Abstract. Traditional approaches to prevent rainfall-induced landslides consist of such stabilization of unstable slopes as installation of retaining walls as well as ground anchors. Although having been useful in mitigation of large slope failures, those traditional measures are not very helpful in mitigation of small slope failures which are less significant in scale but numerous in numbers. It is proposed in the present text for people to install slope instability detectors which find precursors of an imminent slope failure and issue warnings so that people may be able to evacuate themselves prior to fatal slope failures. To achieve this goal, model tests as well as laboratory triaxial tests have been conducted in order to understand the behavior of soil prior to failure. Moreover, numerical analyses on ground water percolation and decrease of factor of safety in the course of rainfall were conducted on a sandy slope in order to support findings from model tests. As a whole, a small instrument is proposed for a use of people which can detect minor displacement and change of moisture content prior to failure in a slope and issue warning through internet.

Keywords. Landslide, rainfall, warning, monitoring, model test

16.1 Introduction

There is a long history in prevention and mitigation of rainfall-induced landslides. Typical measures to prevent slope failure are retaining walls and ground anchors which improve factor of safety against failure. These measures have been widely used everywhere in the world and have been effective.

One of the limitations of the traditional measures lies in their cost of installation. Consequently, the traditional measures have been constructed only by governmental money in order to avoid relatively larger landslides such as shown in Fig. 16.1.

In consequence of recent residential developments in hilly area, the risk of smaller landslides has been realized. Figures 16.2 and 16.3 illustrate examples of this kind in which a small slope instability caused by rainfall endangered only a few houses upon heavy rainfall. It is important that such minor slope instability is many in number and difficult to be investigated by conventional engineering. Although efforts are needed to avoid risks of this kind, financial limitations make it difficult to install retaining walls and other conventional measures everywhere.

Early detection of slope failure and quick evacuation are always of significant importance. It has been known empirically that slope failure is preceded by the following precursors:

Fig. 16.1.
Site of rainfall-induced landslide at Sakashi-dani in Niigata, Japan, in 2004
1. Sound of cutting tree roots,
2. Falling of stones from a slope which is normally stable,
3. Such distortion as cracking and heaving within or near a slope,
4. Generation of new water spring within or near a slope, and
5. Unusual roaring sound which is probably generated by distortion of ground at depth.

Although the knowledge is very important for disaster mitigation, monitoring of sound, falling stones, and detection of water spring during heavy rainfall is very difficult. It is obvious that meaningful underground sound is erased by the noise of rainfall and possibly thunder storm. Thus, it is desired to find out other precursor which can be monitored by any equipment during rainfall.

### 16.2 Warning of Rainfall-Induced Landslide

The problem of small landslides during heavy rainfall is now widely acknowledged. In efforts to mitigate this problem, the Meteorological Agency of Japan issues slope instability warnings when heavy rainfall and high moisture content in soil are expected. Although this idea is good, the moisture content is assessed on a regional basis based only on the regional intensity of rainfall, and the issued warning simply indicates the regionally averaged extent of risk. Note that the said “region” stands typically for one third or fourth of prefectures where hundred of thousands of people are living. Certainly, therefore, local topography, soil conditions, and the intensity of rainfall at indi-