Improving tailings management from the ground up

The ability to map soil moisture and changes in it is key to understanding geotechnical risk, write the developers of GroundSat, a new, innovative remote sensing technique that utilises L-band synthetic aperture radar (SAR) satellite images to provide soil moisture mapping at a high resolution.

Brumadinho Dam failure, Brazil, January 2019.

Surface Mining > Geomechanics-ground-control

Comments

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Understanding soil moisture mapping is an important component in assessing assets from the geotechnical perspective and when trying to assess asset resilience to climate change. The analysis method has been adapted from earlier academic projects that searched for water on other planets.

GroundSat technology exploits two basic principles. The first is that different materials have different dielectric constants. Thus, through the development of patented algorithms, it is possible to map the signature of water in the ground. Secondly, L-band SAR offers advantages over other frequency bands such as X- or C-band, as the wavelength of L-band is significantly greater (15-30 cm). This higher wavelength gives L-band radar the ability to penetrate vegetation and into the ground, which is a significant difference when compared with InSAR surface deformation monitoring and is key for soil moisture mapping.

That L-band backscatter data provide high correlations with gravimetric and volumetric measurements on field soil samples has been demonstrated in a variety of research papers.

GroundSat data have also provided high correlations and repeatability when correlated with field soil samples tested in the laboratory for gravimetric water content and with in-situ soil moisture probes to measure the volumetric water content. The field data were collected within a 2-hour window of the satellite image acquisition.

The relationship between microwave images and soil moisture content has been studied over several decades. The use of satellite microwave remote sensing technologies for quantitative soil moisture mapping was introduced in the 1980s with SAR technology. This method was applied and proven accurate on the upper soil thin layer (5-10 cm in depth).

The main limitation was the spatial resolution, which was too coarse. Other limitations were soil texture, surface roughness and vegetation coverage. The use of novel full (quad) polarimetry SAR imagery and L-band imagery, which is known for its capabilities in soil moisture content detection and penetration of both vegetation coverage and the topsoil layer, played a major role in the improved accuracy of the results.

The development of GroundSat technology focused on providing a data acquisition technique that could provide data to enable proactive assessments of assets. Thomas Telford's statement that "water is the enemy of the civil engineer" highlights the focus of GroundSat technology, as the ability to map soil moisture and changes in it is key to understanding geotechnical risk. By the time ground movement occurs, it is often too late and there is little pre-warning of catastrophic failures.

Tailings management facility failures

Tailings management facilities (TMF) comprise all the structures required for the handling of tailings, including storage facilities, dams, impoundments, clarification ponds and delivery pipelines. Mine tailings pose a significant hazard. Failures of TMFs can cause flash-flood- and debris-flow-type failures that destroy everything in their paths. The high toxicity levels of mine waste causes pollution on a large scale, as it often follows water courses and has the potential to cross boundaries.

The Brumadinho dam failure in Brazil in January 2019 caused destruction over 8 km away from the dam and 259 people tragically lost their lives. The dam failure in Baia Mare, Romania, in 2000 caused large-scale cyanide pollution downstream in Hungary and in the Black Sea. There are many other examples of failures, and the statistics clearly show that the consequences of such failures are becoming more severe. In addition, there are many abandoned facilities that are unmanaged and unmonitored and, that, arguably, pose a significantly higher risk.

Failing to account for asset resilience to climate change, both when managing existing and when designing new facilities, can be very dangerous and costly. The proper management of TMFs is an integral part of the overall success of a mine. Such failures and incidents can lead to significant financial penalties for a mining company for emergency response, remediation and repair costs, disruption of operations, claims for damages, lawsuits, legal costs, unscheduled closure activities and loss of share value. Consequently, accident costs almost universally exceed the costs a company would incur to ensure proper and adequate levels of safety and control to prevent such incidents. A robust TMF operation and management plan incorporating monitoring is essential to its safe operation. GroundSat technology can help inform the short-, medium- and long-term measures required for sites to maintain safety.

GroundSat technology and mining

GroundSat soil moisture mapping is used to assess critical assets in the mining sector. Seepage and piping through tailings impoundments are common causes of failure. By identifying areas of high soil moisture early, it is possible to get an understanding of how tailings impoundments are performing and changing with a view to designing and implementing proactive remediation of the higher risk areas. In the case of TMFs, it is also possible to differentiate between saline and fresh water. The assessment of catchments that may influence TMFs is also important, particularly considering the changing climate and more extreme weather events. Uncontrolled flow into TMFs can lead to overtopping of dams and impoundments. Understanding any TMF in the context of its surroundings is vital, and GroundSat technology enables an assessment of the landslide susceptibility of the natural ground in the surrounding area.

The scale and number of TMFs does not enable large-scale and robust remedial solutions for stabilising assets. Proactive assessments facilitate more focused interventions. Small changes such as drainage improvements focused only where they are needed can tip the balance, thereby improving an asset's safety factor for global stability. An understanding of soil moisture at a high resolution can provide the missing link between drainage and geotechnics.

Figure 1 shows high-resolution soil moisture mapping data for a tailings impoundment. There are clear areas of higher soil moisture that highlight areas where seepage and piping may be occurring through the dam and that have the potential to lead to failure.

Figure 1: Example soil moisture data with highest soil moisture pixels indicated in red.

Combining soil moisture data with a digital elevation model (DEM) enables further analysis to assess the susceptibility of the asset in terms of potential for failure. Figure 2 provides an example of the results of this analysis, which shows a weighted map combining soil moisture with slope angle that essentially highlights the wettest areas on steep slopes.

It is a common error to focus monitoring on the asset itself. TMFs are often constructed in challenging and mountainous environments where the surrounding land and its connectivity to the asset equally need to be monitored and managed. GroundSat technology enables mapping of the surrounding area to inform landslide and geohazard susceptibility mapping.

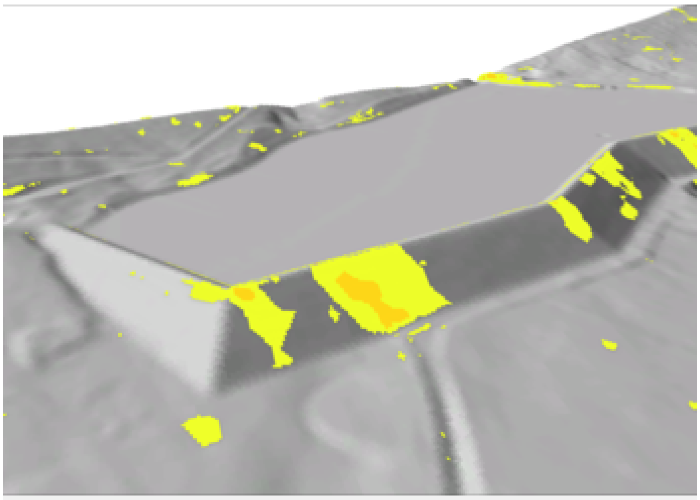

Figure 2: Example of weighted susceptibility map showing the weighted components of soil moisture combed with slope angle.

By using GIS analysis and incorporating soil moisture data with a DEM, it is possible to plot the flow accumulation and the topographic wetness index for a more comprehensive assessment of susceptibility.

Conclusions

GroundSat soil moisture mapping exploits the advantages of spaceborne L-band SAR. The technique provides a remote, proactive approach for assessing the cause of potential TMF failures before they happen, as opposed to other monitoring techniques that focus on detecting the effects. Combined with DEMs and other data, soil moisture maps provide the missing link between geotechnics and drainage: a crucial dataset in the assessment of TMF asset resilience to climate change.

The combination of soil moisture data and an accurate DEM enables a comprehensive desk-based GIS assessment to be undertaken that highlights high-susceptibility areas at TMFs. Simple drainage remedial solutions designed using this susceptibility analysis to address high-susceptibility areas can often be enough to stabilise TMFs and reduce risk.

GroundSat mapping combined with GIS analysis can provide insights into the risks of landslides and geohazards on natural ground surrounding TMFs that could affect the facilities. Wide area coverage also enables assessment of soil moisture and runoff from watershed areas or catchments that directly affect and feed in to TMFs, thereby enabling management of runoff, an essential requirement with the changing climate and more severe weather events.

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