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Potentialities and limitations of thermography to assess landslide risk

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ABSTRACT

The paper deals with the use of thermography to assess landslide risk. Landslide is a natural process which affects soil. In specific conditions, it can even become cause of death and damages to buildings and structures. Due to climate changes, landslide events have increased in the last years. Sensor networks are today widely used to monitor landslide triggering events. Main problems concern the development costs of such networks, so today attention is principally focused on the use of measurement systems which allow to monitor wide zones at distance. Recently researchers are considering the use of infrared thermography as a promising tool for monitoring landslide process.

The paper aims to describe the current potentialities of thermography and its limitations. Several issues and open problems are still to be faced before considering such technique as an effective monitoring tool. For this reason, the author reports the results of a measurement campaign to prove the strengths and weakness of the methodology. Relevant aspects concerning the limits of this measurement technique are described in the following to provide suggestions to users and researchers working in this field.

1. Introduction

Landslide is a geological and natural phenomenon which shapes the Earth surface. When it happens in proximity to populated areas, it can become a cause of death and economic damages. It is widely spread in the Mediterranean area and affects principally mountainous areas and zones with cut slopes, [1–4]. Countries characterized by tectonic activities are particularly susceptible to landslide events. For example, about 70% of Italy territory can be considered exposed to landslide risk. Since, its effects can be catastrophic, today the landslide risk assessment is an interesting and challenging topic for researchers. Risk assessment and hazard prediction are significant tasks to avoid or reduce possible harms for the exposed population. At the same time, the development of new technologies and models is essential to prevent risk. Several models have been defined to characterize or predict a landslide. Such models are mainly based on the processing of data coming from measurement or sensing systems. Sensor networks are widely used to analyse geological processes, [5–10]. This solution offers several advantages, since it is possible to get real time information on soil movements or triggering events. The triggering event represents the starting event of a landslide. Often the time interval between a triggering event and the landslide process is sufficient for executing prompt intervention actions. Landslides are normally not considered hazardous phenomena because of their slow evolution. However, under certain conditions, ground movements can accelerate evolving into faster mass movements. Consequently, landslide prediction models based on such information become more effective and reliable. So damages and death can be predicted and reduced by means of suitable emergency plans. However, if we consider the extension of the zones potentially at risk, such sensing systems are characterized by high costs of implementation and management. In addition, specific knowledge on the slope process and on its relationship with geology, geomorphology, vegetation, weather, hydrogeology features of the soil is necessarily required. So the identification of a landslide requires inevitably specific expertise in the geology field. As a consequence, this is an interesting multidisciplinary topic where metrologists and geologists can collaborate.

Further applications concern the use of topographic and geological data or satellite images in order to detect areas at landslide risk, [11–15]. Since a landslide produces visible marks on the territory, the visual image interpretation may help to recognize possible slope instability processes. In this case, the joint use of hydrogeological models and image processing techniques allows to extract specific soil features and patterns: slope, soil shape curvature, type of soil, precipitation, vegetation, distance from inhabited areas, geology, distance from lineament. Typically, such models are based on historical information about previous events in the area [16,17] in order to draw landslide hazard maps. The main limitation is that these models estimate the probability of a landslide event and cannot be used as a reliable tool to characterize landslide triggering events in progress. Therefore, false alarms are possible.

In the last years, a further proposed solution concerns the use of thermography, [18–22]. Thermography is a technique extensively used

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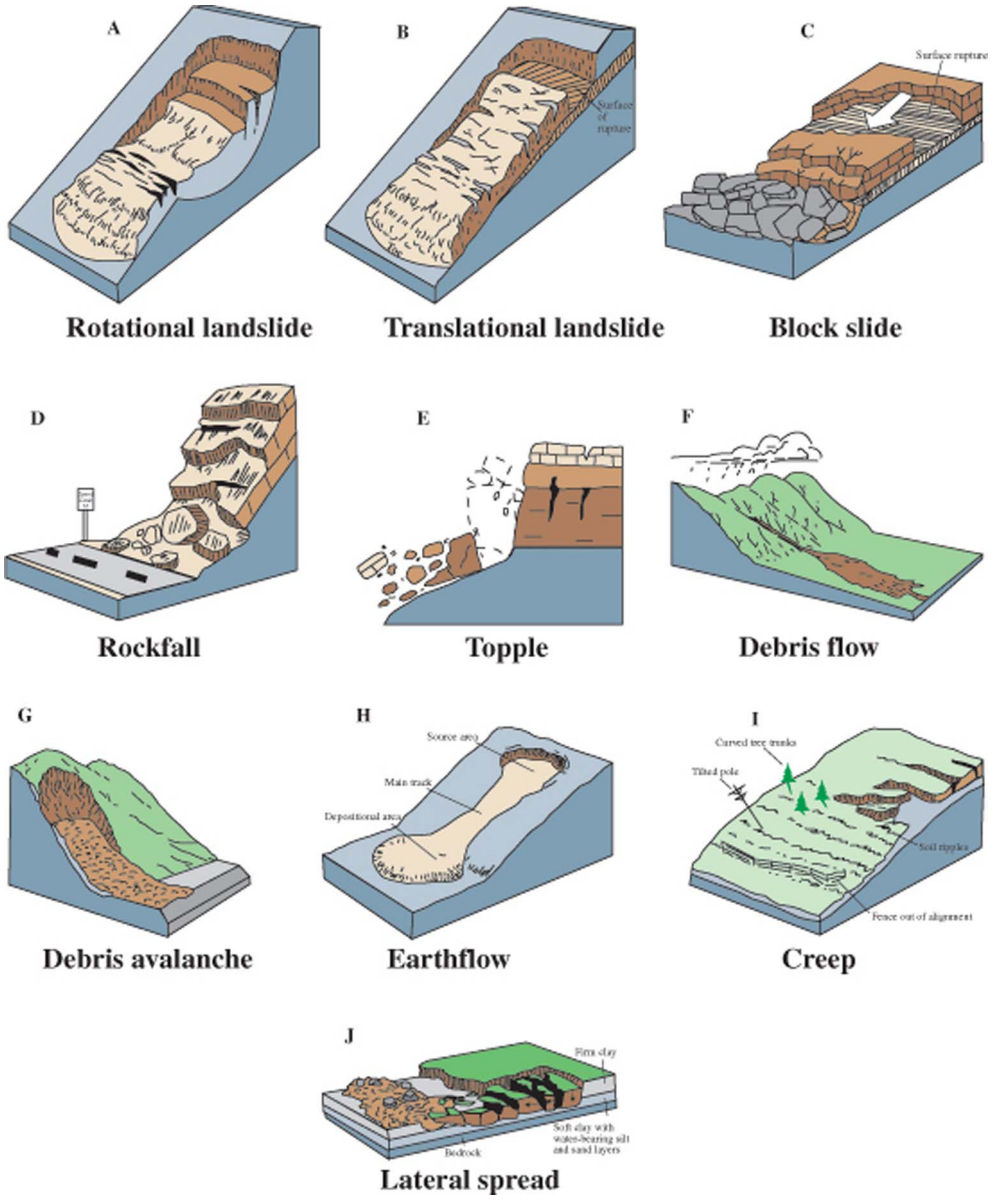

Fig. 1. Landslides classification [7].

in several application fields such as biomedical, buildings diagnostics, environmental monitoring, non-destructive tests, defect and crack detection, etc [23–25]. Its application to landslide risk assessment needs to be still further investigated due to interpretation errors or to poor accuracy of measurement. The main limits concern the reliability of infrared thermal image conversion into thermometric data. In fact, thermal radiation is susceptible to weather and climate changes. In addition, temperature changes can be due to vegetation, soil, slope angle. Even the reflected apparent temperature can affect measurement results. Finally, any substance/material has its emissivity value. This value changes depending on several factors: composition, humidity, features, shininess, etc.

The landslide monitoring needs specific accuracy and reliability requirements. So different issues are still open. For these reasons, the author proposes his interpretation about this topic so to highlight strengths and weakness of the thermographic technique. To this purpose an experimentation has been carried out on a mountainous area situated in Reggio Calabria city, in the southern Italy. The considered case study concerns a populated area near to the urban center. The aim of the present paper is to provide a methodical approach to the interpretation of thermographic images so to avoid the most common errors. It intends to overcome the limits of the present monitoring systems reducing possible false alarm occurrences.

The paper is organized as follows. In Section 2, the landslide process and classification are described. The thermography theory is described in Section 3. Section 4 reports the experimental results to highlight weaknesses and strengths of thermography. Finally, conclusions and further comments are outlined in Section 5.

2. Landslide process and classification

Landslide is a natural phenomenon consisting in soil movement caused by slope. The probability of a landslide event increases with the slope angle. High slope angles are cause of a major stress of the soil. In addition, triggering movements are made easy if the soil is made up unconsolidated material and debris. Consequently, slope and soil type are the main factors to consider in landslide risk analysis.

Earthquakes, rainfall, snow, human activities may be cause of soil movements. As a consequence, they are often triggering events of landslide. Duration, intensity and extent of the triggering mechanism play an important role in defining the geographical extent of the area affected by soil movement. In addition, hydrogeological and