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Assessing soil erosion in a terraced paddy field using experimental measurements and universal soil loss equation

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ABSTRACT

The study assesses the effects of event rainfall on the soil erosion in terraced paddy fields under rice cropping, fallow, and green manure planting. A 0.75-ha terraced rice field was used to investigate the soil erosion under the regular cultivation of rice in 2005, fallow in 2006, and planting with green manure in 2007. The results show that infiltration rates significantly increase when a terraced paddy field is under fallow or is planted with green manure; the paddy is more vulnerable to embankment collapse and increased the rates of soil erosion. In an experimental field, suspended solid in run-off samples reached the maximal concentrations of 1700 mg/l for fallow in 2006, and 3400 mg/l for manure planted field in 2007, during heavy rainfall events. These values were significantly greater than the erosion rate of 500 mg/l recorded for rice cropped field during 2005. The estimated annual erosion rate was 4.15 ton ha^{-1} yr^{-1} for green manure planted field, which was significantly higher than that of the rice-planted terraced paddy (0.77 ton ha^{-1} yr^{-1}). Moreover, terraced paddy runoff significantly increased when planted with green manure. Soil erosion rates calculated by the Universal Soil Loss Equation (USLE) from the optimal available data were considerably higher than the field-measured values. The comparison revealed that soil conservation using rice-planted terraced paddy was more effective than that resulting from other uses. The government should formulate effective measures and maintain sustainable rice planting in the terraced paddies.

1. Introduction

Rice paddies cultivated in monsoonal Asia both provide high rice productivity and maintain a sustainable and environmentally friendly ecosystem appropriate to the regional climatic and topographical conditions. Rice paddy cultivation is a unique way of life, a complex amalgamation of sustainable human activity, society, and the natural environment. In addition, paddies have a positive influence on the urban environment by reducing floods, recharging groundwater, lowering the air temperature, and reducing atmospheric carbon dioxide. A large number of countries have acknowledged the multifunctional roles of paddy fields (Kim et al., 2006; Liu et al., 2010; Matsuno et al., 2006; OECD, 1998; Tsai et al., 2003).

Rapid economic development has greatly reduced the availability of agricultural labor in Taiwan. A large percentage of former terraced paddy fields have either been abandoned or converted to other uses. Terraced paddy fields, located in the middle and upper areas of river valleys, also perform several ecological and environmental functions, including floodwater storage, reducing soil erosion, purifying water, and recharging groundwater. Thus, the conservation of terraced paddy fields is an important environmental issue (Liu et al., 2001, 2004).

Most fallow paddy fields have been converted to the cropping of green manure, or the growing of upland fruit trees, vegetables and horticulture plants in-line with governmental policies. Only a 50% survival rate for green manure crops is required to qualify for government subsidies, and thus, farmers have little incentive to improve the green manure survival rate, or to build a bank of fallow fields to protect sloping land; terraced fields significantly hinder soil and water conservation (Matsuno et al., 2006).

Soil erosion in mountainous areas is a well-recognized problem. The main determinants of soil erosion are topography, soil texture, rainfall patterns, land cover, and land use. Numerous models have been developed to quantify and predict soil erosion. The Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) is a frequently used model to determine areas at risk from erosion, and informs decision making for the reduction of erosion as a part of the long-term management of agricultural land. The amount of potential soil erosion is calculated as

$$A = RKLSCP \quad (1)$$

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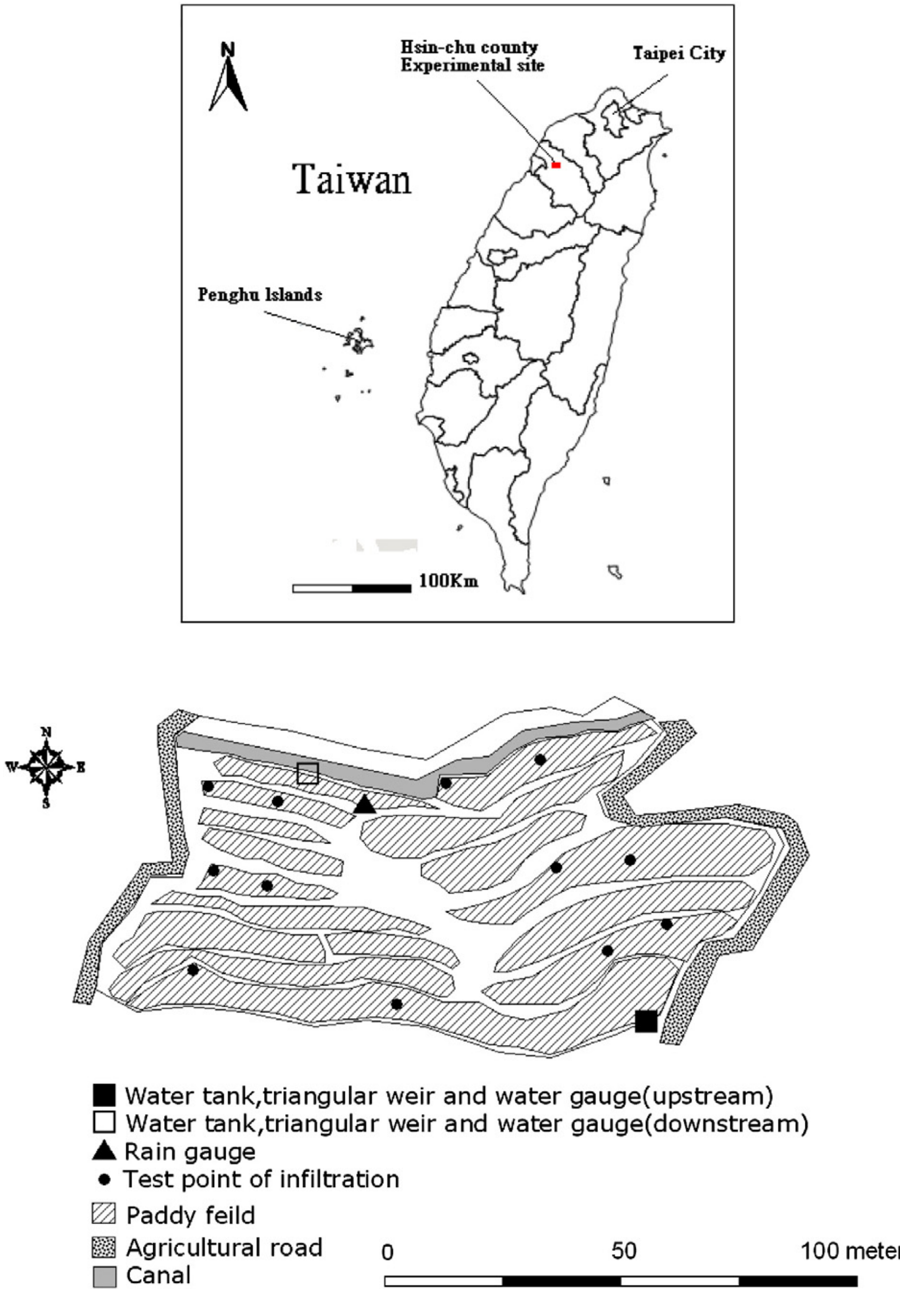

Fig. 1. Location of the experimental site in Taiwan.

where A is the long-term average annual soil loss (ton ha^{-1} year^{-1}) caused by erosion; R is the erosivity factor (Mj mm ha^{-1} h^{-1} year^{-1}), and K is the soil-erodibility factor (ton ha hr h^{-1}Mj^{-1} mm^{-1}) that specifies the tendency of the soil to erode. LS is the topographic factor, which combines the length and steepness of the slope; the ratio of the loss of soil in a given area is of interest to a field of specified length of 22.6 m with a 9% slope. C is a crop management factor, a ratio of soil loss for a given field, compared to that of a standard cultivated bare fallow field, and P is the conservation practice factor, which compares soil loss with that from a field that has undergone no attempts at conservation. In Japan, the Mitsubishi Research Institute (MRI, 1991) used the USLE to estimate soil loss and found that the average annual rate of soil erosion increased 2.56 ton ha^{-1} for abandoned rice paddy fields with slope gradient greater than 5%. In Korea, MAF (1999) indicated that paddy fields play a role to conserve a substantial portion of soils and sands washed away from steep uplands and hills, thereby preventing those soils from being carried downwardly to rivers. Based on the USLE estimation, the average annual amount of soil erosion occurring in uplands was 22.4 ton ha^{-1}. In Taiwan, Lin and Lin (2004) used the USLE to evaluate the rates of soil erosion in rice-planted paddy fields and abandoned paddy fields, assuming that the topsoil had no plant cover. The rates of erosion increased from 4.8 ton ha^{-1} year^{-1} for lowland rice-planted paddies (with mild slope approximate to 1.5°) to 192.5 ton ha^{-1} year^{-1} for abandoned paddies on plains and from 8.3 ton ha^{-1} for terraced rice-planted paddies to 2049.8 ton ha^{-1} year^{-1} for abandoned paddies in mountainous areas (with steep slope approximate to 25°). Although the same USLE and its revised versions were applied for the estimations of soil loss from paddy fields, significantly different results were obtained throughout Asia in the monsoon regions, including China (Cai et al., 2000; Liu and Luo, 2006), Japan (Yoshikawa et al., 2004), India (Shinde et al., 2010) and South Korea (Lee and Choi, 2010). The difference was due to the use of