MIT tool determines landslide risk in tropics

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Engineers at MIT have devised a simple yet effective system for determining an area's landslide risk, a tool that could help planners improve building codes, determine zoning and strengthen mitigation measures in mountainous tropical regions frequently hit by typhoons.

Devised originally for Baguio City, Philippines--a city that averages five typhoons annually and holds the world record for most precipitation received in a 24-hour period (46 inches on July 14-15, 1911)--the risk rating system relies on data commonly available in developing countries. The engineers use information about the history of landslides, the type of bedrock underlying a slope, the inclination of the slope and the type of vegetation growth to determine an area's hazard rating, which they then look at in combination with land use and population density to determine the overall risk rating.

"The system could be applied directly to any country with similar topography, geology and climate, which would be much of Southeast Asia," said Herbert Einstein, a professor in the MIT Department of Civil and Environmental Engineering. He and Artessa Saldivar-Sali, a Filipino who spent summers with her family in Baguio, developed the system as part of her master's degree thesis work.

The two report in the May 2007 issue of *Engineering Geology* that the new landslide risk rating system is especially applicable to many areas of the developing world, where a detailed landslide risk analysis has not previously been performed, because the system is based on characteristics that can be assessed in the field or from available records.

"The fact that the Baguio area has constant, heavy rainfall makes it very susceptible to landslides, which occur frequently. Although everybody knows that, nobody has ever put a system in place to determine where this risk or hazard is higher," said Saldivar-Sali. In her thesis, Saldivar-Sali reports some 65 recorded landslides near Baguio City between 1991 and 2004.

The area is becoming increasingly more populous and built-up, in part because it sits at a higher elevation and has cooler temperatures than most of the country, making it a popular tourist destination. The average annual rainfall for the city on the South China Sea is 142 inches (3,648 millimeters); temperatures rarely reach 80 degrees Fahrenheit (26 degrees Celsius). Deforestation due to illegal logging and slash-and-burn farming, and blasting associated with mining and road construction also are contributing to a decreased ability of the slopes to weather heavy rains brought by typhoons.

Landslides occur when earthquakes or heavy rains loosen layers of surface soil. Surface soils in tropical and subtropical areas tend to be residual--that is, they're created when the underlying bedrock deteriorates--rather than sedimentary, which is soil that has been laid down by flowing water or wind, said Einstein, whose research focuses on rock mechanics, engineering geology and risk analysis of tunnels and landslides. In the Baguio area, heavy rains from typhoons are the most common cause of landslides, although the entire area is also tectonically active.

To prepare their hazard ratings, the researchers mapped the seven types of underlying bedrock in the area, overlaid with data on slope inclination and vegetation growth. Some of their findings are a bit counterintuitive, Saldivar-Sali explained. For instance, steeper slopes don't necessarily indicate greater landslide risk.

"What we found didn't follow any kind of predictable pattern," she said. "The conclusion we reached is that the landslide hazard is determined by a combination of two factors: the underlying bedrock and the slope." They found that landslides are less common in areas with limestone bedrock, even though they may be relatively steep. "Limestone is a very hard rock that forms steep slopes naturally. So the steep slope is the stable condition for this rock," she said.

While roughly half of the 50-square-kilometer area rests on bedrock from the Pliocene Baguio Formation, only 5.7 percent of landslides occur in these areas, and more than half of those took place on moderate slopes. Broadleaf trees provided the least amount of protection on this type of bedrock. But in general, a mix of broadleaf trees or bushes and scrub provided the most protection.

The highest incidence of landslides in the area (14.3 percent) occurs on bedrock from the oldest geologic era represented, the Cretaceous Pugo Formation of volcanic rock, which accounts for only 1.4 square kilometers of the total area.

The researchers assumed uniformity in heavy rainfall associated with typhoons and underground faults, because these are common to the study area. But the system could be easily adapted to a region where that consistency does not hold. Saldivar-Sali, who is now working toward a Ph.D. in building technology at MIT, hopes that the system will be applied in the Philippines and elsewhere and lead to the adoption of flexible building code requirements, which could lead to cost savings at the time of construction and later reduce destruction during heavy rains.

"Building codes as they are now will specify a maximum building height and certain structural requirements that are standard for the entire country," said Saldivar-Sali. "But in an area with a 66 hazard rating, which is relatively high on a scale that goes up to 99, should the building

code be more stringent or be zoned for no building at all""

Saldivar-Sali stresses the importance of using the landslide risk rating system to prioritize mitigation measures, as well. For instance, streams and river channels could be stabilized, buildings could benefit from increased stabilization provided by installing piles at certain points on a slope, blasting could be more stringently controlled during road construction and mining, and reforestation could be hastened in some areas.

"The uncertainty of natural threats and their consequences have to be--and can be--treated in a systematic manner using hazard and risk analysis, assessment and management," said Einstein. "The problem of typhoon-induced landslides is a good example of the sort of natural threat we can address in this way."

Source: Massachusetts Institute of Technology