LANDSLIDE HAZARD MAPPING IN SRI LANKA

CARTOGRAPHIE DES RISQUES DE GLISSEMENT DE TERRAIN AU SRI LANKA

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SYNOPSIS

Landslide Hazard Mapping Programmes are considered basic to planning for sustainable development in the hilly regions of the world but very few of them display adequate sensitivity to the multidisciplinary demands on such a programme with matching professional response in unbiased environment. The paper spotlights the basics of the landslide hazard mapping project in Sri Lanka. The approach adopted favours production of State of nature maps and their eventual synthesis through multidisciplinary expertise. The unique feature of the operational strategy is to recognise dominant of landuse planning and management. Human Settlements and infrastructure maps are added to facilitate risk assessment, and eventually the landslide hazard zonation.

General Guiding Principles

1. The landslide hazard mapping is required in Sri Lanka to aid planning, for ensuring sustainable development of the areas under study. Naturally the mapping methodology was modulated to adequately respond to the requirement.

2. First time landslidies are found to be relatively more difficult to forecast but the repetitive ones could be anticipated based on intensive behavioural follow up.

3. The past and present history of landslide offer key to the prediction of future scenarios.

4. Main conditions that can cause landsliding are only broadly identifiable at the scale of 1:10,000 and mapping work can be modulated to meet specific requirements of a location specific case.

5. Landslides can be tentatively classified and diagnosed at the scale of 1:10,000. A detailed classification may call for mapping to scales larger than 1:10,000, and proper investigation.

6. Since landslide hazard is strongly dependent on degree, extent and rate of human intervention and it is the hardest thing to comprehend, judge and evaluate, the outputs cannot be free from the ensuing limitations.

7. When it comes to slope failures, nothing can replace subtle judgement and collective wisdom.

Reasons for selecting the scale of 1:10,000

The following considerations facilitated the choice:

(1) For the landslide hazard maps to be able to serve as effective tools in the process of development, it was essential to opt for a fairly large scale of mapping. On the other hand, increased demand for time, effort, expertise and cost that usually go up with the scale and grain of hazard mapping required that the field work be toned down to a manageable scale.

The three scales short listed were 1:25,000; 1:10,000; and 1:5000. Scale of 1:25,000 was not considered sufficiently large particularly for use in Government of Sri Lanka's landuse planning & habitat programmes. Scale of 1:5000 was considered too large, time consuming and expensive. It was not favoured also because the process of capability building at NBRO was to develop in step with the project, and a highly ambitious programme was rather out of place, when huge landslide areas of the island yet remained to be mapped.

(2) The Agriculture Base Mapping Programme (ABMP) of the Government of Sri Lanka aims to cover the island to a scale of 1:10,000. Some of the ABMP sheets of the area of interest to the project were already available at this scale and pace of their production was expected to get a fillip with the present programme. Infect, the only other base maps available were either of one inch to one mile or 1:50,000 scale and both these were too small in scale to be acceptable.

(3) Forest and Land Use Mapping Project (FORLUM) for the forest sector development has also adopted a scale of 1:10.000 for their mapping programme. Uniformity of scale in multi-sectoral programme was considered an advantage.

Nature and Type of Landslides and Massmovements in Sri Lanka and the associated risk.

Sri Lanka is blessed with some of the world's most rugged mountain ranges characterized by precambrian rocks. The processes of slope degradation operating over centuries have combined with intensive human activity in recent decades to generate a large number of landslides, inflicting staggering damages and untold misery. Relative abundance of different types of landslides and other massmovements in Sri Lanka is presented in Table 1 and examples of elements at risk are illustrated in Table 2.

Table 1:Relative abundance of different types of landslides & other mass movements in Sri Lanka

Most Abundant	(C) Soil falls & rockfalls
	(C) Cut slope failures
	(C) Ground Subsidences of large areas
	(C) Slumps and block slides in soils
	(C) Earth and debris flows
	(C) Creep
	(C) Landslides on discrete boundary shears
Least Abundant	(U) Mud Avalanches
	(U) Very deep seated landslides
	(U) Slumps in rocks; rock slides
	(U) Subaqueous slides
	(U) Liquefaction failures

(C) Common (U) Uncommon

Most of the landslide problems have so far been tackled as individual problems and it is for the full time that a holistic view has been taken to map the problematic areas geologically, geomorphologically and geotechnically. The studies on landuse and hard management have been added. Former landslides and landslide prone deposits are being combined with hydrogeological information through airphoto interpretation.

Table 2: Examples of elements at risk identified during mapping

Human lives	Ketayapathana, Kahagalla, Uduwara, Katupelellegama, Munwatte
Homesteads and Human Settlements	Ettampitiya, Hulankapolla, Ratnodagama, Ketayapathana
Roads	Beragala, Kahagalla, Lunugala, Pussellawa
Railway lines	Watawala, Ohiya/Pattipola, Uduwara
Communication	Beragala - (telephone system)
Bridges	Liyanghawela, Padiyapelella,Maratuwela
Dams & Reservior	High Forest Estate,Kotmale
Forest Cover, Wildlife, Flora & Fauna	

Table 3 : State-of-Nature Maps & their uses vis-a-vis Scenario prior to launching of the Project in Sri Lanka

Map	Uses	Scenario
Geology	Essential for (a) Scientific study of the causes and mechanisms of landslides (b) for hazard zonation mapping and for (c) studies related to prediction of the landslides and other mass movements, particularly under intensive landuse.	The map of Geology of Sri Lanka is available only at the scale of 1:506880 (8 miles to one inch). The LHMP will deliver, for the first time the maps of geology for parts of Badulla & Nuwara Eliya at 1.10,000 scale.
Slope Category Maps; Landform Maps	Provides a very useful base for assessment of information on landslides and other mass movements. Besides being a powerful tool for terrain evaluation, it also serves as a basic instrument for Landslide Hazard Mapping.	Forlum Project in Sri Lanka are producing slope maps of Kandy and parts of Nuwara Eliya & Badulla to 1:10,000 scale using 20 m contour intervals. The hazard mapping project has not only rationalised the slope ranges but makes use of 10 m. Contour interval for more reliable usage. No such maps are available. The project will deliver these maps for the first time for parts of Badulla & Nuwara Eliya, at 1:10,000 scale.
Former Landslides & Colluvium Map	Directly usable for hazard assessment and risk analysis, and for regulating the process of development. Potential of fresh landslides and mass movements is inferred, interalia, in terms of extent of colluvium, particularly in the high rainfall area.	No such maps are available.
Landuse and Management Maps; Human Settlement maps		- do -
Hydrology & Rainfall	The probability of occurrence of landslides and mass movements is inextricably intertwined with hydrology and rainfall details. Such maps will also help establish nexus (if any) between incidence of landslides & rainfall for early warning.	Since rainfall data available is scanty and number of automatic rain gauges is very few. Only one map of rainfall distribution at Badulla & Nuwara Eliya is envisaged.

Information utilised in classifying landslides

Geometry of landslides in plan	a) lobate b) elongate
Geometry of slip surface	a) Circular b) non-circular c) composite d) complex
Depth of slide	a) surficial b) shallow c) deep seated
Type of material	a) rock intact, fractured, boulders, angular rock fragments b) Soil Gravel, sand Silt, Clay
Nature of basal and side shears	a) discrete b) slicken sided c) Poorly developed
Type of movement	a) fall b) flow c) slide
Speed of Movement	a) creep b) landslide c) avalanche d) mass transport
Velocity distribution	a) plastic flow b) viscous flow c) plugflow

Methodology of hazard mapping used - An outline

(1) The methodology adopted for hazard zonation mapping exclude from consideration the local assessment or detailed landslide hazard assessment of specific sites. Apropos of examining the options of : (a) direct mapping of landslide hazards gauged through Geological, geomophological and geotechnical mapping by a multidisciplinary team, and (b) state-of-nature (factor) mapping, the latter was preferred because factor Maps are, in themselves, of a great value to the users of the output; they provide the best assurance of independent evaluation and constant upgradation, and the method offers tremendous flexibility in not only integration of thematic teams through multi disciplinary inputs but also of their periodic upgradation.

In the methodology adopted, the basic information from the field was obtained through:

(a) Desk studies including air photo interpretation leading to production of maps of landform, landuse and management and slope range and slope category. Slope range and slope category map is based on the rationale of thresholds in the backdrop of global literature review.

(b) Field surveys aided by photogrammetric studies leading to, inter alia, information on former landslides and colluvium cover; bedrock geology and rock structure; hydrology and drainage.

(c) Mapping of human settlements and elements of infrastructure at risk chiefly through air photo interpretation, making use of available maps at the scale of 1:10,000, air photos and information from the records of district authorities.

(d) Socio-economic surveys

Air photo interpretation in advance of field surveys helped to acquire better vision of the area under investigation. But airphoto study had to be pursued throughout not only to add details to the maps but also to encourage checking of field maps. Most maps produced in the programme will go through the process of checking at least once.

The field studies were designed to lead to production of the following state-of-nature-maps.

(a) Slope range and slope category
(b) Bedrock geology and structure
(c) Former landslides and colluvium
(d) Landform
(e) Landuse and management
(f) Human settlement and Infrastructure
(g) Hydrology and drainage

A map of rainfall distribution, based on available rainfall records, was also prepared.

In order to facilitate hazard mapping, the total area is divided into basic terrain units, called components, facets or grid cells. The grid cells of a fixed size have the disadvantage of often relating poorly to the geomorphologically meaningful slope units, distinguishable in the landscape.

While admitting that the best way will be to mimic the behaviour of natural slopes, as far as possible, by opting for natural (irregular) units, recourse is taken to regular grid of identical size and shape, approximately 250m x 250m area. The error which may occur due to this simplification is sought to be minimised through selection of three grid shapes, square, circle and ellipse.

Integration of factor maps required the highest value judgment in assigning scores, weighted scores or numerical ratings. Although it was not possible to obtain a unanimous agreement on a highly subjective matter such as this one, attempts were made to arrive at decisions based on collective wisdom.

Realising the inappropriateness of heavily relying on a single procedure, the methodology was modulated to accomodate not only three different grid units but also the flexibility of separating making use of

(a) Adhoc Weighting Approach
(b) Sighted Weighting Approach
(c) Overlap Approach

Usually adhoc preliminary weightings (relative importances) are given to different factors according to personal experience of a multi-disciplinary team. Thereafter maps are overlaid and ratings summed up for each resulting map unit and total ratings are taken to provide the basis for grouping into hazard categories.

Sighted-weighting is where ratings are improved by using information on former landslides as an aid to judging the weightings of the factor map categories and of the maps themselves. Factor categories with low landslide densities is given lower hazard rating when compared with those with higher hazard rating.

The overlay approach, as usual, required mapping of each of the contributing factors separately and then juxtoposing the map units of each of the factor maps. This multiplied several options.

Landslide Hazard Assessment by Integration of two or more State- of-Nature-Maps

Former landslides were pointer to unquestionable hazard. The combination ratings adopted in the first instance were (a) Colluvium cover + Slope Category + Rainfall (30%); (b) Bedrock Geology + Structure + Colluvium (15%); (c) Landform + Landuse Management + Slope Category (35%); and (d) Climate + Hydrology + Drainage (20%).

Sensitivity of the hazard mapping methodology to Landuse planning and Land Management.

De Alwis and Dimantha (1981) had suggested landuse limitation in Sri Lanka according to the slope class, Table 4. While recognising the above and several such recommendations made by different agencies, slope range and slope category classification were arrived at Table 5. Besides slope range and slope category, mappable criteria like relevant landuse, landform, slope length and physiographic position on slope, ground cover status, hazardous zones for field checking and human settlement categorisation for risk analysis were identified and a suitable legend was evolved for systematic map compilation using relevant mappable criteria, Hettige (1992).

Table 4: Slope classes & landuses De Alwis and Dimantha (1981)

Slope Class	Use limitation
0 - 8%	Suitable for paddy or upland cultivation with minimal restriction.
>8 - 16%	Suitable for agro forestry and tree crops.
>16 - 30%	Suitable for tree crops and agro forestry under very careful management.
>30 - 60%	Suitable for forestry plantation or tree crops under estate management. Unsuitable for smallholder settlement.
>60%	Unsuitable for any agriculture use or economic forestry. Catchment protection only.

Table 5: Slope Classification to be adopted for production of slope category maps

Slope (°)	Description	Limitations
0° - 3° (0 - 5%)	Flat to almost flat	suitable for any type of agriculture
3° - 6° (5 - 10%)	Gently sloping	Felt while walking well drained and easily cultivable with minimal restrictions
6° - 11° (10 - 20%)	Moderately sloping	Upper limit is considered as limiting gradient for hill housing.
11° - 17° (20 - 30%)	Moderately sloping	Upper limit is considered as the limiting gradient for small holder agricultural practices, if without adequate conservation measures.
17° - 31° (30 - 60%)	Steep	Requires appropriate soil & moisture conservation and landuse planning. Not recommended for small holder managed agriculture.
31° - 40° (60 - 84%)	Very steep	Only for existing state managed agriculture and agroforestry type under careful management with strict adherence to recommended conservation measures.
40°+ (84%)	Extremely Steep	According to the national conservation strategy draft action plan - Central Environmental Authority November 1990 - any kind of agriculture is prohibited if the slope of the land surface exceeds

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