

# Chapter 8

## The Rapid Development of Settlements in Flood-Prone Areas in Peri-Urban Ulaanbaatar, Mongolia: Monitoring and Spatial Analysis Using VHR Satellite Imageries

Izuru Saizen and Narumasa Tsutsumida

**Abstract** Mongolia is a mostly arid or semiarid country, so it might seem strange that floods could be one of the disaster threats it faces. However, the low precipitation and high evaporation of surface water are a result of the low absorptive capacity of the soil, and, accordingly, higher than normal precipitation often results in run-offs, which have the potential to become flash floods. In a peripheral area of Ulaanbaatar, the capital municipality of Mongolia, residential areas called *ger areas* have expanded rapidly in an unplanned manner because of the poor execution of land reform policy, and considerable migration has resulted from a natural hazard—*dzud*. These areas have been encroaching on flash-flood-prone areas, which have resulted in a dozen people losing their lives in 2009. This chapter introduces the background of *ger areas* expansion and reveals the actual situation of their spatial distribution over flash-flood-prone areas using VHR satellite imageries.

**Keywords** Ulaanbaatar • Urban sprawl • VHR satellite imageries • Flash flood

### 8.1 Introduction

During the last 15 years, the growth of urbanization in Mongolia has been rapidly accelerated, and the increase in population numbers in Ulaanbaatar, which has over 1.15 million people, had reached approximately 40 % of the total Mongolian population of 2.75 million in 2010 (Huang et al. 2013). In a peripheral area of Ulaanbaatar, residential areas called *ger areas* have developed rapidly in an unplanned manner owing to a land reform policy enacted in 2003, which allows Mongolians to have free private land for residential purposes. Many of the residents of *ger areas* did not

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137

register as citizens because of the lack of registration of land so when they migrated to Ulaanbaatar from other provinces, such immigrants were not reflected in the statistics compiled by the central government (Toshiki et al. 2015). The dramatic transition of Mongolia from a planned economy within the former Soviet-backed state socialist system to an independent state with a free market economy in 1992 has also led to the concentration of the population (Sneath 2003). Mongolians were freed from restrictions on internal migration and occupational choice. Consequently, urban areas absorbed many rural Mongolians who sought opportunities for jobs, education, and public services (Kamata et al. 2010). Minimally, an estimated 81,600 households lived in a *ger* area in Ulaanbaatar in 2012 (Huang et al. 2013).

Ulaanbaatar is located in a valley along the Tuul River, which penetrates Ulaanbaatar. The *ger* area has been encroaching toward the hillside of this valley resulting in a high risk of flash floods. Owing to the uncontrolled expansion of *ger* areas because of the increase of migrants, a dozen people were killed by a severe flash flood in 2009. This chapter points out the spatial expansion of *ger* areas and subsequent development of houses that are not reflected in official statistics of such areas, by spatial analysis using very high resolution (VHR) satellite imageries.

## **8.2 Climate and Natural Hazards in Ulaanbaatar**

### **8.2.1 *Climate in Ulaanbaatar***

An extreme continental climate in Mongolia, the nineteenth largest country in the world, generates cold, harsh, and long winters. The annual average temperature is less than 0 °C, and the capital Ulaanbaatar, the biggest city of the nation, is the coldest capital in the world (Chung and Chon 2014). Monthly average temperatures are around -20 °C during the winter season, and nighttime temperatures can go down to around -40 °C. Precipitation is limited mostly to the short summer period; moreover, the annual rainfall is only about 200–220 mm, while the winter season is extremely dry (Saizen et al. 2010; Worldbank 2009).

### **8.2.2 *Natural Hazards Associated with the Population Concentration in Ulaanbaatar***

Although previous studies concerning natural hazards in the world have focused attention on physical environments, such as coasts (Dewan 2014; Singh-Peterson et al. 2014), mountains (Liu et al. 2011; Manandhar et al. 2015), and small islands (Adrianto and Matsuda 2002; Hiwasaki et al. 2014), synthetic hazard research specifically focused on dry lands is not common (Middleton and Sternberg 2013). Research of particular types of hazard in dry lands, however, can be found, such as geomorphological hazards (Marren 2005) or particular combinations of dryland hazards (Middleton and Sternberg 2013).

In the Mongolian case as well, only particular types of natural hazard named *dzud* had been the primary focus in the relevant academic fields (Fernandez-Gimenez et al. 2015; Tachiiri et al. 2008). A severe hazard in the mid-latitude and high-plateau dry lands of Central Asia known as *dzud* occurs when extreme winter cold, snow, and ice render forage inaccessible or unavailable, resulting in high livestock mortality. However, at least five types of *dzud* are identified by Mongolians according to the combination of climate anomalies (Begzsuren et al. 2004). The most common type is the white *dzud*, the complex of deep snow and drought. When such heavy snowfall is preceded by drought in the previous summer, resulting in poor forage conditions, livestock mortality is often particularly high among animals, which do not gain sufficient weight during the summer to survive the severe winter. Some of the most severe white *dzuds* in Mongolia in recent decades occurred between 1999 and 2002 and in 2010. The *dzud* between 1999 and 2002, which was accompanied by a lack of precipitation during the spring and summer, had disastrous results for Mongolian livestock, with 12 million animals dying on a nationwide basis. Of an estimated 190 thousand herding households, 11,000 households lost all their livestock (Saizen et al. 2010). As a result, many of these herders were forced to quit their nomadic herding and migrate to Ulaanbaatar to find new job opportunities. It seems reasonable to suppose that the *dzud* disasters occurring in recent decades were an indirect cause of population increase in Ulaanbaatar, which exacerbated the living environment in *ger* areas.

### 8.2.3 *Flash-Flood Damages in Ulaanbaatar*

As mentioned above, Mongolia is a mostly arid country where it would be widely unknown that flood was one of the relevant disaster threats. The low precipitation and high evaporation of surface water result in low absorptive capacity of the soil, and, accordingly, higher than normal precipitation often turns into runoff with the potential to become flash floods.

A flash flood is an extreme rainfall event causing rapid runoff from sparsely vegetated slopes on an occasional basis (Middleton and Sternberg 2013). They are often accompanied by other phenomena such as landslides and mudflows and can cause bridge collapses, damage to buildings, and fatalities. Although Jonkman (2005) pointed out that mortality by flash floods in the world is higher than any other form of flooding in terms of the number of fatalities divided by the number of affected persons, it is a poorly understood hazard in dry lands (Foody et al. 2004). Similar to other cities in dry lands, flash floods in Ulaanbaatar have been occurring, and they affect residents every year. The high-risk potential of flash floods is related to their rapid occurrence and typically localized nature; hence both factors leave very limited opportunities for an effective response. Accordingly, the most effective, easiest, and best strategy to reduce their risk potential is to avoid the development of residential areas and other facilities in flash-flood-prone areas.

JICA (2002) reported that flash-flood-prone areas in the *ger* areas mostly correspond with the areas near rivers and, topographically, on steep slopes. According to the land privatization law in the land reform policy, privatizing lands near water is not allowed for Mongolian citizens, but damage to their houses and properties by flash floods has often been reported (UN-Habitat 2010a). The execution of land privatization laws would fail in terms of urban management as it is difficult to confirm the spatial distribution of settlements in *ger* areas because of illegal house construction. Given the nature of flash floods, understanding such distribution is important and should be elaborated in detail for proper management of living conditions and future disasters.

### 8.3 Study Area: The Rapid Development of Settlements in *Ger* Areas

#### 8.3.1 Study Area

We chose a study area with an area of approximately 33 km<sup>2</sup> (Fig. 8.1) located in the western part of the peripheral area of Ulaanbaatar, in which *ger* areas had experienced extreme expansion throughout the last decade. Enkhtaivan Avenue, one of the main roads in Ulaanbaatar, is oriented east to west along the southern edge of the study area. The area on the south side of the road is part of the city center and includes some apartments and commercial facilities as well as other land use types—factories, schools, and governmental facilities. *Ger* areas are primarily spreading on the flatlands and hillsides located on the north side of Enkhtaivan Avenue.

#### 8.3.2 Developments of *Ger* Areas

Rural Mongolians, and especially nomadic people, typically live in a *ger*, which is a traditional nomadic tent designed for a nomadic lifestyle in grassland; it is a circular tent-like structure consisting of a wooden framework covered with felt. As it is mobile, lightweight, and portable, and therefore well suited for easy movement, the *ger* is an ideal living solution for nomadic people and well adapted to sustainable nomadic life (Kamata et al. 2010; Mocellin and Foggin 2008).

Taking advantage of its portability, many migrants relocate to the city or peripheral areas. Migrants declare a right of land possession; build wooden fences named *khashaas*, which mark their property boundaries; and build a *ger* or a detached house on the enclosed land with or without registering the privatization of the land (Kamata et al. 2010). In this way, *ger* areas, which are typically composed of both formal and informal residential plots, have been created (Fig. 8.2). Once they

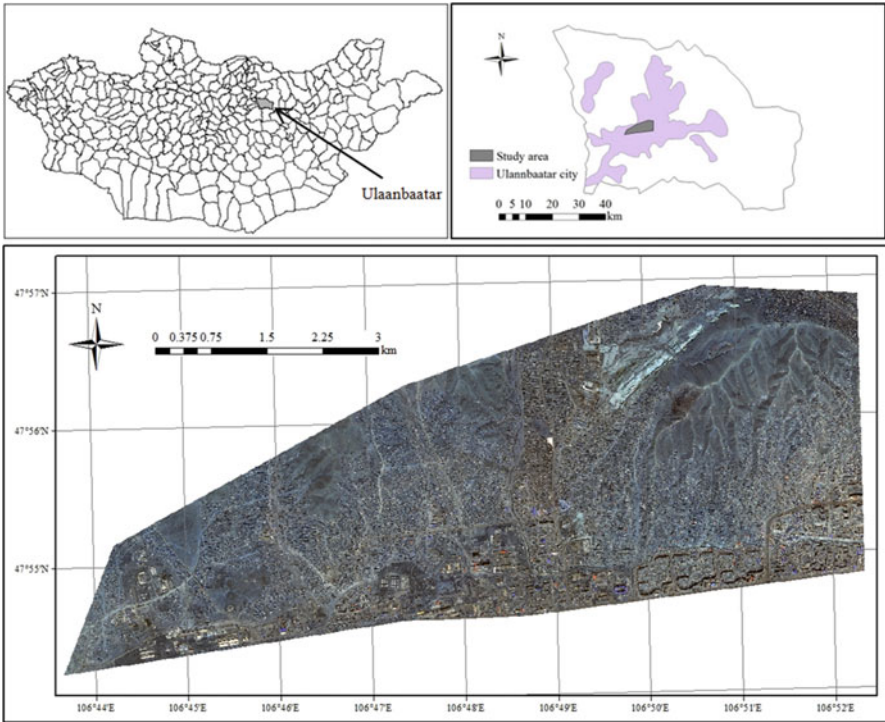


Fig. 8.1 The map of study area showing QuickBird imagery taken in 2008



Fig. 8.2 Landscape of the ger area (Photo by Saizen in August 2011)

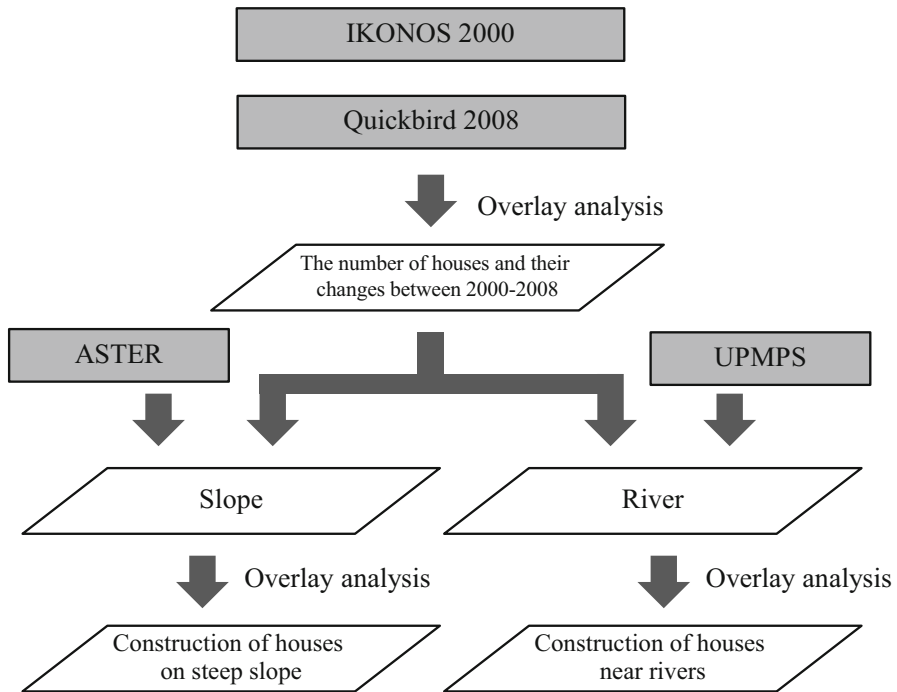
occupy their own land, their houses seldom if ever move again thereby losing the function of portability. As a result of these practices, about 60 % of the population of Ulaanbaatar lives in *ger* areas (Kamata et al. 2010; UN-Habitat 2010b).

### 8.3.3 *The Degradation Living Environments Caused by Ger Areas*

It was widely reported that the expansion of *ger* areas on the peripheral areas of Ulaanbaatar has a negative impact on the natural environment and living conditions of both *ger* areas themselves and city centers (UN-Habitat 2010b). For example, air pollution caused by the emissions from household stoves in winter is one of the critical environmental problems. On average, a *ger* in an urban area consumes a staggering 5 tons of coal and 1.5 tons of wood fuel per year or more than 20 kg of coal per day during the winter season (Sovacool et al. 2011). In addition, the basic infrastructure, such as piped water systems, sanitation facilities, paved roads, public transportation, and heating systems, is not well developed. Social and spatial inequality, water supply and sanitation, waste management, and air pollution have become urgent issues. International donor-funded projects are addressing such issues by assisting with the development of much needed infrastructure (Tsutsumida et al. 2015; UN-Habitat 2010a). In particular, water kiosks, based on funding from international donors, are being constructed to satisfy the basic human need for water because the houses in *ger* areas are not connected to the public water supply system (Tsutsumida et al. 2015). Construction of these water kiosks, however, may encourage disorderly expansion of *ger* areas in some respects because they contribute essential water supplies to all of the residents. Therefore, the lack of basic infrastructure can be considered one of the factors that degrade living environments and induce the chaotic formation of *ger* areas.

## 8.4 Residential Developments in Flash-Flood-Prone Areas

The flow of data processing and construction is shown in Fig. 8.3 We constructed the GIS database on the exact location of the *gers* from VHR satellite imageries to explore the spatial distribution of settlements in flash-flood-prone areas from a topographical perspective. Note that all of the *gers* are not used for settlement, meaning that some residents possess several *gers* to use for storage; however, it is quite difficult to identify each purpose of the *gers*. This study assumed all *gers* are used for residential purposes. GIS data relating to houses and rivers were produced from IKONOS imagery for 2000 and QuickBird imagery for 2008. IKONOS and QuickBird have spatial resolutions of 1.0–4.0 and 0.6–2.8 m<sup>2</sup>, respectively, and have the ability to spatially identify even a small *ger*.

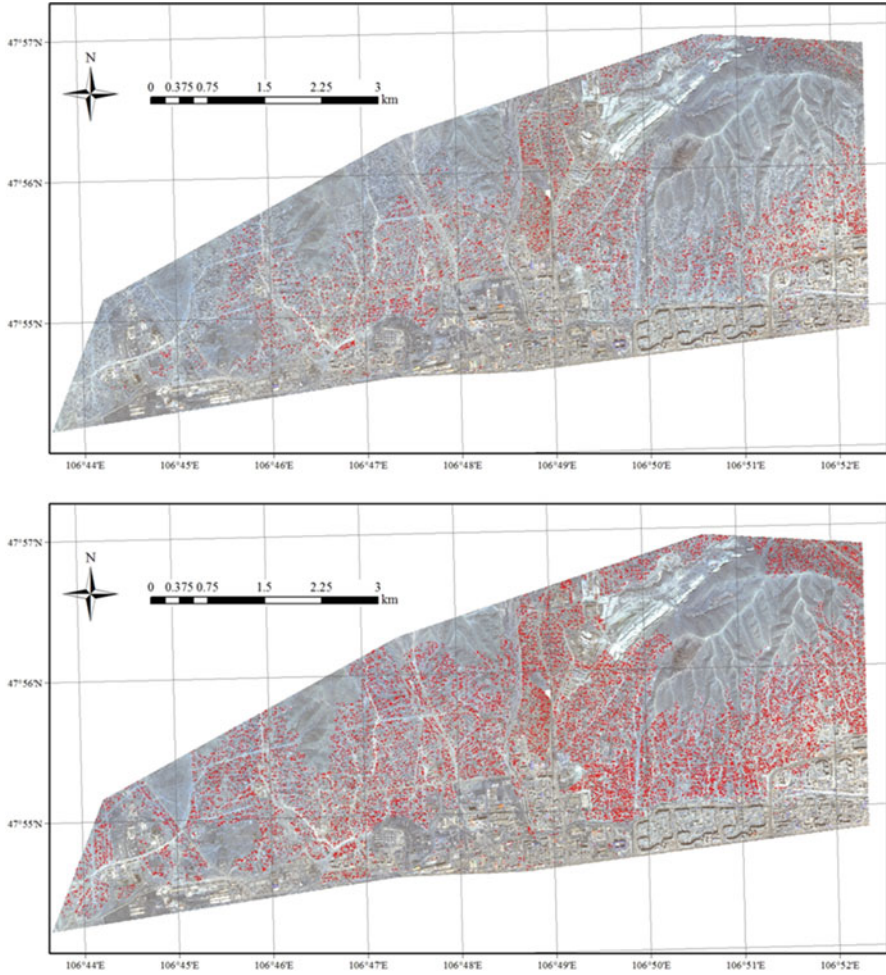


**Fig. 8.3** The flow of data processing and construction by overlay analysis

In this analysis, these images for 2000 and 2008 were used to compare the characteristics of the changes before and after the implementation of the land reform policy. We identified each of the houses on the imageries and digitized them manually in a vector format along with the rivers according to the imageries for the observed years (Fig. 8.4). In addition to VHR satellite imageries as our primary data sources, for the analysis we utilized supplementary GIS data constructed through the international donor project implemented by the JICA, entitled “The Study on City Master Plan and Urban Development Program of Ulaanbaatar City” (UBMPS). These data were obtained previously through the Second Ulaanbaatar Services Improvement Project, which was one of the primary donor projects in Ulaanbaatar implemented by the World Bank in 2007 and subsequently utilized and modified by the JICA (JICA 2009; Tsutsumida et al. 2015). Finally, an ASTER GDEM dataset in which cloudy pixels were removed and residual anomalies corrected was prepared for the analysis.

As mentioned above, according to JICA (2002), the areas prone to flash floods are identified topographically near rivers or on steep slopes, and thus the changes in the number of houses in these vulnerable areas were calculated by overlay analysis. In the results, during the period 2000–2008, the number of houses had increased drastically from 4900 to 15,246, showing an increased rate of 311.1 % in the study





**Fig. 8.4** Ger distribution (red color) derived from IKONOS in 2000 (upper) and from QuickBird in 2008 (lower)

area (Fig. 8.4, Table 8.1). The change rate within 50 m from rivers (378.8 %) is significantly higher than the average in the study area. Those results revealed spatial developments of house construction on the flash-flood-prone areas. Although the increasing rates within 100 m and 200 m from rivers are slightly lower than those within 50 m, both rates are still higher than average.

In addition, the increased number of houses was high in the areas with steep slopes of more than 8 degrees. Compared to the less steep areas, the change rate is higher, and this result indicates that even if the land was on a steep slope, people construct houses without taking the hazardous nature of the topography into account.



**Table 8.1** The number of *gers* in 2000 and 2008 and their change rates by distance from rivers and by degrees of slope

	The number of <i>gers</i> in 2000	The number of <i>gers</i> in 2008	Change rate (%)
Total area	4900	15,246	311.1
Distance from rivers within 50 m	297	1125	378.8
Distance from rivers between 50 and 100 m	393	1140	290.1
Distance from rivers between 100 and 200 m	725	1917	264.4
Distance from rivers more than 200 m	3485	11,064	317.5
Slope (0–3 degree)	1348	4114	306.0
Slope (3–8 degree)	2978	8966	301.8
Slope (8–degree)	574	2166	378.4

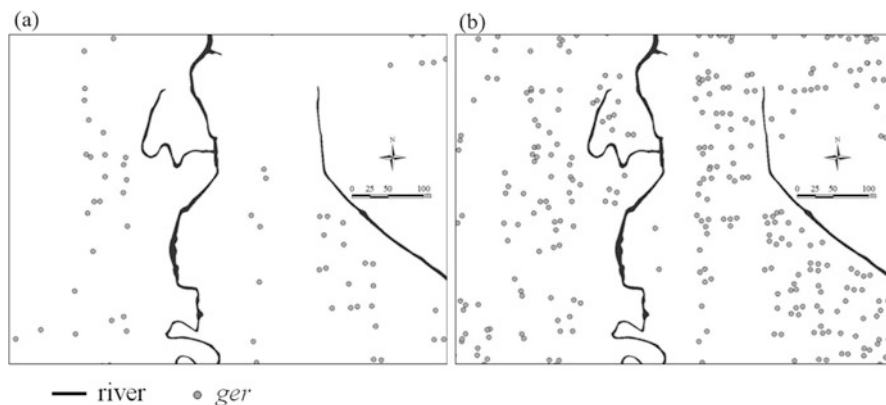
**Fig. 8.5** *Gers* construction on steep slopes by digging and developing lands (Photo by Saizen in August 2011)

Throughout the field survey in 2011, the typical construction of *gers* on steep slopes was observed as shown in Fig. 8.5. The lands on the steep slope were dug and developed for the *ger* construction. After the construction, people enclosed their land by *khashaas* and occupied their private lands (in some cases, unregistered), thus forming new *ger* areas as a result.

## 8.5 Discussion and Conclusion

By focusing on the topographical features where the disorderly formation of *ger* areas had been detected, this chapter has introduced one example of uncontrolled land use and its associated changes. Uncontrolled land use increases vulnerability to flash-flood hazards in Ulaanbaatar. Political and social events, the shift to a free market economy and land privatization, and the natural hazard event—*dzud*—are factors that have led to considerable migration to Ulaanbaatar. Since many migrants have not registered as citizens, official statistics do not yet reflect actual conditions of houses in flash-flood-prone areas, which were revealed in the spatial analyses through maximum utilization of VHR satellite imageries. Tsutsumida et al. (2015) pointed out that the distance from roads appeared to be one of the primary forces governing the formation of *ger* areas in terms of spatial formation patterns. In response to residents' demands for better access to social and political infrastructure, most of the roads in *ger* areas began as informal tracks to private land. Arguably, residents' first priority in selecting their place of residence is not security from hazards but accessibility to urban areas. Tsutsumida et al. (2015) also indicated that social infrastructure influences the formation of *ger* areas much more strongly than topographical factors. In particular, houses are newly constructed near water kiosks which are normally established in areas where residents had difficulty accessing other water supplies. Yet some of these homes are built near rivers or on steep slopes, both of which are prone to flash floods. Figure 8.6 is one example and is a typical area where many houses were constructed near a river during the observed periods.

In addition to flash floods, the lack of a proper drainage system also results in frequent flooding. The problem is exacerbated by the fact that residents in *ger* areas often dispose of garbage irresponsibly, which creates an obstacle to water drainage and leads to flash floods (Uddin et al. 2014). The first priority should be to restrict the construction of houses in areas that are prone to flash floods by creating a zoning



**Fig. 8.6** The distribution of *gers* around rivers in (a) 2000 and (b) 2008

system from the viewpoint of topography. Then, through detailed investigation, proper land use planning—which has not previously existed in *ger* areas—should be established. In addition to these top-down approaches, community and private sector engagement are essential. Most residents in *ger* areas are from outside Ulaanbaatar so that their networks and mutual cooperation are quite weak. This situation would trigger illegal *ger* construction or migration into *ger* areas even if land use planning is established. Well-considered bottom-up planning based on social circumstances and disaster management is urgently needed. Vision is currently lacking in the management and infrastructure programming in *ger* areas. It seems reasonable to conclude that community development programs involving private sectors should be provided to absorb their opinions and strengthen their mutual cooperation in parallel with top-down approaches. The Mongolian government should not only develop legal systems for *ger* areas formation but also conduct initial inquiries and develop bottom-up approaches immediately.

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