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Population and housing grid spatialization in Yunnan Province based on grid sampling and application of rapid earthquake loss assessment: the Jinggu *Ms*6.6 earthquake

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Abstract: Population and housing grid data spatialization based on 340 grid samples (1 km×1 km) is used instead of regional statistical data to simulate the population and housing distribution data of Yunnan Province (1 km×1 km) for rapid loss assessment for the Jinggu *Ms*6.6 earthquake. The results indicate that the method reflects the actual population and housing distribution and that the assessment results are credible. The method can be used to quickly provide spatial orientation disaster information after an earthquake.

Key words: population grid spatialization; housing grid spatialization; rapid earthquake loss assessment; Jinggu earthquake

1 Introduction

Population and housing grid spatialization is the key to improving the accuracy of the rapid assessment of earthquake disaster results. By the end of the 20th century, considerable research had been performed on population grid spatialization models and on the mathematical theory and land use models used to simulate population spatial distributions. Much work has also been done to improve the land use models that make the simulation of population spatial distribution more reasonable; such work has been based on a comprehensive consideration of the degree of urban development, urban and rural residential distributions, altitude, slope, net primary production, traffic distribution, water system distribution, and DMSP-OLS night light. The most representative population distribution data products are the GPW 5-km resolution[1], UNEP/GRID 2.5-km resolution[2], and LandScan 30″×30″ resolution[3] population distribution data.

Although population spatial grid data have potential broad applications for assessing natural disasters, traditional grid spatialization models have used administrative unit statistics data (population, elevation, land use, traffic, water, etc.) as an "approximate sample," based on a comprehensive statistical analysis of "approximate sample" data, the model setup, and simulation of the population spatial grid distribution of the administrative unit. Compared to the "approximate sample" dimension, the scale of the population grid is one or more orders of magnitude larger. The precision of the sample data thus becomes one of the major factors limiting the accuracy of population grid spatial data.

At present, two methods are primarily used in hous-

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ing data spatialization research: One is based on individual housing census data and the other uses a wide range of housing statistics to simulate housing distribution. Using the first national urban housing census data in 1985, combined with seismic intensity earthquake damage prediction data, Yang et al established a housing database for the cities of Sanmenxia, Zhanjiang, and Xiamen[4]. Gan et al surveyed 3558 buildings in Hefei and established a building database[5]. However, the use of individual housing census data is hard to extend over a wide range, because human and financial resources are limited. Consequently, other researchers have made use of a wide range of housing statistics (province, city, and county) (or estimates) to simulate the housing distribution. Gao et al presumed the number and structure of houses in rural areas and units at the county level, based on the proportion of building structures in regional and provincial units[6]. The method's error is larger, so its result cannot be applied in earthquake disaster prediction.

Therefore, the purpose of the present paper is to improve the accuracy of grid data and to find a simple and feasible method for treating population and housing grid data to serve the needs of earthquake disaster prediction, enabling the data to be used more effectively in earthquake disaster assessment. In this paper, based on partitioning by level of economic development in urban and rural areas and grid samples of population and housing, we establish a Yunnan population distribution model and a building distribution model.

2 Partition and Sampling

2.1 Partition

Population and housing distributions have strong regional differences. The population distribution is mainly affected by the layout of urban and rural areas, whereas building structure type distribution is mainly affected by the layout and the influence of the level of local economic development between urban and rural areas. Combined with urban and rural layouts, the level of economic development can be divided into six regions in Yunnan province (Fig.1). To achieve simplified model parameters, partitioning is based on establishing areas with the same population and strongly similar housing space distribution characteristics.

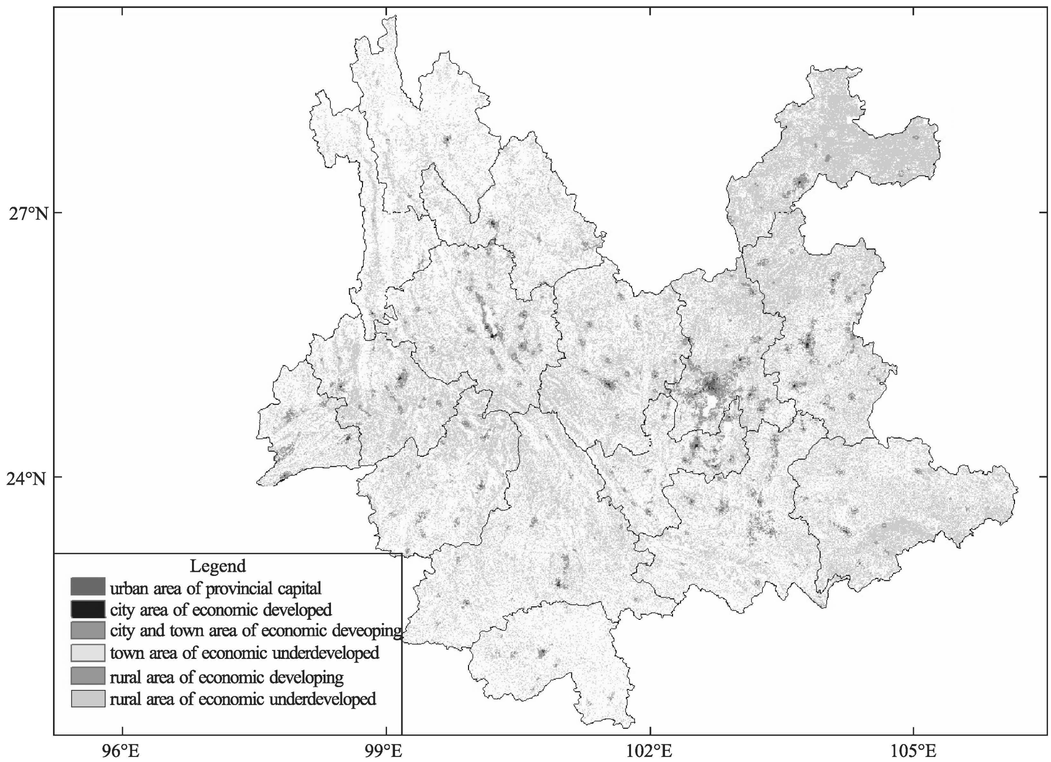

Figure 1 Partitioning of Yunnan Province based on level of economic development in urban and rural areas

2.2 Population and housing sampling

Our project group established a total of 340 site grids (1 km×1 km grid; Fig.2), sampling the population and housing in Yunnan province in 2012–2013. The site grids were involved in each partition and had the same size as the modeling grid units.

3 Data processing

3.1 Data preprocessing

1) To generate the grid map (1 km×1 km), we used the Yunnan province administrative zoning map. The grid map is the basis for the population and housing grid database.

2) The change in village distribution, transportation, urban distribution, Digital Elevation Model (DEM), land used classification data, etc. (Tab.1) were entered into the grid database.

3.2 Population grid based on samples

Using a multiple stepwise regression analysis of sample data from different partitions and a land use model, we established a town and rural population density weighting model.

3.2.1 City and town population density weighting model

Through analysis of sample data from the provincial capital and prefecture-level cities and towns, we determined that the main factors affecting the population distribution are the density of urban construction land, residential land, transportation network, city distribution,

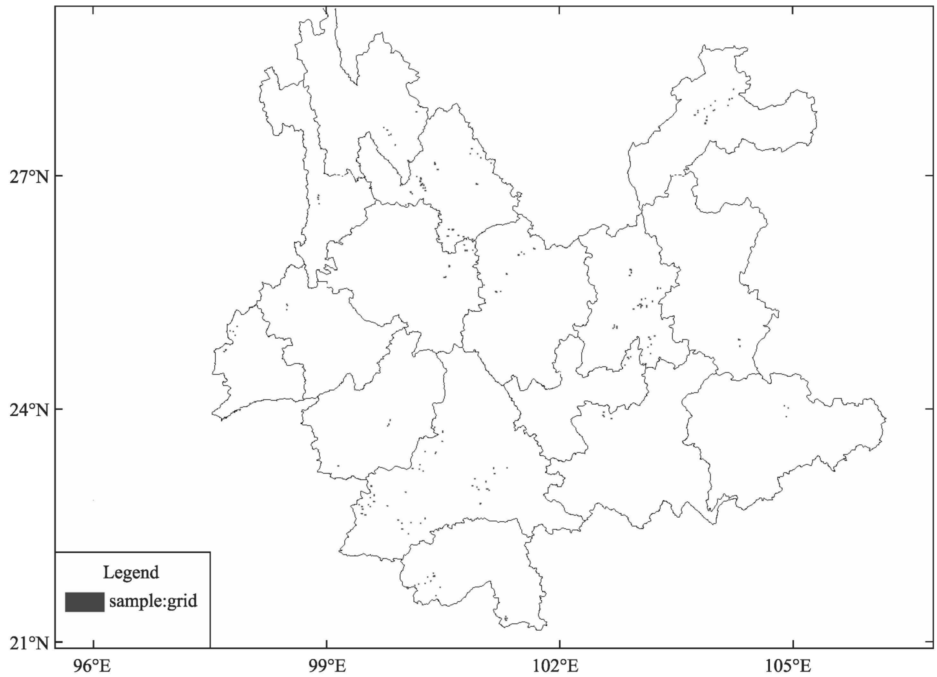

Figure 2 Map of Yunnan showing site sample grid

Table 1 The data and source

Type	Data and source	
Statistical data	The population statistic data in Yunnan in 2013	Yunnan statistic yearbook 2013[7]
	Population statistics of town in Yunnan in 2013	China yearbook of town survey 2012[8]
Social and historical development factors	Villages distribution	Digital rural in Yunnan province[9]
	Urban range and distribution	SPOT5 satellite remote sensing image[10]
Natural geographical factors	DEM	SRTM data[11]
	Land used classification data	Yunnan land use classification data[12]
	DMSP-OLS night light	DMSP data[13]

and distribution of water resources. With the urban construction land and residential land as the foundation, combined with transportation network density and auxiliary modeling, an urban and town population density weighting model was set up[14] as follows:

$$P_{(i,j)} = (Area\_a_{(i,j)} m + Area\_b_{(i,j)} n) Traffic_{(i,j)} \quad (1)$$

where $P_{(i,j)}$ are the population density weightings of the grid, $Area\_a_{(i,j)}$ are the areas of urban construction land, $Area\_b_{(i,j)}$ are the residential areas, m and n represent the weightings of urban construction land and residential area, respectively, $Traffic_{(i,j)}$ are the normalized values of transportation, $W^q_{(i,j)}$ are the weightings of water resources, and $Light_{(i,j)}$ are the normalized values of DMSP-OLS night light.

3.2.2 Country population density weighting model

Through an analysis of the sample data of rural area, we determined that the main factors influencing the rural population distribution are residential area, agricultural area, and the distribution of water resources. Village distribution is used for auxiliary modeling to make the grid data more accurate. The expression for the population distribution[14] is as follows:

$$P_{(i,j)} = [\, (kArea\_b_{(i,j)} + jArea\_f_{(i,j)} DEV^l_{(i,j)} \,] \cup V \quad (2)$$

where $P_{(i,j)}$ are the population density weightings of the grid, $Area\_f_{(i,j)}$ are the agricultural areas, j is the weighting of the agricultural area, $DEM^l_{(i,j)}$ are the normalized values of DEM, and V is the buffer zones of villages.

3.2.3 Population grid spatialization

Using the population statistical data in rural areas, cities, towns, and streets, we generated the density of a population grid cell by the weighted population density data as follows[14]:

$$Pop\_density_{(i,j)} = (P_{i,j} / \sum P_{i,j}) \times Pop_i \quad (3)$$

where $Pop\_density_{(i,j)}$ are the populations of grid cells, $P_{(i,j)}$ are the weightings of grid cells, and Pop_i are the population statistical data. Finally, the population grid data (Fig.3) of Yunnan are generated by merging grid data from each partition.

3.3 Housing grid spatialization

Referring to building structural classification and combining with actual sampling data, we can divide the building structure types in Yunnan province into five classes: civil structures, brick and wood structures, brick

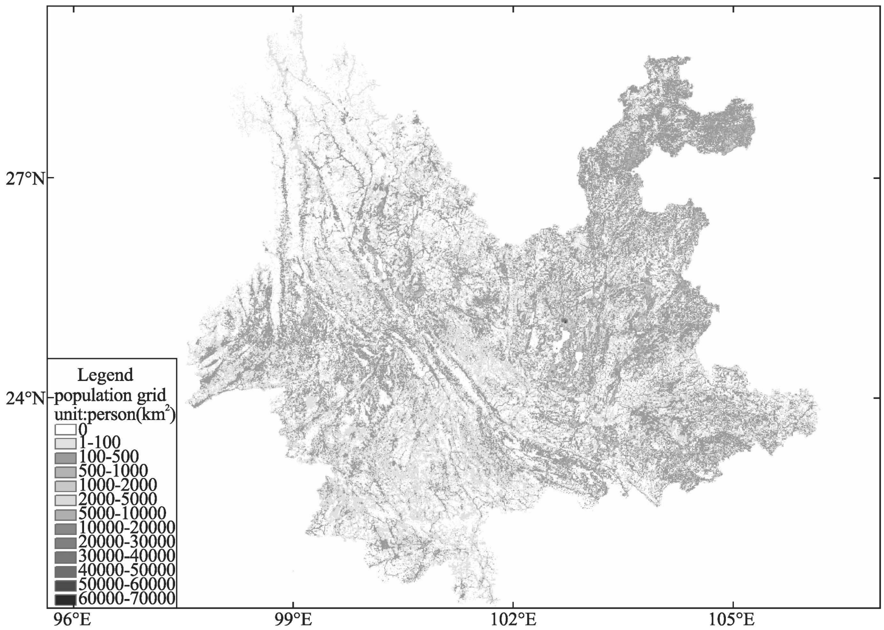

Figure 3 Population distribution map of Yunnan in 2013

concrete structures, reinforced concrete structures, and other structures. Civil structures and brick and wood structures are mainly concentrated in Yunnan rural areas. Brick and wood structures offer little resistance to seismic events, with, generally, wall collapse partially occurring when seismic intensity reaches the VII degree. Civil structure are stronger, with, generally, adobe or rammed walls are weaker and can easily collapse by the Ⅶ degree, tilting or collapse not occurring until a seismic intensity of the Ⅸ degree. Reinforced concrete structures are mainly concentrated in cities and townships. Brick concrete structures are distributed throughout both urban and rural areas. The level of seismic fortification is higher in the provincial capital and in cities, whereas it is generally lower in rural areas.

Based on the partition of the sampling data, different regions were found to have significantly different housing areas per capita and proportions of building structures. The distributions of population grid data and housing area per capita (Tab.2 and Fig.4) can be calculated for the per capita housing area and population grid data, and the areal distribution of building structure types can be calculated from the proportion based on the sample (Tab.2 and Figs.5–7).

Table 2 Ratio of building structure types (unit: %)

Partition	Per capita housing area	Reinforced concrete structure	Brick concrete structure	Civil structure	Brick-wood structure	Other structure
Urban area of provincial capital	30.3	37.0	63.0	0.0	0.0	0.0
City area of economic developed	36.4	33.1	57.0	4.1	5.8	0.0
City and town area of economic developing	38.5	23.0	65.0	3.7	8.3	0.0
Town area of economic underdeveloped	40.1	13.0	62.8	7.7	15.7	0.8
Rural area of economic developing	45.8	3.7	36.4	39.6	19.0	1.3
Rural area of economic underdeveloped	46.2	1.7	27.0	29.8	34.1	7.4

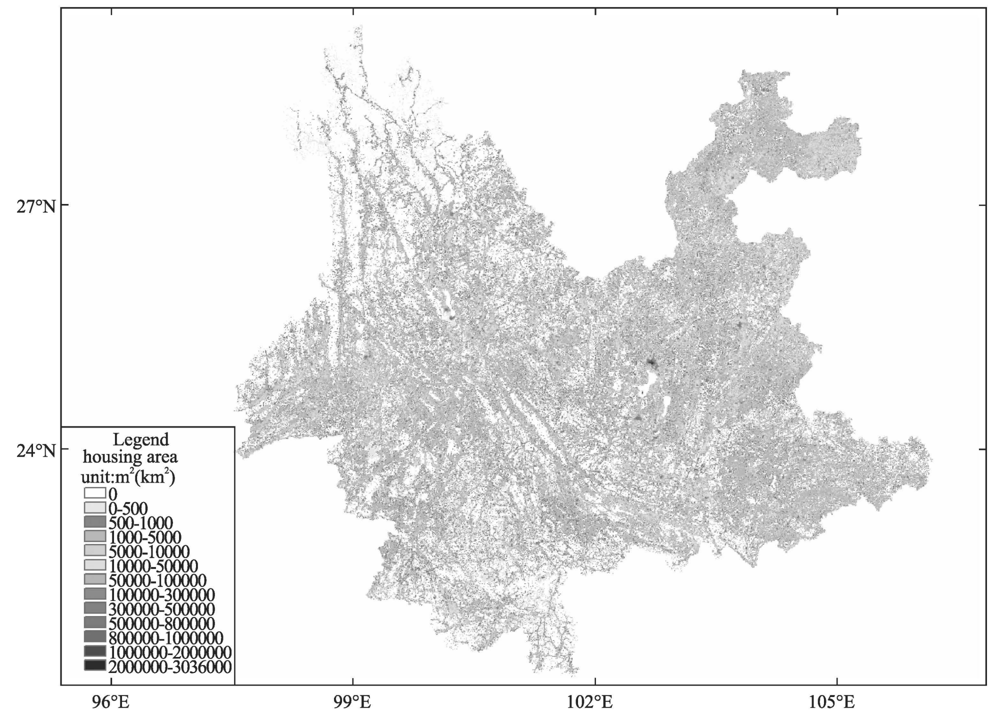

Figure 4 Housing area distribution of Yunnan Province

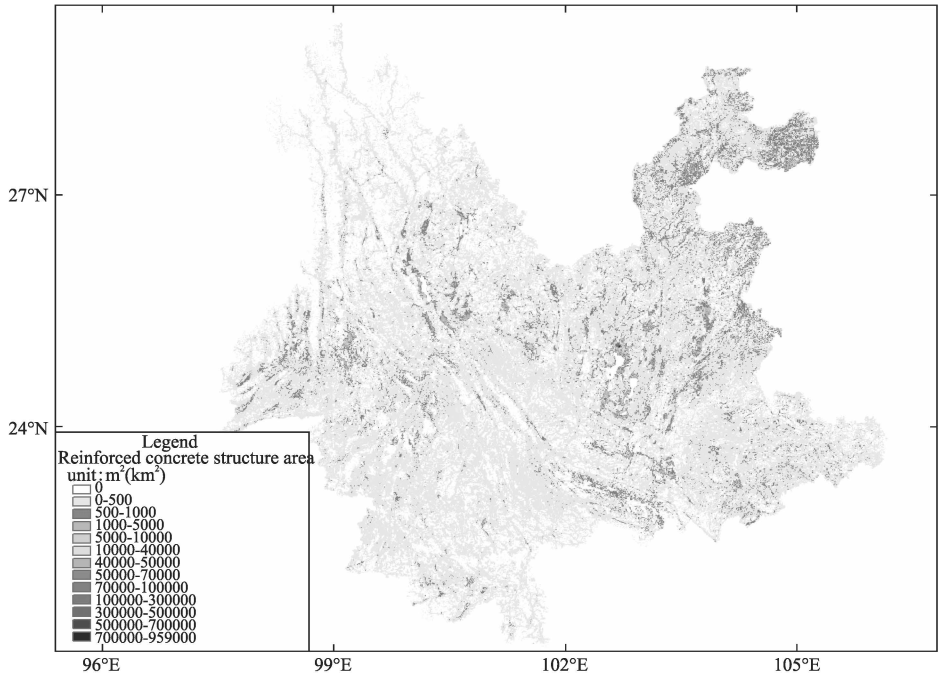

Figure 5 Reinforced concrete structure housing area distribution of Yunnan Province

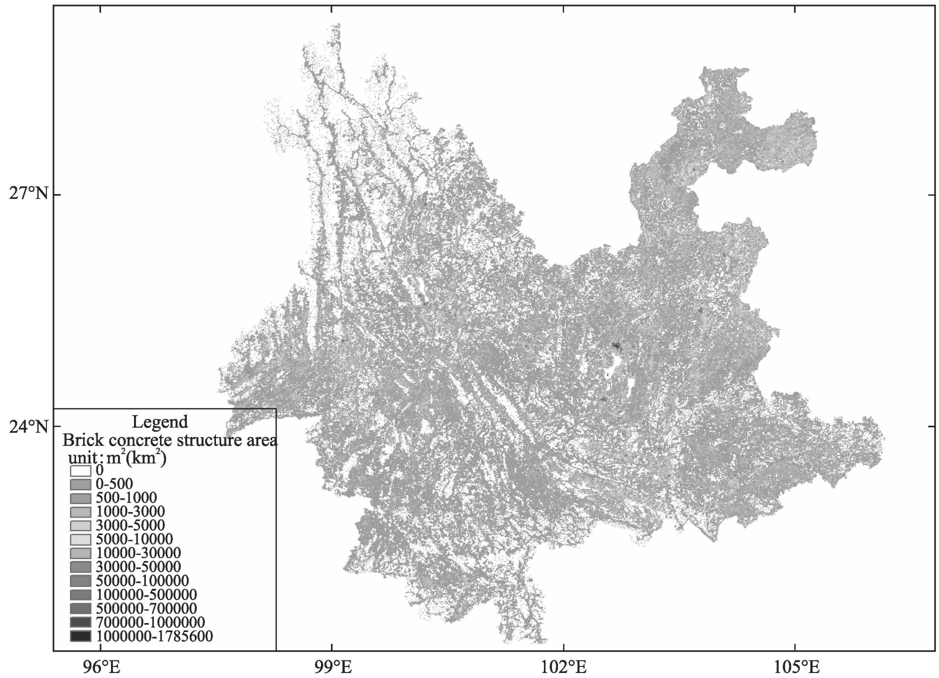

Figure 6 Brick concrete structure area distribution of Yunnan province

4 Rapid earthquake loss assessment for the Jinggu earthquake

The disaster area of the Yunnan Jinggu *M*s6.6 earthquake, extended to about 15537 km^2, involving 37 towns. However, the max seismic intensity area is Ⅷ degree, that did not encompass many urban areas, with only parts of Yongping town affected (Figs. 8 and 9).

Rapid earthquake loss assessment yields the following results: The number injured is calculated to be 356 (with an error of 10.2%), the damaged housing area in the urban area is calculated to be 124000 m^2(with an error of 18.1%), and the number of damaged houses in the rural area is calculated to be 64590 (with an error of 5%) (Tab.3 and Fig.10). These loss assessment results are more accurate than those from the "China Earthquake Administration Rapid Assessment of Earthquake Disaster System (CEAREDS)," which is based on countywide and townwide demographic data (Tab.3).

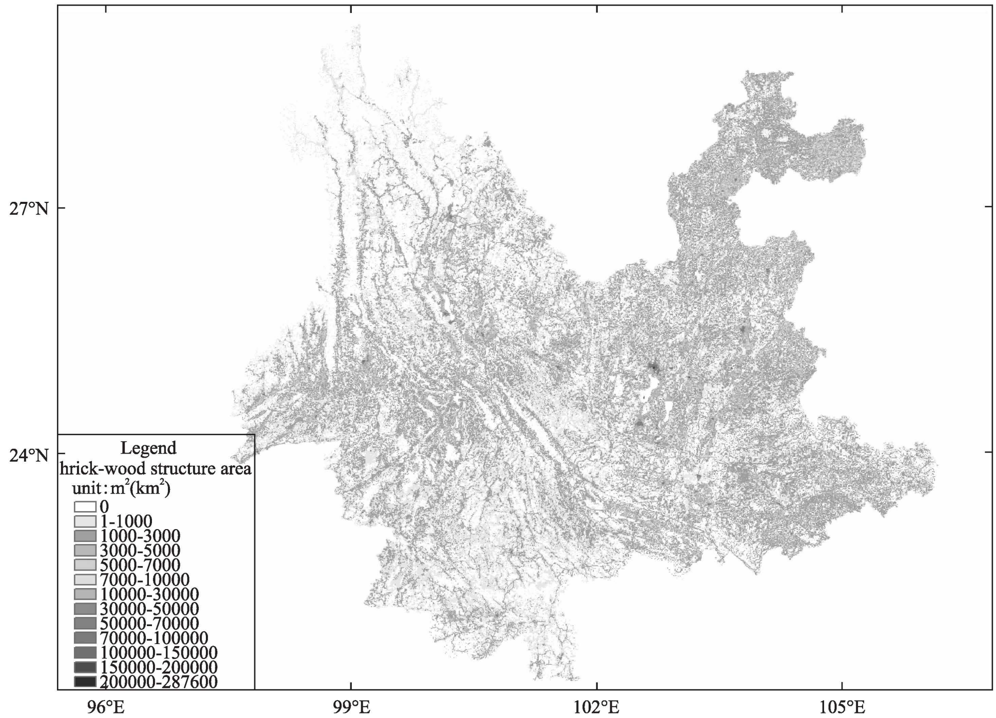

Figure 7 Brick and wood structure housing area distribution of Yunnan Province

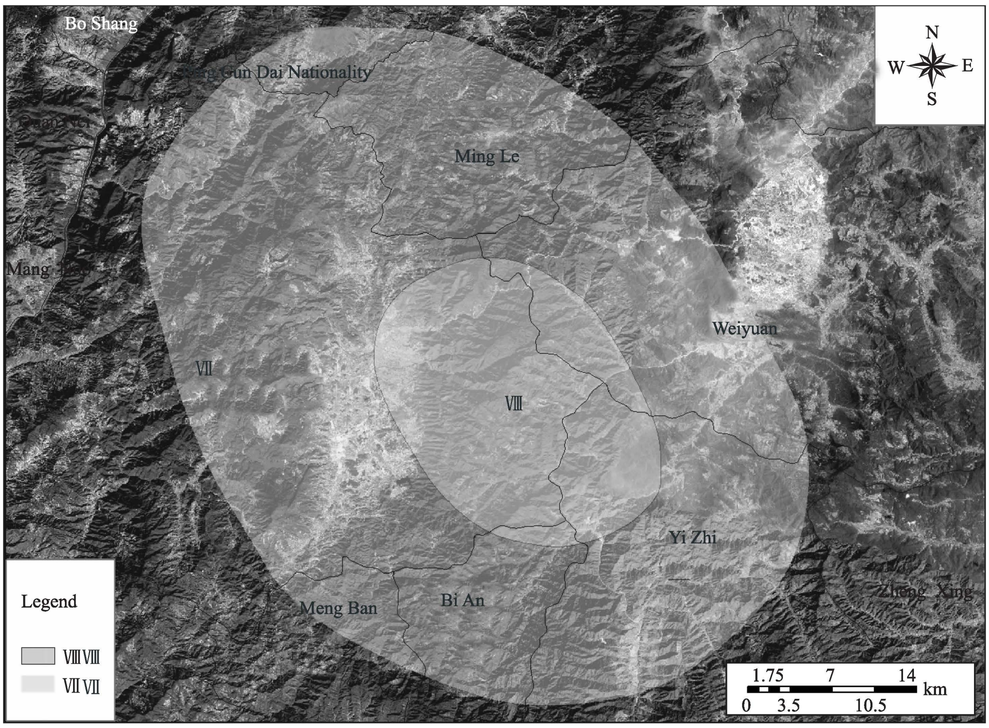

Figure 8 SPOT 5 remote sensing image of the Jinggu earthquake disaster

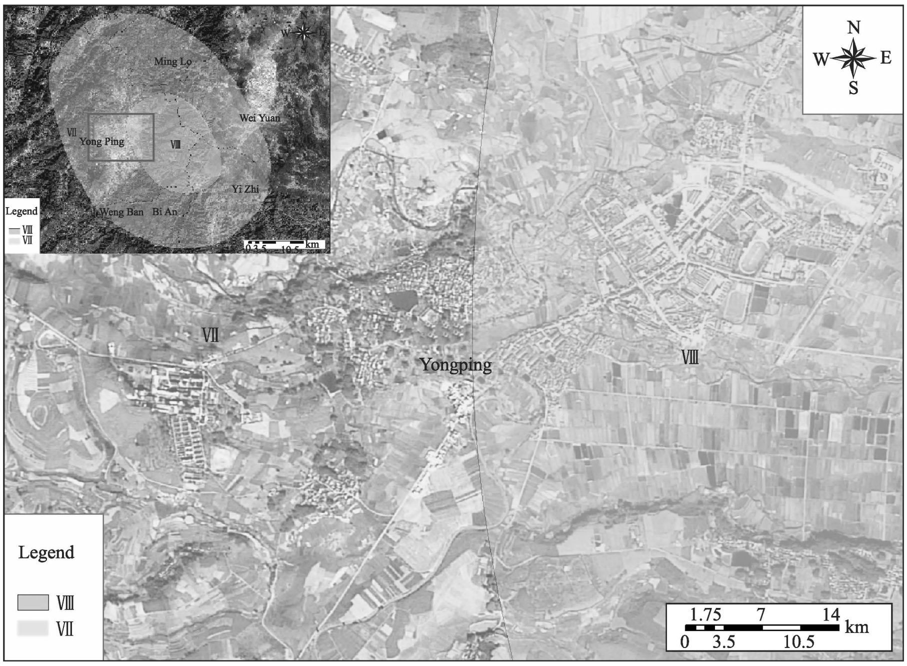

Figure 9 SPOT 5 remote sensing image of Yongping

Table 3 Rapid assessment results

	Disaster investigation result	Demographic data		Grid data of this paper	
		CEAREDS result	Error (%)	Loss assessment result	Error (%)
Amaged housing room in rural	61524 room	54503 room		64590 room	5
Damaged housing area in urban area	105000 m^2			124000 m^2	18.1
Number of injured	323	Nearly a thousand	210	356	10.2

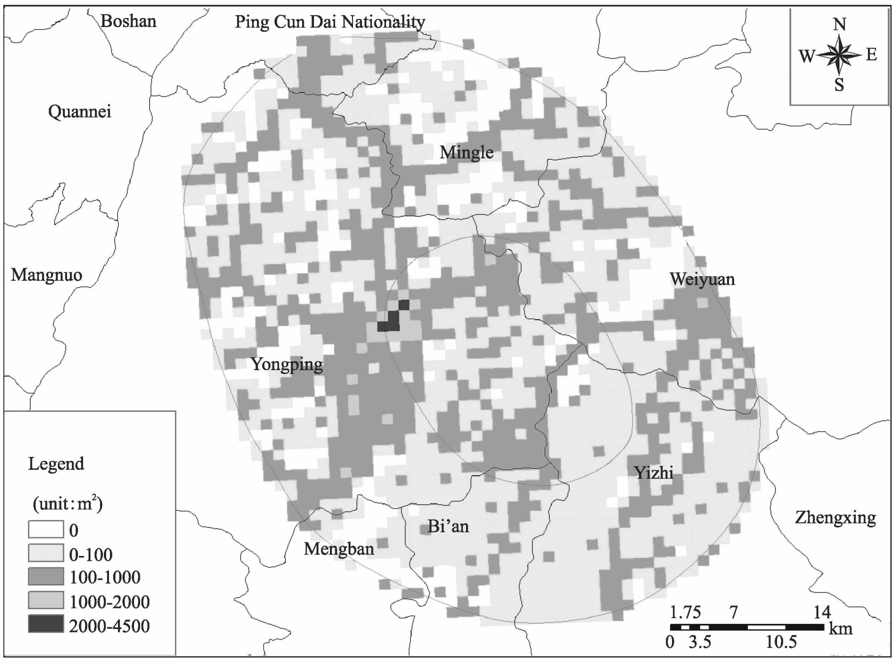

Figure 10 Areal distribution of houses completely destroyed or seriously damaged

5 Conclusion

1) A sampling grid cell provides the data support needed to establish a population and housing distribution model. The evaluation results in this paper from the grid data are obviously better than results from demographic data. This further illustrates the higher precision of models based on sampling. The estimation results from these grid data at the beginning of the earthquake have higher credibility and can provide basic distributions of casualties and house damage.

2) The estimated number of injured based on the grid data of this paper slant big, and thus indicating a gap between the distribution of simulation data in this paper and the actual distribution. This gap occurs for two reasons: (1) From a statistical standpoint, we treated just 340 samples, which cannot completely cover all characteristics of the population and housing distribution in Yunnan Province. (2) The actual building structure type distribution is relatively complicated. The proportion of housing types in this paper is the average of each partition based on a limited number of samples. It reflects the overall large-scale trend of the housing type distribution. Use of a more elaborate small-scale housing type distribution will be the subject of future research.

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