Landslides in Sri Lanka

Of the 65,000 sq km of land extent of Sri Lanka, an area of nearly 20,000 sq km encompassing 10 districts is prone to landslides. It is about 30% of Sri Lanka's land area and spread into several districts, namely, Badulla, Nuwara Eliya, Kegalle, Ratnapura, Kandy, Matale, Kaluthara, Mathara, Galle and Hambantota. Investigations carried out by National Building Research Organisation indicate that haphazard and unplanned land use, inappropriate construction methods and wanton human intervention have lead to an increase in landslide susceptibility (see Figure 1 depicting locations of landslides). To cite the extent of some catastrophic landslide events of recent memory, in 1986, 51 lives were lost with an estimated 10,000 families being displaced. Again, in 1989 and 2003 due to severe landsliding, several lives as well as a sizeable extent of property were lost.

Apart from the damage to life and property, several infrastructural as well as economically important facilities have also been affected, especially water distributory pipes, hydro electricity generating centres, and communication systems. At times, social interests such as educational and health services are also severely disrupted. Moreover, frequent landsliding has threatened the destruction to the environment including the flora and fauna of the areas concerned. Such damage caused to the environment, at times is irreversible and therefore cannot be estimated and perhaps will never be known.

One important factor that is related to landslides but not readily visible is the rising population and the consequent demand for land. This reminds us how important it is to look after usable land when analysing the damage of landslides.

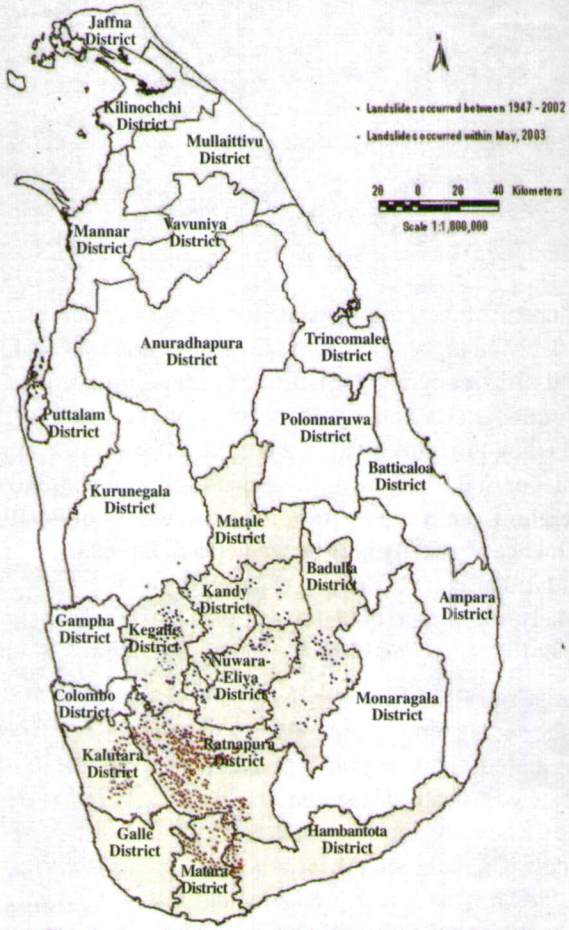

Fig. 1 : Landslide susceptible locations of Sri Lanka

Sudden movement of rock or soil mass are fairly common and are generally termed as landslides. A landslides can be a movement of either a sloping mass or the crest or the foot of a hill or even the cut surface of a slope. Similarly, the materiel that flows down can also vary according to circumstances. It could be a sliding huge soil mass at one time or a giant mudslide at another. It may also be an instance of a falling mixture of rock and soil down a slope. At times, it is possible for a large boulder resting unstably on higher ground to fall down a slope. As such, a landslide can mean differently depending on the circumstances and conditions.

What is a landslide ?

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a slope. At times, it is possible for a large boulder resting unstably on higher ground to fall down a slope. As such, a landslide can mean differently depending on the circumstances and conditions. However, generally speaking, **the movement of a considerable mass of rock and / or soil along with the vegetation and structures thereon from a higher to a lower elevation under the influence of gravity may be termed as a landslide.** These landslides consist of three parts, namely, the crown, the body and the toe or foot of the landslide.

The "Crown" is the upper most part of the sliding terrain from where it is originated. This region is usually subjected to subsidence and cracks. The "Body" of the landslide is the middle part of the sliding mass below the crown. This zone is usually wide and contains most of the sliding matter which collects material and swell causing crack in the lower area of the landslide body. "Toe" is the lowermost part of a slide. When a landslide occurs, the debris that it carries flow down spreading over the lower terrain area with a forward motion of the toe. Often, the toe consists of a moist mixture of soil and strewn stone.

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Types of landslide

Although the various types of mass movement of the terrain are termed as landslides in general, if does not really indicate a clear idea of the actual nature of the event. Therefore, landslides are categorized in the following manner.

* Fall
* Subsidence
* Debris flow
* Toppling
* Lateral displacement

Fall

Here, soil or rock material on a higher elevation falls down freely as a fragments, splinters etc.

Toppling

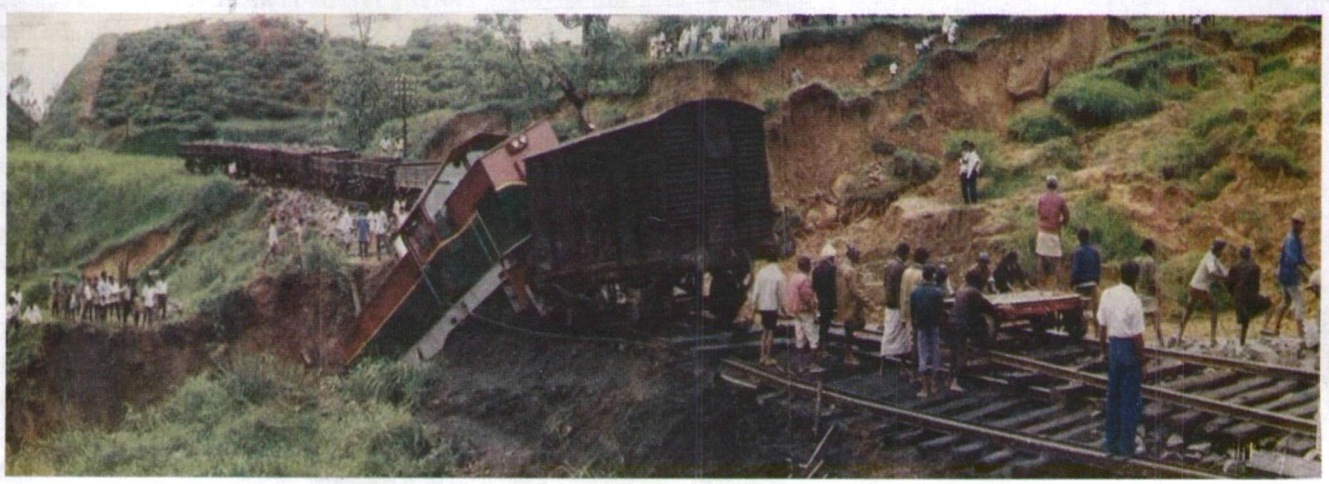
Generally, rock boulders separated from the bedrock along joint lines of joint systems existing on scarps are subjected to toppling. They may drop directly on to the ground or may roll over along slopes. Usually, rock disintegrates or weather easily along joint lines in the bedrock, especially with seepage of rainwater into the joints, causing rock fragment to fall.

Subsidence

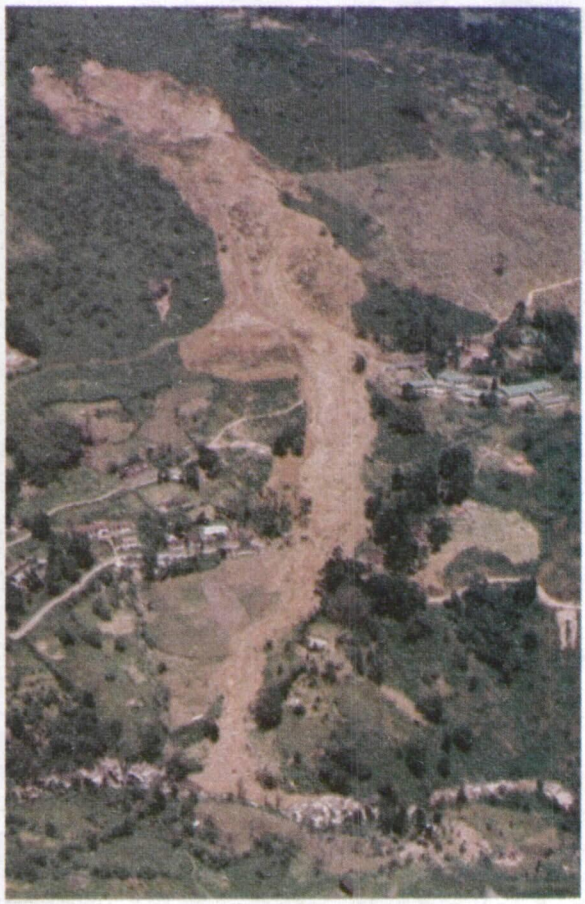
This is a process in which a portion of the terrain subsides or dips from its natural topographic relief level with reference to its surrounding. Soil characteristics and the behavior of different soils with water, internal soil serous and the nature of the bedrock, all of them directly influence the pattern and rate of subsidence.

Lateral displacement

A slow, gentle circular movement of a soil mass laterally or downwards along



the slip surface can be termed as a lateral or downward displacement. The upper region of a such movement is often subjected to tension cracks while down slope can take an irregular form and have the appearance of a disturbed nature and springs and seepages could be observed



Debris flow

This is a downward flow of a muddy water and soil, stone, as well as clay and gravel, They occur mostly on escarpments with a very rapid flow causing much destruction. The speed of such a flow can reach 160 km/h.

Where do landslides occur?

Landslides can occur almost anywhere on the land from sloping terrain, valleys to even plains - even the seabed can be subjected. However, it is usually believed that they commonly occur on hill slopes at an inclination ranging from 15^0 to 45^0 to the horizontal. Although landslides are common at inclinations below 45^0 occurrences at inclinations above 45^0 are seldom for the obvious reason that soil layers will not accumulate on such surfaces for sliding at such angles. Rock falls may occur in such areas instead, but it as been clearly observed that only terrain unduly tampered is subjected to such landslides.

Causes of landslide

Landslides do not occur usually due to a single reason, but it is the nett effect of several, processes and factors, persisting for long periods on the hilly terrain. No single cause can be attributed for the occurrence of a landslide, or rock fall, but it is due to the interaction of a multitude of factors, either natural or man-made.

Natural causes are

* Steepness of hill slope
* Type of rock material
* Deep weathering of rock material and the depth of the weathered rock.
* Density of the joint pattern and the structure of the rock.
* Thickness of colluvium deposits collected down slope due to gravity.
* Poor drainage conditions leading to excessive water seepage in sub strata.
* High intensity of precipitation
* Earthquake as a triggering factor
* Flood and reservoirs in hilly areas

Inclination of hill slopes

It is very seldom for a landslide to occur of on a flat area or a plain, the obvious reason being that there is no space or opportunity for any soil mass in the area to fall or slide any more. However, landslides do occur in such terrain too, but that can only happen due to an excessive weight or pressure placed on top of the hill slope, the tendency for landsliding increases. Slope surfaces with thick soil layers and slope angle between 15^0 and 45^0 have been found to have a greater preponderance for landsliding with maximum tendency of hill slope of angle 26^0 to 35^0 to the horizontal.

Geomorphology and Bedrock characteristics

Generally speaking, soil and rock types having different characteristics or less cohesive properties are the ones mostly subjected to fall or sliding. Various rock characteristics including the structure contribute directly to this looseness of a rock or soil and consequently to such sliding.

Rock is composed of various minerals in different proportions. The rock so formed are subjected to various natural elements such as sunlight, rain, wind, hot and cold temperatures and also to penetration of plant root systems for long periods thus causing disintegration, and weathering.

Also by the impact of various pressures rock materiel can be subjected to splitting, which spreads and in various quantities. The resulting material consisting of soil, clay and the like, have their own characteristics. The above processes finally cause the deposition and settling in various layers or strata on the slopes thus leaving a conductive background for landslides.

Similarly, the action of deferent temperature and pressures on the rock also create fractures in the rock and these fracture systems can be easily lead to separation of the boulders and rock fragments from the parent rock. The separated rock fragment and weathered components can be later transported to lower regions of the slope by erosion and rolling. The increase in the thickness of the overburden deposits (colluvium) so collected can lead to landslides.

Heavy precipitation

Often we hear of a landslide and the consequent damage after heavy precipitation. The background for a landslide to move down a slope is actually created by the action of various environmental factors and undue human activities persisting for long periods is finally triggered by intensive rainfall to a landslide. The heavy rainfall not only causes water penetration into the sub soil layers, thereby loosing the interlayer cohesion but also increases the weight of soil mass. The penetrated water also acts as an easy lubricant flowing down slope. The net effect of these processes is the sliding of the soil mass down the slope as a landslide. According to preliminary investigations carried out, it has been found that if a hill slope receives continuous rainfall of about 200 mm within a period of 3 days, the susceptibility to land sliding in such an area increases. It has been observed that as a result of the current poor, ill-planed land use practices, even a rainfall of 75-100 mm for a 2 day period is sufficient to trigger a landslide.

An earthquakes can influence the occurrence of a landslide directly and indirectly. The vibrations of an earthquake can break up the exciting bond between soil particles and similarly the bond between rock layers can also be weakened considerably. Such tremors can cause an instantaneous earthquake. Sri Lanka has felt some tremors in the recent past and it is necessary to be alert about landslides that could be triggered by earthquakes.

Impact of Earthquakes

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Flood and reservoirs in the hilly terran

Flood and reservoirs in the hill areas can influence the incidence of landslide in several ways. One such instance is the failure of riverbanks scoured by following of swollen rivers after heavy rains. The bottom areas of the banks are eroded by the flowing river water leaving the top areas of the riverbanks without the toe support, which can easily cause the top mass to come down.

Floodwate can also contribute significantly for the collapse of hill slope. The ground water level of the area usually rises after floods and consequently the natural drainage pattern of the area is charged. This cause an increase in the internal water pressure within the slope sub surface while also blocking water from upper soil layers along sub-soil passages resulting in accumulation of water in the slope. As a result of the additional weight due to the water mass and the slope. The recent landslides in Rathnapura are tangible examples of those initiated by such a deluge .

A similar reaction takes place in large water reservoirs with huge dams built on hilly terrain, which happened when impounding and emptying of water in Kothmale Tank. That is what precisely happened with fluctuating ground water levels, the hill slopes abutting the bound slid down in the case of Kothmale reservoir.

Undue human intervention strongly influences the incidence of landslides

Example of some wanton land use practices:

- Denudation of forest areas exposes the topsoil, which affects the stability of slope. The soil cracks and is eroded with the rains causing lanslide.
* The use of land without proper planning.
* Construction on hilly terrain without due investigation or design.
* Quarrying for metal without due investigation and adherence to norms.
* Obstruction of natural water paths and storage of water on high ground.

Identification of area previously struck by landslides

* Abrupt changes of vegetation cover in landslide stricken area from that of the ambient area.
* Clear, sharp delineating boundaries between areas struck by landslide and the balance stable area (Fig 2).

Fig. 2 : A site previously struck by a landslide.

Identification of areas vulnerable to landslide

* In an area vulnerable to landslide, subsidence of the ground and tension cracks could be seen towards the upper region of the slope. Also tall trees may be seen slanting towards the hill. If such observation can be made in any particular are, it is a strong indication of the land area being prone to landslide. Also if cracks are observed on the wall and floors of houses located down slope, it is a further clue to an impending landslide and if these cracks enlarge progressively, it indicates that the landslide is still active in the area.
* Further, in a vulnerable area, water springs, suddenly begin to appear while at the same time water in the wells in the vicinity can get murky. Small streams or superficial watercourses may also disappear suddenly before the occurrence of a landslide in the area.
* Other facts about landslides that cannot be observed in the above manner can be identified by geotechnical and geological investigations. Moreover, by analysing the landform, pattern, water systems, dips, rock types and their structure in the area, maps can be prepared depicting various zones from high to moderate to low hazard level.

How to prevent/mitigate landslide

Although there can be many suitable ways to prevent or mitigate a landslide, an affected area need not be abandoned. An old, traditional method practised to rehabilitate such land profitably has been by cultivating the land in terraces. The tendency for a landslide to occur is also minimized by this method as it affords the slope to be well drained and thereby ensuring the protection of stability of the slope.

It is necessary to establish a suitable drainage system to drain off the surface water properly.

* Landslide struck land should be reforested to protect the exposed soil layer.

* Erosion should be minimized by planting, suitable vegetation such as Vetiver grass, Gliricidia counter fances.

* The upper region or the crown of the slope area should be cut down to lighten the top. Similarly it is also possible to add weight at the base or foot of the slope which will strengthen the base to withstand the sliding forces.

The above procedures can be to followed by anyone in general. However, in addition to them, more effective modern methods, though more expensive, are now available.

Among them are :-

* Tying of the soil layers tending to slide on the ground with wire mesh at staggered anchor points.
* Erecting of concrete or rubble retaining structures.
* Staggered anchoring of the unstable sloping ground with reinforced concrete posts or timber posts or iron fence posts pile-driven into the bedrock.

Future, refraining from conversion of agricultural lands for other purposes, refraining from unauthorized filling up of lands using dug up soil metrical, limiting of the erection of civil structures and implementing of development works on hill slopes under proper technical guidance can all contribute to minimize the occurrence of landslides.

Acknowledgment

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