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# Real-time term monitoring of unstable slopes of Darjeeling Himalayas, India

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Landslides are one of the most occurring natural disaster globally affecting human lives and damaging properties, infrastructure and agricultural land. The Himalayan region is the most landslide prone area in the world with 75% of global landslide occurrences between 2004-2016. Several attempts have been made to calculate the rainfall thresholds for various regions using the existing models for different areas of Himalayas. However, a comprehensive study using an effective and reliable monitoring system is yet to be evaluated especially for Indian Himalayas. To achieve this, a 2D Microelectromechanical Systems (MEMS) based tilt sensor and volumetric water content sensors were installed in Chibo which is one of the most affected regions in Darjeeling Himalayas, India and a real-time monitoring attempt was made. The MEMS-based sensor monitors the tilting angle of the instrument which is installed at shallow depths and the variation of tilting angle corresponds to lateral displacement at the slope surface. The monitoring system was tested over a period of one year including two monsoon seasons (June-October) of 2017 and 2018. The results depict contrasting results over the two monsoon periods. The tilting rate during both the monsoon periods was similar even with a deficiency of over 70% of monsoonal rainfall in 2018 compared to 2017. Out of the six tilt-sensors installed in the area, one showed significant variation and depicted that antecedent rainfall and event rainfall are equally important for landslide occurrences in the region. The displacement in the monsoon of 2017 was due to antecedent rainfall, however, displacement in 2018 was because of event rainfall. The results conclude that less rainfall may not always necessarily lead to fewer landslide occurrences and one needs to consider both antecedent and event rainfall when using threshold models for an early warning system. This work would also help to develop an effective threshold for other Indian Himalayan regions without the need for a monitoring system.