Applied Geography 86 (2017) 118–127

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Urbanization on the Mongolian Plateau after economic reform: Changes and causes

Hogeun Park [a, c, *], Peilei Fan [a, c], Ranjeet John [c], Jiquan Chen [b, c]

[a] School of Planning, Design, and Construction, Michigan State University, East Lansing, MI 48823, USA
[b] Department of Geography, Environment, and Spatial Sciences, Michigan State University, East Lansing, MI 48823, USA
[c] Center for Global Changes and Earth Observation, Michigan State University, East Lansing, MI 48823, USA

ARTICLE INFO

Article history:
Received 18 January 2017
Received in revised form
14 June 2017
Accepted 21 June 2017

Keywords:
Transitional economy
Urbanization
Mongolian Plateau
Coupled natural and human system (CNH)
Urban sustainability
Partial Least Squares Structural Equation Modeling (PLS-SEM)

ABSTRACT

In response to changes in human and natural environments over the past three decades, transitional countries have experienced dramatic urbanization. In the context of socioeconomic and biophysical changes, our knowledge on these urbanization processes remains limited. Here, we used the Mongolian Plateau (i.e., Inner Mongolia (IM) and Mongolia (MG)) as a testbed and applied the coupled natural and human (CNH) concept to understand the processes and causes of urbanization. We selected six cities on the Mongolian Plateau, classified their urban built-up areas using Geographic Object-Based Image Analysis (GEOBIA) from 1990 through 2015, and examined the driving forces of urbanization (i.e., economy, social goods, and environmental variables) through Partial Least Squares Structural Equation Modeling (PLS-SEM). We found that the spatial characteristics of urbanization in IM and MG have both similarities and differences. The cities in IM and MG have experienced rapid urban expansion, with urban areas increasing by 4.36 times and 3.12 times, respectively, since 1990. Cities in IM, however, were less dense and more sprawling whereas cities in MG were linearly aggregated. We also found through PLS-SEM that multiple driving forces affected urbanization in IM and MG during the transitional period. Results (path coef.) demonstrated that economic development (0.559) is a major driver for urbanization in IM, whereas social goods (0.646) and economic development (0.433) strongly influence urbanization in MG. These differences are likely due to the divergent governmental roles in urban development and in infrastructure/social support, as well as the differing economic structures in IM and MG.

1. Introduction

Urbanization is an adaptation of human society to socioeconomic and biophysical changes (Schneider & Woodcock, 2008; Seto, Sanchez-Rodriguez, & Fragkias, 2010). Since similarities between spatial extent and growth rates alone do not imply that the causes of urbanization are the same (Lambin & Meyfroidt, 2010; Seto et al., 2010), identifying the driving forces of urbanization is crucial to understanding the real urbanization mechanism. Consequently, an increasing number of studies have aimed to investigate these driving forces, and have suggested that urbanization has been mainly driven by geographical factors (e.g., slope and elevation), altered socioeconomic status (e.g., GDP and population), and land use policy (Liu, Zhan, & Deng, 2005; Seto & Kaufmann, 2003; Tian, Chen, & Yu, 2014; Zhang, Su, Xiao, Jiang, & Wu, 2013). There is, however, little understanding on how different socioeconomic and biophysical driving forces interactively influence urbanization.

Most cities in transitional economies have faced abrupt transformations in their economic and industrial structures over a relatively short period compared to cities in the global north (Kamata, Reichert, Tsevegmid, Kim, & Sedgewick, 2010; UN-Habitat, 2003). As Ma (2002) and Wu (2003) explained, cities in transitional economies have transformed into gateways, allowing marketization and globalization to develop a new economy. Unlike cities under a socialist regime that have suppressed consumption by regulating low wages and limiting markets, the cities in transitional economies have become highly marketized (Davis, 2000). This transformation consequently led to rapid urban growth. Economic growth and increased non-agricultural activities during the transitional period, particularly in China, are major driving forces

* Corresponding author. Room 202, Manly Miles Building, 1405 S. Harrison Rd, East Lansing, MI 48823, USA.
E-mail address: parkhoge@msu.edu (H. Park).

http://dx.doi.org/10.1016/j.apgeog.2017.06.026
0143-6228/

for urbanization (Bai, Shi, & Liu, 2014; Fan, Xie, Qi, Chen, & Huang, 2014; He, Huang, & Wang, 2014; Li, Wei, Liao, & Huang, 2015). In the former Soviet countries, growth of the tertiary industry and job availability have also had a significant impact on urbanization (Molodikova & Makhrova, 2007; Rudolph & Brade, 2005; Tammaru, Kulu, & Kask, 2004).

While many previous studies have empirically explored the driving forces of urbanization in transitional economies as mentioned above, further insight can be gained if we consider the process of urbanization as an evolving coupled natural and human (CNH) system. In this regard, we employ the CNH concept (Alberti et al., 2011; Chen & Liu, 2014; Liu et al., 2007) as a framework to incorporate the socioeconomic and biophysical driving forces, thus increasing our knowledge on urbanization process. Changes in transitional economies not only transform economic structures and remove governmental controls, but also transform the entire CNH system with emerging properties (McMillan & Naughton, 1992; Roose, Kull, Gauk, & Tali, 2013). This framework will help to advance our understanding of the urbanization process and its implications for future urban sustainability (Xu & Wu, 2016).

We use the Mongolian Plateau (MGP) to comprehend the underlining mechanisms for urbanization in transitional economies. In this region, both Inner Mongolia (IM) and Mongolia (MG) have experienced economic reform and democratic liberalization. Historically, Mongolians were nomads due to limited natural resources (Fernandez-Gimenez, Batjav, & Baival, 2012), and held this traditional pastoral nomad lifestyle until 1990. During the last three decades, however, the collapse of the Soviet Union and the economic liberalization of China have brought dramatic changes to environmental and socioeconomic conditions that led to drastic increases in the urban population in MGP (Fan, Chen, & John, 2016; John, Chen, Lu, & Wilske, 2009). These changes can be illustrated in several dimensions. The responsibility of social good provision has transferred from central government to the individual (e.g., education and healthcare), income gaps between urban and rural areas have enlarged, and new grassland management policies have further accelerated urbanization (Chen, John, Zhang, et al., 2015; Endicott, 2012; Fernandez-Gimenez & Batbuyan, 2004; Wu, Zhang, Li, & Liang, 2015).

By using the MGP as a test bed, we synthesized the economic conditions, social goods, and natural environments, explored the spatiotemporal dynamics of urbanization, and quantified the impacts from socioeconomic and biophysical drivers within a CNH framework to comprehend the process of urbanization. Our primary research questions are: (1) How have spatiotemporal patterns of urbanization changed over the past three decades in IM and MG? (2) What were the major drivers of urban expansion in the Mongolian Plateau from 1990 through 2015? (3) What different relationships did IM and MG experience between urbanization, socioeconomic and biophysical factors? To address these questions, we conducted a spatial analysis with remote sensing images and used structural equation modeling (SEM) to investigate the urbanization process and its driving forces in IM and MG. This comparative analysis will enhance our understanding of the urbanization in transitional economies while considering different socioeconomic and institutional settings.

2. Study area, data, and methods

2.1. Study area

The MGP has experienced dramatic changes in its socioeconomic circumstances and in its relationship with the natural environment over the past three decades. Once collective farms and shareholding companies lost their competitiveness in the emerging market and the state safety net disappeared, jobs were diversified into many different sectors (Endicott, 2012). Major responsibility for employment, education, and health services were transferred from the state to private sectors and individuals. Despite the rapid economic growth during the transitional period, wealth concentrated in the cities of both IM and MG, which enlarged the income gap between urban and rural areas (Liu, Rao, Evans, Chen, & Hsiao, 2001). As a result, urban migration is considered a response to the relative deprivation of income and social goods (Gilbert & Gugler, 1992). Several research teams (Chan & Zhang, 1999; Fan, 1999; Knight & Song, 1999; Zhao, 1999) have empirically examined the importance of jobs and education to the internal migration within China. Shifting economies on the MGP also affected the environment, as massive changes due to new anthropogenic disturbances arose. New land use policies took effect, including the Grassland Law (1985) and the Household Contract Responsibility Systems (1983) in IM, as well as the Law on Land (1994) in MG. These policies transferred the responsibility for grassland management from communities to individual households (Endicott, 2012; Fernandez-Gimenez & Batbuyan, 2004; Wu et al., 2015). Consequently, accelerated overgrazing and environmental degradation was seen across the plateau (Brown et al., 2013; John et al., 2016; Liu et al., 2013; Ojima & Chuluun, 2008; Shao, Li, Dong, & Chen, 2014). Furthermore, growing mining industries have negatively influenced both the vegetation cover and the biophysical health of ecosystems (Qian, Bagan, Kinoshita, & Yamagata, 2014; Stubblefield et al., 2005).

We examined a total of six cities—three in IM and three in MG—that have experienced rapid urban and economic growth and shared a similar biome (i.e., temperate grassland) (Fig. 1). These cities were selected because they are either a capital, mining center, or transportation hub. This promotes comparability between cities, as the process of urban growth and its spatial arrangements depend on city characteristics and regional roles (Antrop, 2004; Kunzmann & Wegener, 1991). Furthermore, these cities are likely to be regional hubs for urban development in the future due to their importance as capital cities in both regions, the rising role of the mining sector in economic development, and due to the strategic location of their transportation routes. These cities are: Hohhot (40°49′N, 111°39′E), Baotou (40°39′N, 109°50′E), and Ulanqab (41°00′N, 113°08′E) of IM, and Ulaanbaatar (47°55′N, 106°55′E), Erdenet (49°01′40″N, 104°02′40″E), and Darkhan (49°28′08″N, 105°57′27″E) of MG. Hohhot and Ulaanbaatar have experienced dramatic urbanization as the capital cities of IM and MG, respectively (Fan, Chen, & John, 2016). Hohhot, located in the southern center of IM, is a major industrial center and the home of one of China's largest dairy producers. As an economic center and a participant in the Western Development Project in China, Hohhot has experienced rapid urbanization. Ulaanbaatar of MG is located near the center of the country and serves as the capital. It is an industrial, political, and cultural hub and has experienced a huge amount of urban migration since 1990. Baotou in IM and Erdenet in MG are industrial cities based on the mining industry. Baotou is the largest industrial city in IM and the home to the world's largest rare earth mine (i.e., the Bayan-Obo mining district). Erdenet is located in the northern part of MG and was established in 1974 after large deposits of copper were discovered nearby. The city possesses the fourth largest copper mine in the world. Ulanqab in IM and Darkhan in MG are transportation hubs that connect their provinces to the country border. Ulanqab, located in the center of IM, connects MG and Hebei Province. The city lies at the intersection of the railway and the Chinese National Highway 208 and 110. Darkhan, Mongolian for “Blacksmith”, was built by the Soviet Union in 1961 as a manufacturing base on the Trans-Mongolian Railroad. It continues to play an important role as a transportation hub connecting Russia and Mongolia.

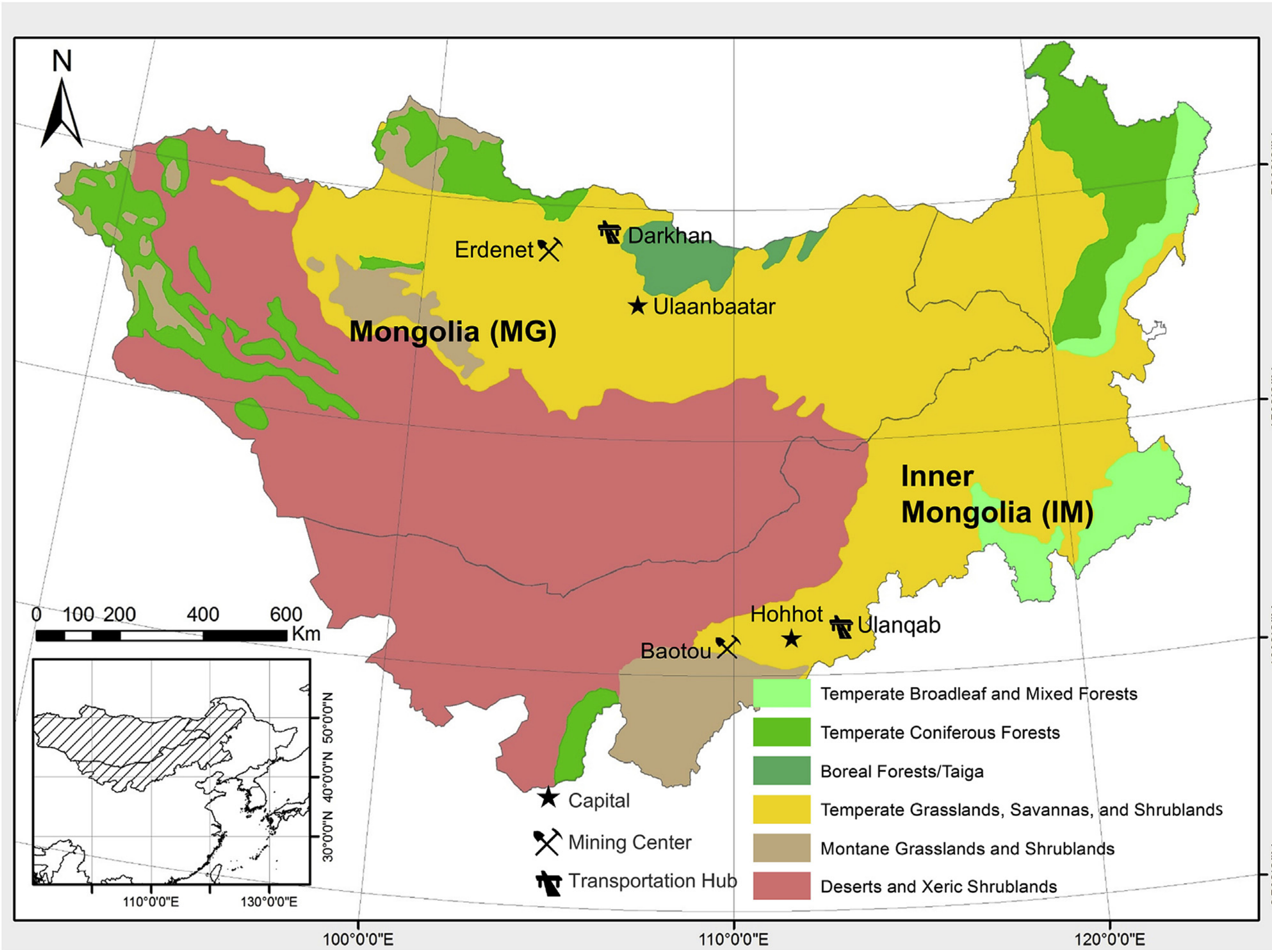


Fig. 1. Location of the selected cities in IM and MG. The cities are selected by their urban characteristics in regards to their regional roles with similar ecological settings.

2.2. Urban land data processing: GEOBIA classification

Given the limited amount of socioeconomic data for MG prior to 1990 and the rapid urbanization following the collapse of the Soviet Union, we chose to study the period from 1990 to 2015. We extracted impervious areas from remotely-sensed images (i.e., 36 different Landsat images from 1990 through 2015, with 5-year intervals) to assess the urban expansion of the six representative cities in IM and MG. We performed two major pre-processing tasks for the images, i.e., Landsat radiometric calibration and Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH), using ENVI 5.1™ software. For the atmospheric correction, we assigned sub-arctic summer (SAS) and mid-latitude summer (MLS) for MG and IM, respectively, based on the MODTRAN standard (ITT, 2009).

Due to the complexity of urban features, Geographic Object-Based Image Analysis (GEOBIA), which classifies images based on spectral, geometric, and textual homogeneity, is a suitable tool to extract urban built-up areas rather than pixel-based classification (Hay & Blaschke, 2010). We first derived water and vegetation cover types from the images through multi-resolution segmentation with certain parameters (100 scale, 0.3 shape, and 0.5 compactness), which were derived empirically through iterative testing of the algorithm parameters. We selected 50 samples to develop functions in fuzzy classification. To extract water and vegetation cover, we re-segmented the rest of area at a small-scale (50 scale) to delineate the urban features through fuzzy classification. Finally, we modified the classification results using visual interpretation to compare them with Google Earth and ground truth (photos taken by authors) to enhance the quality of the classifications. These procedures allowed us to effectively partition the built-up areas from bare soil and agricultural land. Through randomly selecting 50 polygons in a Test and Training Area (TTA) mask module in eCognition, we were able to confirm a sufficient level of overall accuracy (ranging from 0.78 to 0.98) for all images.

2.3. Measuring urbanization

Urbanization can be described as horizontal, vertical, or scattered expansion (Jiang, Liu, Yuan, & Zhang, 2007; Sevtsuk & Amindarbari, 2012). We assessed the degree of urbanization by examining total built-up area, net urban population density, and the scattered pattern of the urban patch from classified images to compare expansion, density, and discontiguity. We employed a discontiguity index (Sevtsuk & Amindarbari, 2012) for scattered expansion (i.e. leapfrog development). Because urban expansion does not always happen at the edge of cities, leapfrog development may indicate that a new regulation on land-use, affordability of land, and transportation costs. To calculate discontinuous growth, we used:

$$Discontiguity = \sum_{n=1}^{N} \left(\frac{\sum_{i=n+1}^{N} A_i}{A_n} \right) \left(\frac{\sum_{i=n}^{N} A_i}{A_{total}} \right)$$

where A_{total} is total built-up area (km^2), A_n is the area of cluster n, and n is the number of clusters.

2.4. Driving forces of urbanization

Given that urbanization is a result of compound processes, we employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to quantify the importance of socioeconomic and biophysical drivers on urbanization. PLS-SEM is a modeling approach used to employ the concept of Structural Equation Modeling (SEM) for non-normally distributed data (Hair, Hult, Ringle, & Sarstedt, 2013). PLS-SEM is more applicable to exploratory research with small samples compared to the Covariance-Based SEM (CB-SEM) (Hair et al., 2013). Bootstrapping analysis in the PLS-SEM setting can be used to test the stability of the estimated model parameters (Chin, 2010). In addition, PLS-SEM has a strong ability to identify the key model driver (Fan, Chen, Shirkey, et al., 2016; Hair, Ringle, & Sarstedt, 2011).

Defining 'urban' or 'urbanization' is challenging as their definitions vary from country to country. For example, urban area may be defined through different measures such as administrative boundaries, size and level of social services, or population density (Saksena et al., 2014). Because our primary goal is to understand the processes of urbanization between IM and MG, we used the total built-up area within the administrative boundaries, a widely acknowledged indicator, as our unit of measurement for urbanization. We utilized the area of built-up land from Landsat as an urban expansion variable instead of land-use statistics because of the long-questioned accuracy of Chinese governmental land-use data from the 1990s (Seto & Kaufmann, 2003) and because MG has limited statistics on land use. The following major socioeconomic and biophysical variables, featuring the economy, social goods, and environment, were selected based on literature (Bai et al., 2014; Brülhart & Sbergami, 2009; Chen, John, Shao, et al., 2015; Dore & Nagpal, 2006; Endicott, 2012; Fan, 1999; Gauri, 2004; Knight & Song, 1999; Zhang et al., 2013) and the field study (Table 1). In particular, Gauri (2004) addressed the importance of social goods (including education and healthcare) in the context of developing countries.

We employed four different socioeconomic variables and two biophysical variables in our PLS-SEM. To understand the economic condition of the urban area, we utilized the employed population ratio at the end of the year in each city and the GDP per capita (i.e., the annual gross regional domestic product per capita; Yuan for IM and Tugrik for MG). These two indicators have been widely used to indicate the economic development level of a place (Brülhart & Sbergami, 2009; Henderson, 2002). We calculated GPD per capita using the local currency rather than converting it to USD due to the fluctuating exchange rate in the transitional period of MG. In addition, we applied a student-to-teacher ratio and a ratio of medical personnel to population to represent the condition of social goods (Dempsey, Bramley, Power, & Brown, 2011; Gauri, 2004) and to quantify its level for each city. These variables were mainly retrieved from the statistical yearbooks of Inner Mongolia (1990–2012), China Data Online (http://chinadataonline.org/) (2012–2015), and from the Mongolia National Statistical Bureau (http://www.1212.mn/en/) (1990–2015). We utilized the composites (June–August) of two-band enhanced vegetation index (EVI2) and the Self-calibrated Palmer Drought Severity Index (scPDSI) to quantify the environmental conditions as the potential drivers for urbanization. Because EVI2 has improved sensitivity and long-term consistency (Kim, Huete, Miura, & Jiang, 2010), we used this as a proxy variable to indicate the condition of the grassland during the growing season. The data was obtained from the Vegetation Index and Phenology (VIP) dataset, created by the NASA MEaSUREs (Making Earth System Data Records for Use in Research Environments) program (http://vip.arizona.edu/). Since scPDSI is more reliable in comparing different locations and times than PDSI (Wells, Goddard, & Hayes, 2004), we adopted this method to indicate environmental stressors in the study area. This data ranged from −10 (dry) to +10 (wet) and was retrieved from the database of the Climate and Global Dynamics Laboratory (CGD) at the National Center for Atmospheric Research (NCAR) (http://www.cgd.ucar.edu/cas/catalog/climind/pdsi.html). All remote sensing data extracted for the province of each city was standardized prior to model application.

3. Results

3.1. Urban expansion

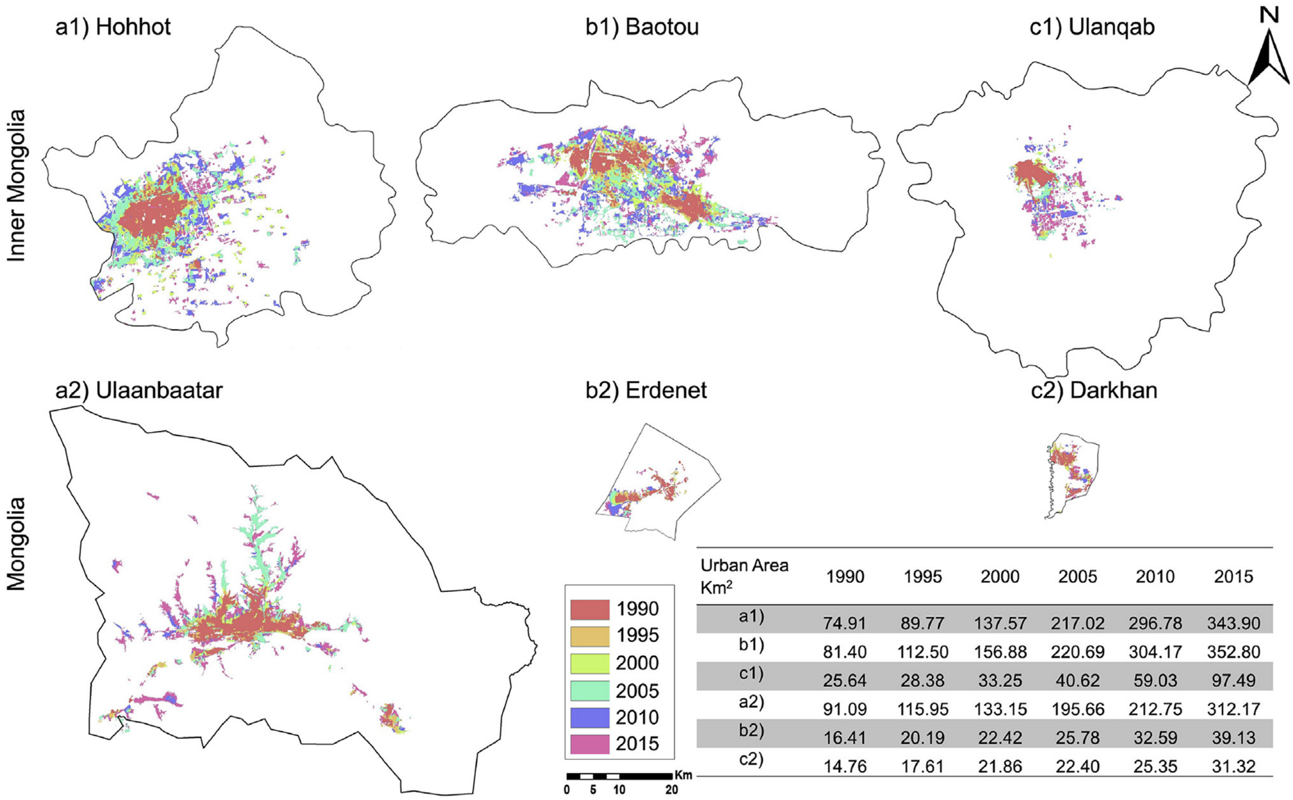
During the study period of 1990–2015, the total urban area for each of the six cities doubled in size. These cities not only expanded but also lowered in population density. In IM, the urbanized area grew by 359% in Hohhot (a1), 333% in Baotou (b1), and 280% in Ulanqab. In MG, the urbanized area grew by 243% in Ulaanbaatar (a2), 138% in Erdenet (b2), and 112% in Darkhan (c2) (Fig. 2). Interestingly, the urban population density in both IM and MG decreased from 1990 to 2015, with dramatic declines of 57%, 68%, and 55% in Hohhot, Baotou, and Ulanqab, respectively, and 34%, 34%, and 42% in Ulaanbaatar, Erdenet, and Darkhan, respectively. IM and MG also differed in discontiguity, with an average discontiguity increase of 193% in IM versus a decrease of 26% in MG.

Although the cities' growth rates varied in different time periods, they all showed positive growth rates in total built-up area for each five-year period (Fig. 3). In IM, Hohhot and Baotou exhibited similar trends (inverted-U curves) of urban growth over the study period, while Ulanqab showed a gradual increase in urban growth (Fig. 3a). In MG, urban growth rates fluctuated (Fig. 3b). While Ulaanbaatar showed a sharp increase in urban growth rates for 2000–2005 and 2010–2015, the other two cities in MG, Darkhan and Ulanqab, had relatively low growth rates.

The spatial patterns of urbanization in IM and MG also differed. The urbanization pattern in IM was more sprawled (low-density urban development and high discontiguity) than that of MG. Our correlation analysis verified that urban expansion and population

Table 1
Selected socioeconomic and biophysical variables used in PLS-SEM (Partial Least Squares Structural Equation Modeling).

Category	Variable	Definition
Urbanization	Built-up area	Total built-up area (km^2)
Economy	GDPpc	Annual gross regional domestic product per capita (Yuan, IM/Tugrik, MG)
	Employment	Employed population ratio at the end of year
Social goods	Education	Number of teachers per number of students
	Healthcare	Number of medical personnel per person
Environment	EVI2	The proxy of Leaf Area Index in the growing season (June, July, and August) of the province where cities are located
	scPDSI	Self-calibrated Palmer Drought Severity Index (scPDSI)



Urban Area Km²	1990	1995	2000	2005	2010	2015
a1)	74.91	89.77	137.57	217.02	296.78	343.90
b1)	81.40	112.50	156.88	220.69	304.17	352.80
c1)	25.64	28.38	33.25	40.62	59.03	97.49
a2)	91.09	115.95	133.15	195.66	212.75	312.17
b2)	16.41	20.19	22.42	25.78	32.59	39.13
c2)	14.76	17.61	21.86	22.40	25.35	31.32

Fig. 2. Urbanization in the six selected cities from 1990 through 2015. Using Geographic Object-Based Image Analysis (GEOBIA), we extracted the urban built-up (impervious) areas over the last three decades in the six cities. Different-colored shapes on the maps describe their diverse trend of urban extension and growths. The table also notes the different rates of urbanization.

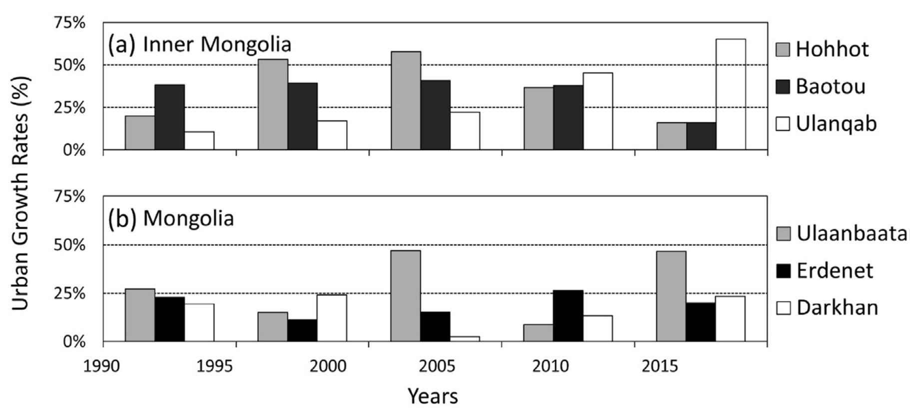


Fig. 3. The growth rates of total built-up areas measured every five years in the six cities from 1990 through 2015. In Inner Mongolia, Hohhot and Baotou had similar trends (inverted-U curve) in urban growth over the last two decades, while Ulanqab showed a gradually increasing urban growth trend. In Mongolia, growth rates vary on time periods and regions. For 2000–2005 and 2010–2015, Ulaanbaatar showed excessive growth rates, while Erdenet and Darkhan had relatively low growth rates.

density were negatively correlated for IM (Fig. 4a), but not for MG (Fig. 4b). This comparison indicates that the cities in IM tend to sprawl more than the cities in MG. Further analysis between discontiguity and urban expansion supported this finding. Urban expansion and discontiguity were positively correlated for cities in both IM (Fig. 4c) and MG (Fig. 4d). The correlation between urban expansion and discontiguity in IM was stronger than that of MG (Fig. 4c and d). Among the three cities in IM, Ulanqab showed a steeper trend for urban sprawl compared to Hohhot and Baotou (Fig. 4a and c).

3.2. *Driving forces of urbanization*

The PLS-SEM provided further empirical evidence on the importance of economic, social, and environmental factors on urban expansion in both IM and MG (Fig. 5). The collinearity statistics of the latent variables for both IM and MG models were high (variance inflation factor (VIF) > 0.2), with the latent variables of each at a high convergent validity (average variance extracted (AVE) > 0.5), suggesting that the results are statistically robust enough to explain the hypothesized causal connections. The four

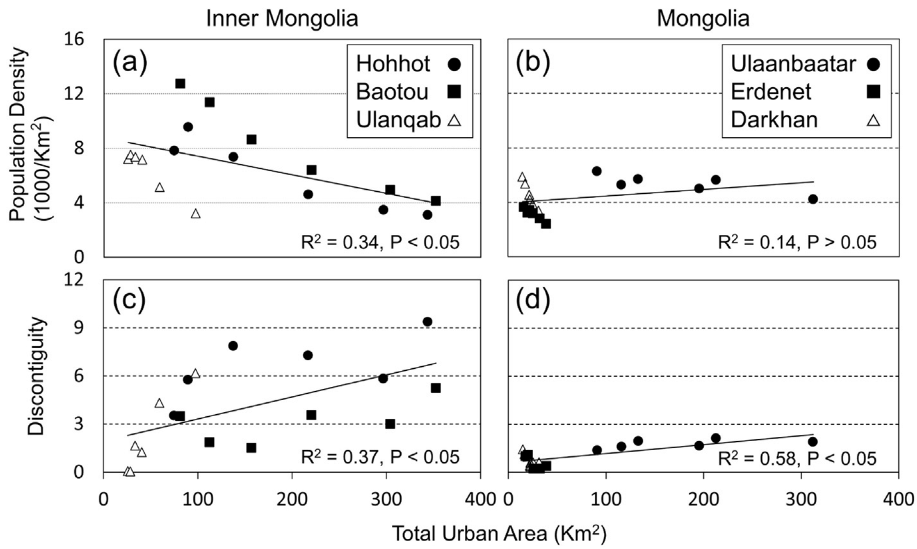


Fig. 4. The relationship between total urban built-up and population density in Inner Mongolia (IM) is negatively correlated, whereas the relationship in Mongolia (MG) is not statistically significant. The total urban built-up and discontiguity are positively correlated in both IM and MG, with the slope of IM higher than that of MG.

latent variables had a different relationship in IM and MG, and the models' explanations of urbanization also varied.

In the IM model, the combined factors of economy, environment, and social goods explained 42.2% of the variance in urbanization. The path coefficient between economy and urbanization was statistically significant, with economy having the strongest positive effect on urbanization (0.559). Two paths of the environment were statistically significant. The environment had a weak, negative effect on the economy (−0.209) and on urbanization (−0.212). However, the hypothesized path relationship between

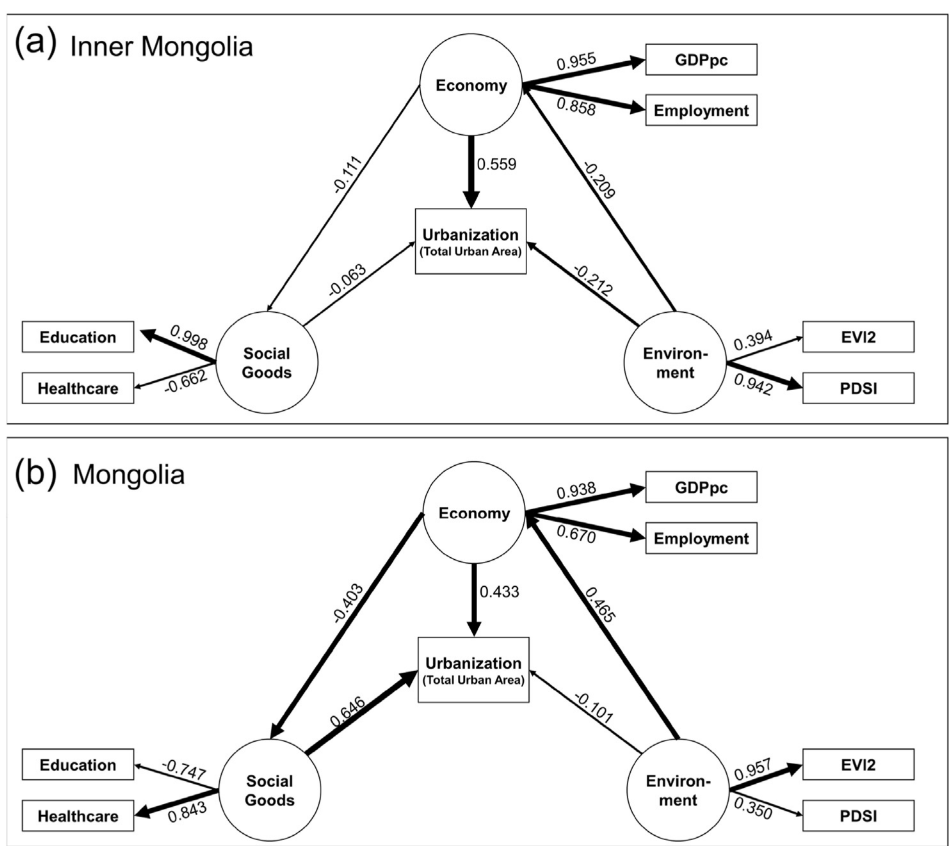


Fig. 5. Partial Least Squares Structural Equation Modeling (PLS-SEM) of socioeconomic and biophysical drivers on urbanization in both Inner Mongolia (IM) and Mongolia (MG). Latent variables are circular shapes, and measured variables are squares. The path coefficients describe the relationship between variables. The IM model illustrates that the economy is a major driver of urbanization ($R^2 = 0.422$) whereas the MG model demonstrates that both economy and social goods drive urbanization ($R^2 = 0.342$).

urbanization and social goods as well as economy and social goods were not statistically significant. Thus, we can conclude that economy is a strong predictor of urbanization, environment is a weak predictor, and that social goods do not predict urbanization directly in IM (Fig. 5a).

In the MG model, the combined factors of economy, environment, and social goods explained 34.2% of the variance in urbanization. Four paths were statistically significant in the model. Social goods had the strongest positive effect on urbanization (0.646), followed by the economy (0.433). In addition, the environment had the strongest positive effect on the economy (0.465), and the economy had the strongest negative effect on social goods (−0.403). Thus, we can conclude that social goods and the economy did not strongly predict the urbanization, and that the environment was not a direct predictor of the urbanization in MG (Fig. 5b).

Since we used five-year interval built-up area data from remote sensing analysis, the models have relatively small samples ($N = 36$, $n = 18$ for IM, and $n = 18$ for MG) compared to the standard sample size in CB-SEM. However, unlike CB-SEM, PLS-SEM does not require strict sample sizes (Chin, 2010; Fan, Chen, Shirkey, et al., 2016). To confirm the stability of estimated path coefficients, we proceeded with boot strapping analysis (i.e. 500 iterations). The bootstrapping in PLS-SEM generates sub-samples randomly drawn from the original data to test statistical significances of estimated path coefficients (Hair et al., 2013). The estimated path coefficients of Economy to Urbanization in IM, Economy to Urbanization, Social goods to Urbanization, Environment to Economy, and Economy to Social goods in MG were statistically significant (Table 2).

4. Discussion

4.1. The role of local government on urbanization

Differences in local governance systems (i.e., key measures of institution) led to distinct urbanization processes in IM and MG. The decentralization of administrative and economic power from central to local governments in IM brought divergent pathways of urbanization. Local governments have taken key roles in new urban development since the reform (Ma, 2002, 2005). Local governments converted the urban fringe from rural collectives into state-owned urban lands to establish economic development zones and build infrastructure (World Bank, 2014). Meanwhile, they sold land use rights for these converted areas as means of increasing revenue under the name of marketization, consequently stimulating new residential development on the periphery of the city (Wong & Zhao, 1999; Wu & Yeh, 1999; Liu et al., inpress). As a result, in the last three decades nearly 95% of urban growth in China occurred at its edges or in suburban areas, while only a small percentage occurred in the city center (World Bank, 2014). Our results also verified that IM is in line with the urban sprawl trend of China (Fig. 2a1, b1, & c1). This urban sprawl has been continuous since 2000, as the Central Committee of the Chinese Communist Party and the State Council have encouraged small towns to attract investments through which residents could acquire urban household status if the town offered stable jobs (Ma, 2002). Since the new development often resulted in higher tax rates from increased employment and productivity, local governments encouraged the growth of collectively and privately owned small enterprises (Wei, Li, & Wang, 2007). This, in turn, has brought about the emergence of small urban towns near the city. In addition, the growth of local governance also promoted the growth of road development in China (Li et al., 2015). Thus, the growth of governance and resulting high accessibility of road infrastructure may encourage urban sprawl in IM (Liu, He, Tan, Liu, & Yin, 2016; Su, Jiang, Zhang, & Zhang, 2011).

Contrary to local government in IM, MG's local government has a limited role in urban development. Local government in MG was not in charge of new development, and private sectors played a more important role (Diener & Hagen, 2013). Although the central government legislated the Medium-Term Development Strategy in 2003—a plan for encouraging regional development within select cities—detailed plans for providing adequate financial and infrastructure investment schemes for local governments were not established (Dore & Nagpal, 2006). In an effort by private developers, most urban developments occurred alongside existing infrastructure (Fig. 2a2, b2, & c2). The limited road infrastructure thusly resulted in a linear development pattern and restricted urban sprawl. The non-statistically significant relationship between urban growth and population also supported the argument that urban growth does not imply urban sprawl in MG (Fig. 4b). MG's land allocation laws further reinforced this urbanization pattern (Bauner & Richter, 2006). Under this law, married couples and households using the land for a residential purpose are free to gain land ownership. This encouraged incoming rural-to-urban immigrants to settle in the fringe areas, where they could ensure some accessibility to the downtown area within the otherwise limited road infrastructure (Tsutsumida, Saizen, Matsuoka, & Ishii, 2015). In summation, the limited roles of local government and insufficient infrastructures in MG resulted in a more densely populated urbanization compared to IM.

4.2. The role of economy on urbanization and the contrasting role of pastoral economy

Economic development is the major driver of urbanization for IM and MG (Fig. 5a and b). As Chen, John, Zhang, et al. (2015) and John et al. (2016) suggested, better-paying jobs and new job opportunities are critical to land-use change on the MGP. Increased GDP per capita and employment ratios explain the variance of urbanization in the model for IM (0.559) and MG (0.433) (Fig. 5a and b). After IM and MG were transformed into market-based

Table 2
Estimated model coefficients from PLS-SEM and bootstrapping results with sub-samples (i.e., 500 iterations).

Region	Path	Original sample estimate	Mean of resamples	Standard deviation	T-statistics
Inner Mongolia	Economy > Urbanization	0.559***	0.622	0.205	2.754
	Social goods > Urbanization	−0.063	−0.021	0.249	0.254
	Environment > Urbanization	−0.212	−0.137	0.328	0.679
	Environment > Economy	−0.209	−0.331	0.241	0.965
	Economy > Social goods	−0.111	−0.171	0.382	0.295
Mongolia	Economy > Urbanization	0.433*	0.390	0.245	1.767
	Social goods > Urbanization	0.646**	0.660	0.286	2.256
	Environment > Urbanization	−0.101	−0.212	0.170	0.553
	Environment > Economy	0.465***	0.522	0.147	3.165
	Economy > Social goods	−0.403**	−0.493	0.200	2.015

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

economies (Chen, John, Shao, et al., 2015; Dore & Nagpal, 2006), urban areas continued to strongly attract rural migrants.

IM and MG, however, have different relationships between economy and environment, which correspond well with the level of importance that the pastoral economy holds. While both IM and MG hold long-lasting pastoral lifestyle and livestock herding traditions, the importance of the pastoral economy in IM over the last three decades has substantially decreased in relation to the overall regional economy (Chen, John, Shao, et al., 2015; Wu et al., 2015). The links between environmental conditions (e.g., grassland cover) and the economy for IM was not statistically significant (Table 2), as the economic system in IM was dramatically restructured to favor the secondary and tertiary sectors during the study period (Chen, John, Zhang, et al., 2015; Chen, John, Shao, et al., 2015). The portion of the primary industry contributing to GDP gradually decreased over time in IM from 35.3% in 1990 to 9.2% in 2014. During the same time period, the proportion of the secondary industry increased from 32.3% to 51.3% (China Data Center, n.d.). This declining share of the primary industry in GDP attenuated the linkages between economy and environmental conditions (i.e., primary productivity in grassland and drought). On the contrary, MG exhibited a stronger relationship (0.465) between economy and environment than IM (Fig. 5b). Livestock grazing and herding remain the major economic activities in MG (Dore & Nagpal, 2006; Ulambayar, Fernández-Giménez, Baival, & Batjav, 2016). Approximately 25.2% of total MG households still practice livestock farming (National Statistical Office of Mongolia, 2015). Considering that the pastoral economy (i.e., livestock mortality and productivity) in MG is more sensitive to environmental variations due to the lack of infrastructure (i.e., animal shelters and hay storage), environmental conditions still play a major role in the economy of MG.

4.3. The role of social goods on urbanization

IM and MG have divergent connections between social goods and urbanization. While IM does not have statistically significant path coefficients (−0.063), MG has strong path coefficients (0.646). This indicates that social goods are strong drivers of urbanization in MG but not in IM (Fig. 5a and b).

In IM, strong governmental subsidies and support have lowered the importance of social goods as a driver of urbanization. Since the central government ubiquitously distributed social goods and offered social assistance programs to the region (Leung, 2003), the difference in social goods became small among all cities. The difference in urban and rural ratios for doctors to population in IM is relatively narrow compared to other parts of China (Bhalla & Luo, 2012). Promoted by the Western Development Project and the Compulsory Education Program, the central government supported IM by reallocating the education budget and by building schools in rural areas (Wang & Lewin, 2016). Following the guidelines of the central government, local governments also began evenly distributing social goods across the region (Duckett, 2013). For example, the current state policy “8337 Development Strategy” promotes development packages, including education and health facilities for suburban and rural areas, which improves the livelihood of the people. These facts imply that social goods are not the main stimulus for urban migration.

In contrast to IM, the MG government did not provide the same/similar level of social goods nation-wide, but instead concentrated social good provision in its capital and certain cities (Janzen, 2005), making social goods a strong stimuli for rural-urban and even urban-urban migration. Budget cuts to education in the early 1990s in MG serve as one example. The government has not been able to fully support educational systems since the beginning of the 1990s due to the loss of subsidies from the Soviet Union. The national educational expenditure dropped in 1992, matching only 56% of the level that was seen in 1990 (Hall & Thomas, 1999). The health care sectors also saw changes, with primary-level hospitals in rural areas insufficiently equipped with medical professionals or facilities (Spiegel et al., 2011). As individuals are ultimately responsible for their own education and healthcare, migration to cities has become a vital option to get necessary social services.

Many rural-to-urban migrants in the cities of MG were attracted by the relatively well-established availability of social goods. However, the cities soon experienced an excessive demand for these social goods. The path coefficient between the economy and social goods (−0.404) indicates that the growing economy has a negative relationship with the level of social goods, implying that the supply failed to meet the growing need for social goods. The current health care system situation in MG supports our view. Health care reform in the mid-1990s began to provide medical services in major city hospitals. Since 1990, the soum hospitals—mainly located in rural centers—declined in number as the gross number of medical doctors within cities increased. Nevertheless, the ratio of medical doctors to residents in the city has declined since 1990, owing in large part to the increasing populations and limited governmental investment and support that does not adequately accommodate them (UNFPA, 2012).

4.4. Implications for sustainable urban development

China ranks high in the avoidance of common urbanization issues, including urban poverty and unemployment, during the transitional period (World Bank, 2014). Our study verified that IM had a low level of disparity compared to MG in terms of social goods. Like other Chinese local governments, IM local governments played a critical role during the transition by triggering new urban development (Song & Zenou, 2012). Consequently, this new development offered employment opportunities and alleviated the severe disparity. However, growing concerns about the local governmental-led projects and efficiency have arisen due to the appearance of ghost towns and improvident urban development (Sorace & Hurst, 2015). While we do not equate dense urban development with efficiency, it is a necessary consideration in preventing more urban sprawl and more fragmented urbanization in IM. In this regard, it is important to focus on the balance of low and high-density urban development for urban sustainability in IM.

Although MG has a relatively low level of urban sprawl and a linear aggregation pattern of urbanization, which does not directly imply urban sustainability. As previously discussed, the supply of social goods and services are currently insufficient in selected cities of MG. These limited and unevenly distributed social goods led linearly aggregated urban form. Only 43.3% of households in Ulaanbaatar are fully equipped with basic utilities such as heating, electricity, and a fresh water/sewage system (The Asia Foundation, 2014). The remaining 56.7% of households suffer from a lack of these basic utilities. Therefore, as a fundamental first step toward urban sustainability, local and central governments would need to fulfill the basic needs of their citizens. In this regard, any future master plan based on substantive new development should incorporate the installation of basic infrastructure, access to social goods, and adequate public services for urban sustainability in MG.

5. Conclusions

The Mongolian Plateau, including IM and MG, provides an excellent example to study the processes and causes of urbanization in transitional countries where human and natural systems have experienced fundamental change. We found that IM and MG have similarities and differences in their urbanization processes.

Urban expansion occurred rapidly in both IM and MG, with the total built-up areas increasing by 4.36 times and 3.12 times than that of 1990 in the three cities of IM and MG, respectively. However, the cities of IM and MG exhibited different spatial characteristics. Cities in IM were characterized as less dense and more sprawled, while cities in MG showed linearly aggregated urban build-up. We also identified that economic development is a major driver for urbanization in IM, whereas social goods and economic development have both strongly influenced urbanization in MG. These differences may be due to the divergent roles of local government, the different economic structures, and the different governmental approaches for providing social goods in IM and MG. For urban sustainability in the Mongolian Plateau, special attention must be paid to the economy, environment, and social goods on the national, institutional, and environmental scale when developing future policies.

Acknowledgements

We would like to acknowledge the financial support from the National Science Foundation's Dynamics of Coupled Natural and Human Systems (CNH) Program (#1313761) and National Aeronautics and Space Administration (NASA)'s Land Cover and Land Use Program (NNX14AD85G and NNX15AD51G). We thank the Asian Foundation for a research fellowship, which supports field research in Mongolia. We thank Gabriela Shirkey and Connor Crank for editing the manuscript. Any opinions, findings, and conclusions described in this paper are those of the authors and do not reflect the views of the NSF, NASA, or the Asian Foundation.

References

Alberti, M., Asbjornsen, H., Baker, L. A., Brozovic, N., Drinkwater, L. E., Drzyzga, S. A., et al. (2011). Research on coupled human and natural systems (CHANS): Approach, challenges, and strategies. *The Bulletin of the Ecological Society of America, 92*, 218–228.

Antrop, M. (2004). Landscape change and the urbanization process in Europe. *Landscape and Urban Planning, 67*(1–4), 9–26.

Bai, X., Shi, P., & Liu, Y. (2014). Realizing China's urban dream. *Nature, 509*(7499), 158–160.

Bauner, S., & Richter, B. (2006). *Real estate market, mortgage market and cadastre in Ulaanbaatar and Darkhan-city, Mongolia*. Gebhard, Heusenstamm: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

Bhalla, A. S., & Luo, D. (2012). *Poverty and exclusion of minorities in China and India*. Basingstoke: Palgrave Macmillan.

Brown, D. G., Agrawal, A., Sass, D. A., Wang, J., Hua, J., & Xie, Y. (2013). Responses to climate and economic risks and opportunities across national and ecological boundaries: Changing household strategies on the Mongolian plateau. *Environmental Research Letters, 8*(4), 045011.

Brülhart, M., & Sbergami, F. (2009). Agglomeration and growth: Cross-country evidence. *Journal of Urban Economics, 65*(1), 48–63.

Chan, K. W., & Zhang, L. (1999). The hukou system and rural-urban migration in China: Processes and changes. *The China Quarterly, 160*, 818–855.

Chen, J., John, R., Zhang, Y., Shao, C., Brown, D. G., Batkhishig, O., et al. (2015). Divergences of two coupled human and natural systems on the Mongolian Plateau. *BioScience, 65*(6), 559–570.

Chen, J., John, R., Shao, C., Fan, Y., Zhang, Y., Amarjargal, A., et al. (2015). Policy shifts influence the functional changes of the CNH systems on the Mongolian plateau. *Environmental Research Letters, 10*(8), 085003.

Chen, J., & Liu, Y. (2014). Coupled natural and human systems: A landscape ecology perspective. *Landscape Ecology, 29*(10), 1641.

Chin, W. W. (2010). How to write up and report PLS analyses. In V. Esposito, W. W. Chin, J. Henseler, & H. Wang (Eds.), *Handbook of partial least squares: Concepts, methods and applications* (pp. 655–690). Berlin, Heidelberg: Springer.

China Data Center. (n.d.). China Data Online. Retrieved from: http://chinadataonline.org.

Davis, D. (2000). *The consumer revolution in urban China*. Berkeley: University of California Press.

Dempsey, N., Bramley, G., Power, S., & Brown, C. (2011). The social dimension of sustainable development: Defining urban social sustainability. *Sustainable Development, 19*(5), 289–300.

Diener, A. C., & Hagen, J. (2013). City of felt and concrete: Negotiating cultural hybridity in Mongolia's capital of Ulaanbaatar. *Nationalities Papers, 41*(4), 622–650.

Dore, G., & Nagpal, T. (2006). Urban transition in Mongolia: Pursuing sustainability in a unique environment. *Environment: Science and Policy for Sustainable Development, 48*(6), 10–24.

Duckett, J. (2013). Health and social policy. In C. Ogden (Ed.), *Handbook of China's governance and domestic politics* (pp. 67–77). New York: Routledge.

Endicott, E. (2012). *A history of land use in Mongolia: The thirteenth century to the present*. New York: Palgrave Macmillan.

Fan, C. C. (1999). Migration in a socialist transitional economy: Heterogeneity, socioeconomic and spatial characteristics of migrants in China and Guangdong province. *International Migration Review, 33*(4), 493–515.

Fan, P., Chen, J., & John, R. (2016). Urbanization and environmental change during the economic transition on the Mongolian plateau: Hohhot and Ulaanbaatar. *Environmental Research, 144*(B), 96–112.

Fan, Y., Chen, J., Shirkey, G., John, R., Wu, S. R., Park, H., et al. (2016). Applications of structural equation modeling (SEM) in ecological studies: An updated review. *Ecological Processes, 5*, 19.

Fan, P., Xie, Y., Qi, J., Chen, J., & Huang, H. (2014). Vulnerability of a coupled natural and human system in a changing environment: Dynamics of Lanzhou's urban landscape. *Landscape Ecology, 29*(10), 1709–1723.

Fernandez-Gimenez, M. E., & Batbuyan, B. (2004). Law and disorder: Local implementation of Mongolia's land law. *Development and Change, 35*(1), 141–166.

Fernandez-Gimenez, M. E., Batjav, B., & Baival, B. (2012). *Lessons from the dzud: Adaptation and resilience in Mongolian pastoral socio-ecological systems*. Washington DC: World Bank.

Gauri, V. (2004). Social rights and economics: Claims to health care and education in developing countries. *World Development, 32*(3), 465–477.

Gilbert, A., & Gugler, J. (1992). *Cities, poverty and development: Urbanization in the third world*. Oxford: Oxford University Press.

Hair, J. F., Hult, G. T. M., Ringle, C., & Sarstedt, M. (2013). *A primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. London: Sage Publications.

Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. *Journal of Marketing Theory and Practice, 19*(2), 139–152.

Hall, D., & Thomas, H. (1999). Higher education reform in a transitional economy: A case study from the school of economic studies in Mongolia. *Higher Education, 38*(4), 441–460.

Hay, G. J., & Blaschke, T. (2010). Special issue: Geographic object-based image analysis (GEOBIA). *Photogrammetric Engineering and Remote Sensing, 76*(2), 121–122.

He, C., Huang, Z., & Wang, R. (2014). Land use change and economic growth in urban China: A structural equation analysis. *Urban Studies, 51*(13), 2880–2898.

Henderson, V. (2002). Urbanization in developing countries. *The World Bank Research Observer, 17*(1), 89–112.

ITT. (2009). *Atmospheric correction module: QUAC and FLAASH user's guide* (Vol. 4). ITT Visual Information Solutions Inc.

Janzen, J. (2005). Changing political regime and mobile livestock keeping in Mongolia. *Geography Research Forum, 25*, 62–82.

Jiang, F., Liu, S., Yuan, H., & Zhang, Q. (2007). Measuring urban sprawl in Beijing with geo-spatial indices. *Journal of Geographical Sciences, 17*(4), 469–478.

John, R., Chen, J., Kim, Y., Ou-yang, Z., Xiao, J., Park, H., et al. (2016). Differentiating anthropogenic modification and precipitation-driven change on vegetation productivity on the Mongolian Plateau. *Landscape Ecology, 31*(3), 547–566.

John, R., Chen, J., Lu, N., & Wilske, B. (2009). Land cover/land use change in semi-arid inner Mongolia: 1992–2004. *Environmental Research Letters, 4*(4), 045010.

Kamata, T., Reichert, J., Tsevegmid, T., Kim, Y., & Sedgewick, B. (2010). *Mongolia: Enhancing policies and practices for Ger area development in Ulaanbaatar*. Washington, DC, USA: World Bank.

Kim, Y., Huete, A. R., Miura, T., & Jiang, Z. (2010). Spectral compatibility of vegetation indices across sensors: Band decomposition analysis with Hyperion data. *Journal of Applied Remote Sensing, 4*(1), 043520.

Knight, J., & Song, L. (1999). *The rural-urban divide: Economic disparities and interactions in China*. Oxford: Oxford University Press.

Kunzmann, K. R., & Wegener, M. (1991). The pattern of urbanization in Western Europe. *Ekistics, 58*(350/351), 282–291.

Lambin, E. F., & Meyfroidt, P. (2010). Land use transitions: Socio-ecological feedback versus socio-economic change. *Land Use Policy, 27*(2), 108–118.

Leung, J. C. B. (2003). Social security reforms in China: Issues and prospects. *International Journal of Social Welfare, 12*(2), 73–85.

Liu, J., Dietz, T., Carpenter, S. R., Folke, C., Alberti, M., Redman, C. L., et al. (2007). Coupled human and natural systems. *AMBIO: A Journal of the Human Environment, 36*(8), 639–649.

Liu, Y., He, Q., Tan, R., Liu, Y., & Yin, C. (2016). Modeling different urban growth patterns based on the evolution of urban form: A case study from Huangpi, Central China. *Applied Geography, 66*, 109–118.

Liu, Y., Rao, K., Evans, T., Chen, Y., & Hsiao, W. C. (2001). China: Increasing health gaps in a transitional economy. In T. Evans (Ed.), *Challenging inequities in health: From ethics to action* (pp. 76–89). New York: Oxford University Press.

Liu, Y., Yue, W., Fan, P., Peng, Y., & Zhang, Z. (2016). Financing China's suburbanization: capital accumulation through suburban land development in Hangzhou. *International Journal of Urban and Regional Research, 40*(6), 1112–1133.

Liu, J., Zhan, J., & Deng, X. (2005). Spatio-temporal patterns and driving forces of urban land expansion in China during the economic reform era. *AMBIO: A Journal of the Human Environment, 34*(6), 450–455.

Liu, Y., Zhuang, Q., Chen, M., Pan, Z., Tchebakova, N., Sokolov, A., et al. (2013). Response of evapotranspiration and water availability to changing climate and land cover on the Mongolian Plateau during the 21st century. *Global and Planetary Change, 108*, 85–99.

Li, H., Wei, Y. D., Liao, F. H., & Huang, Z. (2015). Administrative hierarchy and urban land expansion in transitional China. *Applied Geography, 56*, 177–186.
Ma, L. J. C. (2002). Urban transformation in China, 1949–2000: A review and research agenda. *Environment and Planning A, 34*(9), 1545–1569.
Ma, L. J. C. (2005). Urban administrative restructuring, changing scale relations and local economic development in China. *Political Geography, 24*(4), 477–497.
McMillan, J., & Naughton, B. (1992). How to reform a planned economy: Lessons from China. *Oxford Review of Economic Policy, 8*(1), 130–143.
Molodikova, I., & Makhrova, A. (2007). Urbanization patterns in Russia in the post-Soviet era. In K. Stanilov (Ed.), *The post-socialist city: Urban form and Space transformations in central and Eastern Europe after socialism* (pp. 53–70). Dordrecht: Springer Netherlands.
National Statistical Office of Mongolia. (2015). *Mongolian statistical yearbook 2015*. Ulaanbaatar, Mongolia: National Statistical Office of Mongolia.
Ojima, D., & Chuluun, T. (2008). Policy changes in Mongolia: Implications for land use and landscapes. In K. A. Galvin, R. S. Reid, R. H. B. Behnker, Jr., & N. T. Hobbs (Eds.), *Fragmentation in semi-arid and arid landscapes: Consequences for human and natural systems* (pp. 179–193). Dordrecht: Springer Netherlands.
Qian, T., Bagan, H., Kinoshita, T., & Yamagata, Y. (2014). Spatial–temporal analyses of surface coal mining dominated land degradation in Holingol, Inner Mongolia. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 7*(5), 1675–1687.
Roose, A., Kull, A., Gauk, M., & Tali, T. (2013). Land use policy shocks in the post-communist urban fringe: A case study of Estonia. *Land Use Policy, 30*(1), 76–83.
Rudolph, R., & Brade, I. (2005). Moscow: Processes of restructuring in the post-Soviet metropolitan periphery. *Cities, 22*(2), 135–150.
Saksena, S., Fox, J., Spencer, J., Castrence, M., DiGregorio, M., Epprecht, M., et al. (2014). Classifying and mapping the urban transition in Vietnam. *Applied Geography, 50*, 80–89.
Schneider, A., & Woodcock, C. E. (2008). Compact, dispersed, fragmented, extensive? A comparison of urban growth in twenty-five global cities using remotely sensed data, pattern metrics and census information. *Urban Studies, 45*(3), 659–692.
Seto, K. C., & Kaufmann, R. K. (2003). Modeling the drivers of urban land use change in the Pearl River Delta, China: Integrating remote sensing with socioeconomic data. *Land Economics, 79*(1), 106–121.
Seto, K. C., Sanchez-Rodriguez, R., & Fragkias, M. (2010). The new geography of contemporary urbanization and the environment. *Annual Review of Environment and Resources, 35*, 167–194.
Sevtsuk, A., & Amindarbari, R. (2012). *Measuring growth and change in metropolitan form: Progress report on urban form and land use measures*. City Form Lab. Retrieved from: http://web.mit.edu/11.521/papers/sevtsuk_measuring_growth_and_change_in_metropolitan_form.pdf.
Shao, C., Li, L., Dong, G., & Chen, J. (2014). Spatial variation of net radiation and its contribution to energy balance closure in grassland ecosystems. *Ecological Processes, 3*(1), 7.
Song, Y., & Zenou, Y. (2012). Urban villages and housing values in China. *Regional Science and Urban Economics, 42*(3), 495–505.
Sorace, C., & Hurst, W. (2015). China's phantom urbanisation and the pathology of ghost cities. *Journal of Contemporary Asia, 46*(2), 304–322.
Spiegel, D. A., Choo, S., Cherian, M., Orgoi, S., Kehrer, B., Price, R. R., et al. (2011). Quantifying surgical and anesthetic availability at primary health facilities in Mongolia. *World Journal of Surgery, 35*(2), 272–279.
Stubblefield, A., Chandra, S., Eagan, S., Tuvshinjargal, D., Davaadorzh, G., Gilroy, D., et al. (2005). Impacts of gold mining and land use alterations on the water quality of central Mongolian rivers. *Integrated Environmental Assessment and Management, 1*(4), 365–373.
Su, S., Jiang, Z., Zhang, Q., & Zhang, Y. (2011). Transformation of agricultural landscapes under rapid urbanization: A threat to sustainability in Hang-Jia-Hu region, China. *Applied Geography, 31*(2), 439–449.
Tammaru, T., Kulu, H., & Kask, I. (2004). Urbanization, suburbanization, and counterurbanization in Estonia. *Eurasian Geography and Economics, 45*(3), 212–229.
The Asia Foundation. (2014). *Ulaanbaatar 2020 master plan and development approaches for 2030*. Ulaanbaatar, Mongolia: The Asia Foundation.
Tian, L., Chen, J., & Yu, S. X. (2014). Coupled dynamics of urban landscape pattern and socioeconomic drivers in Shenzhen, China. *Landscape Ecology, 29*(4), 715–727.
Tsutsumida, N., Saizen, I., Matsuoka, M., & Ishii, R. (2015). Addressing urban expansion using feature-oriented spatial data in a peripheral area of Ulaanbaatar, Mongolia. *Habitat International, 47*, 196–204.
Ulambayar, T., Fernández-Giménez, M. E., Baival, B., & Batjav, B. (2016). Social outcomes of community-based rangeland management in Mongolian steppe ecosystems. *Conservation Letters.*. http://dx.doi.org/10.1111/conl.12267.
UN-Habitat. (2003). *The challenge of slums: Global report on human settlements 2003*. London: Earthscan.
UNFPA. (2012). *Implication of demographic trends for socio-economic development and public policy in Mongolia*. Ulaanbaatar, Mongolia: UNFPA.
Wang, L., & Lewin, K. (2016). *Two decades of basic education in rural China: Transitions and challenges for development*. Singapore: Springer Singapore.
Wei, Y. D., Li, W., & Wang, C. (2007). Restructuring industrial districts, scaling up regional development: A study of the Wenzhou model, China. *Economic Geography, 83*(4), 421–444.
Wells, N., Goddard, S., & Hayes, M. J. (2004). A self-calibrating palmer drought severity index. *Journal of Climate, 17*(12), 2335–2351.
Wong, K. K., & Zhao, X. B. (1999). The influence of bureaucratic behavior on land apportionment in China: The informal process. *Environment and Planning C: Government and Policy, 17*(1), 113–125.
World Bank. (2014). *Urban China: Toward efficient, inclusive, and sustainable urbanization*. Washington DC: World Bank.
Wu, F. (2003). Transitional cities. *Environment and Planning A, 35*(8), 1331–1338.
Wu, F., & Yeh, A. G.-O. (1999). Urban spatial structure in a transitional economy. *Journal of the American Planning Association, 65*(4), 377–394.
Wu, J., Zhang, Q., Li, A., & Liang, C. (2015). Historical landscape dynamics of inner Mongolia: Patterns, drivers, and impacts. *Landscape Ecology, 30*(9), 1579–1598.
Xu, G., & Wu, J. (2016). Social-ecological transformations of inner Mongolia: A sustainability perspective. *Ecological Processes, 5*(1), 23.
Zhang, Z., Su, S., Xiao, R., Jiang, D., & Wu, J. (2013). Identifying determinants of urban growth from a multi-scale perspective: A case study of the urban agglomeration around Hangzhou Bay, China. *Applied Geography, 45*, 193–202.
Zhao, Y. (1999). Leaving the countryside: Rural-to-urban migration decisions in China. *The American Economic Review, 89*(2), 281–286.