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Effect of urbanisation on the water retention function in the Three Gorges Reservoir Area, China

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ABSTRACT

Urbanisation activities can greatly alter original landform unit shapes and reduce their water retention function, which is the major reason for serious artificial water and soil losses and widespread urban waterlogging. Taking original landform units (OLU) as a control, this work aimed to reveal the extent to which disturbed landform units (DLU) reduce the water retention function in a special building construction area. Field investigations and physical and chemical laboratory analyses were performed to analyse soil physical characteristics including the soil porosity, soil usable storage and soil stable infiltration rate. The coordinate composite method was used to evaluate the effects of urbanisation on the water retention function of the original landform during the urbanisation construction process. The soil bulk densities in the various DLU were greater than in the OLU, showing the following order: construction road (CR) > 1a slope greening belt (SGB) > 1a disturbed soil accumulation (DSA_1) > 2a disturbed soil accumulation (DSA_2) > 3a disturbed soil accumulation (DSA_3). The soil total reservoir storage and usable storage in the different DLU were lower than in the OLU, with usable storage showing the order DSA_3 > DSA_2 > DSA_1 > SGB > CR, which presented decreases of 12.3%, 16.8%, 22.7%, 28.2% and 33.3%, respectively, compared with sloping land. The soil stable infiltration rate presented the order DSA_3 (2.89 mm/min) > SGB (2.65 mm/min) > DSA_2 (1.89 mm/min) > DSA_1 (1.64 mm/min) > CR (0.45 mm/min), while the soil initial infiltration showed the order DSA_1 > DSA_3 > SGB > DSA_2 > CR. The overall water retention function of the different landform units varied in the following order: native forest land > fruit forest land > Abandoned land > sloping land > DSA_3 > SGB > DSA_2 > CR > DSA_1, with DSA_1 causing the greatest harm to the water retention function of the OLU. In order to avoid causing serious soil and water losses and urban waterlogging, building construction projects should attempt to avoid strongly disturbing, occupying and destroying natural rainfall-flood regulation systems, especially for native forest land. Since soil characteristics are crucial for vegetation, these results could provide relevant knowledge to landscape rehabilitation and recovering the function of soil and water conservation ecological services in project areas during the urbanisation construction process.

1. Introduction

During the rapid development of urbanisation and industrialisation, engineering constructions continuously disturb and destroy land types such as forest land, grass land and sloping land, which have important ecological and hydrological functions in the ecological environmental balance (G. Wang et al., 2014; Wang et al., 2012). All human activities during the production and construction process damage the surface vegetation and original soil to a considerable extent, while also producing artificial landforms, including accumulations of disturbed soil, man-made slopes, construction roads and impervious surfaces, through excavation and piling activities (Biemelt et al., 2005; Li et al., 1996; Peng et al., 2014; Shi, 2006; Wang and Cheng, 2002). The Three Gorges Reservoir Area is one of the areas of China showing the most serious soil erosion, associated with many man-made activities such as reservoir resettlement, relocation of industrial and mining enterprises and road construction. These activities have greatly altered the hydrological cycle of the original underlying surface in the region, causing significant urban soil and water losses (Bunte and Poesen, 1994; Moustakas et al., 1995; Poesen and Ingelmo-Sanchez, 1992) and aggravating the threat of urban waterlogging (Bouwer, 2000; Gan et al., 1999; Sharma et al., 2011). Many authors have recently focused on soil and water losses during the process of building construction. Gan et al. (1999) divided the elements of the soil erosion environment

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during the urban construction process into exogenic agency systems, material source systems and interface systems and systematically analysed the characteristics of their effects on the soil erosion environment. Sun and Gan (1998) studied the erosion and sediment-yielding processes in landform units such as steep slopes formed by dumped soil and natural steep slopes in an urbanising construction area through simulated rainfall experiments. However, there are few studies addressing the effects of building constructions on the water retention function of the original landform in a project area.

Rainfall can be translated into soil water storage and groundwater runoff via infiltration through soil pores (Brakensiek and Rawls, 1994; Poesen, 1986), which directly affects the functions of water retention and soil and water conservation in forest lands (Black et al., 1969; Kefi et al., 2011; Poesen et al., 1990; Ruiz Sinoga and Martinez Murillo, 2009). As the main reservoir involved in conserving water in various lands, conserving and regulating the rainfall function of the soil is mainly attributed to the capacity of the soil to conserve water statically and regulate water dynamically, and the water-conserving capacity of the soil mainly depends on the soil type, soil porosity and soil water content (Arnau-Rosalén et al., 2008; Danalatos et al., 1995; Katra et al., 2007; Liu et al., 2011; Poesen and Lavee, 1994; Ruiz Sinoga et al., 2010). Therefore, taking a special building construction project located in the subtropical evergreen broad-leaved forest area of the Three Gorges Reservoir Area as an example, the specific objectives of this study were as follows: (1) to show the effects of the building construction on soil physico-chemical properties, which could reflect differences in soil physico-chemical properties under various types of vegetation; (2) to illustrate the influence of the building construction on the soil infiltration capability, which could reveal the effect of vegetation on the soil structure; (3) to analyse the reducing effect of the building construction on the soil water storage capacity, which could indicate the soil water available for plant growth; and (4) to evaluate the water retention function of various landform units.

2. Materials and methods

2.1. Experimental site

The experiment site is a typical building construction project for commercial using (latitude 29°47′42″N, longitude 106°23′50″E, altitude 312 m), located at Beibei Shi Li Wen Quan Cheng, in the Jinyun Mountain National Nature Reserve in Chongqing, China (Fig. 1). This area is characterised by a subtropical monsoon climate, with an average annual rainfall of 1611 mm, average annual temperature of 13.6 °C, average annual evaporation of 1181.1 mm and an average annual relative humidity of over 87%. The soil type at this site is dominated

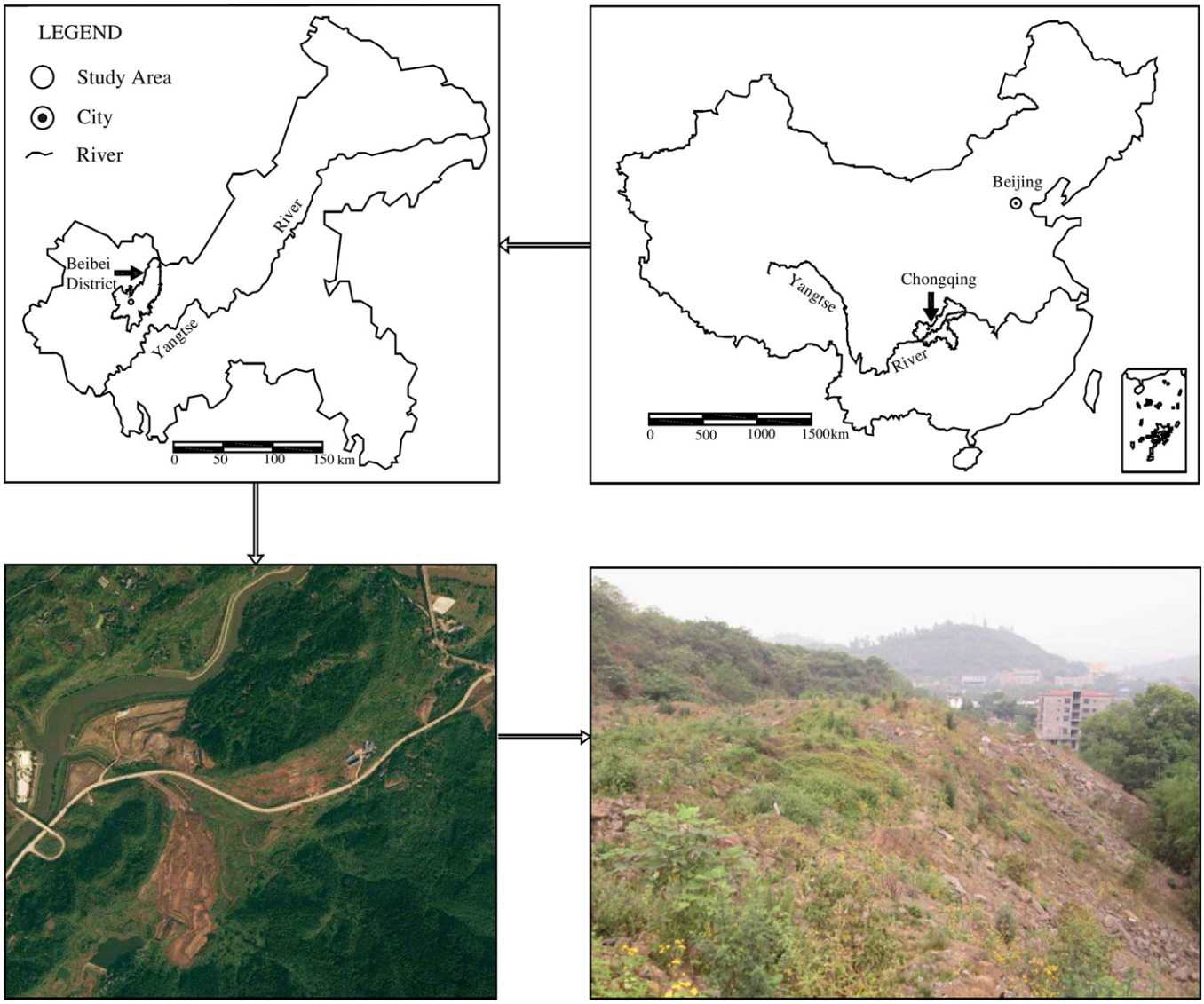

Fig. 1. Maps showing the location of the study site.