Chi-Chi Earthquake-caused Landslide: grey prediction model for pioneer vegetation recovery monitored by satellite images

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(Received May 14, 2001; Accepted August 2, 2001)

Abstract. We applied multiple SPOT satellite remote sensing data to evaluate the recovery rate of vegetation in the Chiu-Feng-Er mountain landslide area after the Chi-Chi Earthquake. The grey theory was also applied to predict the time required for pioneer vegetation to completely reclaim the non-rock landslide area, and this was compared with the results of linear, exponential, and polynomial regression analysis. While complete recovery of vegetation may take 5.2, 1.6 and 3.4 years predicted by the linear, exponential, and polynomial regression analyses, respectively, it may take 2.0 years according to grey analysis. On the basis of ground investigation, the recovery process of pioneer vegetation in Chiu-Feng-Er Mountain landslide may follow the equation of the grey prediction model, i.e. \( x(k+1) = 72387.143e^{0.4704k} \). This recovery process exhibited a lag phase of approximately two months.

Keywords: Earthquake-caused landslide; Grey prediction model; Pioneer vegetation; Recovery; Satellite images.

Introduction

At 1:47 on the morning of September 21, 1999, Taiwan’s largest earthquake (ML=7.3, Mw=7.7) in the past hundred years struck the central part of this island nation near the small town of Chi-Chi, leading to extensive surface ruptures and severe destruction in most the towns of Nantou and Taichung Counties (Ma et al., 1999; Kao and Chen, 2000). The Chiu-Feng-Er Mountain landslide area is the fourth largest of all Chi-Chi Earthquake-caused landslide areas (Chen and Lee, 1999). Very little vegetation remained in the area after the quake.

Satellite remote sensing data has been used to monitor long-term changes in vegetation (Oechel and Reid, 1984; Jakubauskas et al., 1990), photosynthesis of terrestrial plants (Field et al., 1994), changes in canopy structure and density (Malanson and Trabaud, 1987), recovery of primary production (Specht, 1981; Tucker and Sellers, 1986), regrowth rate and biomass production of the forest (Viedma et al., 1996), rate and model of recovery (Viedma et al., 1997), and other aspects during the ecological recovery process following the fires. The immediate damage wrought by the earthquake on the forest (Allen et al., 1999) and the recovery of earthquake-caused landslide area have been studied (Garwood et al., 1979). However, no report using satellite images to monitor the ecological recovery process in a landslide area after a disastrous earthquake is yet available.

The grey system theory was first presented in China. Thereafter it has been increasingly and widely applied in many research fields to deal efficiently with an uncertain system through grey methodologies, including grey generation, grey relational analysis, grey modeling, grey prediction, grey decision making, and grey control (Deng, 1982 and 1989). A grey prediction model GM(1,1) is the main component of the grey system theory and has been used in most research (Deng, 1989). An increasing number of forecasting studies in the life sciences are beginning to apply grey theory to analyzing uncertain systems. Examples include grain yields (Luo and Zhang, 1991), vegetable yields (Ma et al., 1996; Long, et al., 1993), crop breeding (Guo, 1994; Zeng et al., 1993), choosing the best serum markers of liver fibrosis (Chen and Tan, 1995), epidemic diseases (Wei, and Xie, 1994), population growth (Jin and Tang, 1994), and changes in the ecological environment (Che and He, 1993; Yang et al., 1999).

This study considered regression analysis and the grey theory to predict the pioneer vegetation recovery rate, monitored by multiple SPOT satellite remote sensing data obtained during the first year following the Chi-Chi Earthquake. The pioneer vegetation includes the rare residual vegetation after the quake and the new vegetation.

Materials and Methods

Study Area

Chiu-Feng-Er Mountain is located in Kow-Hsin-Shiang of Nantou County (Figure 1). The surface soil and rock along the dip slope of the southern side of Chang-Su-