Geomorphology 201 (2013) 70–79

Contents lists available at ScienceDirect

Geomorphology

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

Shallow and deep-seated regolith slides on deforested slopes in Çanakkale, NW Turkey

Yunus Levent Ekinci [a,*], Murat Türkeş [b], Alper Demirci [a], Ahmet Evren Erginal [c]

[a] Çanakkale Onsekiz Mart University, Engineering Faculty, Department of Geophysical Engineering, TR-17020 Çanakkale, Turkey
[b] Middle East Technical University, Faculty of Arts and Sciences, Affiliated Faculty at the Department of Statistics, TR-06800 Ankara, Turkey
[c] Ardahan University, Faculty of Humanities and Letters, Department of Geography, TR-75000 Ardahan, Turkey

ARTICLE INFO

Article history:
Received 8 July 2011
Received in revised form 28 January 2013
Accepted 10 June 2013
Available online 22 June 2013

Keywords:
Regolith
Soil moisture content
Shallow and deep-seated slides
Electrical resistivity
Çanakkale
Turkey

ABSTRACT

This study deals with the stripping of regolith on a steep slope by surface wash and shallow landslides and a deep-seated landslide at a lower slope that took place on 17 February 2003 at the village of Mazılık, east of Çanakkale, Turkey. Soil loss and shallow slides dominate on the deforested steep slopes in the study area and occur preferentially along slope-parallel sub-horizontal joint planes with clay coatings, particularly oxyhydroxides that are rich in Fe but poor in Mn as a result of weathering under well-drained conditions. Gully erosion also occurs where the regolith cover is relatively thick (up to ~4 m). The area of the deep-seated landslide, however, is dominated by silty clay (46%). A geoelectrical resistivity survey revealed a clay-rich zone at depths of ~3–10 m, corresponding to the slip surface of the slide, which was associated with excessive water content after the snowy day of 14 February 2003 with a daily precipitation of ~16.4 mm. Based on Thornthwaite's water budget analysis, the study area has a slide-prone condition with excess soil-moisture content, heavy rainfall events, snow accumulation and snow melting in winter months, and low soil permeability also favouring slope instability.

1. Introduction

Regolith, a term first suggested by Merrill (1897), is a weathering mantle formed by decomposition of the underlying host rock that can be of various origins and nature. As discussed in detail by Eggleton and Taylor (2001), regolith is of great importance for agricultural activities as well as engineering projects. Nevertheless, regolith, depending on its thickness and other geo-environmental factors, may sometimes be subjected to intensive gully erosion and slope failures of various scales. Although rainfall is a common triggering factor of regolith slides (De Vita and Reichenbach, 1998; Corominas, 2001; Conte and Troncone, 2012; Montrasio et al., 2012; Salciarini et al., 2012), various hydrogeological factors as well as chemical and mineralogical heterogeneities are also important (Duzgoren-Aydin and Aydin, 2006; Che et al., 2012). Shallow landslides often affect long-term hillslope evolution and have a basal surface between regolith and underlying bedrock, where bedding, joints, and faults provide planes of pre-existing weakness with high clay concentration (Skempton and Petley, 1967; Cruden and Varnes, 1996).

We studied shallow and deep-seated regolith slides in the Biga Peninsula, which is underlain by various volcanic rocks including basalt, dacite, and agglomerate of Eocene–Miocene age. The study site, an abandoned small village called Mazılık, is located 20 km east of Çanakkale City. The slope failures and gully erosion in the area date back to the 1950s. Shallow slides occurred on a steep deforested slope (>20°). In mid-February of 2003, a deep landslide also occurred below the shallow landslides, destroying a primary school.

The present study describes the petrography and structural features of weathered volcanic rocks on a deforested steep slope and discusses their relationship with gully erosion and shallow slides. The subsurface characteristics of the deep-seated landslide are also examined using data from electrical resistivity tomography (ERT) and vertical electrical sounding (VES) techniques. The failures are discussed in relation to sub-horizontal joint planes with clay coatings. Hydroclimatological analyses explaining the effects of precipitation on the removal of regolith are also described. Additionally, changes in the landslide area between 1954 and 2008 are documented with aerial photographs and satellite images.

2. The study area

The study area in the village of Mazılık (40°07′31″ N, 26°34′14″ E) (Fig. 1) is now abandoned because of limited arable land and the threat of slope failures and gully erosion. Precipitation in the study area is low from May to September, a typical characteristic of the Mediterranean climate (Türkeş, 1996, 1998). According to long-term meteorological data from the Çanakkale weather station (40°08′28″ N, 26°24′01″ E; 6 m a.s.l.; 20 km west of the landslide area) operated by the Turkish State Meteorological Service (TSMS),

* Corresponding author. Tel.: +90 2862180018 2166; fax: +90 2862180541.
E-mail address: ylekinci@comu.edu.tr (Y.L. Ekinci).

0169-555X/$ – see front matter
http://dx.doi.org/10.1016/j.geomorph.2013.06.008

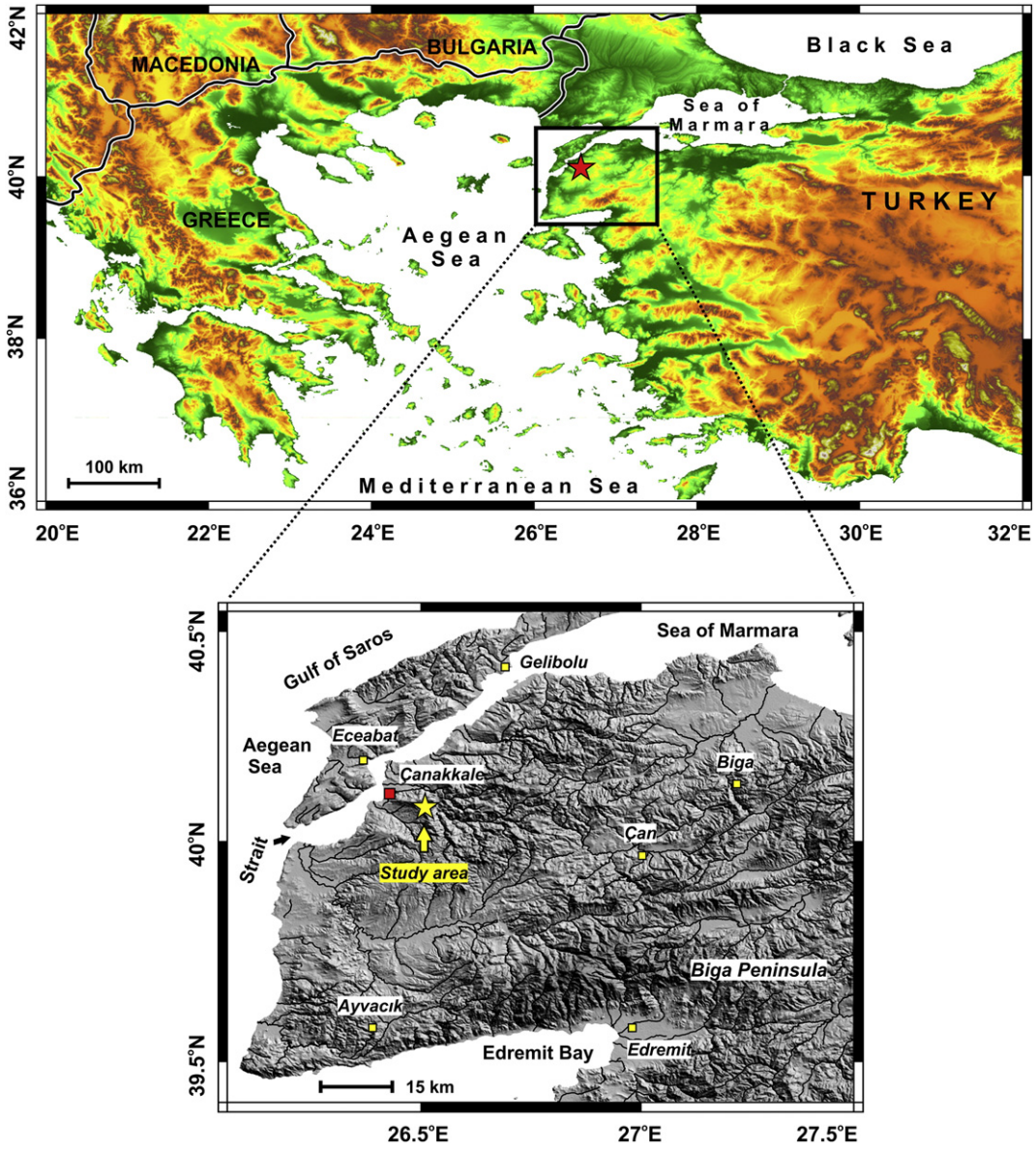

Fig. 1. Location map of the study area.

maximum precipitation occurs in December with a long-term average precipitation of ~109 mm, whereas minimum precipitation occurs in August with a long-term average of ~6 mm. The coldest month, with a long-term average temperature of 6 °C, is January, and the warmest, with an average of 24.8 °C, is July. The aridity index of the United Nations Convention to Combat Desertification (UNCCD, 1995) indicates that a semiarid or a sub-humid climate prevails over the Çanakkale District (Türkeş, 1999).

Vegetation is quite sparse and is characterised mainly by some maquie elements (e.g., *Quercus coccifera*, *Phillyrea latifolia*, and *Styrax officinalis*), pine species (*Pinus brutia* and *Pinus nigra*) and *Quercus* species (e.g., *Quercus cerris*, *Quercus infectoria*, and *Quercus pubescens*). Field studies also showed the presence of *S. officinalis*, *Pyrus amygdaliformis*, *Prunus amygdalus*, and *P. latifolia*. The nearly flat ridge surface behind the steep slope is dominated by *P. brutia*, *Q. cerris* L. var. *cerris*, and *Q. pubescens*. The sparse vegetation around the landslide area, with an altitude of between 350 and 400 m, is mainly a result of deforestation and overgrazing.

The slope with the shallow slides and gully erosion faces southwest with elevation ranges from 350 to 440 m, and angles up to ~27°. The slides occur in an area with a length of 240 m and width of 160 m (Fig. 2A), in which minor slide scars with heights between 10 and 50 cm occur along sub-horizontal joints (Fig. 2B). The regolith mantle on the slope is dissected by nine gullies with lengths between 205 and 514 m (Fig. 2C). These gullies are <3 m in width and their bottoms are congested with basalt blocks with diameters of <1 m. The deep-seated failure extends down to 300 m a.s.l. (Fig. 2D). Besides the concavity of the slip surface and hummocky topography of the landslide toe with accompanying ridges, small ponds and distorted trees and fences typify rotational slides (Cruden and Varnes, 1996).

According to oral and recorded information from elderly villagers and the local administration and to technical reports from the Çanakkale Public Improvements Administration, the slope failures and land degradation of the study area began in the early 1950s. An aerial photograph acquired in 1954 shows that there had been a