Li X (1998) Sustainable land development model for rapid growth areas using GIS. Int J Geogr Inf Sci 12(2):169–189

Yue W, Liu Y, Fan P (2010) Polycentric urban development: the case of Hangzhou. Environ Plan A 42(3):563–577

Yue WZ, Fan PL, Wei YHD, Qi JG (2014) Economic development, urban expansion, and sustainable development in Shanghai. Stoch Env Res Risk Assess. doi:10.1007/s00477-012-0623-8

Zhao M, Pitman AJ, Chase T (2001) The impact of land cover change on the atmospheric circulation. Clim Dyn 17(5–6):467–477

Zhou YX, Ma LJC (2000) Economic restructuring and suburbanization in China. Urban Geogr 21(3):205–236

Zhou Y, Sun YF, Wei YHD, Lin GCS (2011) De-centering "spatial fix"-Patterns of territorialization and regional technological dynamism of ICT hubs in China. J Econ Geogr 11(1):119–150