Climate Risk Management xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Climate Risk Management

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

Distributed probability of slope failure in Thailand under climate change

Daisuke Komori[a], Prem Rangsiwanichpong[a,*], Naotatsu Inoue[b], Keisuke Ono[c], Satoshi Watanabe[d], So Kazama[e]

[a] Graduate School of Environmental Studies, Tohoku University, Sendai 980-8579, Japan
[b] JGC Corporation, Yokohama 220-6001, Japan
[c] CTi Engineering Co. Ltd., Tokyo 103-8430, Japan
[d] Graduate School of Engineering, University of Tokyo, Tokyo 113-8656, Japan
[e] Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan

ARTICLE INFO

Keywords:
Climate scenarios
Extreme rainfall
Global circulation models
Landslide
Thailand

ABSTRACT

Landslides are more widespread compared to any other geological hazards in Thailand. The steep slope and high elevation areas have more potential for landslide hazards. However, weather extremes, particularly extreme rainfall, play a major role in the occurrence of landslides in Thailand. The objective of the present study is to analyze the changes in the probability of landslide occurrences in Thailand due to climate change. For this purpose, probabilistic landslide hazard maps for extreme rainfall values for 5-, 10-, 50-, and 100-year return periods are developed for historical and future climatic conditions, derived from 10 global climate models (GCMs) under two representative concentration pathway (RCP) scenarios, namely, RCP 4.5 and RCP 8.5. The results reveal that the 5-year return period extreme rainfall amount will reach 200 mm/month in the eastern and southern provinces for RCP 4.5 and the northwestern, eastern, and southern provinces for RCP 8.5. The increase in extreme rainfall will cause a sharp increase in the landslide probability in Thailand, except in low altitude regions. The probability of 100-year return period landslide will increase by 90% in 40% and 80% of the areas in Thailand under RCP 4.5 and RCP 8.5, respectively. It is expected that the landslide hazard maps developed in this study will help policy makers take necessary measures to mitigate increasing landslide events due to climate change.

1. Introduction

Landslide research requires the use of soil and geological data, which are not fully available in developing countries due to lack of information concerning the location of and risks posed by landslides in mountainous regions. Landslides can cause significant damage to residents and can lead to economic losses in these countries. Therefore, it is important to assess future landslide risk distribution using quantitative analysis and to designate regions that require reinforcement measures to prevent landslides. Various methods of predicting the vulnerability to rainfall-induced landslides have been developed. Thus, analyzing landslide risks based on the geographic information system (GIS) and remote sensing techniques are necessary in the case of developing countries. In Thailand, a relative abundance of data have supported numerous landslide studies. Soralump (2010) prepared a landslide hazard map for Phuket Island using soil conditions and rainfall information obtained from site surveys. Jotisankasa and Vathananukij (2008) investigated geological features and soils in various districts of

* Corresponding author.
E-mail addresses: daisuke.komori.e8@tohoku.ac.jp (D. Komori), prem.rangsiwaichpong.q8@dc.tohoku.ac.jp (P. Rangsiwanichpong), inoue.naotatsu@jgc.com (N. Inoue), ksk-ono@ctie.co.jp (K. Ono), stswata@sogo.t.u-tokyo.ac.jp (S. Watanabe), so.kazama.d3@tohoku.ac.jp (S. Kazama).

https://doi.org/10.1016/j.crm.2018.03.002
Received 24 October 2017; Received in revised form 14 March 2018; Accepted 14 March 2018

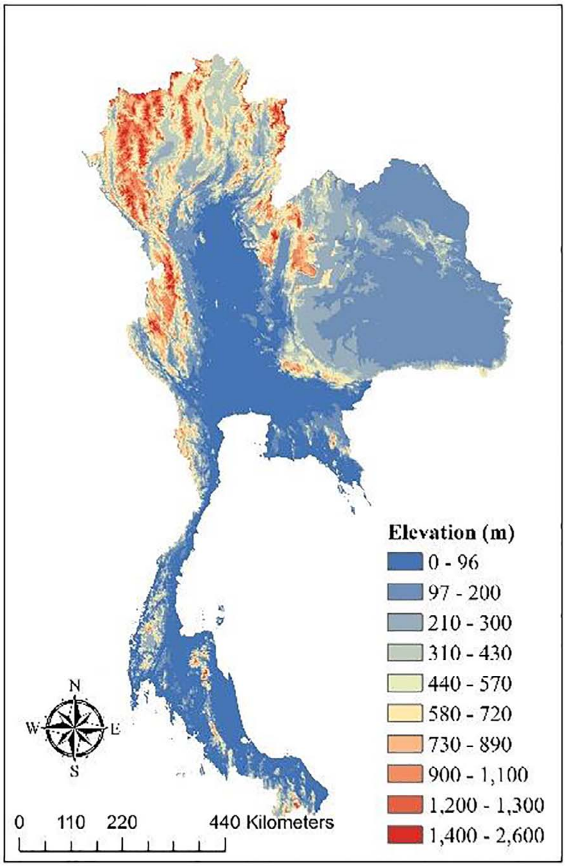

Fig. 1. Elevation of Thailand.

Thailand and assessed local landslide risks qualitatively. Both studies clearly demonstrated that slope failure and landslide damage are becoming more common in Thailand. The Land Development Department (LDD) of Thailand initiated the preparation of a landslide risk map in response to recurring landslide events occurring in recent years, and in 2006, they published a map presenting high, moderate, and low risk areas according to geographic conditions. However, the assessment generated no rainfall information or data in which landslides events in Thailand have occurred as a result of heavy rainfall, especially in the northern and southern regions of Thailand, where land has been eroded by significant water flows from the mountains that have descended to low elevation areas at the base of the mountains. Several researchers have found that rainfall is a key factor that shapes landslide events (Iida, 2004; Fan et al., 2016). However, few studies have analyzed the probability of landslide hazards under conditions of climate change in Thailand. Therefore, the analysis of landslide hazard probability under climate change conditions constitutes an important challenge for this country. Various methods for predicting the vulnerability to rainfall-induced landslides have been developed. The most common and reliable method used in the field of geotechnical engineering is slope stability analysis, which involves the use of a physical model based on in situ geotechnical parameters; however, this method can only be applied to smaller study areas (Wu and Sidle, 1995). Numerous researchers have attempted to make landslide predictions using GIS and regional models (He and Beighley, 2008; Pradhan and Lee, 2009; Wu et al., 2011). Additionally, some studies have used statistical methods to predict landslide probability levels (Komac, 2004; Lee et al., 2008; Goetz et al., 2015). However, the knowledge of rainfall distributions is needed to produce hydraulic gradient estimations. Therefore, the application of these methods requires the various forms of information, especially for economically developing countries that typically present low levels of rainfall observation density. In reference to Thailand, Yumuang (2006) studied landslide and debris flows in Phetchabun Province using GIS and remote sensing techniques. Kawagoe et al. (2010) assessed landslide hazards in Japan via a multiple logistic regression analysis. Ono et al. (2014) assessed rainfall-induced shallow landslides occurring in the Phetchabun and Krabi provinces of Thailand using a shallow landslide instability prediction model (SLIP). Furthermore, Inoue et al. (2014) attempted to project the probability of landslide occurrences in Thailand using a landslide probability model under multiple global climate models (GCMs). The objective of the present study is to analyze the probability of landslide hazard occurrences under climate scenarios for Thailand. We estimated the extreme daily rainfall level from (APHRODITE) to create a spatially distributed extreme rainfall map. The future distribution of extreme rainfall events can be analyzed from 10 types of GCMs under RCP scenarios, and the probability of landslide hazard occurrences across Thailand attributable to future climatic change can be estimated using the probability landslide model.