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## Landslides in Sri Lanka in the 21st Century

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**Abstract:** The Central Highlands of Sri Lanka exceeds 2,500 m in altitude and is predominately made of granulite facies rocks of Precambrian age. Landslides in these areas occurred in the recent past due to excessive rainfall on highly weathered moderate to steep slopes. Topography, geological structure, thunder and lightning also contribute to the acceleration of landslides. The environmental damage caused by landslides has been intensified by human interference during the last 15-20 years. Yet, the enforcement of environmental laws has not been given serious consideration.

By the end of this decade, the forest felling, inappropriate agricultural practices, rapid increase in housing and other constructional activities will lead to more landslides in the hill country. If unchecked the intensification of the above mentioned activities will lead to severe landslides.

### INTRODUCTION

Synonyms such as avalanche, earth-flow, mass-movement, mud-flow and rotational slip are used for the term 'Landslide' which describes the gravitational movement of a body of debris or earth, rock or artificial fill as a unit. The movement may be a slide, flow or fall, acting singly or together (Simonett, 1968). Landslide may be induced by heavy rain on moderate to steep slopes. In recent years, human uses and activities have been extended to the development of steep topography. This has resulted in an increased awareness of landslides actually turn into house slides.

Among the natural hazards (earthquakes, seismic sea waves, volcanic eruptions, catastrophic winds, sea fog, sea ice and iceberg drift) landslides are least documented and researched. This could be because of the occurrence of landslides in restricted areas and inadequacy of statistics (WMNH, 1988; Fig. 1). However, large landslides, involving millions or even billions of cubic meters of debris movement can damage the natural environment, destroying life and property within a short period of time. The environmental damage caused by landslides has been intensified during the last 15-20 year period as a result of the inadequate investigations of geological structure during reservoir and road construction, short-sighted land policies and recent over-exploitation of natural forest resources of the uplands and mountainous areas. The use of high explosives for the mining of graphite, dolomite and other metals as well as mining of gems beyond the

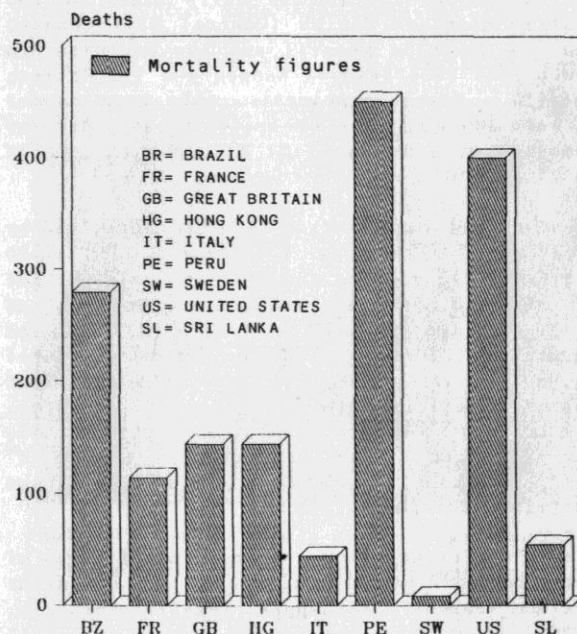


Figure 1. Mortality figures due to mass movements from 1966 to 1987.

sustainable limit are also responsible for the increasing incidence of landslides in recent times. Legislation for the control and management of forest, land, soil and water resources had been enforced during the British Period and after Independence by the National governments. This paper examines the reasons and causes for the landslides and make

recommendations to minimize the future landslide hazards.

#### METHODOLOGY

Landslide prone areas in the Central Highland of Sri Lanka, especially in the Kalu Ganga Basin have been identified by the writer based on topographic sheets (1:63,360) supplemented by field investigations. Data on landslide victims, the damage to property and the environment has been collected from the districts of Kegalle, Ratnapura, Kalutara, Kandy, Matale, Nuwara Eliya and Badulla. Discussions were held with District Land Officers and repeated discussions were carried out with landslide victims and neighbors to examine the damage and to assess the human responses to landslide prone areas from January 1991 to October 1993.

#### LANDSLIDES IN SRI LANKA

##### Physical Conditions of Landslide Prone Areas

The incidence of landslides in Sri Lanka has increased recently in the hilly areas of the Central Highland Series (Central Hill Country and the Knuckles Massif) and the Southwestern Group (the Sabaragamuwa Ranges and the Rakwana Massif). Physiographically, this area ranges between 300 m and 2,525 m and is broadly divided into (a) uplands, and (b) highland (Katupotha 1992).

These upland and highlands are characterized by rolling and hilly terrain (Upland I, 150 - 460 m); dissected rolling and hilly terrain (Upland II, 460-930 m); steeply dissected rolling and hilly terrain (Upland III, 915-1830 m) and mountainous terrain (1830 m and more). All these terrains are laid on the Highland planation and intermediate planation surfaces. The convex creep slopes and free faces of these terrains, are highly dissected by 1<sup>st</sup> and 2<sup>nd</sup> order streams forming different drainage patterns (Katupotha, 1992).

Due to differentiation, the rainfall figures of the upland and highland districts show different maximum seasons. Ratnapura, Kegalle, Kalutara, Kandy, Kurunegala and Matale receive rainfall mainly during the southwest monsoon (May - August) and convectional-cyclonic-depressional inter-monsoon (October - November) period. Diyatalawa, Baddulla and Nuwara Eliya receive rainfall mainly from northeast monsoon (November - February) and from the convectional-cyclonic-depressional inter-monsoon (March - April) period. The occurrence of landslides in Sri Lanka is highly related to these rainy seasons.

#### Indicators for Identification of Landslide Prone Areas

Several visible indicators can be applied to identification slide, fall and flow of rocks, earth and debris in steep slopes. Formation of cracks and fractures, especially as transverse cracks on Convex Creep Slope and Free Face on the crown, encourages seepage of rain-water down to the weathered bedrock layer (Figs. 2 & 3). If there are iron-rich clay materials between bedrock and the top soil layer, lubrication of weathered material and blocks of cracked rock move downwards by force of gravity (Plate 1).

Muddy water springs are another indicator of landslides. Sometimes, seep or saturated water flows through bedrock and the top soil, outward from valley bottoms, intersects of the roads and building foundations. The iron-rich clay materials in these muddy springs indicate that the bond between bedrock and the top soil is broken. This features appear on steep slopes, sometimes even on 15° slopes subject to downward movements.

When the soils of steep slopes are saturated, the bond between bedrock and weathered top soil is broken. Consequently, the vegetation cover would wither due to the petrification of the root-system. This is also indication a slope failure during the heavy rains (Plate 2). Furthermore, gradually inclining wire poles, telephone and electric wire poles, masonry walls, cracked rocks of the convex creep slopes and the free face (Fig. 3). Cracked retaining walls and foundations on fair to moderate and steep slopes also indicate future landslides prone localities.

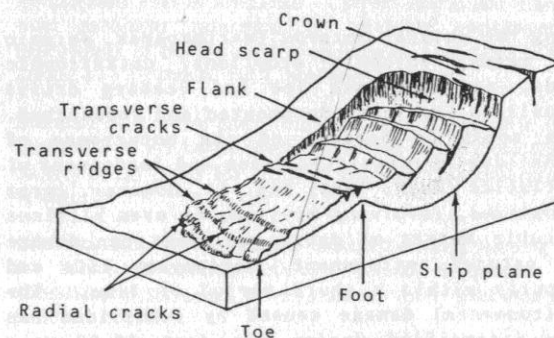


Figure 2. Features of a landslide.

#### Causes of Landslides - Natural Agencies

The land mass of Sri Lanka is made up of highly weathered metamorphosed rocks of Precambrian age (2000 m.y., Rb/Str) and is similar to other Gondwana masses of the Indian Ocean (Crawford



and Oliver, 1969). Although, Sri Lanka is situated in the Australia - Indian Plate, is considered to be tectonically stable. However, several researchers have indicated the occurrence of high seismicity conditions between Sri Lanka and the Cocos Islands, Sri Lanka and the Carlsberg Ridge and along the Carlsberg Ridge (Banghar and Sykes 1969, Sykes 1969).

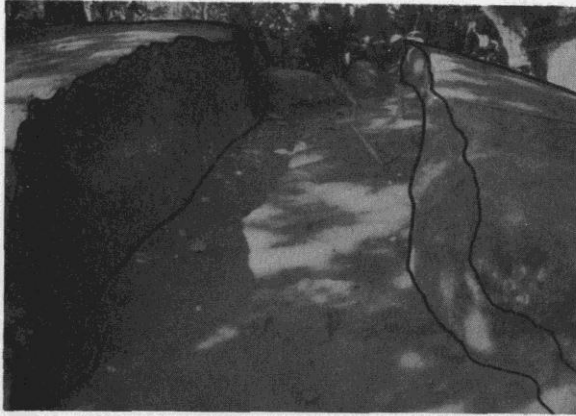


Plate 1. Cracked rock at Palankanda (Opanayaka) indicates the gradual movement of the landmass.

Banghar and Sykes (1969) report that among the 22 earthquakes which had occurred in the Indian Ocean during the period between 1963 and 1966, six occurred between Madagascar, Sri Lanka and Nintyeast Ridge. Sykes (1969) further

recognizes that an incipient tectonic feature, possibly a development of nascent arc, may be associated with a seismic zone in the northeast Indian Ocean between Sri Lanka and Australia. According to Sykes, an earthquake zone between Sri Lanka and Cocos Islands displays a much higher level of seismic activity than any of the other ocean basins of the world. This zone may be developing as a consequence to the relative movement of the Indian - Australian Plate slow down or changes. This is perhaps due to a continental collision. That collision has occurred suggests that the Indian Ocean is a likely place to search for nascent arc or tectonic pressures resulting from a readjustment of plate movements. Furthermore, Sykes indicates that the Sri Lanka - Cocos zone is characterized by relatively high earthquakes with 7 or larger (in Richter scale). During the last 70 years (up to 1969) the Sri Lanka - Cocos zone was nearly as active for these larger events as the three branches of the mid-Indian Ridge combined or that of the entire East African rift system. Activity along the Sri Lanka - Cocos zone may represent deformation within lithospheric plates rather than and incipient feature that will later grow into a



Plate 2. Slope failure at Nivitigala, 1993.

more recognizable tectonic feature. By this mean, the landmass of Sri Lanka can be shaken due to the marginal effects of major earthquakes in the Indian Ocean, west and south of Sri Lanka.

Vitanage (1990 and 1993) has reported that 55 earthquakes had occurred in Sri Lanka between 1891 and 1979. Further, thousands of micro-earthquakes with magnitude 0.2 to 2.25 and two micro-earthquakes with 2.7 magnitude were reported to micro-seismometers during the past ten year-period mainly from the major reservoir areas in the Central Hill Country. The

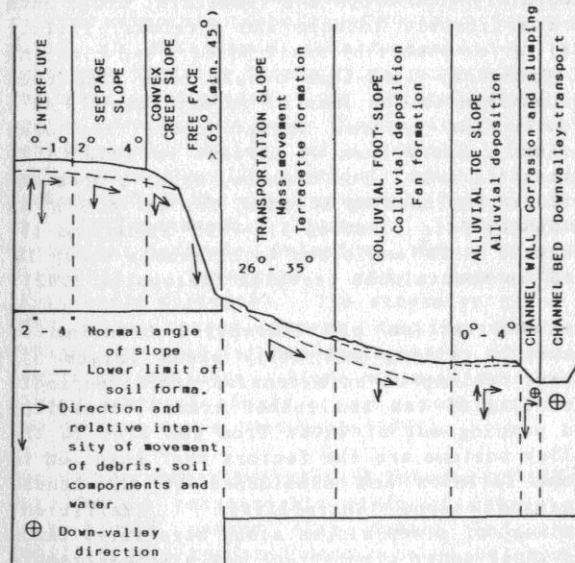


Figure 3. Slope units on a hypothetical land surface (Whittow 1984). Convex creep slope and free face are mainly subjected to landslide.

collection as much as multi-billion cubic meters of water in newly built reservoirs is responsible for the occurrence of local earth tremors.

Furthermore, during the past twenty years, increase in building construction for eg. high building such as sky scraper hotels, shopping centers etc.; Colombo and Galle harbours development (increasing of export and import facilities using thousands of containers) fishing harbours, major industrial plants and construction activities for coastal protection structures have been concentrated along the entire western and southern coastal lowlands (from Puttalam to Hambantota). Although, such activities are essential for the economic development of the country, policy makers should not concerned about the future. Quantitative analysis of regional geology and their possibility of resisting the volume and the pressure of all activities have to be undertaken. The above constructional activities will continue further without any consideration on the future. This causes subsidence of few millimeters of land each year. There is a great possibility in the occurrence of earth tremors in Sri Lanka. Marginal effects of these can detach the deeply weathered surface materials on high slopes and move downwards during the periods of excessive rainfall. Thunder and lightning also affected to accelerate such movement.

Highly weathered metamorphosed rocks in the hill country contain a high proportion of feldspar and they are sometimes well jointed. These rocks weather into reddish brown clayey material known as lithomarge which are embedded boulders of varying size (Cooray, 1984). When this weathered material is saturated with rain water, the iron-rich clayey material acts as a lubricant, causing the mass of earth and rock to move rapidly down the slope under the force of gravity. When there is no natural vegetation cover to bind and hold this material together the lubrication of rocks, debris and earth can be intensified. During heavy rains, the fall or topple of rock material may be further intensified due to shaking of weathered rocks and debris by thunder and lightning or marginal influences of earth tremors.

**Human Activities and Acceleration of Landslide**  
The land policies in Sri Lanka adopted by the Colonial government and by National governments since Independence can be considered as major reason for acceleration of landslide (Madduma Bandara, 1988). Prior to acquisition of the land forcibly under the Land Ordinance Act of

1840, the settlements were largely concentrated in the valleys while the lower slopes of the hills had been cultivated from natural streams. The gentle hill slopes had been used for chena (shifting) cultivation. Due to the forest cover on the ridges, upper slopes and hilltops the soil remained relatively undisturbed under a canopy of Tropical Rain Forests and Mountain Forests.

During the colonial times, the hill slopes were cleaned for the cultivation of coffee and tea. For this purpose, the tropical Rain Forests and Mountain Forests set on fire which broke the structural bond between natural vegetation cover and earth material. Since then, the occurrence of landslide has accelerated in proportion to the rate of clearance of forest cover. Legislation for the control and management of forest, land, soil, water and air were passed during the times of the Colonial government and later by National governments, but it has not been possible to enforce the regulations successfully (Karunanayake and Katupotha, 1990).

Due to the increase of population in villages of the Hill Country, there is an increase in demand for land for urban development, settlement and agriculture. The change in the man/land ratio, due to the pressure of population on land, has caused the dense forests, reservations and patches of grasslands (Patana) in the steeper slopes and peak areas to be utilized mainly for subsidiary food crops and commercial crops such as tea, rubber, tobacco and potatoes. Illicit felling for timber by small holders and clearing of forest by land-less people have also been responsible to the loss of forest cover. As a result, the natural forest cover has been further reduced from 44 percent in 1961 to 24 percent in 1989. Furthermore, upper slopes are utilized for housing schemes, for eg.  $6^{\circ}$  -  $8^{\circ}$  in Upland I; fair to steep  $11^{\circ}$  -  $25^{\circ}$  in Upland II; steep  $18^{\circ}$  -  $25^{\circ}$  and steep to extremely steep  $18^{\circ}$  -  $45^{\circ}$  in Mountainous terrains (Katupotha 1992).

The construction of reservoirs, blasting of rocks in rolling and hilly areas (Plate 3), forest felling on an extensive scale, periodic uprooting of tea and rubber trees, tunnelling and pumping out of water from gem pits in the valley bottoms are the factors that have led to slope failures and subsidence of the lands, creating slope instability. Inefficient drainage of steep slopes along bare rocky lands and those under plantations may also contribute to slope failure.

#### Result of Landslides

The incidence of landslide which had increased

in 1983, 1986, 1989, 1992 and 1993 caused over 223 villages damaged, 383 deaths and the loss of property and livelihood more than 1,370 families (Table 1). Excessive rains between 29 May and 5 June in 1989 for instance caused damage to 56 village in the Ratnapura district (Karunanayake and Katupotha (1990) and 40 villages in the Kegalle district (Katupotha, 1992). During this period, 280 deaths were reported and 346 families (nearly 2100 persons) were rendered destitute in the Kegalle district alone.



Plate 3. Blasting of highly metamorphosed rocks (Kurunegala - Matale Road): a potential landslide location.

During the same excessive rains, the bedrock-related materials (debris and boulder) have been moved at Hettikanda (Hinidunkanda) in the Ratnapura district (Plate 4) and at Berannewa in the Kegalle district. As a consequence, 24 deaths occurred and paddy fields were covered by boulder-rocks slide with earth flow at Bambaragala (Kegalle district) during the same period. Debris and earth movements have occurred at Atalugankanda, Punugala, Minimaruwa, Gatemulla, Warawela, Malmaduwa, Makura (Kegalle district), Wewalgama and Dodamgahaela (Kurunegala district). The excessive rains in 1989 also caused damage to the Kandy - Mahiyangana road (at Hunnasgiriya) by displaced debris and boulders. Slope movement in several places appeared singly or as a combination of two or more types (Katupotha 1991).

Due to the excessive rainfall between 25 and 30 May 1992, a catastrophic slide of debris and rock blocks caused five deaths and three families were rendered destitute at Bulathsinhala in the Kalutara district (Plates 5A & 5B). A major landslide at Helauadakanda in the Ratnapura district caused about 32 deaths and the destitution of 300 persons in October 1993.

Table 1. Villages and Destitute Families Affected by Landslides During the Past Ten Year Period (1983 - 1993) in Sri Lanka

District	Number of Affected Villages	Destitute Families	Deaths
Kegalle	52	346	290
Kandy	11	40	4
Matale	26	275	14
Kurunegala	5	25	3
Badulla	45	562	6
Ratnapura	69	106	35
Kalutara	10	3	18
Nuwara Eliya	5	not known	11
Total	223	1370	381

Source: Katupotha 1991 and 1992; unpublished data from District Land Offices and Field investigations.

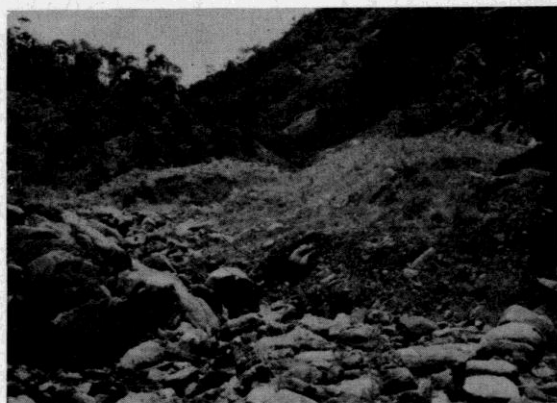


Plate 4. Movement of thousand tons of debris and rock blocks during excessive rains (1989) deposited in a small valley bottom at Hettikanda (Hinidunkanda) in the Ratnapura district more than one kilometer distance.

Based on a recent study, Katupotha (1992) indicated that the occurrence of landslides has increased in the areas of Divisional Secretariat Divisions of Ridigama, Ibbagamuwa (Deduru Oya basin), Matugama, Bulathsinhala, Agalawatta, Ayagama, Elapata, Kalawana, Ratnapura, Kahawatta, Kuruwita, Pelmadulla (Kalu Ganga basin - Fig. 2), Weligepola, Haputale, Godakawela, and Kolonna in the Walawe River basin. Landslides and subsidence in these areas have altered the micro relief causing changes in the flow pattern of streams either through damming or diversion of streams as a result of the deposition of the rock, debris and earth, for eg. at Patulpana, the stream which paralleled to the main road was dammed, and a



Similar occurrences frequently take place around newly constructed reservoirs such as Victoria, Kotmale, Rantambe, Randenigala and Samanawalawa and in tunnel areas. Slope slumping in these areas occurred due to inadequate investigations of local geologic parameters. Blasting of highly weathered metamorphosed rock for road building (e.g. the Kandy - Mahiyangana road), mining of graphite using heavy explosives (Kurunegala and Kegalle district), gem mining, and forest or grassland fires on steep slopes have increased the occurrence of landslides as well as of land subsidence (road subsidence) on steeper slopes.

unchecked the intensification threat of landslides will continue to create more havoc and harm thousands of poor people in valley bottoms and high slopes. Therefore, recommendations to minimize the occurrence of landslides in Sri Lanka propose by the writer are as follows:

- a. Prepare a comprehensive micro-landuse map for the landslide prone districts with the terrain analysis in mind
- b. Identify the marginal lands for protection of natural forest, water sheds and parks for wild-life for Highland districts.

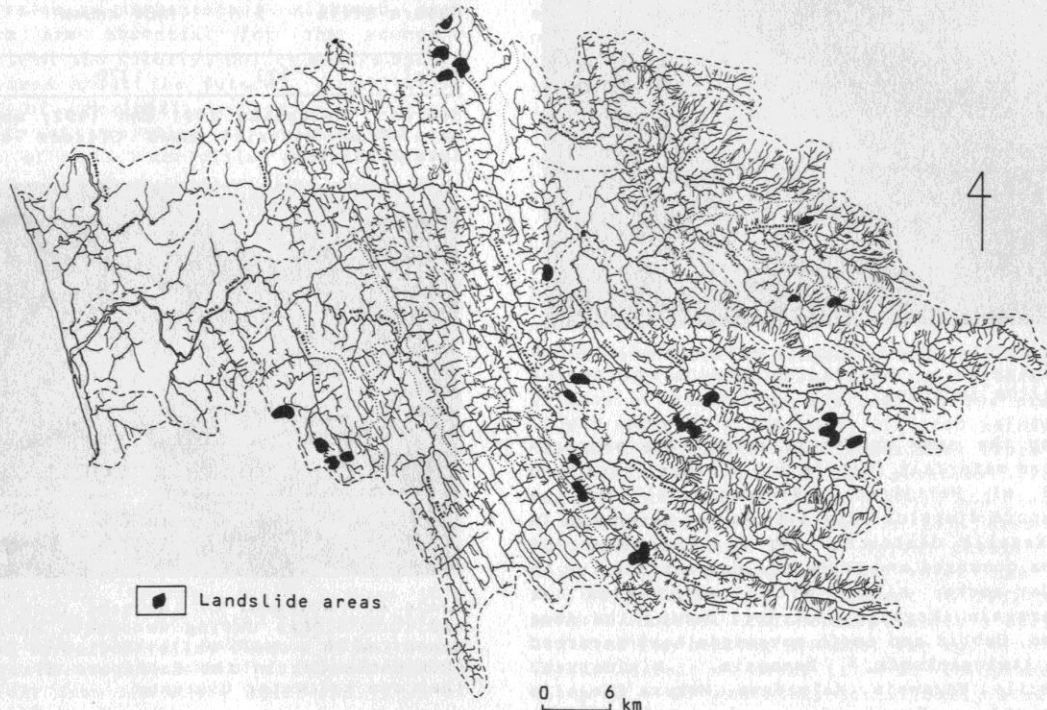


Figure 4. Landslide prone areas of the Kalu Ganga Basin.

The experience of past 15 - 20 years, it is evident that, the wanton forest felling in steep (about  $18^{\circ}$  -  $45^{\circ}$  or more steepness) and moderate slopes (about  $15^{\circ}$  -  $18^{\circ}$  steepness) areas will continue in a acceleration rates by the end of this decade. Furthermore, inappropriate agricultural practices for rubber, tea and other export crops (Plate 6), rapid increase in housing and other unplanned constructional activities, short-sighted land policies of the government (breaking in pieces of lands) will cause more landslides in the Hill country. If

- c. Grade slopes specially from moderate ( $6^{\circ}$  -  $11^{\circ}$ ) to steep and extremely steep ( $18^{\circ}$  -  $45^{\circ}$ ) or over slopes for the management of earthslips and soil erosion. However, fair to steep ( $11^{\circ}$  -  $25^{\circ}$ ) and steep to extremely steep or over slopes should not be used for human settlements, agriculture and other engineering purposes without a detailed investigation of geological structure .
- d. Minimize the use of high slopes for human settlements, grazing and agriculture.
- e. Continue reforestation using indigenous species and strictly forbid the wanton and illicit forest felling in graded slopes.



Plate 5. (A) Location of the area where a catastrophic landslide caused damage to three houses and caused five deaths in Bulathsinhala (Kalutara district), 1992. (B) Damaged rooms in one of the houses shown in Plate 2 B area.

- f. Monitor haphazard quarrying of rocks and other mining activities in moderate to steep or over slopes.
- g. Forbid or limit the use of explosives in mining activities in gneissic and granitic rocks in moderate to extremely steep or over slopes.
- h. Provide contour drains and terracing to protect the high slopes from soil erosion and earthslip.
- j. Care in the uprooting of plantation crops, for eg. tea and rubber to protect bond between surface soil layer and parent

- f. Monitor haphazard quarrying of rocks and other mining activities in moderate to steep or over slopes.
- g. Forbid or limit the use of explosives in mining activities in gneissic and granitic rocks in moderate to extremely steep or over slopes.
- h. Provide contour drains and terracing to protect the high slopes from soil erosion and earthslip.
- j. Care in the uprooting of plantation crops, for eg. tea and rubber to protect bond between surface soil layer and parent material in high slopes by soil erosion and earthslip
- k. Take necessary action to enforce the existing Laws and Legislation on protection and management of natural resources.



Plate 6. (B.2) clearance of forests at Kukulegama (Ratnapura District): a potential landslide location.

The above-mentioned recommendations can be implemented as short-term, medium-term and long-term strategies to landslide hazards.

#### CONCLUSION

The study of landslides in Sri Lanka indicates that their incidence during the past decade (1983 and 1993) increased rapidly. These landslides have caused about 223 village areas damaged, about 381 deaths and the dislocation of 1370 families. The acceleration of present landslide hazards and related other environmental degradation is due to inadequate investigation of geological structure during constructional activities, short-sighted land policies of the government and recent over-



exploitation of natural forest resources in the uplands and mountainous areas. Such activities have been continuing with their concealed and manifest permission. Legislation were passed and Institutions are established for the control and management of forest, land, soil and water during the times of the Colonial government and after independence by the National governments. However, adequate enforcement of laws have not been given serious consideration.

Even during the present decade (1990 - 2000), the forest felling, inappropriate agricultural practices, rapid increase in housing and other constructional activities will continue with direct and indirect influence by both State and Private Sectors. For the period 1950 - 1982 loss of life damage to property caused by landslides is not so severe as compared to the period between 1983 and 1993. This trend reveals an acceleration of landslide hazards in Sri Lanka in the coming years.

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