URBAN TRANSFORMATION IN TRANSITIONAL ECONOMIES: LESSONS FROM THE MONGOLIAN PLATEAU

By

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ABSTRACT

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Over the past three decades, transitional economies have experienced dramatic urbanization in response to changes in the human and natural environments, resulting from economic transitions, industrial restructures, institutional reforms, and climate variability. However, our knowledge of the causes and processes of urbanization in transitional economies remains limited. Here, I used the Mongolian Plateau (MGP), including Inner Mongolia in China (IM) and Mongolia (MG), as a testbed for studying the processes and causes of urbanization. I also investigated urban challenges and the policy implications of those issues. The dissertation is set to three research objectives: (1) understanding the processes of urbanization in the MGP, (2) analyzing the driving forces of rural-to-urban migration, and (3) identifying urban challenges and proposing policy solutions.

For the first objective, I analyzed the spatial characteristics of urbanization in six cities (Hohhot, Baotou, and Ulanqab in IM, and Ulaanbaatar, Erdenet, and Darkhan in MG) using remote sensing analyses, computed the urban growth rates, population density, and discontiguity (i.e., leap-frogging index) of each city from 1990 through 2015, and applied structural equation models. I found divergent spatial patterns of urbanization in IM and MG and the differential institutional supports and industrial structures contributing to these disparities.

For the second objective, I used household surveys to analyze the forces driving rural-to-urban migration, complemented with remote sensing tools to estimate the actual environmental conditions of respondents' former residences. I found that social and economic factors were the

most significant motivators of migration. The statistical models demonstrated that the importance of environmental factors as mediators of economic factors and highlighted remaining gaps between scientific research and policy implementation.

For the third objective, I analyze developmental processes and spatial patterns of the informal settlements, Ger districts, through remote sensing analysis and semi-structured interviews with residents. I identified three different stages of Ger districts' growth: infancy, consolidation, and maturity and Ger districts experienced dramatic growth (588%) and evolution from infancy into consolidation or maturity between 1990 and 2013. These results indicate that to successfully develop future policies, Ger districts must be viewed as heterogeneous and evolving assemblages.

The key contributions of my dissertation are: (1) designing multi-scale and multi-dimensional analyses to understand complex mechanisms of urbanization; (2) identifying unique patterns and drivers of urbanization in transitional economies, with particular consideration of socioeconomic and biophysical changes; (3) adopting interdisciplinary approaches, e.g., qualitative interviews, geospatial analyses, and statistical modeling, to address complex research questions; and (4) providing evidence-based policy suggestions.

Keywords: transitional economy; urbanization; migration; Mongolian plateau; informal settlements; urban sustainability

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KEY TO ABBREVIATIONS

CNH: Coupled Natural and Human system

CB-SEM: Covariance-Based Structural Equation Modeling

EVI2: two-band Enhanced Vegetation Index

GDP: Gross Domestic Product

GEOBIA: Geographic Object-Based Image Analysis

IM: Inner Mongolia in People's Republic of China

MGP: Mongolian Plateau

MG: Mongolia

NDVI: Normalized Vegetation Index

NIR: Near Infrared

OBIA: Object-Based Image Analysis

PLS-SEM: Partial Least Squares Structural Equation Modeling

RS: Remote Sensing

scPDSI: Self-calibrated Palmer Drought Severity Index

SEM: Structural Equation Modeling

SVM: Support Vector Machine

TAF: The Asia Foundation

UNFPA: United Nations Population Fund

UN-HABITAT: United Nations Human Settlements Programme

VHR: Very High Resolution

WB: World Bank

Chapter 1
Introduction

1.1. Introduction

Over the last several decades, urban population has dramatically increased, and more than 60 percent of the global population is expected to live in the urban areas by 2030 (United Nations, 2005). Despite the small physical footprint of urbanized areas, a highly concentrated population with mass consumption has critically influenced both human and natural systems (Jin, Dickinson, & Zhang, 2005), and has significantly transformed the relationships of those systems (Seto, Sanchez-Rodriguez, & Fragkias, 2010). This unprecedented change carried the emerging issues of urban sustainability into focus, e.g., economic disparity, environmental degradation, and poverty; however, our knowledge of causes and processes of urbanization still remains limited.

Particularly in transitional economies, urban growth has accelerated dramatically which has produced significant impacts on both human and natural systems. Since transitional economies are not equipped with the due procedure and policy for regulating and managing urban development during the transitional period, cities in such economies cannot afford the population growth (Kamata et al., 2010; Uddin et al., 2014; UN-Habitat, 2003). The concentrated population fostered environmental burdens such as air pollution and overconsumption of natural resources (Foley et al., 2005). Furthermore, this rapid urban growth has accelerated the distribution of poverty (Hirt, 2013). The cities have transformed spatially segregated areas with a plethora of informal settlement owing to uneven forms of capitalistic urbanization, which primarily built commercial buildings to benefit the elite while basic infrastructures for the majority of non-elites and migrants, were left behind (Goldman, 2014; Hirt, 2013).

Despite these challenges, cities in transitional economies have experienced a continuous urban expansion. Unlike cities under a socialist regime that have suppressed migration by regulating movements through residential policy, cities in transitional economies have become highly accessible without restrictions. This freedom of movement also intensified market mechanism of the cities (Davis, 2000). The restructured industry in transitional economies, growing tertiary industry and increased non-agricultural activities, serve an engine to promote dramatic growth of urbanization (Bai, Shi, & Liu, 2014; Fan et al., 2014; He, Huang, & Wang, 2014; Li et al., 2015). The employment needs in the city center also stimulated rural-to-urban migrations (Molodikova & Makhrova, 2007; Rudolph & Brade, 2005; Tammaru, Kulu, & Kask, 2004).

While many previous studies have empirically explored the current status of cities and its processes in the Global South, the urbanization in transitional economies need more attention owing to its unique characteristics. Since transitional economies have undergone a set of structural transformations including economic liberalization, privatization, and institutional reforms (IMF, 2000), multiple factors were interconnected to influence the human and natural system. Furthermore, urbanization is not a simple aggregation of the population; instead, it is based on the multiple underlying subsystems. That is, the processes of urbanization is based on the diverse stakeholders' aggregated behaviors and provisions corresponding to multiple changes and events (Mbembé, 2004). Therefore, urbanization cannot be solely defined by the impact of single event and policy (i.e., extreme climate events, development projects, land use policies, and industrial transformations). Further insights can be gained through considering the multiple spatiotemporal scales of analysis. This central concept of analyzing the urbanization process with considering multiple scales and presence of diverse stakeholders would provide a better understanding of the complex causes and mechanisms of urbanization in transitional economies.

I propose the Mongolian Plateau (MGP) as a test bed to comprehend the underlying mechanisms for urbanization in transitional economies. MGP has experienced dramatic urbanization corresponding to the change in both socioeconomic and biophysical changes within the relatively short period (Chen et al., 2015a; Fan, Chen, & John, 2016). MGP would be an ideal case to understand the complex mechanism of urbanization (Figure 1.1). In this region, both Inner Mongolia (IM) and Mongolia (MG) have experienced economic reform and democratic liberalization in the last three decades. Since the MGP consisted of two distinct government with the similar ecological setting, this study possibly would compare distinct impacts of governmental policies on urbanization and its process with statistically controlling the environmental impacts.

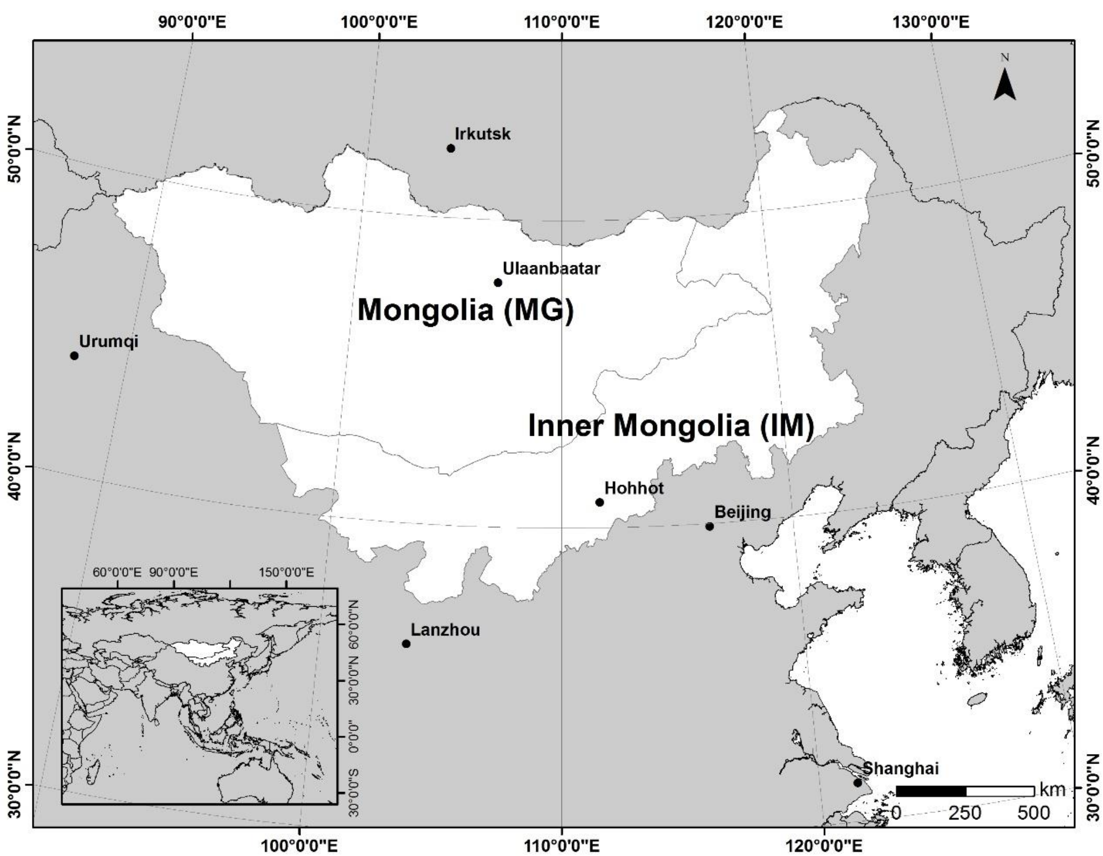

Figure 1.1. The Mongolian Plateau including Inner Mongolia (IM) and Mongolia (MG)

1.2. Background and Framework

1.2.1. Urbanization in transitional economies

People have always moved places in search for better-sustaining their livelihoods. These movements are voluntary and forced upon due to social, economic, political or environmental changes (Miraftab & Kudva, 2014). Many socioeconomic changes, biophysical variabilities, and political events have led to large-scale relocation and displacement (Boyle, Halfacree, & Robinson, 1998; Castles & Miller, 1998). As a response to challenging circumstances, rural-to-urban and smaller urban-to-larger urban center migrations have continued in transitional economies. Most cities in transitional economies have faced abrupt transformations in their economic and demographic structures over a relatively short period compared to cities in the global north (Kamata et al., 2010; UN-Habitat, 2003).

Population flows are highly context-specific and vary with socioeconomic and political environments. Over the last three decades, the population movements in transitional economies could be represented as advocating marketization and globalization (Miraftab & Kudva, 2014). Since the agrarian structure no longer provides sufficient income for rural households, cities became destinations for rural residents (Roberts, 1989). These economic incentives might intensify the trend of rural-to-urban migrations in transitional economies. Furthermore, law and institutional reforms have altered people's responsibility for their livelihoods and perceptions of the public service (Ma, 2002; Zhao, 1999). In particular, the market economy transferred the responsibilities of income, education, and health services, from the government to individual households. After the loss of subsidies from central government, individuals supported themselves by their economic gains (Liu et al., 2001). Economic conditions and associated hardships are widely known as a major push factor of rural-to-urban migration. Employment opportunities in the city became a pull factor in the same context (Fan, 1999; Knight & Song, 1999). Moreover, the positive feedback system of education and employment simultaneously promotes rural-to-urban migration in accordance with industrial restructuring from agriculture-based society to non-agriculture-based one (Seto, 2011).

Transitional economies are relatively more vulnerable to climate variabilities and extreme climatic events than developed countries due to their low adaptive capacity (Mirza 2003, Neil Adger 1999). This low adaptive capacity is drawn from less governmental and institutional supports to prepare extreme climatic events and variability (Adger et al., 2002). Therefore, the increases in frequency of extreme climate events intensified rural-to-urban migration as a coping mechanism (Black et al., 2013a).

1.2.2. Transformation of human system in the Mongolian plateau

Historically, the Mongolia Plateau (MGP) has been a place for practicing nomadic lifestyle due to its unique characteristics (i.e., limited natural resources, low precipitation, and wide-ranging temperatures) (Fernandez-Gimenez, Batjav, & Baival, 2012; Chen et al. 2015). This pastoral nomadic lifestyle has been maintained over several centuries. However, after the collapse of the Soviet Union and the economic liberalization of China. MGP have faced dramatic changes in terms of diversified income sources, emerging needs of public services, intensified climatic events, and divergent institutional supports (Fan, Chen, & John, 2016; John, Chen, Lu, & Wilske, 2009).

During the transitional period, the collective farms and shareholding companies in rural areas lost their competitiveness after losing state subsidy and incentives (Endicott, 2012). As a consequence, jobs were diversified into many different sectors, and the states transferred the responsibilities of employment, education, and health to individuals. While both Inner Mongolia, China (IM) and Mongolia (MG) experienced the rapid economic growth during this period, the accumulation of wealth concentrated in cities and enlarged economic disparity between urban and rural areas (Liu et al., 2001). Rural-to-urban migration, thus, is considered a response to relative deprivation of income and public services (Gilbert & Gugler, 1992). Several studies empirically emphasized on the importance of job and education in the internal migration of transitional economies (Chan & Zhang, 1999; Fan, 1999; Knight & Song, 1999; Zhao, 1999).

1.2.3. Transformation of natural system in the Mongolian plateau

While the Mongolian plateau has faced abrupt changes during the socioeconomic transition, the environment has confronted massive changes as well. The annual average temperature of MGP has been increased 2 degrees Celsius, 7% reduction in annual precipitation during the last seven decades (Liu et al., 2013), and frequency of extreme climatic events (e.g., drought and snowfall) have increased (Fernandez-Gimenez, Batjav, & Baival, 2012; John et al., 2016).

Newly implemented land use policy and management strategies led accelerated urbanization during the transitional period and degraded grassland (John et al., 2016; Ojima & Chuluun, 2008). The Grassland Law in 1985 and Household Contract Responsibility Systems (HCRS) in IM, and the 1994 Law on Land in MG transferred responsibility of grassland management from community to individual households which led overgrazed grassland and environmental degradation (Endicott, 2012; Maria E. Fernandez-Gimenez & Batbuyan, 2004; Wu, Zhang, Li, & Liang, 2015). Moreover, the growing mining industries in MGP negatively influenced on the ecological condition of grassland (Qian et al., 2014; Stubblefield et al., 2005).

Though many studies have been conducted on climate change and its impact on the grasslands because of the unique ecosystem of MGP as a landlocked dryland. However, limited studies have linked this analysis to human system in a broader perspective (Ginger et al., 2017).

While the current studies provided the changes in land cover and land-use (Amarsaikhan et al., 2009; Ji et al., 2001; John et al., 2009), explored the grassland degradation and productivity (Brown et al., 2013; Liu et al., 2013; Wang, Brown, & Bai, 2014; Wang, Brown, & Chen, 2013), and revealed the relationship between the pastoral communities and grassland based on the changes in land laws and governmental policies (Neupert, 1999; Ojima & Chuluun, 2008; Sneath, 2003; Thwaites et al., 1998), the mechanism of urbanization in response to changed natural and human system is yet to be carefully studied.

1.3 Conceptual Framework and Research Objectives

Deriving from the theories and contexts of the MGP discussed above, a conceptual framework has been developed to guide the research design and objectives (Figure 1.2.). During last three decades, both IM and MG have changed from agrarian/centrally-planned societies to industrial/independent ones. Urbanization on the MGP has intensified due to a combination of socioeconomic changes, environmental variabilities, and institutional transformations. Since the population displacements and subsequent urbanization are the results of multi-causal relationships (Montgomery, 2008; Piguet, 2010), this dissertation focused on developing a greater understanding of the mechanisms of urbanization by investigating multiple dimensions.

For this research, I developed a two-level approach to understanding urbanization. At the regional level, I analyzed the divergent patterns and drivers of urbanization in IM and MG. And at the household level, I examined the exogenous and endogenous forces of rural-to-urban migration, referred to as push and pull factors, including socioeconomic, institutional and biophysical factors. I also investigated emerging urban challenges and the growth of informal settlements in the context of drastic urbanization in transitional economies.

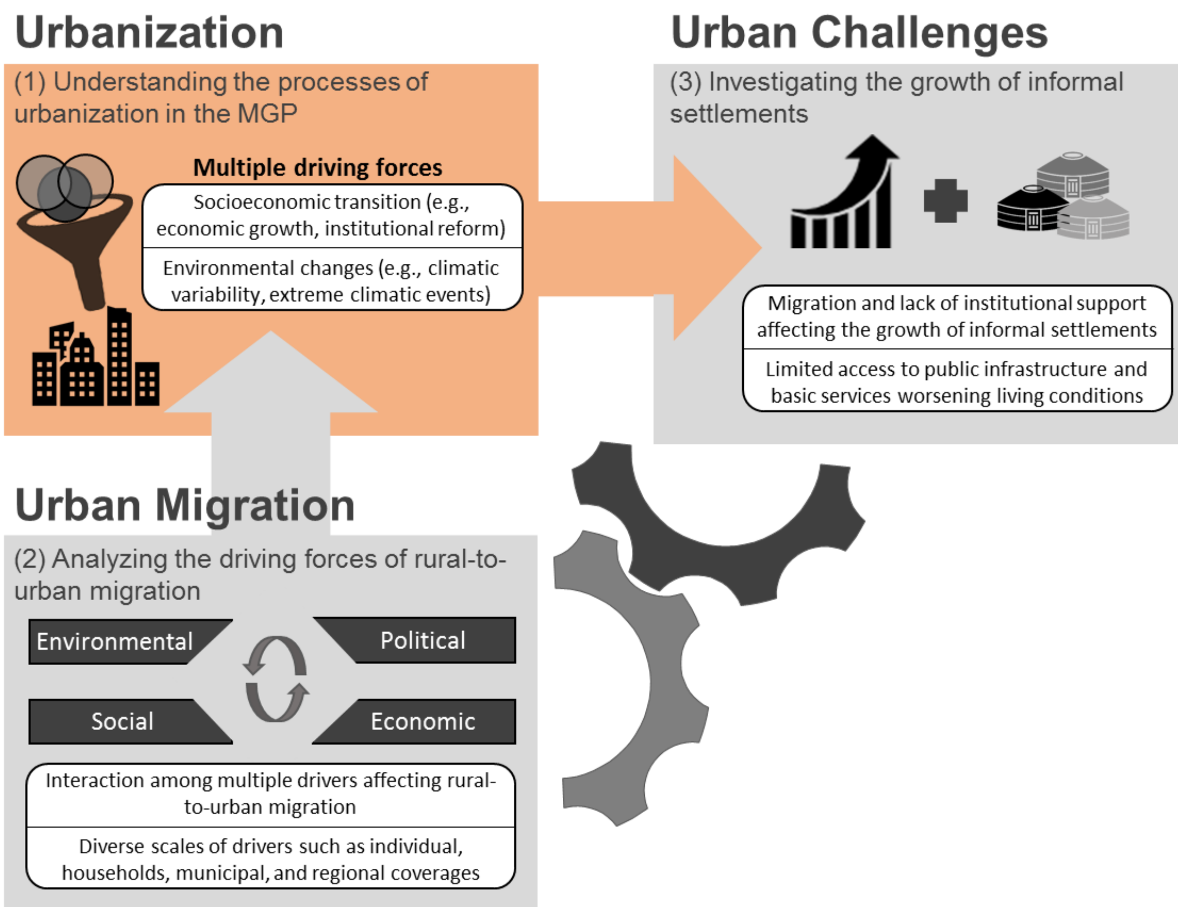

Figure 1.2. The conceptual framework for the research design and objectives, guiding three individual chapters, with Chapter 2 and Chapter 3 analyzing the complex mechanisms of urbanization and rural-to-urban migration and Chapter 4 investigating the growth of informal settlements and possible policy suggestions

As described in the conceptual framework, the objectives of this dissertation are to advance our understanding of the causes and processes of urbanization in transitional economies, identify the challenges in this process, and determine the policy implications and potential solutions for urban sustainability. The dissertation is divided into three chapters in accordance with each of my research objectives: (1) understanding the processes of urbanization in the MGP, (2) analyzing the driving forces of rural-to-urban migration, and (3) investigating urban challenges, i.e., the growth of informal settlements, and proposing policy implications.

Objective One: Understanding the processes of urbanization in the MGP

The primary research questions under this objective 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, I conducted a spatial analysis with remote sensing imagery to investigate the processes and spatial patterns of urbanization. Furthermore, structural equation modeling (SEM) was applied to investigated the causes of urbanization in IM and MG. This comparative analysis enhanced understanding of the urbanization in transitional economies while considering different socioeconomic and institutional settings.

Objective Two: Analyzing the driving forces of rural-to-urban migration

This chapter focused on analyzing the rural-to-urban migration of MG owing to its substantial scale and the greater climate vulnerability of its rural areas compared to IM. Thus, the primary research questions are: (1) What are major driving forces of rural-to-urban migration in Mongolia? (2) How different household characteristics affect rural-to-urban migration? and (3) How are these multiple driving forces of rural-to-urban migration interlinked or interconnected? Given the complexity of the migration mechanism, I developed an empirical model that outline multiple interconnected driving forces of rural-to-urban migration. By using a combination of household surveys, remote sensing (RS) products, and statistical modeling, we investigated the major reasons of rural-to-urban migration, and empirically tested complex causal relationships (i.e., direct and in-direct paths) among driving forces of rural-to-migration.

Objective Three: Investigating urban challenges and proposing policy implications

Rapid growth of informal settlements (i.e., *Ger* districtis) in Ulaanbaatar, the capital of

Mongolia, set off a series of urban environmental and equity issues; however, our knowledge on the growth of informal settlements are limited. To address this rising challenge, following research questions are: (1) What are the development processes of *Ger* districts in Ulaanbaatar? (2) How have spatiotemporal patterns of *Ger* districts changed over the past three decades? (3) What policy implications can be drawn from the analysis of *Ger* districts? To solve these questions, Remote Sensing (RS) image analysis and semi-structured interviews were conducted to understand the developmental stages of *Ger* districts. Further, I applied the machine learning technique to train imagery to develop multi-spatiotemporal *Ger* districts maps from 1990 through 2013. These analyses allowed us to understand the processes and spatiotemporal patterns of *Ger* districts in Ulaanbaatar as well as to suggest plausible policy implications based on the findings.

Chapter 2

Urbanization on the Mongolian Plateau after economic reform: Changes and causes[1]

2.1. 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 et al., 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 et al., 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

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[1] The following chapter contains material reproduced from an article published in the *Applied Geography* with the citation: [Park, H., Fan, P., John, R., & Chen, J. (2017). Urbanization on the Mongolian Plateau after economic reform: Changes and causes. *Applied Geography, 86*, 118-127.]

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 for urbanization (Bai, Shi, & Liu, 2014; Fan et al., 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 it considers the process of urbanization as an evolving coupled natural and human (CNH) system. In this regard, I 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 such as environmental degradation and population flow (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 and Wu, 2016).

I 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 et al., 2015a; Endicott, 2012; Fernandez-Gimenez & Batbuyan, 2004; Wu, Zhang, Li, & Liang, 2015).

By using the MGP as a test bed, I 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. 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, I 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.

2.2. Study Area, Data, and Methods

2.2.1. 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 et al., 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 et al., 2014). Furthermore, growing mining industries have negatively influenced both the vegetation cover and the biophysical health of ecosystems (Qian et al., 2014; Stubblefield et al., 2005).

I 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). These cities were selected because they are either a capital, mining center, or transportation hub. This

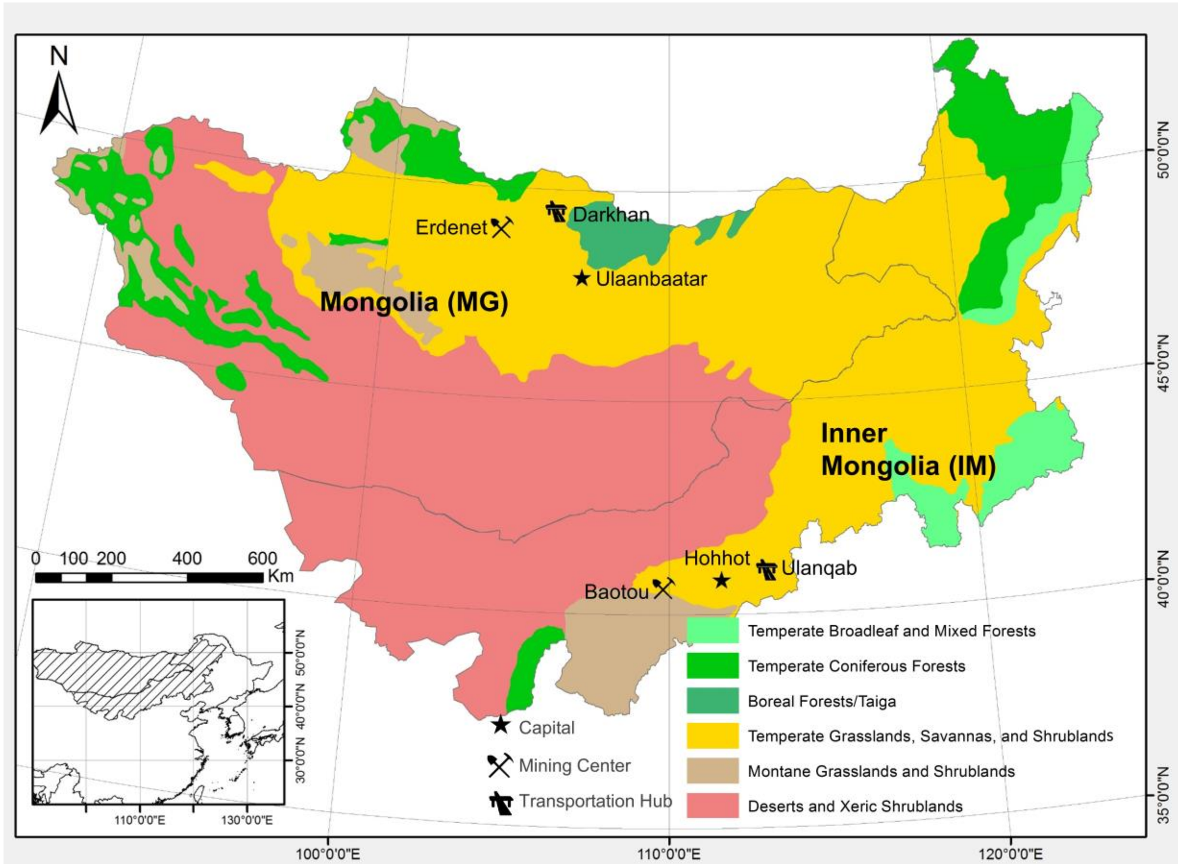


Figure 2.1. Location of the selected cities in IM and MG. The cities are selected by their urban characteristics in regards to their regional roles with similar ecological settings.

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) (Figure 2.1.). 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 P. et al., 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.

2.2.2. 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, I chose to study the period from 1990 to 2015. I 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. I 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, I 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). I 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. I selected 50 samples to develop functions in fuzzy classification. To extract water and vegetation cover, I re-segmented the rest of area at a small-scale (50 scale) to delineate the urban features through fuzzy classification. Finally, I modified the classification results using visual interpretation to co mpare 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, I was able to confirm a sufficient level of overall accuracy (ranging from 0.78 to 0.98) for all images.

2.2.3. Measuring urbanization

Urbanization can be described as horizontal, vertical, or scattered expansion (Jiang et al., 2007; Sevtsuk & Amindarbari, 2012). I 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. I 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 a new regulation on land-use, affordability of land, or transportation costs. To calculate discontinuous growth, I 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_i is the area of cluster n, and n is the number of clusters.

2.2.4. Driving forces of urbanization

Given that urbanization is a result of compound processes, I 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 et al., 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 (Hair, Ringle, & Sarstedt, 2011; Fan Y. et al., 2016).

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 the primary goal is to understand the processes of urbanization between IM and MG, I used the total built-up area within the administrative boundaries, a widely acknowledged indicator, as a unit of measurement for urbanization. I 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 et al., 2015b; Dore & Nagpal, 2006; Endicott, 2012 ; Fan, 1999; Gauri, 2004; Knight & Song, 1999; Zhang et al., 2013) and the field study (Table 2.1). In particular, Gauri (2004) addressed the importance of social goods (including education and healthcare) in the context of developing countries.

Table 2.1. Selected socioeconomic and biophysical variables used in PLS-SEM (Partial Least Squares Structural Equation Modeling).

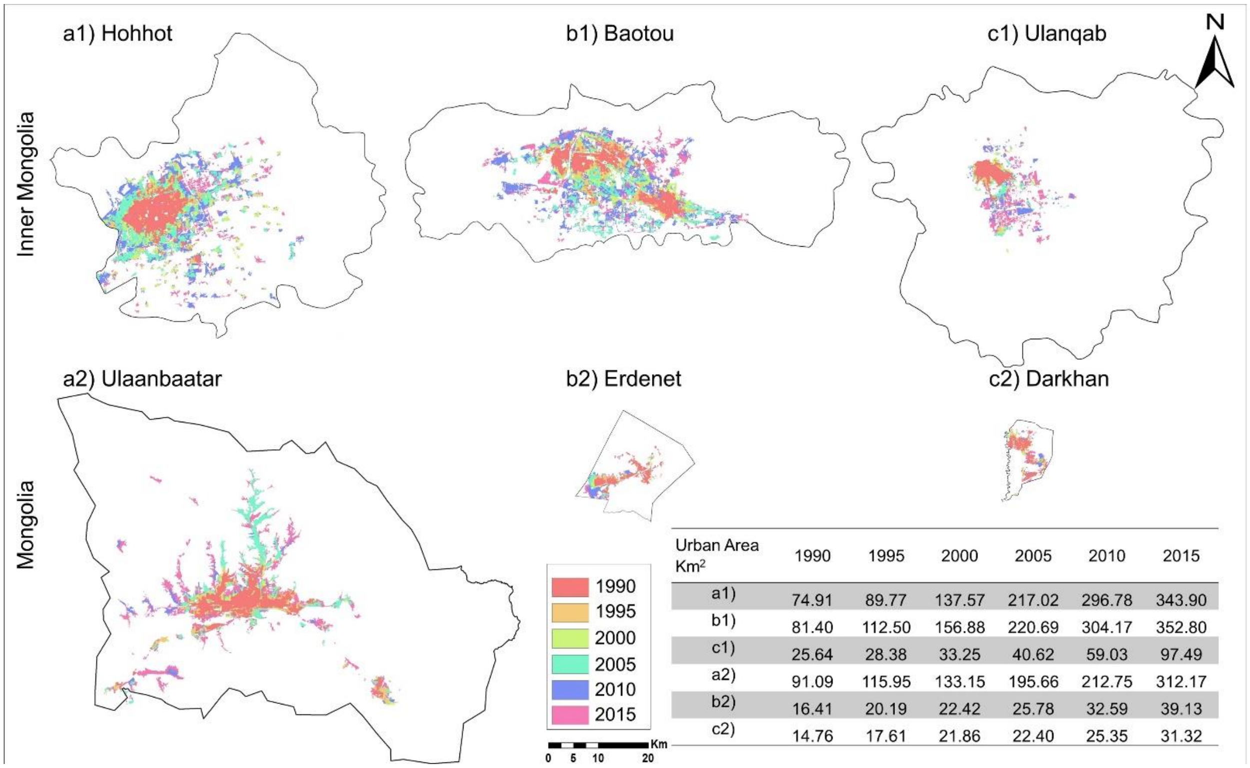
Category	Variable	Definition
Urbanization	Built-up area	Total built-up area (km^2)
Economy	GDPpc	Annual gross regional domestic product per capita (Yuan, IM / Tugrik, MG)
Social goods	Employment	Employed population ratio at the end of year
	Education	Number of teachers per number of students
	Healthcare	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)

I employed four different socioeconomic variables and two biophysical variables in the PLS-SEM. To understand the economic condition of the urban area, I 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). I 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, I 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). I 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 et al., 2010), I 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), I 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.

2.3. Results

2.3.1. 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) (Figure 2.2). 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.



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

Figure 2.2. Urbanization in the six selected cities from 1990 through 2015. Using Geographic Object-Based Image Analysis (GEOBIA)

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 (Figure 2.3). 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 (Figure 2.3a). In MG, urban growth rates fluctuated (Figure 2.3b). 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.

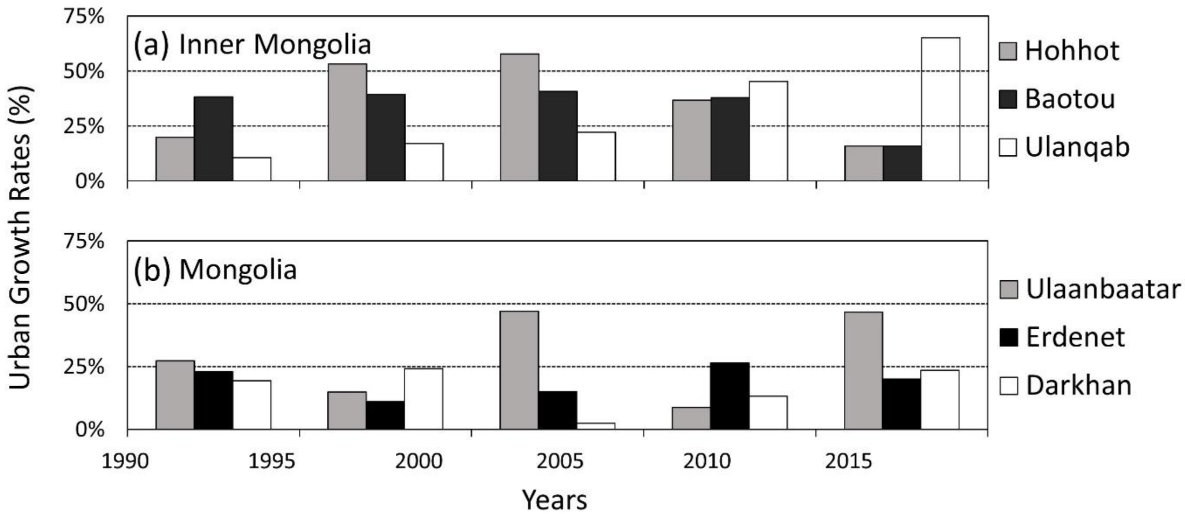


Figure 2.3. The growth rates of total built-up areas measured every five years in the six cities from 1990 through 2015. In Inner Mongolia, Hohhot and Baotou had similar trends (inverted-U curve) in urban growth over the last two decades, while Ulanqab showed a gradually increasing urban growth trend. 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.

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. The correlation analysis verified that urban expansion and population density were negatively correlated for IM (Figure 2.4a), but not for MG (Figure 2.4b). 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 (Figure 2.4c) and MG (Figure 2.4d). The correlation between urban expansion and discontiguity in IM was stronger than that of MG (Figure 2.4c & d). Among the three cities in IM, Ulanqab showed a steeper trend for urban sprawl compared to Hohhot and Baotou (Figure 2.4a & c).

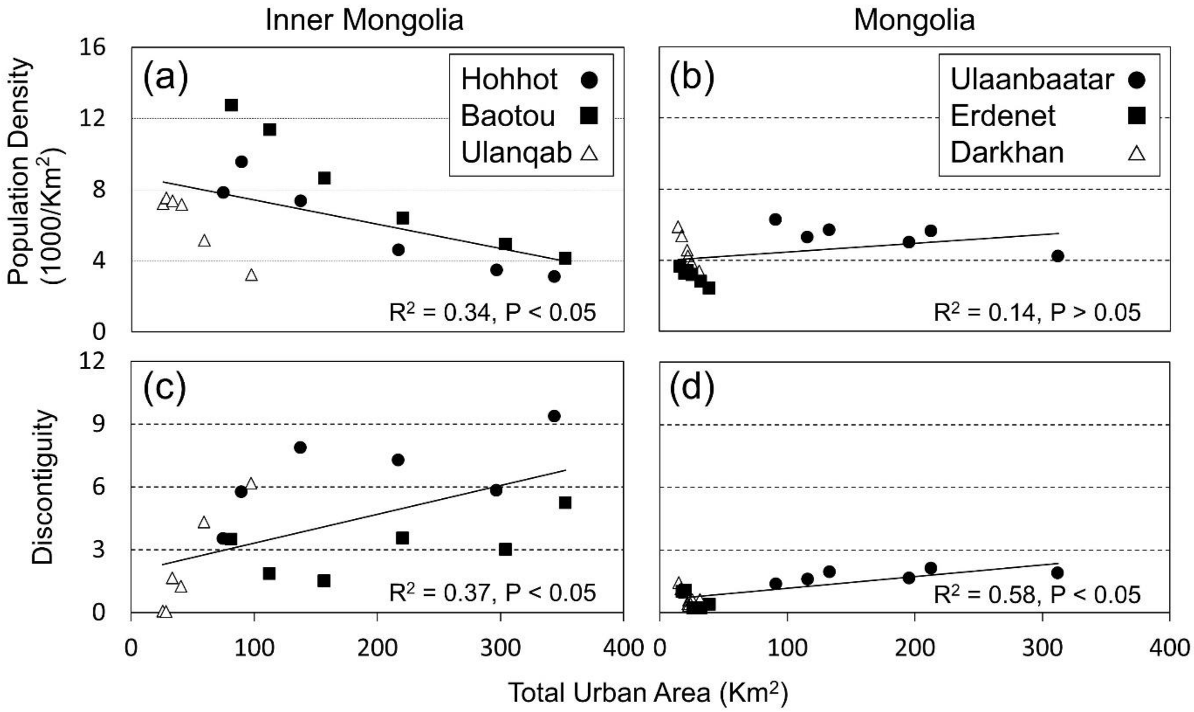


Figure 2.4. The relationship between total urban built-up and population density in Inner Mongolia (IM) is negatively correlated, whereas the relationship in Mongolia (MG) is not statistically significant. The total urban built-up and discontiguity are positively correlated in both IM and MG, with the slope of IM higher than that of MG.

2.3.2. 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 (Figure 2.5). The collinearity statistics of the latent variables for both IM and MG models were high (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 latent variables had a different relationship in IM and MG, and the models' explanations of urbanization also varied.

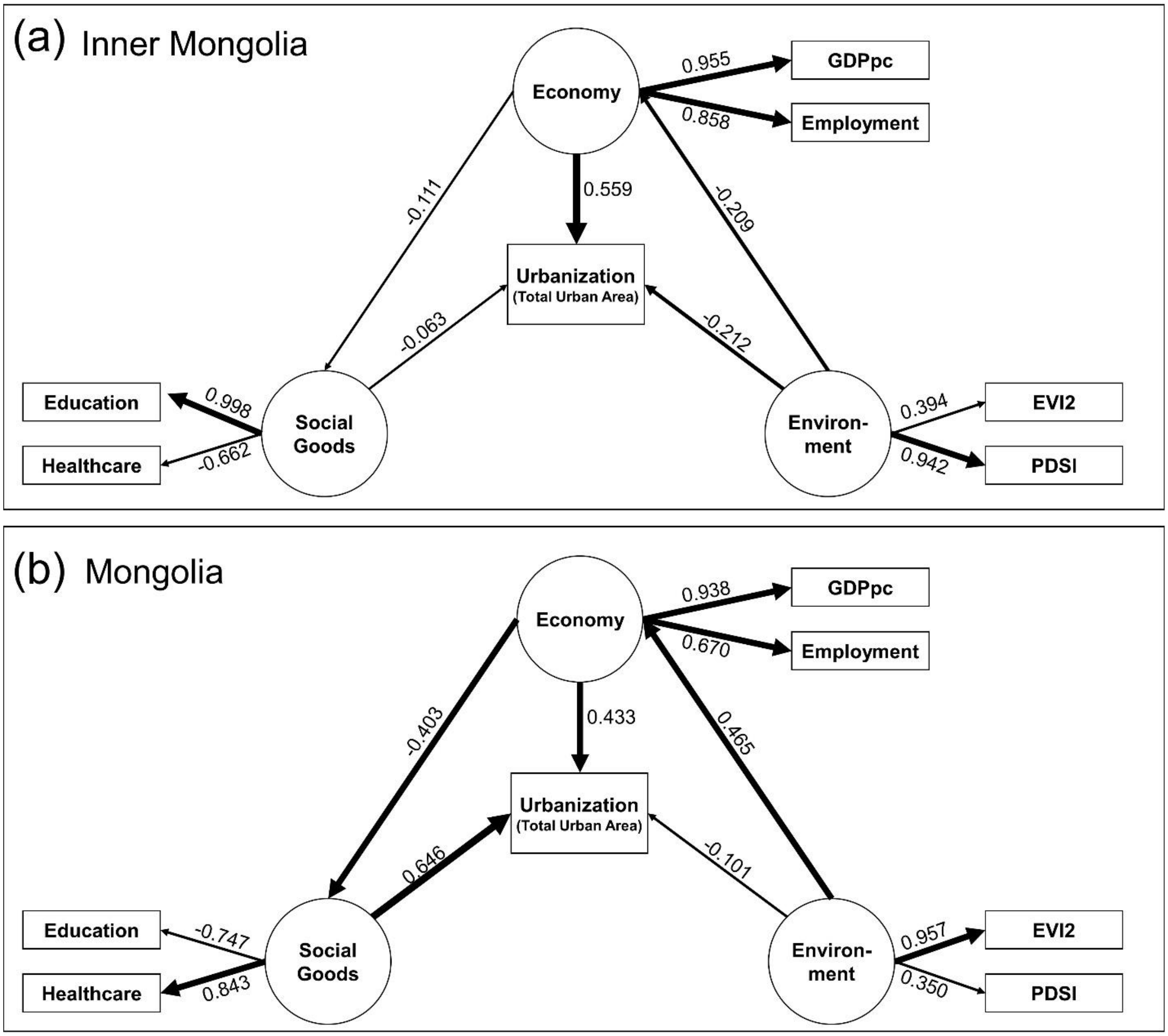


Figure 2.5. Partial Least Squares Structural Equation Modeling (PLS-SEM) of socioeconomic and biophysical drivers on urbanization in both Inner Mongolia (IM) and Mongolia (MG). Latent variables are circular shapes, and measured variables are squares. The path coefficients describe the relationship between 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 ($R^2 = 0.342$).

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 urbanization and social goods as well as economy and social goods were not statistically significant. Thus, I 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 (Figure 2.5a).

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, I 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 (Figure 2.5b).

Since I 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 Y. et al., 2016). To confirm the stability of estimated path coefficients, I proceeded with bootstrapping 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 2.2).

Table 2.2. 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

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

2.4. Discussion

2.4.1. 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., 2016). 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).

The results also verified that IM is in line with the urban sprawl trend of China (Figure 2.2a1, 2.2b1, & 2.2c1). 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 (Su et al., 2011; Liu et al., 2016).

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 (Figure 2.2a2, 2.2b2, & 2.2c2). 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 (Figure 2.4b). 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 et al., 2015). In summation, the limited roles of local government and insufficient infrastructures in MG resulted in a more densely populated urbanization compared to IM.

2.4.2. 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 (Figure 2.5a & b). As Chen et al. (2015a) 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) (Figure 2.5a & b). After IM and MG were transformed into market-based economies (Chen et al., 2015b; 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 et al., 2015b; Wu et al., 2015). The links between environmental conditions (e.g., grassland cover) and the economy for IM was not statistically significant (Table 2.2), as the economic system in IM was dramatically restructured to favor the secondary and tertiary sectors during the study period (Chen et al., 2015a; 2015b). 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 (Figure 2.5b). Livestock grazing and herding remain the major economic activities in MG (Dore & Nagpal, 2006; Ulambayar et al., 2016). Approximately 25.2% of total MG households still practice livestock farming (National Statistical Office Mongolia, 2016). 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.

2.4.3. 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 (Figure 2.5a & 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 healthcare 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 healthcare system situation in MG supports this view. Healthcare 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).

2.4.4. 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). My 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 I 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 freshwater/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.

2.5. 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. I 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. I 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.

Chapter 3

Deciphering the complexity of rural-to-urban migration in a transitional economy

3.1. Introduction

Throughout human history, migration has been a critical strategy for adapting to socio-environmental challenges such as extreme climatic events, political conflicts, and industrial transitions (Black et al., 2011b; Hunter, Luna, & Norton, 2015; McLeman, 2014). In recent decades, migration, particularly rural-to-urban flow, has intensified due to economic transition combining with globalization as well as drastic changes in climatic condition and agricultural production (Barrios, Bertinelli, & Strobl, 2006; Bylander, 2015; Ledent, 1982; Roberts, 1989). These massive migration flows have received wide attention from many researchers, resulting in a great deal of framing/theorizing about the complex mechanisms of migration (Black et al., 2011a; Hunter, Luna, & Norton, 2015; McLeman & Smit, 2006). The complicated and interrelated nature of migration has led researchers to emphasize the need for inclusion of diverse factors associated with migration, instead of using a deterministic view, i.e., assuming a simple causal relationship (Black et al., 2011a; McLeman, 2014; Piguet, 2010). Several studies adopted this diverse approach to provide a comprehensive understanding of migration. Qualitative interviews have been were implemented to explore migration depending on climate variability and various household characteristics (Bylander, 2015; Morrissey, 2013). Large-scale census data were utilized to identify key drivers of migration (Call et al., 2017; Mastrorillo et al., 2016; Thiede, Gray, & Mueller, 2016). As of yet, however, a limited number of studies have empirically utilized the multi-factor approach to rural-to-urban migration in transitional economies.

Transitional economies are those that have faced complicated mechanisms of rural-to-urban migration owing to dramatic socioeconomic transformations (e.g., marketization, industrial restructures, institutional reform) and vulnerability of environmental changes (e.g., precipitation and temperature variability, and extreme events) (Chen et al., 2015b; Fan, Chen, & John, 2016; Park et al., 2017). Prior to transition, the central government often restricts population movement and sets a quota for migration (Mayer, 2016; Tammaru, Kulu, & Kask, 2004). However, as cities of transitional economies have transformed into highly marketized areas (Davis, 2000) and released the restriction of relocation (Endicott, 2012), emerging employment opportunities have promoted rural-to-urban migration (Rudolph & Brade, 2005; Tammaru et al., 2004). Low agricultural productivity in rural areas and environmental vulnerability have accelerated this trend (Bai, Shi, & Liu, 2014; Fan P. et al., 2014; Molodikova & Makhrova, 2007). Since transitional economies were not sufficiently provide proper policies (e.g., regulation of environmental degradation and assistance to agro-pastoralists after extreme events) in response to environmental changes, rural residents have considered migration as a primary coping strategy (Adger, Kelly, Winkels, Huy, & Locke, 2002; Koubi et al., 2016). These combined factors have made rural-to-urban migration in transitional economies challenging to understand.

Migration is a complex process that is the aggregation of multiple factors including socioeconomic, institutional, and environmental conditions (Black et al. 2013b; Morrissey, 2013; Neumann et al., 2015; Thiede et al., 2016). This process is not solely defined by the impact of single events and policies (e.g., extreme climate events, economic development, land use policies, and industrial transformations) but relies on the aggregation of diverse stakeholders' behaviors and corresponds to multiple changes and events (Call et al., 2017; Koubi et al., 2016). To better account for this complex process of rural-to-urban migration, a more nuanced understanding can be achieved by diverse scales of analysis, ranging from household surveys to help understand migrants behaviors, geospatial analysis to estimate biophysical conditions, and statistical modeling to analyze the complex mechanisms of migration. This mixed-methods approach will help identify the heterogeneous drivers of rural-to-urban migration and potential entry points of intervention to ensure sustainable development. In light of this, the three fundamental research questions of this paper are: *(1) What are the major driving forces of rural-to-urban migration in Mongolia? (2) How have different household characteristics affected rural-to-urban migration?* and *(3) How are these multiple driving forces of rural-to-urban migration interlinked or interconnected?*

Here, I used Mongolia—a transitional economy that has faced both socioeconomic transition and dramatic environmental changes (Chen et al. 2015a; Chen et al., 2015b; John et al., 2016)—to address the phenomenon of migration in transitional economies. Proper data acquisition is a crucial challenge to understanding the mechanism of migration (Fussell, Hunter, & Gray, 2014). Despite the importance of including multiple perspectives, census or publicly accessible statistical data were not sufficiently available to address the above research questions. In light of this challenge, I designed and conducted household surveys for migrants and analyzed a suite of remote sensing (RS) products to estimate biophysical conditions. In addition, I developed Structural Equation Models (SEMs) to test hypothesized path relationships, i.e., direct and indirect relationships among different factors, which were developed based on rigorous literature review.

3.2. Conceptual framework of analyzing rural-to-urban migration

Understanding rural-to-urban migration in transitional economies requires multiple perspectives. Since population displacement and concomitant urbanization are the result of complex mechanisms (Montgomery, 2008; Piguet, 2010), I identified a number of driving forces behind rural-to-urban migration in Mongolia including social, economic, environmental, and political factors based on migration-centric literature (Adger, 1999; Black et al., 2011b; Black et al., 2013b; Fussell et al., 2014) and Mongolian case studies (Chen et al., 2015a; Chen et al., 2015b; Endicott, 2012; Fernández-Giménez, 1999; Fernandez-Gimenez, Batjav, & Baival, 2012; John et al., 2016; Liu et al., 2013; Ojima & Chuluun, 2008; Park et al., 2017; Roberts, 1989).

Changing from a pastoral/egalitarian society to a industrial/market-based society alters the peoples' needs for basic public services, i.e., healthcare and education (Park et al., 2017). While pastoral and collective farming industries were common until 1990, the failures of collective farms and shareholding companies due to the loss of government subsidies and incentives led to income loss in rural areas (Endicott, 2012). Furthermore, many rural areas could not maintain their public services; for example the number of medical personnel in rural hospitals has steadily declined since 1990 (UNFPA, 2012). Thus, rural-to-urban migration was considered a response to the lack of income and public services in rural areas.

During the last few decades, the environment in Mongolia has undergone massive changes. The annual average temperature of Mongolia has increased by 2 degrees Celsius and there has been a 7% reduction in annual precipitation in the last seven decades (Liu et al., 2013), along with an increased frequency of extreme climatic events (e.g., drought and snowfall) (Fernandez-Gimenez, Batjav, & Baival, 2012; John et al., 2016). Unfortunately, the agro-pastoral economy and social safety-net no longer provide sufficient income for rural households due to limited support from local and central governments after the collapse of Soviet Union (Endicott, 2012; Fernandez-Gimenez, Batkhishig, & Batbuyan, 2012; Roberts, 1989). This low adaptive capacity might make rural residents more vulnerable to climate variability and extreme climatic events as Mirza (2003) and Adger (1999) studied.

Newly employed land-use laws and policies have operated as push and pull factors of rural-to-urban migration. Following the transfer of land-use management responsibility from the community to the individual based on the *Law on Land* (Endicott, 2012; Fernández-Giménez, 1999), grasslands have consequently suffered from low productivity due to overgrazing and environmental degradation (Brown et al., 2013; John et al., 2016; Ojima & Chuluun, 2008), and therefore has played as a migration push-factor. In addition, the availability of land tenure in Ulaanbaatar has been considered as a pull factor. The *Law of Mongolia on Land* and the *Law on Allocation of Land to Mongolian Citizens for Ownership* allowed incoming citizens to legally claim land ownership for residential purposes (Bauner & Richter, 2006).

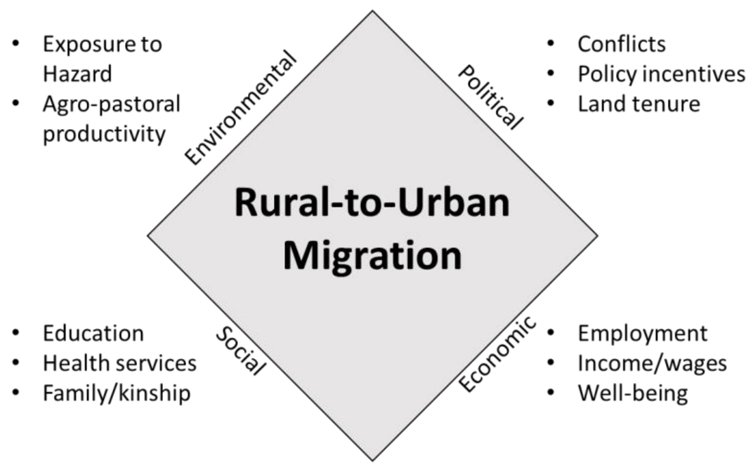


Figure 3.1. Conceptual model of rural-to-urban migration mechanism in MGP. Since the drivers of rural-to-urban migration differ in different regions and circumstances, the factors are determined based on the existing literature focused on transitional economies and the Mongolian plateau.

Building on the work of Black et al. (2011a) which discussed complex and multi-layered drivers of migration, this chapter developed a conceptual model incorporating macro-level driving forces of migration and associated events. Drawing from the socioeconomic and biophysical contexts of Mongolia, I categorized the multiple driving forces of rural-to-urban migration into four dimensions (i.e., economic, social, environmental, and political factors) and multiple events associated with rural-to-urban migration were implemented (Figure 3.1). This conceptual model framework guided not only the structure of this chapter but also all of the survey design and statistical modeling.

3.3. Methods

3.3.1. Study area

Mongolia is a landlocked country in North East Asia (41.570°-52.150° N and 87.690-119.920° E) (Figure 3.2). Owing to the unique characteristics of the Mongolian Plateau, i.e., grasslands steppe and a semi-arid climate, Mongolia has a long history of pastoral livelihood (Chen et al., 2015b; Fernandez-Gimenez et al., 2012). As the most sparsely populated country in the world, Mongolia has a land area of approximately 1.56 million km^2 and a total population of 3.08 million (National Statistical Office of Mongolia, 2016).

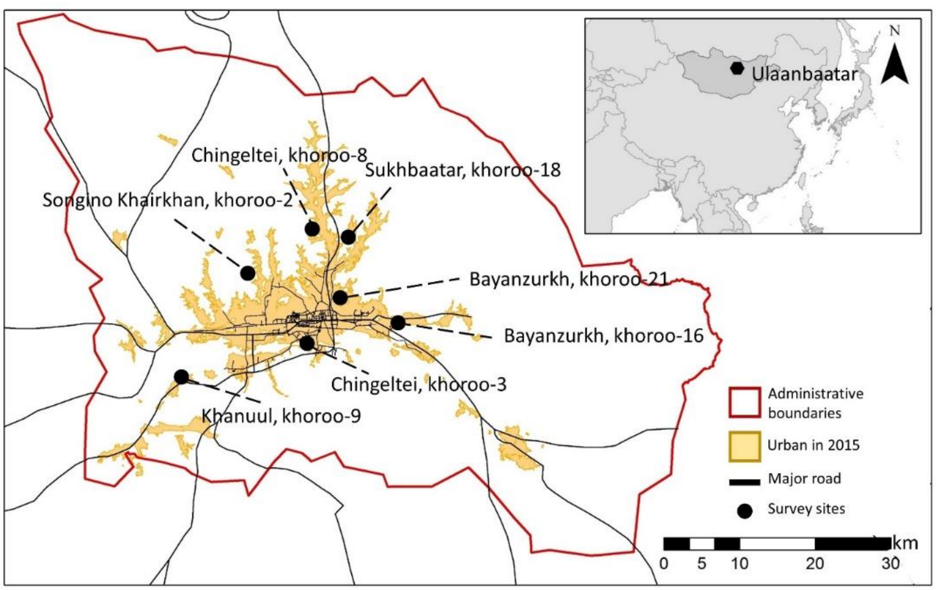


Figure 3.2. The administrative boundaries of Ulaanbaatar and its urban extent by 2015. The black dots indicate sampled areas for the household surveys which were conducted from near the city center toward fringe areas. Surveys were conducted in seven different khoroo (sub-districts).

Given dramatic changes in socioeconomic and biophysical conditions (Chen et al., 2015a; Chen et al., 2015b; Fernández-Giménez et al., 2017), this chapter targeted Mongolia to investigate the dynamics of rural-to-urban migration. During the transitional period following the collapse of the Soviet Union, Mongolia experienced accelerated rural-to-urban migration (Neupert, 1999; Sneath, 2003). Ulaanbaatar, the capital city of Mongolia, has been a major migratory destination (Fan P. et al., 2016; Park et al., 2017). During 1990 to 2016, 47.7% of nationwide in-migration (1,307,000) was toward Ulaanbaatar with increases from 536,000 to 1,440,000, i.e., 46.2% of nation's total population (National Statistical Office of Mongolia, 2016). Therefore, for this chapter, I chose to conduct household surveys in Ulaanbaatar in order to identify the mechanisms of rural-to-urban migration.

3.3.2. Household survey design

The household survey was designed to understand the driving forces of rural-to-urban migration and their relationships. To address these, I developed Likert scale about the questionnaires to ask quantitative contributions of social, economic, environmental, and political factors as reasons behind on rural-to-urban migration. I also collected data on demographic characteristics, major income sources, and income level to understand how household socioeconomic status affects rural-to-urban migration. Awareness of 'climate change' was included to inverstigate how it influenced perceptions of migration factors. Additionally, I collected the respondents' year of migration and their former residential location including province (*aimag)* and district (*soum)* to spatially link biophysical data to survey respondents. It is difficult to get the exact latitude and longitude from survey respondents, so I utilized district as a proxy of geocoordinates (Supplementary 3.1).

Since this research focused on analyzing driving forces of rural-to-urban migration, this research solely surveyed migrants. In particular, I conducted household surveys in newly urbanized areas during the past three decades. Furthermore, household surveys were conducted in seven different khoroo (sub-districts)—from the city center to fringe areas—of Ulaanbaatar, Mongolia, to alleviate possible biases owing to limited geographical regions (Figure 3.2).

3.3.3. Processing Remote Sensing (RS) products

Multiple RS products were used to estimate the biophysical conditions of respondents' former residential locations. I derived vegetation indices including Normalized Vegetation Index (NDVI) from the MODIS Nadir BRDF Adjusted Reflectance (NBAR) (MCD43A4 V006) combined Terra and Aqua product through NASA EOSDIS's data portal (https://earthdata.nasa.gov/). The 8-day composites of 500 m resolution MODIS NBAR products were converged to the seasonal NDVI composites of June, July, and August. To acquire spatially explicit precipitation and temperature data, I utilized total surface precipitation (PRECTOTCORR) and 2m air temperature (T2M) of NASA's Modern-Era Retrospective Analysis for Research and Applications (MERRA) global dataset via the Goddard Space Flight Center simple subset portal (http://disc.sci.gsfc.nasa.gov/SSW/). The monthly data were converged to seasonal composites of June, July, and August to represent the environmental conditions of peak growing seasons. Three major biophysical variables were scaled-up to administrative boundaries—i.e., 331 *Soum* (districts), to establish a biophysical data set matching with survey respondents' former residential locations.

Since this chapter is interested in the impact of climate variability on rural-to-urban migration, I calculated standardized anomalies (*sa)* of NDVI, precipitation, and temperature:

$$sa = \frac{x - \bar{x}}{\sigma}$$

where *sa* is the standardized anomaly of environmental variables, i.e., NDVI, temperature, and precipitation, for the peak growing season mean during the study period relative to the long-term peak growing season mean ($\bar{x}$) and standard deviation (σ) over the long-term data (1980-2016).

3.3.4. Partial Least Squares-Structural Equation Modelling (PLS-SEM)

Given that migration is a result of compounded processes (Black et al., 2011a, 2011b; Hunter, Luna, & Norton, 2015), I employed PLS-SEMs to quantify the relationships of social, economic, environmental, and political drivers associated with rural-to-urban migration. SEM is a modeling approach used to employ the concept of multivariate path analyses to address the complex relationships among multiple variables (Gefen, Rigdon, & Straub, 2011). It has been widely used to address complicated relationships among multiple observed/un-observed variables (Fan Y. et al., 2016). This approach has advanced earlier studies by addressing the complex nature of migration considering inter-connected relationships among multiple factors.

Since the primary goal of this chapter is to understand the relationships among multiple driving forces, I established the causal relationships among social, environmental, economic, and political drivers (Figure 3.1). The four Likert scale questions—the degree of importance of social, economic, environmental, and political reasons—were utilized to primary measured variables for each driver (i.e., latent variable). However, the current form of questionnaires often has limitations in indicating socioeconomic and environmental conditions (Bilsborrow & Henry, 2012; Fussell et al., 2014).

Multiple biophysical variables from RS products and the auxiliary questionnaire from household surveys were included to develop PLS-SEMs. For the *Social Driver*, *Gender Ratio* and *Mean Age* of households which have long been studied in empirical migration studies (Call et al., 2017; Koubi et al., 2016) were implemented. I also included *Social Capital* (a binary variable) that indicates the respondents for whom the main reason behind relocating was that they knew a person/had a family member who lived there. *Social Capital* has been considered a significant factor to promote domestic migration (Frey, 1996; Massey, 1990).

Climate-induced migration is often associated with migrants' former occupation (Bylander, 2015) as well as diversified adaptive capacity relying on their income level (Koubi et al., 2016). Therefore, the model included *Income Level* (1 to 5 on the Likert scale) and *Former Agro-Pastoralists* (a binary variable) from household surveys for the *Economic Driver*. To address environmental variability, the model included three biophysical variables including standardized anomalies (*sa*) of *NDVI*, *Precipitation*, and *Temperature* for the *Environmental Driver*. Vegetation Index, NDVI, is suitable to estimate the overall condition of grassland (John et al., 2013). As Barrios et al. (2006) and Mastrorillo et al. (2016) have studied, I utilized precipitation and temperature as environmental stressors. Additionally, migration often occurred with a time lag of environmental variability (Call et al., 2017); thus, I averaged biophysical variables based on the respondents' migration year (t), previous year (t-1), and two years before the migration year (t-2). *For the Political Driver*—often considered a major driver of migration trends (Mayer, 2016; Seto, 2011)—the model included two land-use policy dummy variables: *Rangeland Management Implementation* and *Land Tenure Availability in Urban area* based on respondents' former location (district) and years of migration (Table 3.1).

Table 3.1. Selected socioeconomic and biophysical variables used in PLS-SEM (Partial Least Squares Structural Equation Modeling).

Category	Variable	Definition
Social Driver	Social Reason	Likert scale (1 to 5: not at all influential, slightly influential, somewhat influential, very influential, and extremely influential)
	Social Capital	Knowing people who lived current neighborhoods (binary variable)
	Gender Ratio	Female ratio in household
	Mean Age	Mean of household members
Economic Driver	Economic Reason	Likert scale (1 to 5: same scale as of Social Reason)
	Income Level	Likert scale (1 to 5: poor, below average, average, above average, wealthy)
	Agro-Pastoralists	Households' former major income source (binary variable)
Environmental Driver	Environmental Reason	Likert scale (1 to 5: same scale as of Social Importance)
	NDVI (sa)	Average of past two years' standardized anomalies of NDVI
	Precipitation (sa)	Average of past two years' standardized anomalies of precipitation
	Temperature (sa)	Average of past two years' standardized anomalies of temperature
Political Driver	Political Reason	Likert scale (1 to 5: same scale as of Social Importance)
	Rangeland Policy	Implementation of range land management (binary variable)
	Land Tenure	Availability of urban land tenure (binary variable)

3.4. Results

3.4.1. Unique characteristics of migrants to Ulaanbaatar

I collected 211 surveys of migrants from rural areas to Ulaanbaatar from 1990 to 2017. Contrary to the general assumption that the majority of migrants had limited assets and moved due to economic hardships, 68% of respondents indicated that they held the national average income in their former residence, and 79% of respondents had land tenure before moving. This implied that the rural-to-urban migration is not simply the process of moving from an impoverished area to a wealthier place (Black et al., 2011a), but is instead a process associated with multiple underlying factors.

Based on the year of relocation, the survey found that 2000 was a peak year of rural-to-urban migration in the collected samples. Considering the extreme climatic events and high mortality of livestock in 1999 and 2000 (Qi et al., 2012), this trend may indicate that rural-to-urban migration combines environmental stressors and concomitant economic hardship. Additionally, this permanent relocation contrasts the finding from Black et al., (2011a) which claimed that event-driven displacements are temporary and that those migrants return back to their original location after a certain period of time. While pastoral societies often temporarily migrate to secure livelihoods (Fernandez-Gimenez et al., 2012), current rural-to-urban migration in Mongolia is likely a permanent displacement.

3.4.2. Driving forces of rural-to-urban migration

The primary questions related to the four major reasons for rural-to-urban migration exhibited the divergent outcome. The mean (std) of social, economic, environmental, and political reasons were 3.51(1.21), 3.42(1.21), 2.89(1.31), and 1.23(0.75), respectively (Figure 3.3). Social and economic reasons were critical for urban migration, and environmental and political reasons followed. These results are along the same lines as those found by Black et al. (2011a) that social and economic reasons are perceived as dominant drivers of migration across diverse regions.

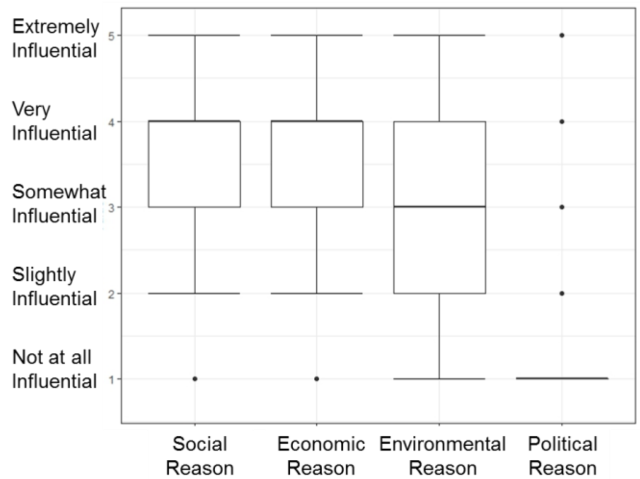


Figure 3.3. A boxplot quantifying the importance of the social, economic, environmental, and political reasons for rural-to-urban migration—by a Likert scale from Not at all influential (1) to Extremely influential (5)—with mean (std) scores of 3.51(1.21), 3.42(1.21), 2.89(1.31), and 1.23(0.75), respectively.

Reasons for migration vary based on household income, former occupation, gender ratio, and awareness of climate change (Black et al., 2011a; Hunter, Luna, & Norton, 2015). To address these heterogeneous factors, I explored reasons for migration by categorizing household characteristics (Figure 3.4). Income was divided into five different groups, i.e., poor, below average, average, above average, and wealthy. During the survey, I provided the median income of Mongolia as a reference to assist in responding to the income level question. No respondents claimed to be wealthy households. The group of former occupation was classified into two categories based on households' former primary income sources. Based on households' gender ratio (%), I categorized households into three groups: male dominant, balanced (50%), and female dominant households. I also classified respondents based on the question: "Have you observed any changes in climate in the last 15-20 years?" (Supplementary 3.1).

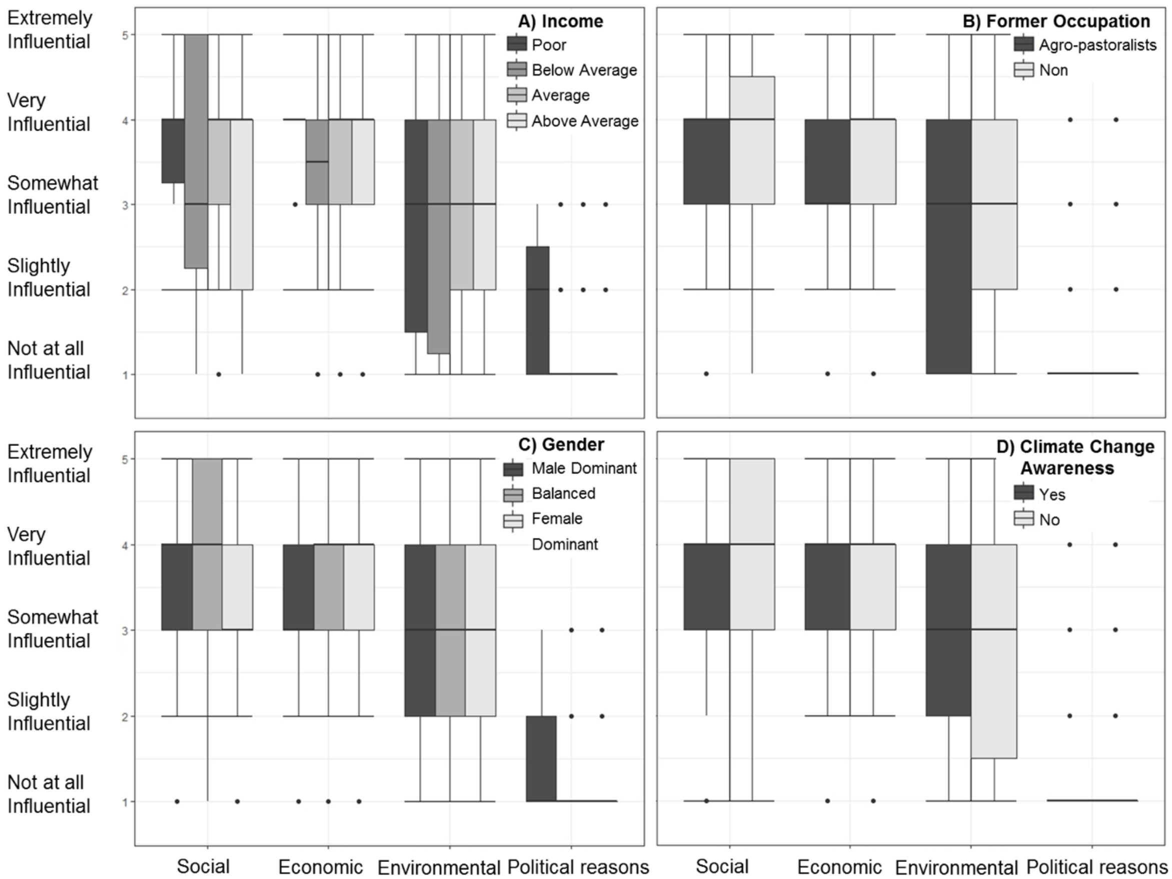


Figure 3.4. The social, economic, environmental, and political reasons for rural-to-urban migration categorized by (a) income, (b) former occupation, (c) gender, and (4) awareness of climate change.

The analysis based on a single factor, i.e., income level, occupation, gender, and climate change awareness did not adequately explain the divergent factors associated with rural-to-urban migration (Figure 3.4). ANOVAs and T-tests only partially explained the differences (Table 3.2). The political reason can be differentiated by the households' gender ratio (8.35), and the environmental reason (0.03) also can be differentiated by former occupation. These overall results indicated that migration does not rely on a single factor; rather, it is a mixed outcome associated with multiple factors. Again, the results stressed a need for appropriate statistical approaches to address complex relationships among multiple drivers of rural-to-urban migration.

Table 3.2. ANOVA and T-test for different groups: rejected *null* hypothesis that there is no difference between groups as of 95% confidence interval in bold

Test	Category	Social Reason	Economic Reason	Environmental Reason	Political Reason
ANOVA	Income (Figure 3.4a)	0.19	0.27	0.19	0.00
(F-value)	Gender (Figure 3.4c)	1.10	0.23	0.24	**8.35**
T-test	Occupation (Figure 3.4b)	0.62	0.21	**0.03**	0.78
(p-value)	Awareness (Figure 3.4d)	0.94	0.09	0.19	0.08

3.4.3. Feedback and interactions of multiple driving forces

Drawing from the prior research described in the conceptual framework (Figure 3.1), I outlined a PLS-SEM that encompasses the four drivers (i.e., latent variables) and other observed variables (Figure 3.5). Building on the four drivers, specific measurements including observed variables from both household surveys and biophysical data were placed under each latent variable.

Based on the iterative procedures of model testing, I concluded with a PLS-SEM (Figure 3.5). The Standardized Root Mean Square Residual (SRMR) (<0.1) and Collinearity (<3) across measured variables confirmed the statistical robustness to explain the hypothesized causal connections. Bootstrapping analysis (i.e., 5000 iterations) was also applied to test the stability of estimated path coefficients (Table 3.3).

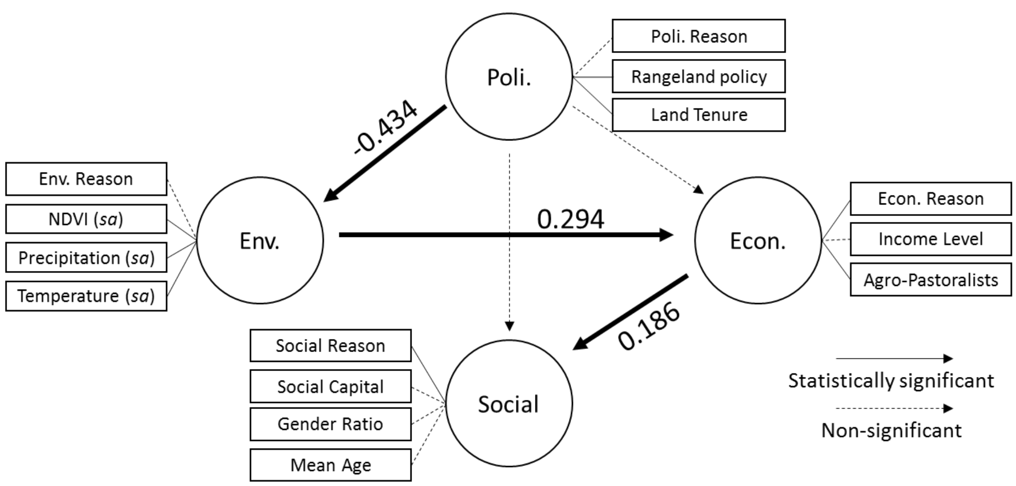


Figure 3.5. Partial Least Squares Structural Equation Model (PLS-SEM) of four drivers influencing the migration in Mongolia. Drivers (Latent variables) are circular shapes, and measured variables are squares. The path coefficients describe the relationship between variables. (*sa*) indicates values of standardized anomalies to account environmental variability.

Three paths from the *Political Driver (Poli)* to the *Environmental Driver (Env)*, the *Economic Driver (Econ)*, and the *Social Driver (Social)* exhibited divergent relationships. The path coefficient between the *Poli* and the *Env* is statistically significant, with the *Poli* having a strong negative effect on the *Env* (-0.434). The other two paths were not statistically significant. However, we could observe that the *Poli* exhibits indirect impacts on the *Econ* and *Social* through the *Env.* The *Env* also exhibited a statistically significant positive relationship on the *Econ* (0.294). In addition, the *Econ* had a positive effect on the *Social* (0.186). While the current model cannot explain all hypothesized causal relationships, it demonstrated some ways in which to better understand the complex direct and indirect relationships among four drivers of migration (Figure 3.5).

Table 3.3. Estimated model coefficients from PLS-SEM and bootstrapping results with sub-samples (i.e., 5000 iterations). *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Path	Original sample estimate	Mean of resamples	Standard deviation	T-statistics
Econ. > Social	0.186**	0.217	0.094	1.981
Env. > Econ.	0.294**	0.294	0.129	2.269
Poli. > Social	-0.036	-0.133	0.085	0.424
Poli. > Econ.	0.065	0.087	0.063	1.042
Poli. > Env.	-0.434***	-0.428	0.083	5.196

3.5. Discussion

3.5.1. Impact of transitional economy and socioeconomic transformation

Social and economic drivers are key factors behind rural-to-urban migration in Mongolia as identified by the household surveys (Figure 3.3). During the transitional periods, Mongolia has experienced a socioeconomic transformation following a marketized economy, changed industrial structures, and a major reduction in public healthcare and education systems (Chen et al., 2015b; Dore & Nagpal, 2006; Park et al., 2017). In particular, foreign investment concentrated in either the mining industry or Ulaanbaatar (Mayer, 2016), subsidies on collective farms and factories were reduced (Endicott, 2012); and rural residents had faced limited access to public healthcare and education systems due to the collapse of state subsidies based on the sparse population (Dore & Nagpal, 2006). This urban-centric transformation promoted unbalanced development between rural and urban areas and led rural-to-urban migration.

More importantly, the ideology of socialism has been replaced by capitalism while the tradition of pastoralism has not been espoused by younger generations (Mayer, 2016). The idea of capitalism has shaped the notion of ownership that transferred from 'public' to the 'individual' (Sneath, 2003). By breaking up ownership of land and resources, unfortunately, many agro-pastoral activities and rural industries have lost their competitiveness without state incentive and subsidies (Endicott, 2012; Neupert, 1999). As society transitioned to 'modernity' and a 'free market', perceived social and economic opportunities became pull factors that attracted migrants to Ulaanbaatar to stay permanently. As illustrated in Figure 4, this trend was shown across diverse groups of people. The removal of the restrictions on personal movements has fostered this increasing trend of migration (Dore & Nagpal, 2006).

3.5.2. Environmental driver: A mediator of the economic driver

While social and economic reasons were as perceived primary factors associated with rural-to-urban migration in the household surveys (Figure 3.3), the PLS-SEM (Figure 3.5) revealed a critical role of the environmental driver that exhibited direct and indirect impacts on the economic (0.294) and social (0.055) drivers, respectively.

These positive relationships indicate the importance of the environmental driver as a mediator of other migration drivers in the Mongolian context. Considering the scale of pastoral activities in Mongolia—with 25.2% of total households practicing livestock herding and working in the related business (National Statistical Office of Mongolia, 2016)—the robust relationship between environment and economy is plausible. In addition, the low adaptive capacity of households substantiates this connection. Bearing in mind that limited governmental supports (e.g., insufficient animal shelters, hay storage, and financial programs) were provided in response to extreme climatic events and environmental variability (Fernandez-Gimenez et al., 2012), the environmental driver is able to critically influence the economic condition of households in the Mongolian context.

As Black et al. (2011a) and Piguet (2010) also explored, the environmental driver often was not perceived as a major factor influencing migration due to its complex nature. Respondents, i.e., stakeholders, often stated their reasons for migrating as the ‘results’ without considering the ‘processes’. During the field interview, I found that many of the respondents answered that their reason for migration was economic hardships and/or economic opportunities; however, they did not often mention *how* and *why* they had experienced economic hardships. In the household surveys, although the extreme climate events, i.e., a combination of extreme snowfall and drought, contribute high mortality rates of livestock (Fernandez-Gimenez et al., 2012; Qi et al., 2012), many respondents simply answered with result that followed: e.g., that their reason behind migrating was to find new economic opportunities and to work in the city, without mentioning the failures of pasture and agricultural activities owing to environmental stressors. In this regard, the interdisciplinary approach of combining surveys and geospatial analyses is pivotal to addressing the environmental drivers of migration. This enabled us to incorporate both the perceived and actual measurements of the environmental driver into the statistical modeling. Again, this result stressed the importance of the standardized measurement to estimate the environmental conditions, which can alleviate personal biases and reconfirmed the usefulness of remote sensing data in migration studies (Bilsborrow & Henry, 2012; Fussell et al., 2014).

3.5.3. Institutional supports: Remaining challenges

While the scientific community has focused on climate/environment induced migration and has suggested several policy implications in response to environmental challenges in recent decade (Bilsborrow & Henry, 2012; Fussell et al., 2014), a gap remains between scientific findings and policy actions. This chapter also indicated the presence of remaining challenges in policy implications and implementations in Mongolia.

Although the conceptual diagram (Figure 3.1) described the importance of the political driver as a core variable that may have substantial causal relationships with other drivers of migration, the household survey (Figure 3.3) resulted in the opposite outcome (i.e., the least important reason compared to the others). Additionally, the political driver in PLS-SEM did not have a statistically significant relationship with the economic and social drivers and exhibited a negative relationship (-0.434) with the environmental driver. These results can be interpreted two ways. On one hand, the Mongolian government did not introduce proper policies to regulate/manage rural-to-urban migration. Further, the land-use policy might disregard the care of the environment during the policy implementations. The land-use policies implemented in the model, the *Law on Land*, i.e., rangeland management, and the *Law on Allocation of Land to Mongolian Citizens for Ownership*, i.e., urban land tenure, encouraged rural residents to become migrants and to be less aware of environmental conditions. Additionally, based on the non-significant path relationships between the social and economic drives (Figure 3.5), I presume that existing land-use policies were largely responsible for the lack of protections and concerns regarding socioeconomic challenges. Given the limited legal support and the positive relationship (0.186) between economic and social drivers (Figure 3.5), the implementation of social protection for the migration framework is critical in the context of the growing economy. On the other hand, the respondents did not clearly understand the impact and influence of land-use laws and policies due to their ‘fuzziness’ and ‘ambiguity’ (Fernandez-Gimenez & Batbuyan, 2004; Undargaa & McCarthy, 2016). Individuals or households often interpreted the phenomenon based on the situation they personally faced (e.g., socioeconomic challenges or hardships) instead of analyzing the underlying facts or root-causes (Black et al., 2011a; Piguet, 2010). Acknowledging the previous studies on the importance of political drivers for rural-to-urban migration in other transitional economies (Adger et al., 2002; Aide & Grau, 2004; Mastrorillo et al., 2016), the political driver cannot be ignored in the migration context. Based on these interpretations, I conclude that while land-use policy and legal ownership were studied as major tools to regulate/control the rural-to-urban migration, they were not only fully implemented but also not informed to the general public in Mongolia. These factors highlighted the need for land-use policies that, respond to changes in environmental and socioeconomic conditions, and the necessity of capacity building for citizens to be able to understand complex policy issues and how policies have has been implemented.

3.5.4. Implication for future migration studies and limitations

While there is a consensus that analysis of migration is required to combine multiple factors (Fussell et al., 2014), relatively few studies have empirically explored the complex system of rural-to-urban migration. Based on a combination of household surveys and RS products, this chapter empirically tested causal connections among multiple drivers of rural-to-urban migration. The results indicated that no single measurement, i.e., income, occupation, gender, and climate change awareness, is able to explain the mechanism of rural-to-urban migration

(Figure 3.4 & Table 3.2). Owing to the complex nature of the environmental drivers of migration, this research also recommends utilizing the standardized measurement, e.g., RS products, to estimate biophysical conditions.

Despite the comprehensive analysis on rural-to-urban migration, some limitations still existed in this research. First, this chapter focused on domestic migration rather than both domestic and international migrations. While international migration has received a wide attention in migration studies recently (Black et al., 2013a; Bylander, 2015), it is more complex to control receiving countries' economic and political status; thus, this chapter limited its study area to Mongolia in order to understand the migration mechanism in response to socioeconomic and environmental changes at the national scale. Second, while there were interesting cases of urban-to-rural migration reported by Neupert (1999) and Fernandez-Gimenez & Batbuyan (2004) after economic failure in the urban areas, in this study, I targeted only the major flow of migration, i.e., rural-to-urban migration. Future research will revisit how these two distinct flows were differently processed. Finally, it requires discretion to directly apply these findings to other contexts because migration varies depending on the local and regional contexts (Black et al., 2011a; Fussell et al., 2014). Thus, I limited the interpretation of the results to a transitional economy withholding a large portion of agro-pastoral livelihoods, where both socioeconomic and environmental changes are simultaneously related. Hence, careful consideration must be given when applying these results to another context.

3.6. Conclusions

Utilizing the principles and findings of interdisciplinary research, I developed an empirical model that outline the four interconnected driving forces of rural-to-urban migration—social, economic, environmental, and political factors. Given the complexity of the migration mechanism, I used both household surveys and Partial Least Squares-Structural Equation Modeling (PLS-SEM) to address the dynamic system of rural-to-urban migration in Mongolia. The survey results stressed the critical importance of social reasons (3.51 out of 5) and economic reasons (3.42 out of 5) for rural-to-urban migration in the context of socioeconomic transformation. While the environmental reasons (2.89 out of 5) was not duly weighed during the surveys, the PLS-SEM revealed the importance of environmental driver as a mediator of the economic drivers. This result also indicated the importance of standardized measurement for estimating environmental conditions. Since survey respondents or residents often linked their reasons for rural-to-migration based on the 'results' rather than 'processes', the variable enabling the measurement of environmental variability is critical. Furthermore, the low score of political reasons (1.23 out of 5) in the household surveys and the non-significant relationships between the political driver and other drivers in the PLS-SEM model indicated the remaining challenges that scientific communities and policymakers are required to address. Thus, the main implication is that existing land-use policies and regulations need to incorporate socioeconomic challenges as well as environmental changes in order to properly manage the trends of rural-to-urban migration. To address this aim, more policy-targeting studies are necessary to enhance society's coping capacity to socioeconomic transformations with dramatic environmental changes.

APPENDIX

Supplementary 3.1

Household Surveys

1) Where does your family live now?
   Which düüreg [ ] and Khoroo [ ]

2) Did your family moved to Ulaanbaatar from the other Aimag during 1990 to 2017?
   1 = Yes
   2 = No

3) Year moved to Ulaanbaatar
   [ ]

4) Where did you live prior to Ulaanbaatar?
   Previous Aimag [ ] and Soum [ ]

5) Why did your family move from your former location? Of all the reasons, could you please measure them corresponding to the importance? Please circle it.

   5-1) Social reasons: for example, Marriage; To seek healthcare (inadequate healthcare in area); To seek schooling (e.g., no school in area); To seek a better quality of life; moved to join other family members.

Not at all influential	Slightly influential	Somewhat influential	Very influential	Extremely Influential

   5-2) Economic reasons: for example, not enough income from livelihood sources; unreliable harvest; crop failure; livestock failure; unemployment in the former place; job opportunity in new place; higher income in new place

Not at all influential	Slightly influential	Somewhat influential	Very influential	Extremely Influential

   5-3) Environmental reasons: for example, water shortage/drought; Dzud (*tsagaan:* heavy snowfall, *tumor:* freezing land, *khuiten:* extreme cold weather).

Not at all influential	Slightly influential	Somewhat influential	Very influential	Extremely Influential

   5-4) Political reasons: for example, landuse rights are not well protected; government provided incentives for us to go; government forced us to move.

Not at all influential	Slightly influential	Somewhat influential	Very influential	Extremely Influential

6) Could you tell us which was your (household) main source(s) of income in your former location?
   1 = Agriculture/Farm / fishing income
   2 = Herder (livestock)
   3 = Shop/business owner
   4 = Civil servant salary
   5 = Salary from industry (firm, factory, corporation)
   6 = Salary from labor (handicrafts, construction)
   7 = Day Labor-Temporary
   8 = Artisanal Mining
   9 = Remittances
   10 = Other ( )

7) Please describe your households

	Respondents(You)	Other Household member					
Gender							
Age							

8) Could you tell us how was your household status in your former residence regarding your economic activity? Please circle it.

Poor	Below Average	Average (middle income)	Above Average	Wealthy

c.f., the monthly average of household income is MNT 263.7 thousand in 2007 and MNT 573.5 thousand in 2011.

9) What was the main reason why your household chose your current location?
   1 = I knew people here
   2 = I had information about the place
   3 = I had a job offer here
   4 = Better wages here
   5 = Better job opportunities here
   6 = More/better land here
   7 = Better quality of life here
   8 = Better education opportunities here
   9 = Better climate
   10 = Better medical care
   11 = Close to family, friend
   12 = Cost of moving is low

10) Have you observed any changes in climate in the last 15-20 years?
   1 = Yes
   2 = No

Chapter 4

Spatiotemporal dynamics of informal settlements: Ger districts in Ulaanbaatar, Mongolia

4.1. Introduction

Over the last half-century, many cities in the Global South have experienced dramatic urban growth (Bolay, 2006; Cohen, 2006). The lack of housing and public services have led to the growth of informal settlements—emerging housings lacking due planning procedure (UN-Habitat, 2003). Based on continuing population growth and urbanization, the UN-Habitat (2010) estimated that the proportion of informal settlers (i.e., slum dwellers) was approximately 32 % of the total global urban population in 2010. Owing to limited public infrastructures and services, this radical growth of informal settlements set off a series of urban environmental issues such as unhygienic condition, waterborne diseases, public health issues, and pollution (Uddin et al., 2014; UN-Habitat, 2003). Though many central and municipal governments in the Global South have introduced diverse instruments (e.g., eradication and re-development) to regulate the growth of informal settlements (Bolay, 2006), they have not slowed down the growth. As cities in the Global South face a severe deterioration in physical, economic, and social living conditions characterized by informal settlements, timely innovative studies are urgently needed to examine the growth of informal settlements.

Since traditional urban planning instruments, i.e., technocratic approaches such as comprehensive and infrastructure planning as well as land reallocation, are not well suited for direct application to cities in Global South (Bolay, 2006), it is necessary to consider remedial solutions with unique local and regional contexts and socio-economic environments. Therefore, understanding the status quo and historical changes of informal settlements would be the first step for incorporating both formal urban planning and informal urban contexts.

Informal settlements studies have been conducted with different perspectives separately including (1) monitoring research for mapping informal settlements (Kohli et al., 2012; Kuffer, Pfeffer, & Sliuzas, 2016; Taubenböck & Kraff, 2014), (2) theorizing the development process of informal settlements (Dovey, 2012; Stroke, 1962), and (3) policy analysis to suggest plausible policy suggestions (Chatterji, 2005; Marx, Stoker, & Suri, 2013, Ward, 1976). However, very few studies have addressed the issues of informal settlements by integrating diverse yet inter-related perspectives of spatial analysis, theoretical approaches, and policy suggestions. While previous studies have developed multiple techniques to improve the detection technique of informal settlements, relatively few studies have conducted extensive analyses based on multi-spatiotemporal scales (Kuffer et al., 2016). In addition, much research has considered informal settlements in the context of "the product" rather than "the process" (Flores-Fernandez, 2011), i.e., the heterogeneity of informal settlements associated with the development processes has not been duly recognized. The informal settlements are mixtures of heterogeneous components and often transformed to different developmental stages as an urban fabric such as upgraded informal settlements and formal housings (Cobbett, 2013; Taubenböck & Kraff, 2014). Thus, it is critical to study the multi-temporal scales and the processes of informal settlements for the purpose of enhancing our understanding of the complexity of informal settlements as well as to propose site-specific pro-poor policies.

With this regard, this chapter aimed to provide (1) multi-spatiotemporal analysis of city-wide informal settlements, (2) analysis of development processes of informal settlements, and (3) policy suggestions in accordance with the land law and evolvement of informal settlements. I targeted Ulaanbaatar, the capital city of Mongolia, which has experienced rapid urbanization over the last three decades (Park et al., 2017). Currently, the city hosts a significant proportion of its residents (45% of the total city population) in informal settlements, referred to as *Ger* districts (The Asia Foundation, 2014). Relatively few informal settlements studies have been conducted on Ulaanbaatar that have considered diverse spatiotemporal scales. Although Amarsaikhan et al. (2009) and Tsutsumida et al. (2015) performed geospatial analysis of the expansion of *Ger* districts, they covered limited temporal and spatial frames and treated *Ger* districts as homogeneous urban fabric. Considering the heterogeneous forms of *Ger* districts (Anderson, Hooper, & Tuvshinbat, 2017; Miller, 2017), it is vital to differentiate the development stages of *Ger* districts to fully understand their growth.

To address the aforementioned research goals, my primary research questions are: (1) What are the development processes of *Ger* districts in Ulaanbaatar? (2) How have spatiotemporal patterns of *Ger* districts changed over the past three decades? and (3) What policy implications can be drawn from the analysis of *Ger* districts? To answer these questions, remote sensing image analysis and semi-structured interviews were conducted to understand the developmental stage of Ger districts. Further, this research applied the machine learning technique to train imagery to develop multi-spatiotemporal *Ger* districts maps from 1990 through 2013. These analyses helped us understand the processes of spatiotemporal patterns of *Ger* districts in Ulaanbaatar as well as to establish policy implications based on the findings.

4.2. Study Area, Data, and Methods

4.2.1. Study Area

Founded in 1639, Ulaanbaatar has been the capital of Mongolian People's Republic since 1924. The city is located on the *Tuul* River in the north-central part of Mongolia (Figure 4.1). As the capital and the largest city of Mongolia, Ulaanbaatar has been the political, economic, educational, and cultural center of Mongolia (Byambadorj, Amati, & Ruming, 2011). According to the 2016 national statistics, Ulaanbaatar has a population of 1,440,000 which accounts for 46.2% of the total national population. Most of its urban population growth happened after the collapse of Soviet Union in 1990 (Neupert, 1999; Sneath, 2003). As the growth of Ulaanbaatar was regulated under the state socialism before the transition, the population of Ulaanbaatar was below 600,000 in 1990 (Miller, 2017). However, dramatic changes in environmental and socioeconomic conditions have led to rural-to-urban migration during the transitional periods (Chen et al., 2015a; Chen et al., 2015b; Fan P. et al., 2016; Park et al., 2017). Consequently, Ulaanbaatar has experienced a significant expansion of informal settlements, mostly in the form of small, portable felt tents used by nomads in grasslands, known as a *Ger* (Tsutsumida et al., 2015*)*. Since the areas are not equipped with public water and sewage systems, most of the residents are vulnerable to disease and contamination issues.

Ulaanbaatar has a unique land distribution system that has had mixed outcomes. While most informal settlers in developing countries struggle to own land legally (Taubenböck & Kraff, 2014), the *Law of Mongolia on Land* and the *Law on Allocation of Land to Mongolian Citizens for Ownership* allow citizens to privatize land for residential purposes (Bauner & Richter, 2006, Miller, 2017). These policies have allowed residents to hold the legal ownership of *Ger* districts. On the other hand, these unique laws may have unintentionally led to the deterioration of urban environments and living conditions owing to limited infrastructures and services. Since the government did not regulate the number of household registration until 2017, most *Ger* districts have been built without proper planning and management.

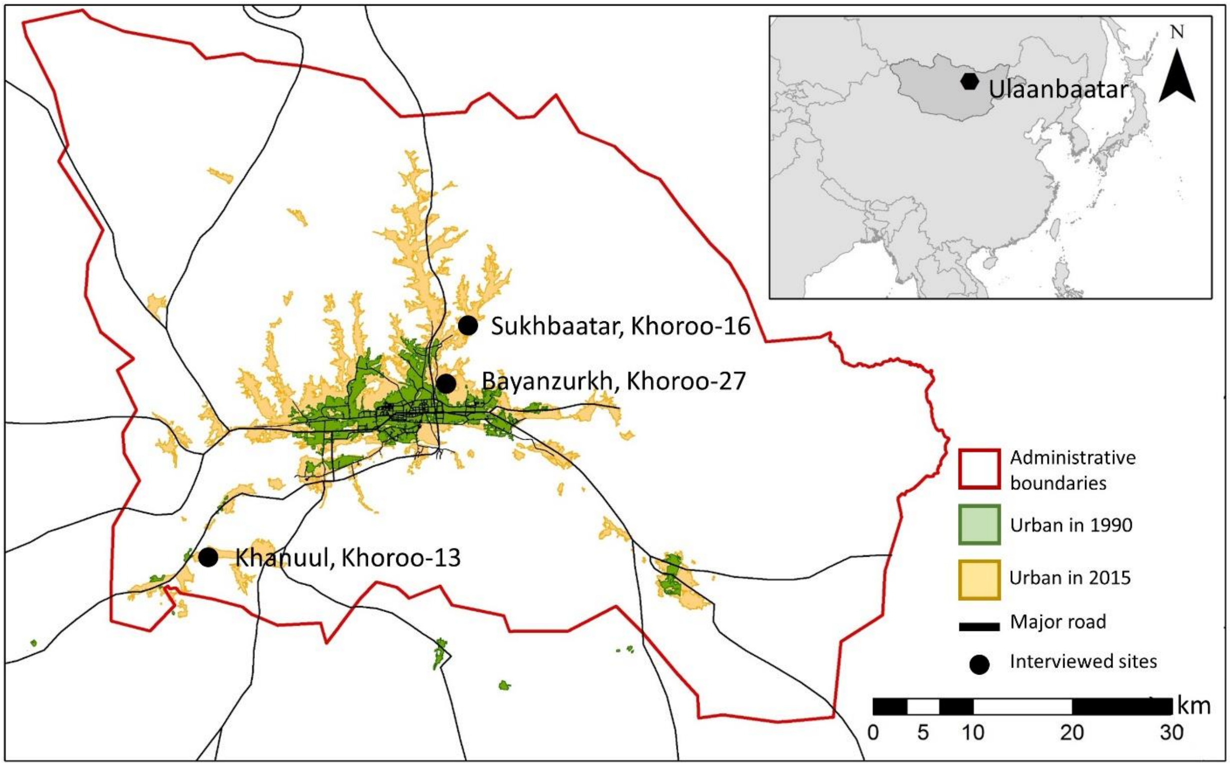


Figure 4.1. The growth of Ulaanbaatar from 1990 to 2015. Interviews were conducted near the city center as well as fringe areas. Sukhbaatar, Bayanzurkh, and Khanuul are districts of Ulaanbaatar, Mongolia. Khoroo is an administrative sub-district.

4.2.2. Remote sensing data and pre-processing

I utilized one Very High Resolution (VHR) QuickBird image and four multi-temporal Landsat images for delineating *Ger* districts identification (Supplementary Table 4.1). The QuickBird imagery was used to delineate complex urban features—such as Gers, detached houses, vegetation, soil, and impervious area. Combining the Landsat imagery and QuickBird classification results, this chapter aimed to highlight changes of informal settlements during three decades. The QuickBird image was provided by National Geospatial-intelligence Agency (NGA) commercial archive data (https://cad4nasa.gsfc.nasa.gov/). This image originally consisted of four standard color bands (red, green, blue, and near-infrared bands) at from 2.44m (nadir) to 2.88m (off-nadir) spatial resolution and one panchromatic band at 0.61m (nadir) to

0.72m (off-nadir) spatial resolution. To produce a single high-resolution multispectral image at 0.65m resolution, the Subtractive Resolution Merge (SRM) tool in ERDAS 2014 was applied to fuse the higher resolution panchromatic band with the lower resolution multispectral bands. While the optimal way to produce the classification of *Ger* districts is to replicate the same algorithm to other QuickBird Imagery, QuickBird imagery has limited historical records (i.e., only available since 2003). I therefore collected Landsat images for four years (1990, 2000, 2005, and 2013) from USGS (https://earthexplorer.usgs.gov/) for change analysis of *Ger* districts (Supplementary Table 4.1). I selected periods after 1990 because the rapid urbanization started after the collapse of the Soviet Union in 1990. Additionally, to minimize the effects of atmospheric fluctuations for multi-temporal imagery, I selected same season data (i.e., September or October) and conducted radiometric calibration and atmospheric corrections by using Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) in ENVI 5.1™ software. All images are re-projected into the same projection: Albers conical equal area (Figure 4.2).

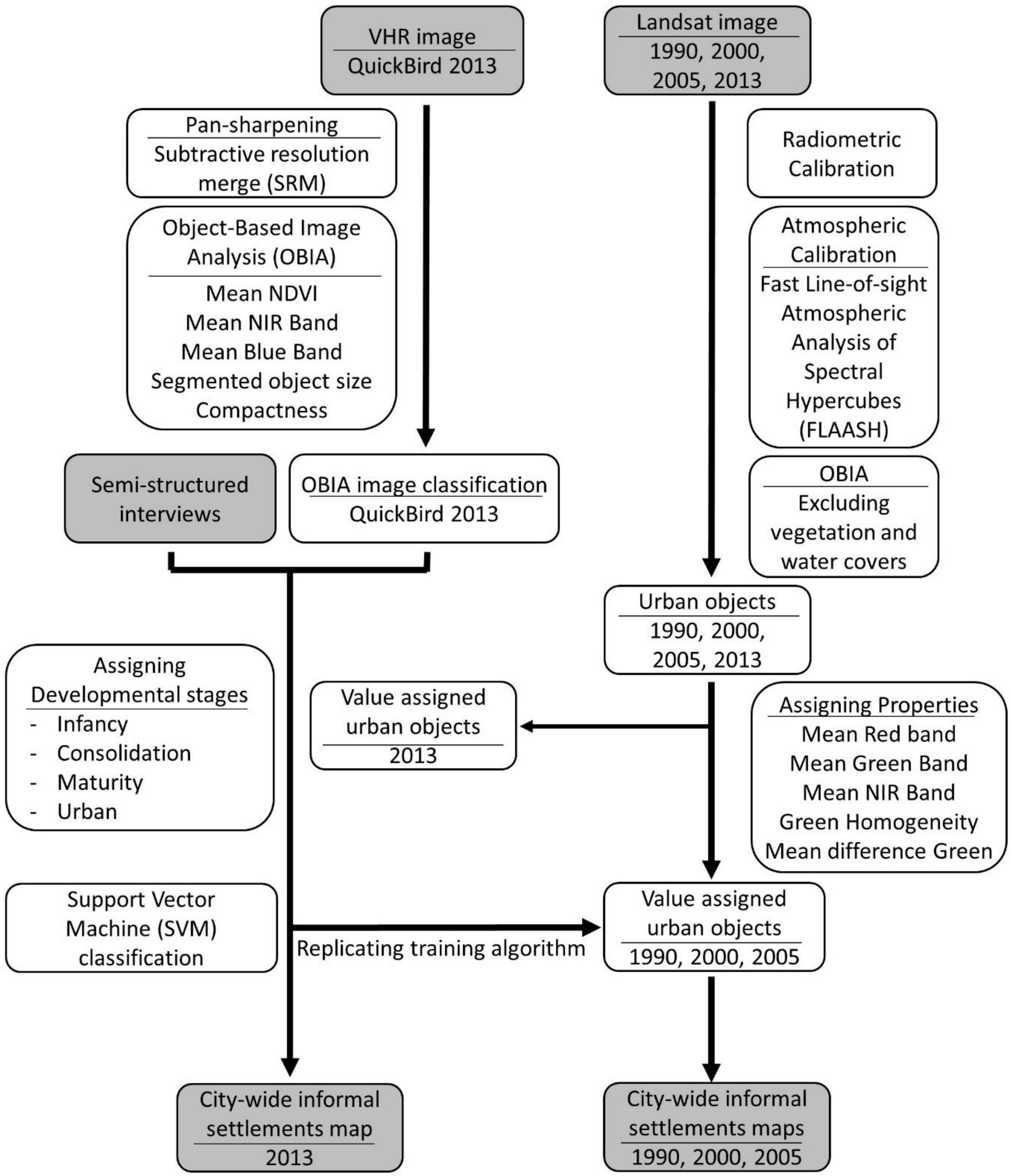


Figure 4.2. Flowchart describing the classification process of *Ger* districts (i.e., informal settlements) using VHR image and trained Landsat imagery to analyze the developmental stages of *Ger* districts in 1990, 2000, 2005 and 2013.

4.2.3. Detecting Ger districts from QuickBrid imagery

I applied Object-Based Image Analysis (OBIA) to the QuickBird image as a viable alternative to ground surveys for effectively identifying informal settlements (Duque et al., 2015; Kohli et al., 2016; Kuffer et al., 2016). Due to the large spectral variation and heterogeneity among pixels of VHR imagery, OBIA is regarded as a more suitable approach for VHR images than pixel-based approaches because of its ability to utilize spectral, geometric, contextual, and textual information (Hay & Blaschke, 2010). The objective of this section was to classify *Ger* districts based on their unique spatial elements (i.e., circular shape and white color of *Gers*). This research used eCognition™ for the OBIA analysis.

To reduce merging and processing time, I delineated different land use and land cover types at three different levels (Table 4.1). First, the image was segmented into "homogeneous" image objects using multi-resolution segmentation (Scale = 30, W_{shape} = 0.3, $W_{compactness}$ = 0.5, where Scale defines the maximum standard deviation of the homogeneity, the shape parameter W_{shape} modifies the weighing between spatial homogeneity and spectral values of image, and the compactness parameter $W_{compactness}$ determines the objects based on the spectral contrasts) (Trimble, 2014). I then classified image objects into two classes; vegetation, and impervious area, based on rulesets defined by NDVI and NIR thresholds (Table 4.1). The unclassified image objects were merged and re-segmented into the second level of image objects with a larger scale (Scale= 60). After exploring the unique color and shapes of Gers, image objects that satisfied three rules, NIR ≥ 500 and 40 ≤ Area ≤ 96 and Compactness ≤ 1.6, were classified as Gers. (Table 4.1). The remaining unclassified areas again were re-segmented into a higher level (third level) with a larger scale parameter (Scale=100, W_{shape} = 0.5, $W_{compactness}$ = 0.5) to classify soil and detached houses. Images objects were classified as soil if their mean value of NIR ≤ 510) and Blue band ≥ 300. Detached houses were classified based on the mean value of NIR (Mean NIR > 510) and the size (Area ≤ 300 pixels) of the image objects. All optical threshold values were determined empirically through iterative trials and testing.

Table 4.1. Ruleset summary and the quantitative classification criteria with the sequence from top to bottom.

Sequence	Classification steps	Ruleset
1	Generate object primitives at level 1	Multiresolution segmentation (Scale =30, W_{shape} = 0.3, $W_{compactness}$ = 0.5)
2	Classify vegetation	Mean NDVI ≥ 0.24
3	Classify impervious area	Mean NIR ≥ 300, Mean NDVI ≤ 0.15
4	Generate object primitives at level 2	Multiresolution segmentation (Scale=60, W_{shape} = 0.3, $W_{compactness}$ = 0.5)
5	Informal settlement (*Ger*) classification	Mean NIR ≥ 500, 40 ≤ Area (pixels) ≤ 96, Compactness ≤ 1.6
6	Generate object primitives at level 3	Multiresolution segmentation (Scale=100, W_{shape} = 0.5, $W_{compactness}$ = 0.5)
7	Soil Classification	Mean NIR ≤ 510, Mean B ≥ 300,
8	Informal settlement (detached house) classification	Mean NIR > 510, Area ≤ 300 pixel

4.2.4. Understanding developmental stages of Ger districts

Two major benefits can be gained from establishing the developmental stages of *Ger* districts: 1) addressing the heterogeneity and transitional status of informal settlements, and 2) scaling up the spatial resolution of the results from VHR QuickBird to match the resolution of Landsat imagery (30m). I conducted semi-structured interviews with local staff from the Asia Foundation—a philanthropic organization that supports less-privileged communities—in July and August 2015, in order to understand the developmental stages of *Ger* districts. The research team contacted the residents through Kheseg (micro district) leaders, regarding the possibility of conducting interviews on the following topics: current status of living, housing status, history of housing and their plan for upgrading (Supplementary Questionnaires). Under these main topics, I conducted 10-15 minute semi-structured interviews.

Based on these field observation and interviews, I interpreted development stages of *Ger* districts into three different groups: infancy, consolidation, and maturity. As described in the case of Mongolia (Miller, 2017) and other examples of Latin American countries (Flores-Fernandez, 2011), the residents built better homes or transformed building materials based on the capital accumulation. These three groups can be described based on their physical conditions and surrounding environments: a) *Gers* with detached houses on the open areas of natural space; b) *Gers* with a relatively large portion of detached houses surrounded by some soil and impervious area; and c) *Gers* with a relatively large portion of impervious area and buildings (Figure 4.3).

a) Infancy b) Consolidation c) Maturity

Figure 4.3. Examples of different development stages of *Ger* districts (i.e., informal settlements) in Ulaanbaatar, Mongolia. The white circular felt tent is an example of a traditional Mongolian house, a *Ger,* which is commonly used by nomads.

4.2.5. Delineation of Ger districts in different developmental stages

Based on the OBIA classification in section 4.2.3, this research successfully extracted the *Ger* districts in Ulaanbaatar (Figure 4.4). The snapshots of (a), (b), and (c) demonstrate the three different typologies of *Ger* districts in line with the field observations and semi-structured interviews in section 4.2.4.

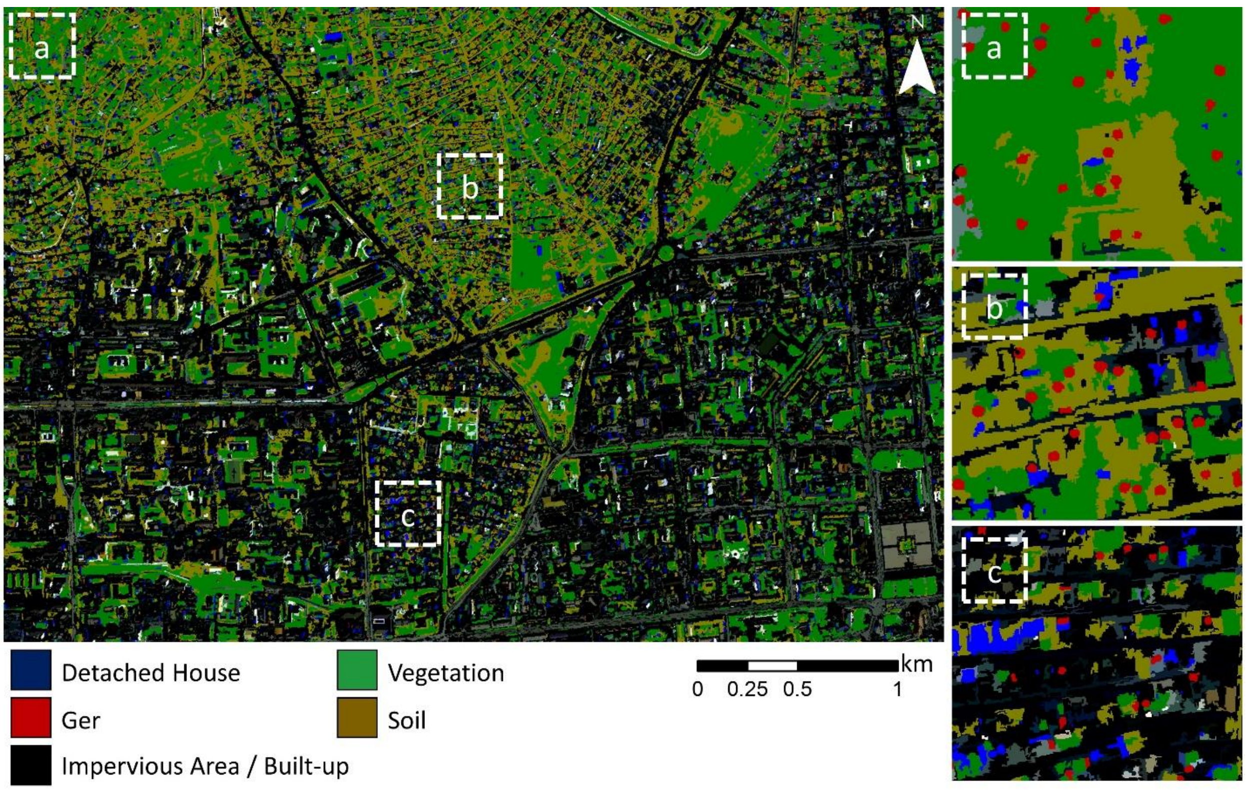


Figure 4.4. Ger districts delineations using OBIA analysis: (1) detached house; (2) *Ger*; (3) impervious area; (4) vegetation; and (5) soil. The Ger districts are described as three different types: (a) infancy: *Ger*s with detached houses on a relatively large portion of vegetation and soil; (b) consolidation: *Gers* with relatively large numbers of detached houses; and (c) maturity: *Gers* with a relatively large portion of impervious areas.

While the OBIA analysis (Figure 4.4) accomplished the above-detailed objectives, complex urban features are necessary to be categorized in order to match spatial resolution with Landsat imagery (30m). The OBIA result from QuickBird and segmented urban features from Landsat imagery were utilized to assign developmental stages of *Ger* districts. I selected the

Landsat imagery in September 2013 because it was close to the acquisition time of the QuickBird imagery. The image was first segmented at a relatively larger scale (Scale = 100, $W_{shape} = 0.3$, $W_{compactness} = 0.5$), which was used to mask out vegetation and water. I then re-segmented the rest of the area with a smaller-scale (i.e., 50) to delineate urban features. Using a set of 50 urban samples, I classified a superclass: urban objects which includes built-up areas and informal settlements using the Nearest Neighbor Classifier in the eCognition™. Lastly, I overlaid the OBIA result on the urban objects and assigned the developmental stage of *Ger* districts. Particularly, I categorized urban objects as having over 80% impervious area into urban areas. Further, I classified *Ger* districts based on the existence of *Gers,* detached houses, and surrounding environments (e.g., soil, vegetation, and impervious areas). The developmental stage classification was conducted by integrating local knowledge and object features' characteristics to meet a visually satisfying level of classification throughout the iterative procedure. First, I classified the infancy *Ger* districts based on the existence of *Ger* and the proportion of soil and vegetation cover (80%>) in the segmented urban objects. The *Ger* districts with a higher proportion of detached houses (30%>) were reclassified as the consolidation stage. The *Ger* districts with a higher proportion of impervious area (25% >) were classified as the maturity stage.

4.2.6. Landsat imagery and Support Vector Machine (SVM) classification

I used the developmental stages of *Ger* districts developed in section 4.2.5. as a training data set of Support Vector Machine (SVM) classification algorithm for multiple years of imagery. I processed Landsat imagery of 1990, 2000, 2005 to produce a superclass, urban objects, just as I did for 2013 Landsat imagery in section 4.2.5. The SVM was applied to classify the superclass of urban objects into four sub-classes: built-up area, infancy, consolidation, and maturity stages of

Ger districts. SVM is a classification methodology that can enhance the level of accuracy while considering nonlinear functions (Hsu, Chang, & Lin, 2004). I assigned properties (i.e., spectral and textural characteristics) in each classified urban objects, and I named those as the value assigned urban objects. As informal settlements consist of heterogeneous features, it is critical to include parameters that quantify this heterogeneity (Kohli et al., 2016). Thus, I incorporated textural characteristics in the classification process (Supplementary Table 4.2). Notably, I assigned Gray Level Co-occurrence Matrix entropy for Green band (GLCM_G) and Mean Difference of Green band intensity to neighbors (Mean_DG). Further, I assigned Mean Red band intensity (Mean_R), Mean Green band intensity (Mean_G), and Mean NIR band intensity (Mean_NIR).

The development stages of *Ger* districts were applied to train the SVM algorithm to develop a function between selected features (i.e., Mean red band, Mean green band, Mean NIR band, GLCM Green, and Mean difference G) and the developmental stages of *Ger* districts (i.e., infancy, consolidation, and maturity stages of *Ger* districts and urban) in 2013 Landsat imagery. This training algorithm was then used on Landsat images of 1990, 2000, and 2005.

4.2.7. Validation and accuracy assessment

Due to the unique characteristics of OBIA (i.e., various scales of segmented objects), there is no universal rule for validation of OBIA classification (MacLean & Congalton, 2012; Ouyang et al., 2016). I thus adopted the pixel-based accuracy assessment method (Ouyang et al. 2011 & 2016). The 200 stratified random polygons within urban-objects (60m x 60m)—i.e., 50 polygons for each classification of urban, infancy, consolidation, and maturity—were selected within the boundary of the urban objectives. Since this research classified *Ger* districts rather than individual households, the polygon size was determined by considering both Landsat resolution and average *Ger* household sizes (700 m^2). The reference classes of each of the selected polygons were then determined by manual interpretation of VHR images from Google Earth. I overlaid the selected polygons on Google Earth VHR images to interpret the proportion of *Ger*s, detached houses, impervious area, soil, and vegetation. According to the proportions suggested in section 4.2.5., I assigned each polygon as one of four classes: urban, and infancy, consolidation, and maturity stages of *Ger* districts. The reference classes of the selected polygons were then compared to the OBIA classifications results in order to develop developing user's, producer's, and overall accuracies (Supplementary Table 4.3).

The polygon-based accuracy assessment confirmed the decent quality of the informal settlement classification. The overall accuracies of the *Ger* district maps for 2005 and 2013 were 74% and 76%, respectively (Supplementary Table 4.3). While this chapter successfully conducted the validation of 2005 and 2013 imagery with Google Earth Pro application, the limited history of high-resolution images restricted us from applying the same method for 1990 and 2000 images validation. Instead of using visual interpretation, I referenced previous literature to support the results. Cities Alliance (2010) and The Asia Foundation (2014) confirmed the growth trend of *Ger* districts and categorized the chronological and geographical order as central, mid-tier, and fringe areas, which corresponded to the growth pattern shown in the 1990 and 2000 development stage maps of *Ger* districts (Figure 4.6).

4.3. Results

4.3.1. Growth of Ger districts and conversions.

During the study period of 1990-2013, the total urbanized area of Ulaanbaatar increased by 242%. In the meantime, *Ger* districts exhibited a steeper rate of increase from 32.15 km^2 to 221.15 km^2. While the built-up area grew by 62% during the study period, the area of *Ger* districts including infancy, consolidation, and maturity stages increased by 588 % (Figure 4.5). The infancy stage of *Ger* districts consistently expanded from 19.94 km^2 to 153.49 km^2. The area of the infancy stage districts became a major land cover type in Ulaanbaatar in 2000, and has since drastically increased. Impervious area showed a sharp increase between 2005 and 2013 (Figure 4.5).

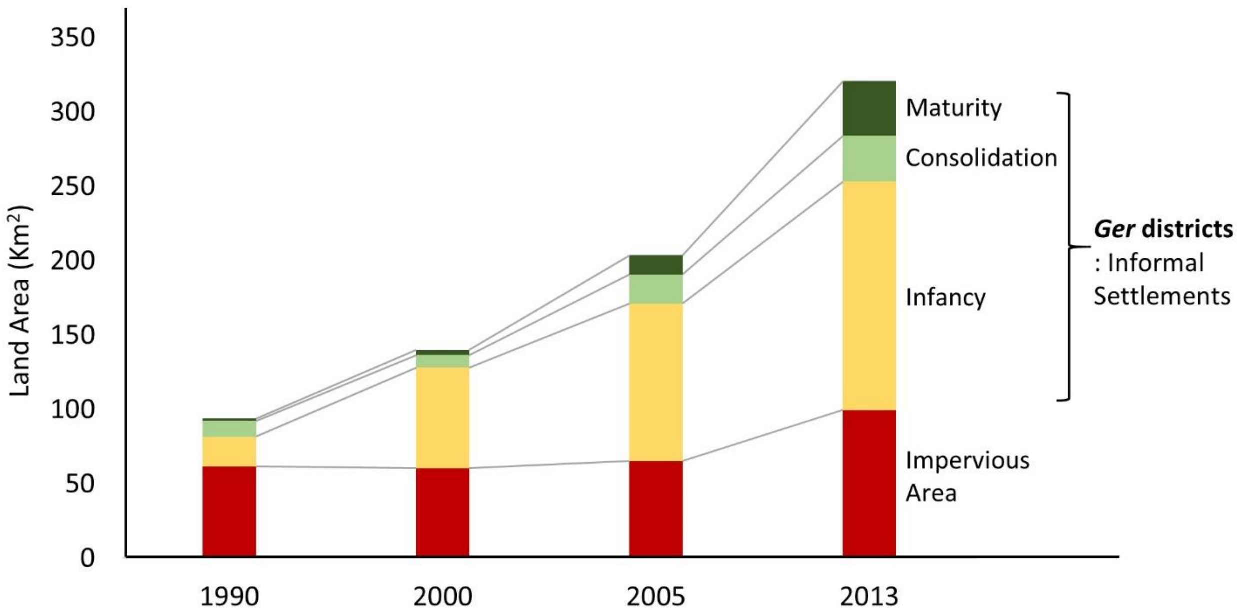


Figure 4.5. The growth of *Ger* districts (i.e., informal settlements) in Ulaanbaatar, Mongolia. The *Ger* districts including infancy, consolidation, and maturity exhibited the continuous growth trend, and the impervious area (built-up) significantly expanded between 2005 and 2013.

The infancy stage of *Ger* districts has changed/evolved to different stages of development as infill development occurred. Particularly, the infancy stages of *Ger* districts in 1990 have existed 65.55% in 2005 and 44.81% in 2013 (Table 4.2). The results exhibited the transformation of *Ger* districts from infancy to consolidation and maturity stages, or urban built-up areas. By 2013, more than half of the infancy-stage *Ger* districts that existed in 1990 had been converted to different types of settlements. The 27.53% of infancy-stage *Ger* districts have transformed to maturity-stage *Ger* districts (27.53%)—those having physically transformed housings and public infrastructure—and the 11.08% of ones have converted to impervious area, which referred to the formal urban housings (e.g., apartment blocks) and paved roads (Table 4.2).

Table 4.2. Results of cross-tabulated areas between infancy stage of *Ger* districts in 1990 and the classified map of 2000, 2005 and 2013

	Infancy	Consolidation	Maturity	Impervious area
2000	87.92% (17.44 km^2)	1.90% (0.38 km^2)	2.36% (0.47 km^2)	7.83% (1.55 km^2)
2005	65.55% (13.03 km^2)	13.35% (2.65 km^2)	4.87% (0.97 km^2)	16.23% (3.23 km^2)
2013	44.81% (8.92 km^2)	16.58% (3.30 km^2)	27.53% (5.48 km^2)	11.08% (2.21 km^2)

4.3.2. Spatiotemporal dynamics of Ger districts

The spatial growth of *Ger* districts differed in each time period (Figure 4.6). The increase of *Ger* districts mainly appeared along the periphery of the cities (i.e., spill-over patterns) in both 1990 and 2000 and the leap-frogging patterns were not as apparent. For this period, it is hard to track the growth stage progression of *Ger* districts (e.g., from infancy to consolidation or maturity). In 2005, however, the expansion of *Ger* districts occurred in the northern part of the city along the major roads (i.e., linear aggregation) and the leap-frogging pattern became apparent approximately 20 km away from the city center. Furthermore, I observed the changed status of *Ger* districts near the city center (i.e., infill development) across the study period (Table 4.2). In 2013, the city itself largely expanded, including the impervious area (i.e., built-up and road) and *Ger* districts. Interestingly, the growth of *Ger* districts has proceeded in multiple ways (i.e., spill-over, linear aggregation, infill, and leap-frogging patterns). The areas of infancy stage develpments along the major roads have increased over time and leap-frogged settlements have also expanded and increased in number, while infancy-stage *Ger* districts near the city center have been largely converted to either consolidation or maturity-stage *Ger* districts (Table 4.2).

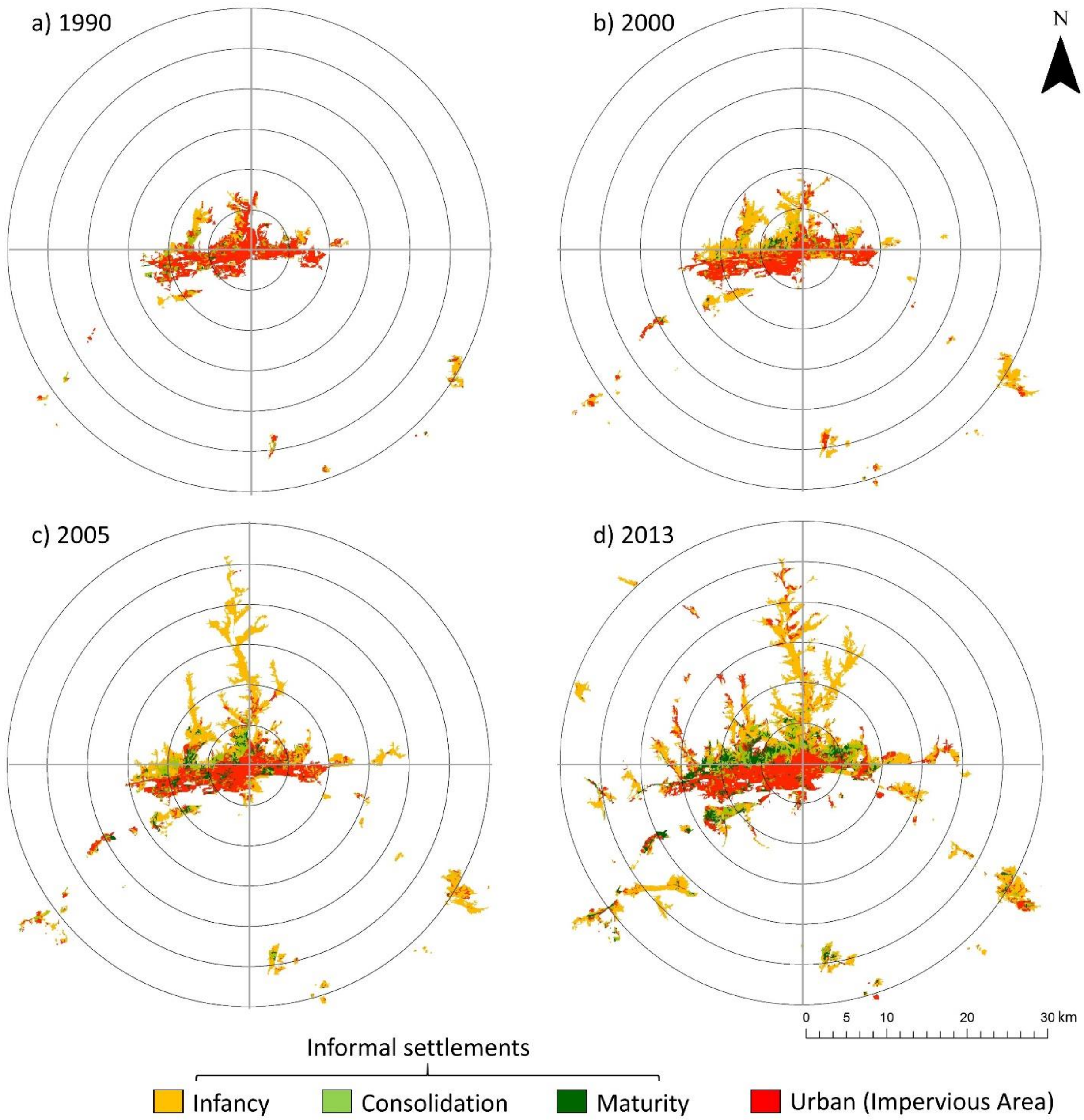


Figure 4.6. Spatiotemporal dynamics of *Ger* districts (i.e., informal settlements) on Ulaanbaatar in 1990, 2000, 2005, and 2013, overlaying with 5km-interval multiple buffers (six buffers: 30km) from the city center.

4.4. Discussion

4.4.1. Spatial dynamics of Ger districts in response to urban challenges

The growth of *Ger* districts exhibited distinct spatial patterns (i.e., linear aggregation, spillover, infill, and leap-frogging) during the study period. This research verified that the emergence of

Ger districts in the infancy stage occurred along major roads. As discussed in Dore and Nagpal (2006) and Byambadorj et al. (2011), the limited accessibility of public transportation has led incoming residents to reside in areas close to major roads (i.e., linear aggregation). Based on these linear aggregations, the maps of 2005 and 2013 exhibited star-shaped urban patterns, which occurred due to transportation accessibility and physical conditions similar to those described by Antrop (2004) in other urbanized areas.

Meanwhile, the expansions of *Ger* districts, i.e., spillover, have been represented throughout the study period. Since many areas adjacent to the city center and major roads—areas with highly accessible public infrastructure and services—have been rapidly occupied, the incoming residents reside as described in the following interview excerpt (Supplementary Questionnaires-2).

> *Usually they (migrants) come to the khoroo (sub-district) through families and relatives. Since most of the lands that are close to the city center or main road are taken, they settle wherever they can find land.* - Anonymous *khoroo* coordinator from Bayangol district, Ulaanbaatar, July-August 2015

These spillover patterns are usually observed in the emerging cities of the Global South due to the availability of employment opportunities and workplaces accessibility (Vermeiren et al., 2012; Inostroza, 2017). Unfortunately, this spillover pattern often leads to incoming residents residing physically vulnerable regions (e.g., high slope, and hazard-prone areas). In Ulaanbaatar, incoming residents often occupy such areas due to the lack of available land close to the city center (Figure 4.7). These spillover areas are prone to landslides and floods (Cities Alliance, 2010) and suffer from a widespread of waterborne diseases (Uddin et al., 2014).

Figure 4.7. The growth of *Ger* districts; many incoming residents used to settle down on the physically vulnerable regions.

Infill developments (i.e., those that have changed/evolved to different stages of development) are widely observed for 2005 and 2010 (Figure 4.6 & Table 4.2). As described by Miller (2017) and confirmed by our interviewees, the process of auto-construction is widely adopted after a household accumulates capital. Two anecdotal pieces of evidence from the semi-structured interview described auto-construction and the gradual development process of *Ger* districts (Supplementary Questionnaires-3).

> *"We live in a Ger; the house needs renovation. We would like to build a better house using blocks or wood"*- Anonymous interviewee from Bayanzurkh district, Ulaanbaatar, July-August 2015

> *"We used to live in a Ger when we first moved in and built this bigger house in 2008."* - Anonymous interviewee from Bayanzurkh district, Ulaanbaatar, July-August 2015

The leap-frogging patterns, referring to as urban sprawl as the development interspersed with vacant land, occurred as a response to the above physical challenges. The maps of 2005 and 2010 described these patterns outside of the city center (ring-buffer range beyond 10km). Notably, 2013 map shows the emerging *Ger* districts compared to the other years. A combination of limited accessibility of transportation infrastructures and public services, overcrowded populations, and accompanying environmental problems promoted the leap-frogging patterns for the incoming residents. The interviewees from *Ger* districts in the outskirts of Ulaanbaatar substantiated the above findings, as emphasized in this interview excerpt (Supplementary Questionnaires-5):

> *"I don't really want to move there because of the air pollution and constant car traffic. This area is much calmer"*- Anonymous interviewee from Khanuul district, Ulaanbaatar, July-August 2015

As Anderson, Hooper, and Tuvshinbat (2017) asserted the growing concerns of the density and physical environments on *Ger* districts, the leap-frogging patterns would be maintained upon exacerbated environments and living conditions of the city. Therefore, governmental support for the provision of basic needs including the supply of water and electricity are urgent issues. Effective support systems of public services and infrastructure also need to be considered in the fringe areas.

4.4.2. Drivers of the growth of Ger districts

The availability of economic opportunities and public services are widely known as strong drivers of the growth of informal settlements (Bolay, 2006; Cohen, 2006). I found similar trends in Ulaanbaatar, Mongolia. During the transitional period from the 1990s until now, the wealth concentration of the capital has been fortified (Chen et al., 2015a; Park et al., 2017). Withdrawal of state subsidies led a concomitant closing down of collective farms and shareholding companies in rural areas (Endicott, 2012). The unbalanced economic opportunities and public services promoted rural-to-urban migration and concomitant growth of *Ger* districts (Dore & Nagpal, 2006). An interview with a *khoroo* (sub-district) coordinator also described economic opportunity as a primary reason for settling in *Ger* districts as below (Supplementary 4.2.1):

> *Main reason for the growth is for better economic opportunities. The khoroo has a relatively large marketplace, which provides jobs, and easy access for shopping for the residents.* - Anonymous *khoroo* coordinator from Sukhbaatar district, Ulaanbaatar, July-August 2015

In addition to economic opportunity, land privatization has played a pivotal role in the growth of *Ger* districts. As I discussed earlier, Mongolia has a unique land distribution system that allows new urban residents to own land (Miller, 2017). The 89% of *Ger* districts households privatized their land (Cities Alliance, 2010), which is exceptionally higher than informal settlements of other developing countries. Considering the two land privatization laws that were implemented in 2002 and the Supreme Court's decision for the free movement of population in 2003, I tentatively concluded that the laws and institutional supports have promoted the drastic growth of *Ger* districts post 2000. Further evidence can be found in an interview with Governor's office in *Khan-Uul* districts: "*The land in the khoroo has been open for the citizens for the last few years, so many citizens without land settled there to own their land*."

4.4.3. Future of Ger districts and policy implications

While I have discussed the low qualities of living conditions and environmental challenges of *Ger* districts represented as a spatial disparity, the analysis of different stages of development brought optimistic views on the *Ger* districts based on the observations of infill development: namely auto-construction. The early *Ger* districts near the city center have evolved into the consolidation and maturity stages (Table 4.2). This result empirically proved how legal land ownership contributes to auto-construction (i.e., self-help housings or self-upgrading). As illustrated in figure 4.3, many residents built/transformed their housings based on their capital accumulation during the study period. Considering the importance of land ownership on poverty alleviation (Inostroza, 2017), the *Ger* districts withholding legal land ownership would be alternative solutions for affordable housings given limited resources. Although Ulaanbaatar's master plan 2020 aimed to provide affordable apartments by bulldozing *Ger* districts and redeveloping (The Asia Foundation, 2014), their targets were not met due to a limited budget and lack of financial support. While I cannot claim that *Ger* districts are suitable for permanent living, the stable land ownership and subsequent capital accumulation of household would be plausible tools for urban-land management in the emerging cities of the Global South. During the field interviews, I also observed the optimistic views of the residents on the future of *Ger* districts. Many residents told us their plans for housing upgrades and small businesses in their parcels. Therefore, proper municipal/governmental interventions (e.g., providing public services and transportation infrastructures) will enable residents to sustain their livelihoods. City and central governments, thus, should not only consider *Ger* districts as objectives for bulldozing but also as an opportunity to alleviate the lack of housing and interconnected societal problems.

4.4.4. The limitations of this study and beyond

This chapter aimed to study spatiotemporal dynamics of *Ger* districts in Ulaanbaatar. Combining with satellite imagery and field interviews appeared to be a suitable tool for mapping dynamics of *Ger* districts. While this approach still necessitates a manual process to include local knowledge and ground truths, this would provide alternative guidance for mapping informal settlements under limited time and human resources.

While the analytical methods of this chapter illustrated several benefits, some challenges ramain. First, current results cannot be generalized to other regions. Since the characteristics of informal settlements and following spatial patterns are highly contextual relying on local and regional contexts, it requires discretion to directly apply this finding to other regions. Thus, I strongly suggest that qualitative interviews be conducted to understand the local context, as each site has distinct land laws and institutional supports. Second, as noted in the result section, there is some limitation in the validation of the image classification results of 1990 and 2000. Though I validated the classification results based on previous literature due to the limited data, more ground-truth or ancillary data (e.g., official planning documents or geo-referenced photography) would make the results more plausible.

4.5. Conclusions

This chapter analyzed the spatiotemporal dynamics of informal settlements, known as *Ger* districts, in Ulaanbaatar by using qualitative interviews and satellite imagery analysis. I found that *Ger* districts have increased from 32.15 km^2 to 221.15 km^2 from 1990 to 2013. Furthermore, the continued growth of *Ger* districts indicated that the informal settlements are facing ongoing challenges in Ulaanbaatar. The presence of both spill-over and leapfrog development patterns indicated that the government should consider not only urban redevelopment in the inner-city area but also support basic facilities for the fringe area of Ulaanbaatar. Furthermore, the infill development (i.e., conversion from infancy to consolidation or maturity stages) implies that proper government intervention would be an alternative option to support *Ger* districts as affordable housing areas. While this chapter mainly discussed the processes and spatial patterns of *Ger* districts, I hope that this paper could be a stepping-stone for follow-up studies to understand the mechanisms of informal urbanization and to design urban policies for sustainable urban management in Mongolia and beyond to other cities of the Global South.

APPENDIX

Supplementary Table 4.1. Description of remote sensing data applied in the image processing

Category	Date	Function
QuickBird (0.61 m – 0.72 m resolution)	2013-10-17	To classify complex urban features
Landsat TM/ETM+ (30 m resolution)	1990-09-10 2000-09-13 2005-10-21	To classify developmental stages of *Ger* districts (i.e., informal settlements)
	2013-09-25	To develop the classification algorithm between QuickBird and Landsat imagery.

Supplementary Questionnaires. Sample Questions from Semi-Structured Interviews

Date:

District (Duureg):

Sub-district (Khoroo):

Interviewer:

Duration:

1) **General Introduction**
   - Please introduce yourself, and how long have you been in this town? During your stay, did you rent a house or hold an ownership of the land?
   - If you are not from Ulaanbaatar, where is your previous living places, and when you moved to Ulaanbaatar? What is the primary reason for you to settle down in Ulaanbaatar?
   - Why you choose this specific places?

2) **History of town**
   - Could you tell us about history about this town? Please describe the neighborhoods when you settled down.
   - When and why the town is becoming bigger?
   - What is the biggest challenge in your neighborhoods?

3) **Housing status**
   - Please describe your housing when you move to this town.
   - Did you fix or upgrade housings? If yes, which part did you fix/upgrade?
   - Do you have any plan to fix/upgrade some part of your housing?

4) **Current status of living**
   - How many family members do you have?
   - Do they have a job? If yes, what kind of jobs they have? Whether is full-time, part-time, or seasonal employment? And where are their employment locations?
   - What is the main income source of your household?

5) **Plan for relocation**
   - If you want to move to the other location shortly? Where do you consider? What factors may affect you decide?

Note: Additional follow-up questions were asked to interviewees in order to acquire in-depth information of topics.

Supplementary Table 4.2. Definitions of the parameters used in the classification. The detailed information is provided in Trimble (2014)

Parameter	Description
Mean_R	Mean red band intensity value of an image object
Mean_G	Mean green band intensity value of an image object
Mean_NIR	Mean NIR band intensity value of an image object
GLCM_G	Gray Level Co-occurrence Matrix entropy for Green. The measure of orderliness within the green band of an image object
Mean_DG	The difference of green band intensity values between an image object and its neighbor image objects.

Supplementary Table 4.3. The accuracies: User Accuracy (UA), Producer Accuracy (PA), and Overall Accuracy (OA), of the *Ger* districts (i.e., informal settlements) classification resulting from visual interpretation in 2005 and 2013.

	Reference Data							
Classified Image	**2005**	Infancy	Consolidation	Maturity	Urban	Row Total	UA (%)	PA (%)
	Infancy	46	2	0	2	50	92	67
	Consolidation	9	33	2	6	50	66	83
	Maturity	8	3	29	10	50	58	88
	Urban	6	2	2	40	50	80	69
	Column Total	69	40	33	58		**OA (%)**	**74**
	2013	Infancy	Consolidation	Maturity	Urban	Row total	UA (%)	PA (%)
	Infancy	43	6	1	0	50	86	66
	Consolidation	7	37	3	3	50	74	80
	Maturity	4	3	36	7	50	72	84
	Urban	11	0	3	36	50	72	78
	Column Total	65	46	43	46		**OA (%)**	**76**

Chapter 5
Conclusions

5.1. Conclusions

5.1.1. Divergent mechanisms of urbanization in IM and MG

While previous studies have identified the driving forces of urbanization, relatively few studies have empirically investigated the many factors that affect this phenomenon (e.g., socioeconomic and environmental changes). Here, I used the Mongolian Plateau (MGP) (i.e., Inner Mongolia (IM) and Mongolia (MG)) to investigate how different socioeconomic and institutional factors influence the process of urbanization while controlling for environmental conditions.

There are both similarities and differences in the spatiotemporal patterns of urbanization in IM and MG. The six MGP cities studied in this dissertation research (Hohhot, Baotou, and Ulanqab in IM and Ulaanbaatar, Erdenet, and Darkhan in MG) displayed similarly rapid urban expansion from 1990 through 2015. Urban areas in IM increased 4.36 times in that period of transition, and ones in MG increased 3.12 times. On the contrary, though cities in IM exhibited less dense and more sprawling patterns, cities in MG showed linearly aggregated urbanized patterns along major roads. These differences were influenced by the divergent governmental roles in urban development in these two contexts. In IM, local governments played a substantial role in the developments seen in urban areas through the establishment of economic development zones and provision of public infrastructure. In MG, however, local government has had a more limited role in urban development, meaning most of the observed development projects were initiated by private-sector entities.

The multiple forces driving urbanization (i.e., economic development, social goods, and the environment) differentially affected urbanization in IM and MG during the transitional period. Partial least squares structural equation models (PLS-SEM) demonstrated that economic development is a major driver of urbanization in IM; however, in MG, economic development and social goods strongly influenced urbanization. While many previous studies focused on the importance of economic and employment opportunities as a significant driver of urbanization, this result indicated the importance of social goods as a major driver in the transitional period particularly when experiencing a lack of governmental supports. Furthermore, the environmental driver and the economic development is highly associated with it in MG. This implies that the varying degrees of institutional support for social goods and public services, and the importance of the pastoral sector each nation's economy, brought different mechanisms of urbanization.

5.1.2. Urban migration as a coping mechanism to socioeconomic and environmental changes

Since rural-to-urban migration relies on diverse stakeholders' aggregated behaviors corresponding to multiple changes and events, a more nuanced understanding of household-level decision-making is vital for quantitatively examining *why* and *how* rural-to-urban migration occurred. Given the complex factors associated with rural-to-urban migration, a conceptual model outlining the four interconnected forces driving rural-to-urban migration—social, economic, environmental, and political—was developed and employed to design household surveys and statistical modeling.

Household surveys investigated the perceived importance of the social, economic, environmental, and political reasons behind rural-to-urban migration, using a Likert scale ranging from 1 (not at all influential) to 5 (extremely influential)—with mean (std) scores of 3.51 (1.21), 3.42 (1.21), 2.89 (1.31), and 1.23 (0.75), respectively. From this, I determined that social and economic reasons have a significant influence on rural-to-urban migration in MG. Considering the socioeconomic-transformations (e.g., marketization of the economy, restructuring of industry, and significant reduction in public healthcare and education systems) and urban-centric development seen during the study period, it is clear that many rural residents migrated to urban areas as a strategy for coping with socioeconomic transformation.

While environmental reasons were less significant in the survey results, a combination of biophysical variables from RS products and statistical modeling revealed their underlying importance (as a mediator) in influencing rural-to-urban migration. Given the high share of the national economy that is comprised of the livestock industry and recent climate variability, environmental conditions must be considered in relation to recent migration trends. Since the general public often misinterprets the reasons for rural-to-migration based on its “outcomes” (e.g., economic challenges) rather than ”processes” (e.g., extreme weather causing high livestock mortality), a standardized measurement for estimating environmental variability is required. For this, using a combination of surveys and biophysical variables is crucial for exploring both the perceived and actual environmental conditions that affect migration and understanding complex rural-to-urban migration mechanisms.

Political reason from surveys and political driver (i.e., latent variables from statistical modeling) were the least weighted. This finding showed the challenges that remain to be bridged between scientific research and policy implementations in the MG. Despite political factors not being viewed by survey respondents as a significant driver of rural-to-urban migration, many previous studies have discussed the importance of land-use policies and regulations in addressing socioeconomic and environmental challenges. Therefore, I concluded that existing policies in Mongolia did not adequately accommodate recent challenges and were not fully introduced to or accessible by the general public. Thus, to learn how best to enhance rural residents’ capacity to cope with socio-economic transformations and dramatic environmental changes, more research into policy implications is necessary.

5.1.3. Informal urbanization and urban sustainability

After the collapse of the Soviet Union, Ulaanbaatar, the capital of Mongolia, experienced unprecedented growth in informal settlements (i.e., *Ger* districts). Its unique land distribution system—allowing migrants to privatize land in the city for residential purposes—exacerbated this trend. In addition to investigating the processes of urbanization in the MGP and the factors driving household-level migration decisions, my research provides insight into the developmental stages and spatial patterns of informal settlements to suggest policy improvements that could plausibly achieve urban sustainability.

The satellite image analyses found that *Ger* districts in Ulaanbaatar increased by 588% between 1990 and 2013. Multi-temporal imagery analysis identified spill-over and linearly aggregated patterns of informal settlements. Due to the limited accessibility of infrastructure and public services, informal settlements have been developed in areas adjacent to the city center and along major roads.

Using narratives collected via semi-structured interviews, I identified three different developmental stages of *Ger* districts (infancy, consolidation, and maturity). Residents of *Ger* districts upgraded their current dwellings or built better (more stable) housing as they accumulated capital. These processes of updating and additional building were also observed during the study period in the satellite imagery analyses, in particular, infill development (i.e., when infancy-stage *Ger* districts are converted into consolidated or mature ones). This confirmed that these *Ger* districts are heterogeneous and evolving.

While the growth of *Ger* districts is one of its greatest problems of emerging cities, the evolution of *Ger* districts (i.e., self-upgrading) in Ulaanbaatar can be viewed optimistically. Unlike many cities in the Global South, the unique land laws and policies in Mongolia allow migrants to gain ownership of land. Based on this, informal settlers are able to sustain their livelihoods. Considering the limited access of freshwater, electricity, and heating services, the infancy stage of *Ger* districts is not suitable for permanent living. However, if adequate resources are provided (e.g., public services and transportation infrastructure), similar policies to create stable land ownership, and subsequently capital accumulation, could be utilized as plausible tools for emerging cities in the Global South. Razing and redeveloping informal settlements cannot be the only solution for informal urbanization, nor can these practices achieve sustainable urban land management in the Global South.

5.1.4. Policy Implications

The results presented above imply diverged patterns and drivers of urbanization and emerging urban challenges in the MGP. While IM and MG both share a similar biophysical setting, it is obvious that differences in institutional support and context introduced diverging urbanization characteristics in IM and MG. Chapter 2 revealed the importance of social goods in the process of urbanization in MG, as they have been highly concentrated in the limited urban areas and unevenly distributed. This demonstrates a lack of institutional support towards social goods, which is critical for sustainable urban development, from central and local governments in MG. This finding is reconfirmed in Chapter 3: a non-significant relationship between political and social factors imply that the lack of social protections and services in MG. Mongolia's central government also must consider development packages that effectively reach both urban and rural areas, such as those of IM's central and regional governments that provide public education and healthcare services, including: "Western Development Project", "Compulsory Education Program" and "8337 Development Strategy". Since rural residents of MG have faced growing poverty and disparity compared to residents in urban areas (Dore et al., 2008), the improvement of social goods in rural areas would alleviate rural-urban disparities as well as the excessive rural-to-urban migrations. Given the critical role of local government in effective public services (Bardhan, 2002), it is necessary to assess the possible decentralization of public services (i.e., healthcare and public education) at the local level when considering policy implementation. Due to the sparse rural population of MG and its physical distance to the capital, the central government has not effectively responded to local challenges (Levitas, 2008). An active local government in MG and decentralization of public services would enable an effective response to local challenges and residential needs.

Given the high vulnerability the pastoral economy of MG to climate variability, it is vital that proper land-use regulation be adopted. As Chapter 2 points out, MG has experienced a drastic increase in livestock that may lead to land degradation and lower the adaptive capacity of pastoralists. Following the collapse of collective and state-owned farms in MG, no formal regulation of land-use and a lack of mobile coordination arose. In IM, the outcomes of "Grassland Law" and "Household Contract Responsibility System" (Table 5.1) promoted a growth of livestock and ecological fragmentation. MG had also experienced a drastic growth of livestock following land degradation. However, unlike IM, the grassland conservation policies are not fully developed in MG. Appropriate conservation policies in grassland are necessary, as MG has faced several land degradation challenges due to rapid urbanization, overgrazing, and surface mining.

Table 5.1. Summaries of land-use regulation and policies in pre- and post-transitional periods in IM and MG.

<table>
<tr><td colspan="3">Inner Mongolia, People's Republic of China (IM)</td></tr>
<tr><td>Pre-"Open-door" policy
(1949 – 1978)</td><td>Post-"Open-door" policy
(1978 – 2000)</td><td>Current
(2000 – Present)</td></tr>
<tr><td>• Land Revolution
• Grains First
: large portion of grassland was transformed to agricultural land</td><td>• Grassland Law in 1985
• Household Contract Responsibility System
: resulted in increasing number of livestock and reducing mobility</td><td>• Natural Forest Protection Projects
• Grain to Green Project
: grassland has shown increasing trends</td></tr>
<tr><td colspan="3">Mongolia (MG)</td></tr>
<tr><td>Soviet period
(1960-1990)</td><td colspan="2">Post-Soviet period
(1991 – Current)</td></tr>
<tr><td>• Collectives
• State-owned farms
: enforced/managed seasonal movements of livestock</td><td colspan="2">• Law on Land in 1994
• Law on Allocation of Land to Mongolian Citizens for Ownership in 2002
: transferred responsibility of grassland management from community to individual households, and promoted rural-to-urban migration by distributing land-ownership</td></tr>
</table>

Climate variability and its impact is still abstract to the public. However, the capacity building and education on extreme climate events would be important avenues toward climate action. In turn, this will enhance the adaptive capacity of residents in the MGP. As discussed in Chapter 3, extreme climatic events have influenced the rural-to-urban migrants' agricultural and economic failures. Many respondents in the household surveys in Chapter 3 did not fully recognize the impacts of climatic events. Furthermore, the associated policies and laws have also not been clearly understood by the public due to 'fuzziness' and 'ambiguity' (Fernandez-Gimenez & Batbuyan, 2004; Undargaa & McCarthy, 2016). Thus, capacity building aims to target not only governmental officers but also local stakeholders. Particularly, as the "2030 Agenda for Sustainable Development" stated, raising awareness of local stakeholders, tailoring broader goals to a realistic agenda, and engaging local stakeholders in policy development processes are critical. Climate variability awareness capacity building and education in the MGP is the first step to implement broader Sustainable Development Goals (SDGs) into local and regional planning.

5.2. Limitations and future research

5.2.1. Possible spatial mismatches of geospatial data

In this dissertation research, I utilized RS imagery as a proxy data for measuring urbanization and environmental conditions. There is a limitation coming from spatial resolution mismatches. Particularly in Chapter 2, due to limited publicly available data, I constructed an SEM model based on municipal statistics rather than district statistics. Since the spatial characteristics of the city could vary across district by district, my analysis only exhibits general trends of urbanization. For Chapter 3, I calculated environmental conditions (e.g., temperature, precipitation, and NDVI) by averaging the values of the respondents' former residential districts (i.e, *Soum).* However, this may cause over- or underestimation due to the diverse district size—the smallest of which is 100.32km^2 and the largest is 28014.91km^2. Districts served as proxies of geo-coordinates as it was impossible to determine the exact latitude and longitude from each survey respondent. More precise measurements would make for better estimations of environmental conditions. For Chapter 4, due to the limited availability of high-resolution imagery, I referenced previous literature to validate the informal settlements. This may also cause over- and under- estimation of growth of informal settlements. For a more robust result, historical maps may be used to validate the result of RS imagery analyses.

5.2.2. Data before the transitional period

This dissertation focused on urbanization in the MGP during a period of significant transition, 1990–2015. Combined findings from three chapters illustrated several complex mechanisms of transitional economies. In principle, however, it would have been best if I had had baseline data (e.g., socioeconomic information and urbanization ratios) from prior to the transitional period to facilitate comparisons of different trends and patterns in urbanization ante- and post-transition. This approach would help better identify potential entry points for intervention to help ensure successful and sustainable urban development. Due to the limited availability of public-use datasets for the MG during the Soviet period, it was not possible to secure the necessary pre-1990 data to establish such baselines. A further study is being planned to collect such data, after which the relevant comparisons will be conducted.

5.2.2. Rural-to-urban migration mechanism in Inner Mongolia, China

The exploration of motivations for migration, discussed primarily in Chapter 4 above, focused on the complex mechanisms of rural-to-urban migration in MG owing to its substantial scale and the greater climate vulnerability of its rural areas compared to IM. A comparative analysis of rural-to-urban migration mechanisms in IM and MG would help us understand how different institutional settings affect these mechanisms at the household level. Building on this comparative analysis, existing policies and proposed future changes could be tested while controlling for the environmental conditions of the MGP. Therefore, conducting household surveys among residents of IM would be a logical next step in expanding our understanding of the complex mechanisms of rural-to-urban migration in this region, and in transitional economies more broadly.

5.2.3. Urban-to-rural migration in Mongolia

Throughout my dissertation, I have focused exclusively on urbanization and rural-to-urban migration, which were the major demographic changes in MG during the study period. Recent studies, however, have reported some cases of urban-to-rural migration after economic failure or maladjustment to urban areas. Given growing evidence of inequality in cities stemming from the lack of employment opportunities and limited access to public services (e.g., healthcare and education), this urban-to-rural migration may increase even further. Therefore, future research is necessary to revisit this trend and investigate the causes and processes of urban-to-rural migration, as well as comparing these opposing trends in migration.

BIBLIOGRAPHY

BIBLIOGRAPHY

Adger, W. N., Kelly, P. M., Winkels, A., Huy, L. Q., & Locke, C. (2002). Migration, remittances, livelihood trajectories, and social resilience. *AMBIO: A Journal of the Human Environment, 31*(4), 358-366.

Aide, T. M., & Grau, H. R. (2004). Globalization, Migration, and Latin American Ecosystems. *Science, 305*(5692), 1915-1916.

Alberti, M., Asbjornsen, H., Baker, L. A., Brozovic, N., Drinkwater, L. E., Drzyzga, S. A., Jantz, C. A., Fragoso, J., Holland, D. S., Kohler, T. A., Liu, J., McConnell, W. J., Maschner, H. D. G., Millington, J. D. A., Monticino, M., Podestá, G., Pontius, R. G., Redman, C. L., Reo, N. J., Sailor, D., & Urquhart, G. (2011). Research on coupled human and natural systems (CHANS): Approach, challenges, and strategies. The Bulletin of the Ecological Society of America, 92, 218–228.

Allington, G. R., Li, W., & Brown, D. G. (2017). Urbanization and environmental policy effects on the future availability of grazing resources on the Mongolian Plateau: Modeling socio-environmental system dynamics. *Environmental Science & Policy, 68*, 35-46.

Amarsaikhan, D., Blotevogel, H. H., Ganzorig, M., & Moon, T. H. (2009). Applications of remote sensing and geographic information systems for urban land-cover change studies in Mongolia. *Geocarto International, 24*(4), 257-271.

Anderson, R., Hooper, M., & Tuvshinbat, A. (2017). Towers on the steppe: Compact city plans and local perceptions of urban densification in Ulaanbaatar, Mongolia. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 10*(2), 217-230.

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

Augustijn-Beckers, E.-W., Flacke, J., & Retsios, B. (2011). Simulating informal settlement growth in Dar es Salaam, Tanzania: An agent-based housing model. *Computers, Environment and Urban Systems, 35*(2), 93-103.

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

Bardhan, P. (2002). Decentralization of Governance and Development. *Journal of Economic Perspectives, 16*(4), 185-205

Barrios, S., Bertinelli, L., & Strobl, E. (2006). Climatic change and rural–urban migration: The case of sub-Saharan Africa. *Journal of Urban Economics, 60*(3), 357-371.

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.

Bilsborrow, R. E., & Henry, S. J. F. (2012). The use of survey data to study migration–environment relationships in developing countries: Alternative approaches to data collection. *Population and Environment, 34*(1), 113-141.

Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011a). The effect of environmental change on human migration. *Global Environmental Change, 21*, S3-S11.

Black, R., Adger, W. N., Arnell, N. W., Dercon, S., Geddes, A., & Thomas, D. (2011b). Migration and global environmental change. *Global Environmental Change, 21*, S1-S2.

Black, R., Arnell, N. W., Adger, W. N., Thomas, D., & Geddes, A. (2013a). Migration, immobility and displacement outcomes following extreme events. *Environmental Science & Policy, 27*, Supplement 1, S32-S43.

Black, R., Kniveton, D., & Schmidt-Verkerk, K. (2013b). *Migration and Climate Change: Toward an Integrated Assessment of Sensitivity.* In T. Faist & J. Schade (Eds.), *Disentangling Migration and Climate Change: Methodologies, Political Discourses and Human Rights* (pp. 29-53). Dordrecht: Springer Netherlands.

Bolay, J.-C. (2006). Slums and urban development: Questions on society and globalisation. *The European Journal of Development Research, 18*(2), 284-298.

Boyle, P. J., Halfacree, K., & Robinson, V. (1998). *Exploring Contemporary Migration*. Harlow: Longman.

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.

Byambadorj, T., Amati, M., & Ruming, K. J. (2011). Twenty-first century nomadic city: Ger districts and barriers to the implementation of the Ulaanbaatar City Master Plan. *Asia Pacific Viewpoint, 52*(2), 165-177.

Bylander, M. (2015). Depending on the Sky: Environmental distress, migration, and coping in rural Cambodia. *International Migration, 53*(5), 135-147.

Call, M. A., Gray, C., Yunus, M., & Emch, M. (2017). Disruption, not displacement: Environmental variability and temporary migration in Bangladesh. *Global Environmental*

Change, 46, 157-165.

Castles, S., & Miller, M. J. (1998). *The age of migration: International population movements in the modern world* (2nd ed.). London ; Basingstoke: Macmillan.

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

Chatterji, R. (2005). Plans, habitation and slum redevelopment: The production of community in Dharavi, Mumbai. *Contributions to Indian Sociology, 39*(2), 197-218.

Chen, J., John, R., Zhang, Y., Shao, C., Brown, D. G., Batkhishig, O., Amarjargal, A., Ouyang, Z., Dong, G., Wang, D., & Qi, J. (2015a). 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., Brown, D.G., Qi, J., Han, H., Lafortezza, R., & Dong, G. (2015b). 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

Cities Alliance (2010). Citywide pro-poor Ger area upgrading strategy of Ulaanbaatar city. *Cities Alliance Project.* Ulaanbaatar, Mongolia.

Cobbett, W. (2013). How cities can get rid of slums by supporting them. *Informal City Dialogues, 22*.

Cohen, B. (2006). Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society, 28*, 63-80.

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.

Dovey, K. (2012). Informal urbanism and complex adaptive assemblage. *International Development Planning Review, 34*(4), 349-368.

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.

Duque, J. C., Patino, J. E., Ruiz, L. A., & Pardo-Pascual, J. E. (2015). Measuring intra-urban poverty using land cover and texture metrics derived from remote sensing data. *Landscape and Urban Planning, 135*, 11-21.

Dürr, E. (2012). Urban poverty, spatial representation and mobility: Touring a slum in Mexico. *International Journal of Urban and Regional Research, 36*(4), 706-724.

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, 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.

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

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.

Fernandez-Gimenez, M. E., Batkhishig, B., & Batbuyan, B. (2012). Cross-boundary and cross-level dynamics increase vulnerability to severe winter disasters (dzud) in Mongolia. *Global Environmental Change, 22*(4), 836-851.

Fernandez-Gimenez, M. E., Batkhishig, B., & Batbuyan, B. (2012). Cross-boundary and cross-level dynamics increase vulnerability to severe winter disasters (dzud) in Mongolia.

Global Environmental Change, 22(4), 836-851.

Fernández-Giménez, M. E., Venable, N. H., Angerer, J., Fassnacht, S. R., Reid, R. S., & Jamyansharav, K. (2017). Exploring linked ecological and cultural tipping points in Mongolia. *Anthropocene, 17*, 46-69.

Fernández-Giménez, M. E. (1999). Sustaining the steppes: a geographical history of pastoral land use in Mongolia. *Geographical Review, 89*(3), 315-342.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., . . . Snyder, P. K. (2005). Global Consequences of Land Use. *Science, 309*(5734), 570-574.

Frey, W. H. (1996). Immigration, domestic migration, and demographic balkanization in America: new evidence for the 1990s. *Population and Development Review,* 741-763.

Flores-Fernandez, R. (2011). Physical and spatial characteristics of slum territories-vulnerable to natural disasters. *Les Cahiers d'Afrique de l'Est, 44*, 5-22.

Fussell, E., Hunter, L. M., & Gray, C. L. (2014). Measuring the environmental dimensions of human migration: The demographer's toolkit. *Global Environmental Change, 28*, 182-191.

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

Gefen, D., Rigdon, E. E., & Straub, D. (2011). Editor's comments: An update and extension to SEM guidelines for administrative and social science research. *MIS Quarterly, 35*(2), A1-A7.

Gilbert, A., & Gugler, J. (1992). *Cities, Poverty and Development: Urbanization in the Third World*. Oxford: Oxford University Press.

Goldman, M. (2014). Development and the city. In F. Miraftab & N. Kudva (Eds.), *Cities of the Global South Reader* (pp. 54-65). New York: Routledge.

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.

Hirt, S. (2013). Whatever happened to the (post)socialist city? *Cities, 32, Supplement 1*, S29-S38.

Hunter, L. M., Luna, J. K., & Norton, R. M. (2015). Environmental dimensions of migration. *Annual review of sociology, 41*, 377-397.

Hsu, C.-W., Chang, C.-C., & Lin, C.-J. (2004). A practical guide to support vector classification. Retrieved from http://www.csie.ntu.edu.tw/~cjlin/papers/guide/guide.pdf.

IMF. (2000). Transition economies: An IMF perspective on progress and prospects. Retrieved from http://www.imf.org/external/np/exr/ib/2000/110300.htm

Inostroza, L. (2017). Informal urban development in Latin American urban peripheries: Spatial assessment in Bogotá, Lima and Santiago de Chile. *Landscape and Urban Planning, 165*, 267-279.

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.

Ji, C. Y., Liu, Q., Sun, D., Wang, S., Lin, P., & Li, X. (2001). Monitoring urban expansion with remote sensing in China. *International Journal of Remote Sensing, 22*(8), 1441-1455.

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.

Jin, M., Dickinson, R. E., & Zhang, D. (2005). The footprint of urban areas on global climate as characterized by MODIS. *Journal of Climate, 18*(10), 1551-1565.

John, R., Chen, J., Kim, Y., Ou-yang, Z.-t., Xiao, J., Park, H., . . . Qi, J. (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.

John, R., Chen, J., Ou-Yang, Z.-T., Xiao, J., Becker, R., Samanta, A., . . . Batkhishig, O. (2013). Vegetation response to extreme climate events on the Mongolian Plateau from 2000 to 2010. *Environmental Research Letters, 8*(3), 035033.

Kamata, T., Reichert, J., Tsevegmid, T., Kim, Y., & Sedgewick, B. (2010). Mongolia: Enhancing

Policies and Practices for Ger Area Development in Ulaanbaatar. *The World Bank: Washington, DC, USA*.

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.

Kit, O., & Lüdeke, M. (2013). Automated detection of slum area change in Hyderabad, India using multitemporal satellite imagery. *ISPRS Journal of Photogrammetry and Remote Sensing, 83*(0), 130-137.

Knight, J., & Song, L. (1999). *The Rural-urban Divide: Economic Disparities and Interactions in China*. Oxford: Oxford University Press.

Kohli, D., Sliuzas, R., Kerle, N., & Stein, A. (2012). An ontology of slums for image-based classification. *Computers, Environment and Urban Systems, 36*(2), 154-163.

Kohli, D., Sliuzas, R., & Stein, A. (2016). Urban slum detection using texture and spatial metrics derived from satellite imagery. *Journal of Spatial Science, 61*(2), 405-426.

Koubi, V., Spilker, G., Schaffer, L., & Bernauer, T. (2016). Environmental Stressors and Migration: Evidence from Vietnam. *World Development, 79*, 197-210.

Kuffer, M., Pfeffer, K., & Sliuzas, R. (2016). Slums from space—15 years of slum mapping using remote sensing. *Remote Sensing, 8*(6), 455.

Kuffer, M., Pfeffer, K., Sliuzas, R., Baud, I., & Maarseveen, M. (2017). Capturing the diversity of deprived areas with image-based features: The case of Mumbai. *Remote Sensing*, *9*(4), 384.

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.

Ledent, J. (1982). Rural-urban migration, urbanization, and economic development. *Economic Development and Cultural Change, 30*(3), 507-538.

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

Levitas T. (2008). Rethingking state-local relations in Mongolia Today: Possible directions for local government reform, *UNDP Local Government Support Project,* NY: UNDP.

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.

Liu, J., Dietz, T., Carpenter, S. R., Folke, C., Alberti, M., Redman, C. L., Schneider, S. H., Ostrom, E., Pell, A. N., Lubchenco, J., Taylor, W. W., Ouyang, Z., Deadman, P., Kratz, T., & Provencher, W. (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, 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., Yue, W., Fan, P. (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, Y., Rao, K., Evans, T., Chen, Y., & Hsiao, W. (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., Zhuang, Q., Chen, M., Pan, Z., Tchebakova, N., Sokolov, A., Kicklighter, D., Melillo, J., Sirin, A., Zhou, G., He, Y., Chen, J., Bowling, L., Miralles, D., & Parfenova, E. (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.

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.

MacLean, M. G., & Congalton, R. G. (2012). Map accuracy assessment issues when using an object-oriented approach. Paper presented at the *Proceedings of the American Society for Photogrammetry and Remote Sensing 2012 Annual Conference*.

Massey, D. S. (1990). Social structure, household strategies, and the cumulative causation of migration. *Population Index*, 3-26.

Marx, B., Stoker, T., & Suri, T. (2013). The economics of slums in the developing world. *The Journal of Economic Perspectives, 27*(4), 187-210.

Mastrorillo, M., Licker, R., Bohra-Mishra, P., Fagiolo, G., D. Estes, L., & Oppenheimer, M. (2016). The influence of climate variability on internal migration flows in South Africa. *Global Environmental Change, 39*, 155-169.

Mayer, B. (2016). Climate migration and the politics of causal attribution: A case study in

Mongolia. *Migration and Development, 5*(2), 234-253.

Mbembé, J.-A. (2004). Aesthetics of superfluity. *Public Culture, 16*(3), 373-405.

McMillan, J., & Naughton, B. (1992). How to reform a planned economy: Lessons from China. *Oxford Review of Economic Policy, 8*(1), 130-143.

McLeman, R., & Smit, B. (2006). Migration as an adaptation to climate change. Climatic Change, 76(1-2), 31-53.

McLeman, R. (2014). *Climate and Human Migration: Past experiences, Future Challenges.* New York: Cambridge University Press.

Miller, R. (2017). Settling between legitimacy and the law, at the edge of Ulaanbaatar's legal landscape. *Traditional Dwellings and Settlements Review, 29*(1), 7-20.

Miraftab, F., & Kudva, N. (2014). *Cities of the Global South Reader*. New York: Routledge.

Mirza, M. M. Q. (2003). Climate change and extreme weather events: can developing countries adapt? *Climate Policy, 3*(3), 233-248.

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.

Morrissey, J. W. (2013). Understanding the relationship between environmental change and migration: The development of an effects framework based on the case of northern Ethiopia. *Global Environmental Change, 23*(6), 1501-1510.

Montgomery, M. R. (2008). The urban transformation of the developing world. *Science, 319*(5864), 761-764.

National Statistical Office of Mongolia. (2015). *Mongolian statistical yearbook 2015.* Ulaanbaatar, Mongolia: National Statistical Office of Mongolia.

Neil Adger, W. (1999). Social vulnerability to climate change and extremes in coastal Vietnam. *World Development, 27*(2), 249-269.

Neumann, K., Sietz, D., Hilderink, H., Janssen, P., Kok, M., & van Dijk, H. (2015). Environmental drivers of human migration in drylands – A spatial picture. *Applied Geography, 56*, 116-126.

Neupert, R. F. (1999). Population, Nomadic Pastoralism and the Environment in the Mongolian Plateau. *Population and Environment, 20*(5), 413-441.

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. Jr, & N. T. Hobbs (Eds.), *Fragmentation in Semi-Arid and Arid Landscapes: Consequences for Human and Natural Systems* (pp. 179-193). Dordrecht: Springer Netherlands.

Ouyang, Z., Fan, P., & Chen, J. (2016). Urban built-up areas in transitional economies of Southeast Asia: Spatial extent and dynamics. *Remote Sensing, 8*(10), 819.

Ouyang, Z., Zhang, M.-Q., Xie, X., Shen, Q., Guo, H.-Q., & Zhao, B. (2011). A comparison of pixel-based and object-oriented approaches to VHR imagery for mapping saltmarsh plants. *Ecological Informatics, 6*(2), 136-146.

Park, H., Fan, P., John, R., & Chen, J. (2017). Urbanization on the Mongolian Plateau after economic reform: Changes and causes. *Applied Geography, 86*, 118-127.

Piguet, E. (2010). Linking climate change, environmental degradation, and migration: a methodological overview. *Wiley Interdisciplinary Reviews: Climate Change, 1*(4), 517-524.

Qi, J., Chen, J., Wan, S., & Ai, L. (2012). Understanding the coupled natural and human systems in Dryland East Asia. *Environmental Research Letters, 7*(1), 015202.

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.

Roberts, B. R. (1989). Urbanization, migration, and development. *Sociological Forum, 4*(4), 665-691.

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., Sultana, N., Finucane, M., Nguyen, L., & Vien, T. D. (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. (2011). Exploring the dynamics of migration to mega-delta cities in Asia and Africa: Contemporary drivers and future scenarios. *Global Environmental Change, 21, Supplement 1*(0), S94-S107.

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.

Sneath, D. (2003). Land use, the environment and development in post-socialist Mongolia. *Oxford Development Studies, 31*(4), 441-459.

Sobreira, F., & Gomes, M. (2001). The geometry of slums: Boundaries, packing and diversity. *CASA Working Paper Series, 30*, Retrieved from http://www.casa.ucl.ac.uk.

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., & Govind, S. (2011). Quantifying surgical and anesthetic availability at primary health facilities in Mongolia. *World Journal of Surgery, 35*(2), 272-279.

Stokes, C. J. (1962). *A theory of slums. Land Economics, 38*(3), 187-197.

Stubblefield, A., Chandra, S., Eagan, S., Tuvshinjargal, D., Davaadorzh, G., Gilroy, D., . . . Hogan, Z. (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.

Taubenböck, H., & Kraff, N. J. (2014). The physical face of slums: A structural comparison of slums in Mumbai, India, based on remotely sensed data. *Journal of Housing and the Built Environment, 29*(1), 15-38.

The Asia Foundation. (2014). *Ulaanbaatar 2020 Master Plan and Development Approaches for*

2030. Ulaanbaatar: The Asia Foundation.

Thiede, B., Gray, C., & Mueller, V. (2016). Climate variability and inter-provincial migration in South America, 1970–2011. *Global Environmental Change, 41*, 228-240.

Thwaites, R., de Lacy, T., Hong, L. Y., & Hua, L. X. (1998). Property rights, social change, and grassland degradation in Xilingol Biosphere Reserve, Inner Mongolia, China. *Society & Natural Resources, 11*(4), 319-338.

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.

Trimble. (2014). *eCognition Developer: 9.0 User Guide*. Munich, Germany: Trimble Germany GmbH.

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.

Uddin, S. M. N., Li, Z., Gaillard, J. C., Tedoff, P. F., Mang, H.-P., Lapegue, J., . . . Rheinstein, E. (2014). Exposure to WASH-borne hazards: A scoping study on peri-urban Ger areas in Ulaanbaatar, Mongolia. *Habitat International, 44*, 403-411.

Ulambayar, T., Fernández-Giménez, M. E., Baival, B., & Batjav, B. (2016). Social outcomes of community-based rangeland management in Mongolian steppe ecosystems. *Conservation Letters, 10*(3), 317-327.

Undargaa, S., & McCarthy, J. F. (2016). Beyond property: Co-management and pastoral resource access in Mongolia. *World Development, 77*, 367-379.

UNFPA. (2012). *Implication of Demographic Trends for Socio-economic Development and Public Policy in Mongolia.* Ulaanbaatar, Mongolia: UNFPA.

UN-Habitat. (2003). *The Challenge of Slums: Global Report on Human Settlements 2003*. London: Earthscan.

UN-Habitat (2010). *State of the World's Cities 2010/11: Bridging the Urban Divide*. Nairobi, Kenya: Earthscan.

Vermeiren, K., Van Rompaey, A., Loopmans, M., Serwajja, E., & Mukwaya, P. (2012). Urban growth of Kampala, Uganda: Pattern analysis and scenario development. *Landscape and Urban Planning, 106*(2), 199-206.

United Nations. (2005). *World Urbanization Prospects: The 2005 Revision*. New York: Department of Economic and Social Affairs, Population Division, United Nation.

Wang, J., Brown, D. G., & Bai, Y. (2014). Investigating the spectral and ecological characteristics of grassland communities across an ecological gradient of the Inner

Mongolian grasslands within situhyperspectral data. *International Journal of Remote Sensing, 35*(20), 7179-7198.

Wang, J., Brown, D. G., & Chen, J. (2013). Drivers of the dynamics in net primary productivity across ecological zones on the Mongolian Plateau. *Landscape Ecology, 28*(4), 725-739.

Wang, L., & Lewin, K. (2016). *Two Decades of Basic Education in Rural China: Transitions and Challenges for Development*. Singapore: Springer Singapore.

Ward, P. M. (1976). The squatter settlement as slum or housing solution: evidence from Mexico City. *Land Economics, 52*(3), 330-346.

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.