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The influence of land urbanization on landslides: An empirical estimation based on Chinese provincial panel data

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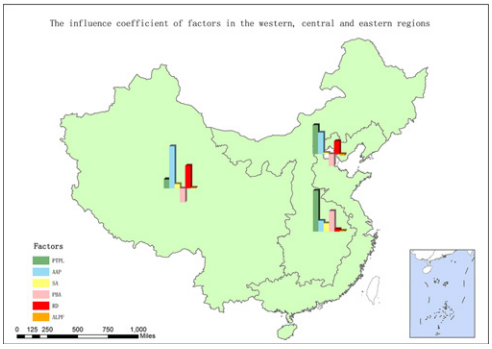
HIGHLIGHTS

- Landslides are widely distributed, and cause a large number of economic loss and casualties in China.
- The quantitative relationships between land urbanization and landslides are studied by employing the panel multiple regression.
- Land urbanization has a significant influence on landslides at the national level. The number of landslides is negative to percentage of built-up area and positive to road density.

GRAPHICAL ABSTRACT



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ABSTRACT

This study used panel data for 28 provinces and municipalities in China from 2003 to 2014 to investigate the relationship between land urbanization and landslides by building panel models for a national sample and subsamples from the three regions of China and studied the problems of landslide prevention measures based on the relationship. The results showed that 1) at the national level, the percentage of built-up area and road density are respectively negative and positive for landslides. 2) At the regional level, the improvement of landslide prevention measures with increasing economic development only appears in built-up areas. The percentage of built-up areas increases the number of landslides in the western region and decreases the number in the central and eastern regions; the degree of decrease in the eastern region is larger than in the central region. Road density increases the number of landslides in each region, and the degree increases gradually from the west to the east. 3) The effect of landslide prevention funding is not obvious. Although the amount of landslide prevention funds decreases the number of landslides at the national level, the degree of increase is too small. Except in the central region, the amount of landslide prevention funding did not decrease the number of landslides effectively in the western and eastern regions. We propose a series of policy implications based on these test results that may help to improve landslide prevention measures.

1. Introduction

Land urbanization is the changing of land use type by the conversion of rural areas into urban areas. The percentage of built-up area and road

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density are usually used as land urbanization rate indices (Lee et al., 2004; Zope et al., 2016). The construction of urban areas and infrastructure in the process of land urbanization causes serious disturbance to the geological environment by reducing the area of vegetation cover and cutting slopes. This disturbance increases the likelihood of landslides and makes landslides the natural hazard that causes the most economic loss and casualties in some countries (Alimohammadlou et al., 2013). Developing countries, the most active areas of urbanization in the world, are suffering the most serious landslide effects due to the lack of landslide prevention measures (Holcombe and Anderson, 2010; Listo and Carvalho Vieira, 2012). As the world's largest developing country, China's land urbanization rate increased significantly over 30 years of rapid economic development. In 2014, the percentage of built-up area accounted for 0.52%, and the road density was 46.5 km/100 km^2, 2.22 and 2.66 times those in 2003, respectively (National Bureau of Statistics of China 2004–2015). China is also a country where landslides occur frequently. From 2003 to 2014, there were 288,946 places with geological disasters (including landslides, ground cracks and land subsidence) that caused economic losses of 56.55 billion Yuan and 9560 casualties. Among them, the number of landslides was 261,673, accounting for 96.72% and causing the most economic loss and casualties (Ministry of Land and Resources of the People's Republic of China 2004–2015). Landslides are widely distributed in China. Except Beijing, Tianjin and Shanghai, they occurred frequently in the other 28 provinces, autonomous regions and municipalities (Fig. 1).

The close relationship between land urbanization and landslides has attracted the attention of scholars. The existing literature argues that land urbanization impacts landslides in three ways: changing the severity and frequency of the landslide, changing the extent and value of building exposure to landslides, and changing the degree of vulnerability to damage. Firstly, the construction of urban areas and infrastructure reduce the stability of slopes by reducing the area of vegetation cover and cutting the slope, increasing the severity and frequency of landslides in a direct way (Smyth and Royle, 2000; Zêzere et al., 1999). Land urbanization changes the regional hydrological conditions by reducing the water area and trigging the greenhouse effect, increasing the severity and frequency of landslides in an indirect way (Crozier, 2010b; Mohan and Kandya, 2015; Polemio and Sdao, 1999; Rianna et al., 2016; Zope et al., 2016). Secondly, the expansion of urban land is accompanied by the concentration of economic activity and population. Land urbanization not only increases the extent of buildings exposed to landslides but also increases the economic losses and casualties caused (Fedeski and Gwilliam, 2007). Lastly, reasonable prevention measures, including land planning, standards of building construction, and landslide prevention funds, reduce the vulnerability of buildings, which decreases the number of landslides and casualties, as well as the amount of economic losses. With the improvement of economic development levels, the government and the people's awareness of landslide prevention are enhanced and will lead to more reasonable landslide prevention measures (Bernstein, 1992; Douglass et al., 2005; Listo and Carvalho Vieira, 2012; Mandasari et al., 2016; Smyth and Royle, 2000).

Landslide prevention measures determine the relationship between land urbanization and landslides. Compared with developing countries, awareness of landslide prevention is stronger in the developed countries, and more reasonable landslide prevention measures are taken. In the developed countries, land urbanization reduces the frequency of landslides, economic losses and casualties to a certain extent. However, the land urbanization increases them in developing countries due to inadequate and unreasonable landslide prevention measures

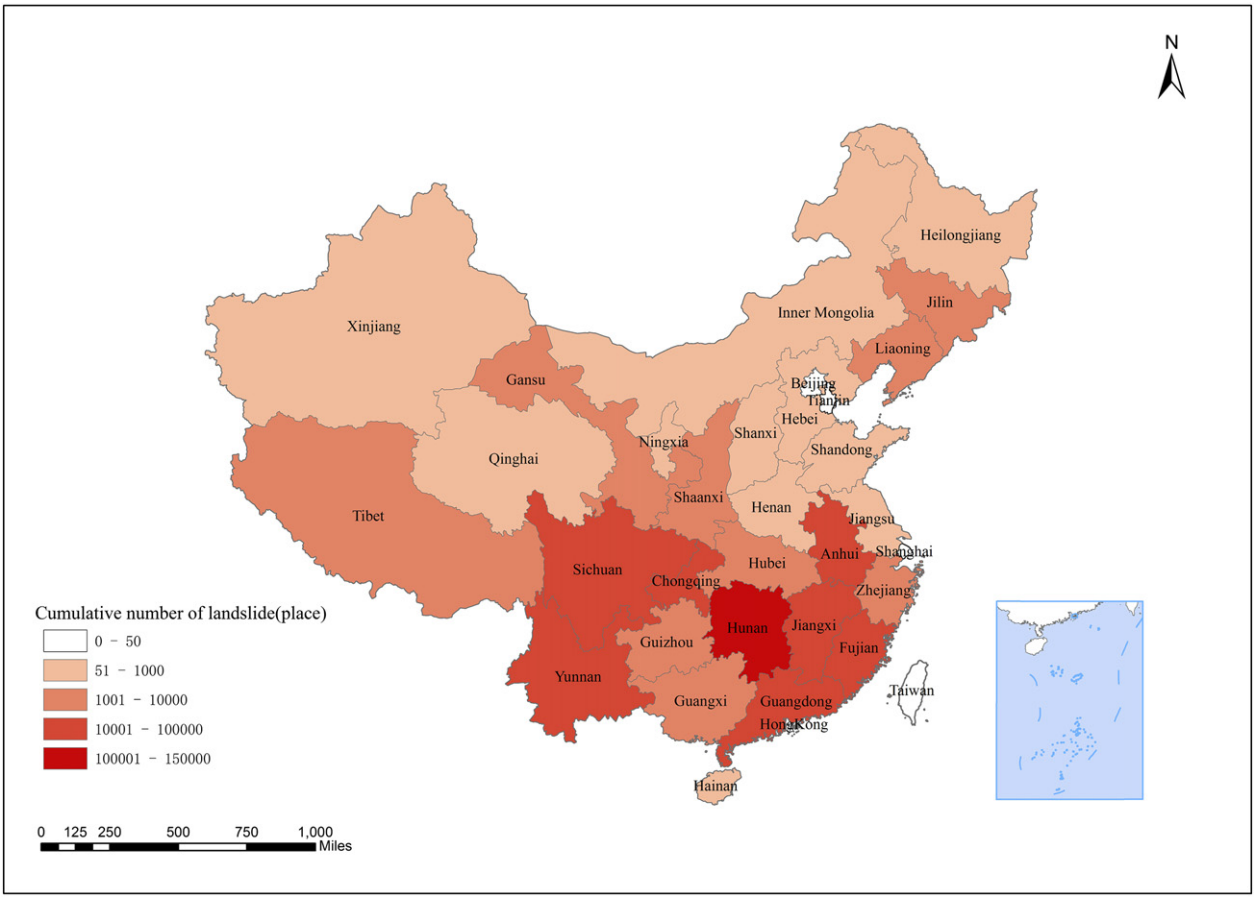

Fig. 1. The cumulative number of landslides: 2003–2014. Notes: The data for Taiwan is unavailable.
Source: China Land and Resources Statistical Yearbook, 2004–2015.