Catena 89 (2012) 22–30

Contents lists available at SciVerse ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Extent of soil erosion and surface runoff associated with large-scale infrastructure development in Fujian Province, China

Guangyu Wang [a], John Innes [a,*], Yang Yusheng [b], Chen Shanmu [c], Judi Krzyzanowski [a], Xie Jingsheng [b], Lin Wenlian [c]

[a] Sustainable Forest Management Research Group, Faculty of Forestry, University of British Columbia, 2045-2424 Main Mall, Vancouver, B.C, Canada V6T 1Z4
[b] College of Geographic Science, Fujian Normal University, 350007, China
[c] Fujian Soil and Water Supervision Station, Fuzhou, 350003, China

ARTICLE INFO

Article history:
Received 13 January 2011
Received in revised form 31 August 2011
Accepted 7 September 2011

Keywords:
Erosion
Runoff
Geologic hazards
Sustainable development
Fujian China

ABSTRACT

We examined runoff and sediment transport associated with large-scale construction projects in Fujian Province, China. Six experimental plots, comprised of four plot types, were designed to mimic typical conditions immediately following disturbance. It was found that natural vegetative cover reduces both runoff and erosion by approximately 36 and 7457 times over bare ground, and 16 and 1801 times over typically planted grasses, respectively. The increase in erosion associated with the replacement of native vegetation with bare ground or grasses due to large-scale infrastructure projects in Fujian from 1999 to 2004, amounted to an estimated loss of 1.76×10^7 tonnes of top soil and 3.04×10^8 m^3 of surface runoff from the province during the bare soil construction phase, and an additional 4.25×10^6 tonnes of top soil and 1.35×10^8 m^3 of surface runoff from the province associated with the first year of operation for each project. This has implications for frequency and occurrence of landslides and other geographic hazards, the transport of chemicals into waterways, the transport of goods through shipping passages, and the fertility of land in Fujian.

1. Introduction

China is developing rapidly. However, the sustainability of these social, economic and structural developments may be limited by the widespread occurrence of soil erosion (e.g. Chen, 2000; Wang, 2003; Wang et al., 2008). Construction activities are integral to this development, and have the potential to increase soil erosion by up to 40,000 times (Harbor 1999). The subsequent sediment loads can adversely affect surface water quality (Edwards and Burian, 2002; Harbor, 1999), and obstruct waterways. The effects of agriculturally induced soil erosion and sedimentation on streams, lakes and wetlands have been well documented in the United States (e.g., Booth, 1990; Knox, 2001) and Europe (e.g. Stoate et al., 2009; Veihe et al., 2003). However, compared to sediment generated from agricultural areas, individual construction sites can contribute much larger loads of transported sediment to small areas over short time periods (Kaufman, 2000), and are not well documented.

Rapid economic growth in China over the last 20 years has resulted in massive infrastructure development and construction. This construction has altered landforms, vegetation, and waterways; and has led to surface runoff, soil erosion, sedimentation and land degradation. However, a lack of economic incentives for land developers in China, combined with a lack of both research and regulations to control erosion, have limited the adoption of runoff and sediment control techniques. The magnitude and impact of soil erosion from construction sites are poorly documented and generally underestimated in China, partly due to centralized planning and control systems and potential issues associated with the criticism of government-funded infrastructure projects.

From 1991 to 1995, the annual amount of soil and rock displaced by construction in China exceeded 3 billion tonnes (Jiao, 1998). For example each year in the middle and upper reaches of the Yangtze River, an additional 1200 km^2 of land is impacted by erosion. In the Three Gorges area, 127 construction projects between 1996 and 2000 resulted in more than 100 million tonnes of soil being released into the river (Wang, 2003). Further north, annual erosional soil losses in Shanxi province now total approximately 75 million tonnes, predominantly from mining and rock exploitation. In neighbouring Shaanxi province to the west, the area impacted by soil erosion from road construction increased by 5278 km^2 between 1949 and 1978, representing approximately 6% of the province's area (Jiao, 1998).

A variety of temporary methods can be implemented to reduce erosion and trap sediment on site, such as construction-phase surface covers, siltation fences, and sedimentation basins. However, the design and implementation of these techniques require an understanding of erosion and sedimentation processes; and in many cases, incorrect installation and maintenance has limited their effectiveness (Harbor, 1999; Price and Birge, 2005). For this research, Fujian Province, at the lower reaches of the Min River, was chosen as a study area to estimate the magnitude and distribution of soil erosion and surface

* Corresponding author. Tel.: +1 604 822 3542.
E-mail address: john.innes@ubc.ca (J. Innes).

0341-8162/$ – see front matter
doi:10.1016/j.catena.2011.09.001

runoff caused by the construction of large-scale infrastructure in China (Fig. 1).

Fujian lies on the south-eastern coast of China (Fig. 1). It has a land area of approximately 120,000 km^2 and a population of over 32.6 million. Fujian's GDP reached $183.8 billion in 2009–a nine-fold increase since 1980–and it is one of China's most rapidly developing regions (Fujian Statistical Bureau, 2009). In response to this growth, Fujian's infrastructure has been promptly improved. Projects include a new highway network, a highly developed railway system, a water transportation network, and a number of large and medium-sized power generating stations.

We examined how infrastructure development affects soil erosion and sedimentation, and assessed the extent of erosion and sediment transport occurring in Fujian Province by combining two research methods: 1) experimental plots to replicate surface runoff and soil loss in the period during and immediately following construction, and 2) a survey of 90 large-scale construction projects in Fujian during 1999–2004 in which the surface impacts of construction were assessed. Measures used to quantify construction impacts include: the existence of soil protection techniques, the area of disturbed ground, the volume of soil displacement, and the extent of soil erosion.

2. Methodology

2.1. Experimental assessment of soil erosion

An experimental research site was established close to Jianou City (118°57′11″ E, 27°20′26″ N) within the Min River Watershed of Fujian Province (Fig. 1), in order to estimate soil erosion and surface runoff associated with construction projects. The region is sub-tropical with an annual average temperature of 18.7 °C, and an annual rainfall of 1664 mm concentrated between March and September. Ultisol soils, derived from Quaternary red clay and granitic parent material, dominate the study area (Higgiti and Rowan, 1996; Zhu et al., 2003).

The plots were designed to simulate annual runoff and soil erosion following precipitation events in the period immediately following ground disturbance. Six permanent observation plots were developed, comprised of four different plot types (Table 1). Two plots had exposed soil without grass (ESWOG) — representing construction period conditions, two had exposed soil with grass (ESWG) — representing conditions during the first year of operation, and two originally functioned as control plots — one with natural barren land (NB), the other with natural

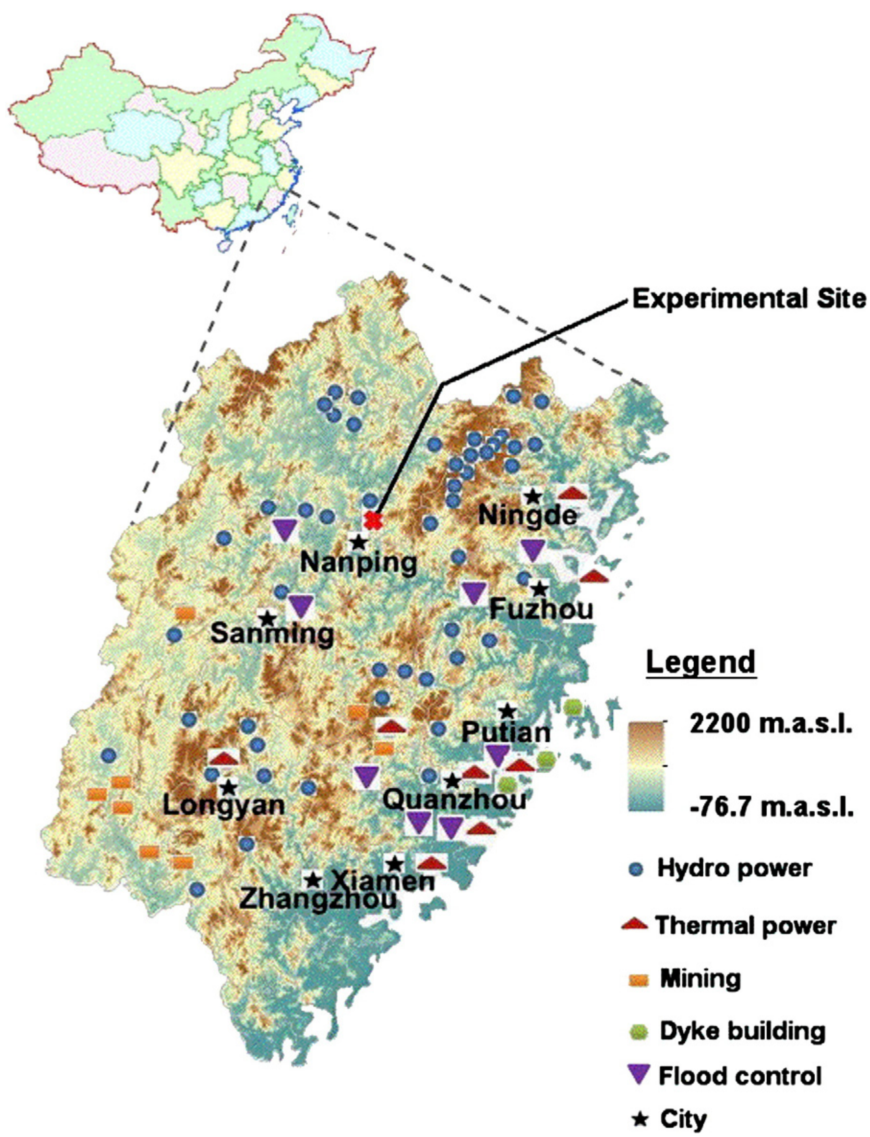

Fig. 1. Map of China (top left inset), showing location of Fujian Province in the southeast. The main map shows locations of the experimental sites in Dongmen, Jianou County, elevation, and the locations of major infrastructure construction projects (see legend). Linear infrastructure projects are not represented.