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The June 2018 Kakrud landslide in northern Iran: Process understanding using satellite remote sensing data

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Landslides are among the most destructive geologic hazards, causing significant damage to infrastructure such as buildings, roads, and bridges, and often resulting in loss of life. These events pose a significant risk, especially to communities living near steep slopes. Satellite optical remote sensing images are widely used in geohazard studies due to their detailed content and high resolution. Interferometric Synthetic Aperture Radar (InSAR) is effective in monitoring subtle deformations over large areas and is particularly suitable for quantifying deformations and accurately measuring slope instability. Combining optical data with Synthetic Aperture Radar (SAR) data provides a more comprehensive understanding of landslide dynamics, leading to improved monitoring and analysis.

The Kakrud landslide occurred in Gilan Province, northern Iran, in June 2018, resulting in fatalities, property damage, and the destruction of key access roads. This study used multi-source remote sensing data, including Planet and Sentinel-2 optical images and Sentinel-1 SAR data, to analyze the life cycle of this catastrophic failure. Precipitation, snowmelt, and soil moisture data were also incorporated to identify the causes and influencing factors of the landslide. Cross-correlation of high-resolution optical images from Planet and Sentinel-2 revealed significant displacement between June 14 and 18, 2018, with a maximum horizontal > 50 m. InSAR analysis of Sentinel-1 data from October 2014 to June 2018 revealed pre-landslide instability, with an average deformation rate of 2 mm/year. Precipitation data indicate that rainfall in June 2018 was 10 mm above the average for the same period from 2014 to 2017, when the region experienced a dry cycle with an average annual rainfall of 1,400 mm; 2018 marked the onset of a wet cycle, with total rainfall reaching 2,000 mm. The initial failure of the landslide occurred on its lower left side, triggered by river undercutting, which washed debris into the channel and obstructed the valley. This increased water flow exacerbated erosion at the landslide toe, leading to further collapse. MODIS snowmelt data show a negative correlation between snow cover and temperature, with snowmelt intensifying from spring (March–May) and peaking in summer (June–August) as temperatures rose and snow cover diminished. Combined with soil moisture data, the cumulative effect of snowmelt in June significantly increased pore water pressure and reduced soil shear strength. A combination of these factors ultimately triggered the landslide.

In conclusion, this study explores the kinematic changes in the Kakrud landslide over a long time series throughout its life cycle using multi-source remote sensing techniques.

Keywords: Landslide; Remote Sensing; Multi-temporal InSAR; Cross-correlation