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Soil erosion characteristics of ditch banks during reclamation of a saline/sodic soil in a coastal region of China: Field investigation and rainfall simulation

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ABSTRACT

Understanding soil erosion processes is essential for assessing the extent and causes of soil erosion and for planning soil conservation including those on the banks of excavated ditches. Based on a field investigation and laboratory rainfall simulation experiments, the soil erosion characteristics of a saline/sodic soil undergoing reclamation that was exposed on irrigation/drainage ditch banks in a coastal region of China were investigated. Preliminary analyses of the data indicated that the soil erosion was more severe from the ditch banks in the coastal region than from those in other areas of China. The annual erosion loss from ditch banks in the most recently reclaimed farmland (2007) was 140 kg/m^2, but the erosion modulus decreased significantly ($p < 0.05$) with increasing reclamation time. Increasing rainfall intensity and/or slope gradient increased runoff and sediment yield rates. However, there was a critical slope gradient of about 25°, above which no further increases occurred. As rainfall intensity and/or slope gradient increased, the overland flow velocity and the Froude number (*Fr*) increased notably. The Reynolds number (*Re*) increased with increasing rainfall intensity, but decreased and was more affected by increases in slope gradient. Positive parabolic relationships were found between sediment yield rates and *Re*. The resistance to flow decreased with increasing rainfall intensity and slope gradient. Negative correlations were found between the sediment yield rate and the resistance force (f and n). Covering the soil surface greatly decreased runoff and soil erosion by increasing the surface roughness and decreasing the runoff velocity. Compared with covers of stones or netting, and with no cover, the slope runoff coefficient and sediment yield rate of soil under straw mulch were the lowest with values of 0.043 and 0.14 kg/m^2 min, respectively. Therefore, using straw mulch would be a way to control erosion until salt-tolerant plants colonized and protected the ditches.

1. Introduction

Soil erosion by water is a complex phenomenon involving the processes of detachment, transport and deposition of soil materials by the combined erosive forces of raindrop impacts and overland flow resulting from runoff (Assouline and Ben-Hur, 2006; Ellison, 1945). Erosion is of great concern due to its negative impacts on natural and managed ecosystems as well as on construction (Guo et al., 2013; She et al., 2011; Xu et al., 2009). Most erosion studies have concentrated on croplands or natural hillslopes and have indicated that the problem of severe soil erosion is affected by a number of factors including slope gradients, inherent soil erosive properties, land cover conditions, climate and inappropriate land management practices (Chaplot and Le, 2003; Kinnell, 2005; Ouyang et al., 2010). However, relatively few studies have investigated soil erosion processes during construction, and these have mainly focused on construction spoil deposits comprising excess excavated materials and on unpaved engineered surfaces (Dong et al., 2012; Xu et al., 2009). Soil erosion processes on construction spoil deposits exhibit significantly stronger spatial variability than those on cropland and on natural hillslopes, and are affected by different factors (Dong et al., 2012; Riley, 1995; Schroeder, 1987).

Tidal flat resource exploitation plays a crucial role in coastal development strategy in Jiangsu Province in China. Since the construction of the Fan-Gong Dike in the 11th century A.D., about 2 million hectares of tidal flats have been reclaimed and cultivated in Jiangsu (Fig. 1). In 2009, a proposal ("Development Planning of Coastal Areas of Jiangsu") was made to further reclaim about 2.70 million hectares of the coastal region by 2020; about 60% of the reclaimed area would be used for farmland, 20% for construction, and 20% for environmental conservation purposes. During the reclamation of the tidal flats, supporting water conservancy

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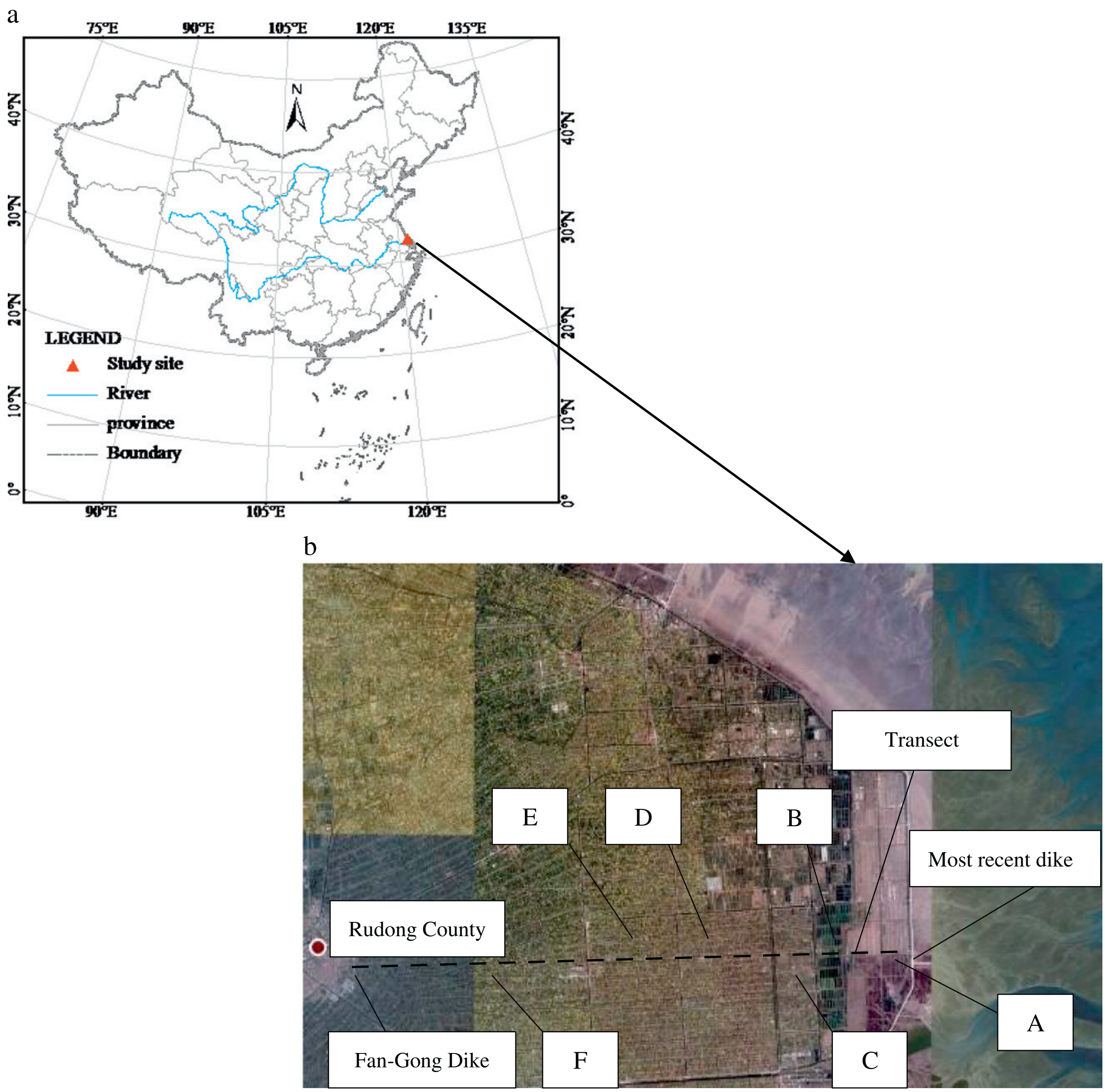

Fig. 1. Location of the study site (a) and the six farmland areas reclaimed at different times (b) (A: 2007; B: 1981; C: 1960; D: 1950; E: 1940; F: 1916).

construction will result in many exposed excavated slopes such as those of the banks of ditches, drainage channels, streams and rivers. Given the region's abundant rainfall and high soil sodium salinity, these slopes would likely be highly erodible and unstable, possibly leading to collapse.

On exposed soil slopes, soil erosion is likely to be affected by a greater degree of surface seal formation that results from the physical impact of high-energy rainfall and physico-chemical dispersion (Assouline and Ben-Hur, 2006; Kim and Miller, 1996). Soil sealing reduces infiltration thereby increasing the amount of runoff and its transport capacity, but its effect on soil surface shear strength or soil detachment is less clear. The process of aggregate breakdown, which is a component of the surface sealing process, also reduces the particle size of soil material at the soil surface that, when loose, provides a source of more readily transportable material. However, it is also possible that these smaller sized particles will be incorporated into the surface seal, which reduces its availability for transport.

Increasing the sodicity of soils or decreasing the salinity of the soil solution increases the repulsion forces between soil clay particles. For a particular soil, there is a point at which the combination of sodicity and salinity values results in the dispersion or swelling of the soil clay (Pratt and Suarez, 1990). Both dispersion and swelling lead to obstruction of the soil's water-conducting pores by the clay, reducing infiltration rates. Increased clay dispersion also enhances the process of aggregate breakdown. The combination of increased runoff and aggregate breakdown increases the erodibility of sodic soils. Furthermore, high sodicity combined with low salinity results in clay swelling that also reduces water movement into and within the soil even before the full development of a surface seal, which contributes to increased runoff (Oster and Shainberg, 2001). Clay swelling is reduced in sodic soils when the salinity of the soil solution is higher.

Field investigations in the Jiangsu coastal region (unpublished data) have shown that ditches were filled with massive amounts of eroded material due to the high erodibility of the sodic soils, which would