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Environmental Sustainability and Mass Movement Hazard in Kothmale Reservoir Surroundings

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Abstract

Sri Lanka experienced several devastations due to mass movements in the past with the Central Highlands being the most vulnerable and mostly affected region. There was a significant increase in mass movements following the alterations to the environment and this is especially true in the sensitive environment of the Kothmale Reservoir surroundings. The introduction of Reservoir directly and indirectly made pathways to mass movements. Many other factors also interact and combine in complexity to influence such movements.

The study utilized field observations and existing Maps of the area with Landsat ETN satellite images that were analyzed using MFWORKS software. 100 square kilometre surroundings of Kothmale Reservoir was the study area. Geological, Soil, Land Use, Hydrological and Slope parameters were utilized to analyze the hazard of mass movement.

By comparing above parameters it was concluded that, 33% of the surroundings of the Kothmale Reservoir is highly susceptible to Mass Movements even without the Reservoir. What the reservoir has done was to contribute further to the causation of Mass Movements and thus the high hazard region had increased to 38% with 15% increase purely due to the addition of the reservoir. But it is not only the reservoir that has contributed to Mass Movements in this region. Lack of measures to regulate the dynamics of land use in this fragile environment has further worsened this critical scenario. For example, when comparing the Hazard Maps of 1992 and 2001, there was an increase in the high hazard zones. The least hazard zones which were almost 50% of the total had been reduced to 20% by the 2001 and conversely high Hazard zones had doubled their share from 20 % to almost 42%.

Thus stabilization of the Land Use dynamics in the Kothmale Reservoir Surroundings will be of utmost significance for the future sustainability of the Kothmale environment and to reduce the hazard of Mass Movements.

Keywords: Mass Movement Hazard, Environmental Sustainability, Kothmale Reservoir, Land Use Dynamics, MFWORKS, Hazard Zones

Introduction

Rapid population growth and advances in technology in the last two centuries have placed a heavy demand on natural resources, and allowed man to modify the natural environment. In this process of modification, man has occupied a wide variety of vulnerable geographical and climatic environments. The price paid for this occupation, has been an increase in the number of natural disasters. Impact of natural disasters such as landslides, floods, droughts, cyclones, etc. has increased in recent times, due to increased migration population pressure and utilization of these vulnerable areas concern for environmental sustainability.

The Brundtland Report, defined sustainable development as development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (United Nations Organization, 1987). Sustainable activities should improve the quality of life of all people without doing harm (International Hydropower Association, 2006). The word *sustainability* was used for the first time in 1712 by the German forester Hannss Carl von Carlowitz in his book *Sylvicultura Oeconomica*. Since the introduction of the term, environment was a key factor in sustainability issues, but sustainability objectives should encompass economic, and social performances as well (Wikimedia Foundation, 2006). Environmental sustainability refers to the long-term maintenance of valued environmental resources in an evolving human context (Daniel, C. et al, 2005).

The World Summit on Sustainable Development in Johannesburg, September 2002 identified Water, Energy, Health, Agriculture and Biodiversity (WEHAB) as the five key areas for sustainable development (Wikimedia Foundation, 2006). Reservoirs and multipurpose hydropower projects contribute to development in variety of ways. But ensuring environmental sustainability should be of prime importance as it affects the sustainability of the projects themselves. Although hydropower provides an eco-friendly and eco-efficient energy source, environmental impact of such development programs should be viewed cautiously.

Kothmale Reservoir was built in the upper catchment area of the *Mahaweli Ganga* which is the longest river in Sri Lanka. *Kothmale Oya* is one of the major tributaries of *Mahaweli Ganga*. *Kothmale Oya* Catchment Area is one of the intensively studied areas of Sri Lanka, due to the creation of a major reservoir. Both prior to and after the construction of the reservoir many studies were conducted to assess the dynamics of the landscape in the catchment area to provide recommendations for the future sustainability of the dam, reservoir and the catchment area.

In the Kothmale valley there is an unusual combination of geological, structural and topographical features which give rise to a strong tendency towards mass movements. Superimposed on these features, a set of human related conditions had increased the potentiality for mass movements in the area. These are in the main: (1) Removal of forest cover on the upper slopes of the catchments, and from talus debris at the foot of scarp faces; (2) inefficient drainage of steep slopes under plantations; (3) Ponding of water for paddy cultivation on terraces above unstable slopes (MacLagan Gorrie, 1954).

The Kothmale valley is bordered by steep cliffs near the perimeter of the reservoir. The cliffs have gentle foot slopes, so called talus slopes, formed by colluviums and debris derived from high cliffs and upslope sources by various processes of mass movement. These include landslides i.e. deep rotational slumps, rock falls and debris flows (Johansson, 1989).

Brunsden and Doornkamp in 1979 - 1980, identified the whole area as a mecca of mass movement with over 300 discrete failures during a study done prior to the reservoir construction. They identified a variety of adverse geological features such as unstable soil and rock masses in the reservoir area, solutioned and cavernous limestone in the reservoir and below the dam site and deep and irregular weathering rock associated with strong lineaments representing either as master joints or faults (Brunsden and Doornkamp, 1980).

Mass movements occurred in the *Kothmale Oya* Catchment in 1933, 1947, 1957, 1958, 1970 and 1979 even prior to the reservoir construction. A survey of houses damaged by mass movements was done in 1986 after the impoundment of the reservoir and identified seven vulnerable villages surrounding the reservoir.. Vithanage stated that there was some correlation of the orientation of the cracks observed in these houses and the orientation of the fractures (joints and lineaments) previously mapped in the Kothmale Reservoir Catchment Area. He observed that the series of deep, well developed fractures along the paddy fields and the village gardens indicating the creeping movements of the land along the lower slopes towards the reservoir. These movements were probably due to the draw down effect of the reservoir (Vithanage, 1981 & 1986).

After the construction, surroundings of the Kothmale Reservoir were declared as reserve areas with minimal human interference to ensure environmental sustainability and it was done after evacuating the inhabitants of the area. Although the evacuee settlements were located in the same geographical area, there were considerable changes in the micro-climate, terrain, soil conditions and water availability. These physical problems contributed in large measure to discourage a number of evacuees settling-in in the new settlements. Some have gone to the extent of abandoning the allotments after relocation. Further, the lack of social amenities and the inadequacy of infrastructure facilities have also affected family welfare adversely (Karunanayake and Abeyratne 1989). For these reasons, some from subsequent generations of evacuee families were regaining occupation of the reserve areas, posing a grave threat to the environmental sustainability of the region.

This lack of environmental sustainability due to occupation of reserve lands in the aftermath of the construction of a massive reservoir in a sensitive landscape have caused an increase in hazard of mass movements in the Kothmale Reservoir surroundings. This imposes a threat to the social and economic sustainability of the project.

Concept of Mass Movement and Landslides

Mass movement can be either flow or slide or fall depending on the rate of speed of movement (Blij and Muller, 1993). Thus a Mass moving event is defined as 'the movement of a mass of rock, debris or earth (soil) down a slope under the influence of gravity. A comprehensive definition would be 'Mass movement is a phenomenon of denudational process, where by soil or rock is displaced along the slope by mainly gravitational forces, usually occurring on unstable slopes due to various reasons which are either natural or man made' (National Building Research Organization, 2003). Mass Movement is the collective term for all gravitational or down slope movements of weathered rock debris (Abeysinghe, A.M.K.B. and et. al., 2003).

The difference between Landslides and the Mass Movements was explained by Coates (1977) under the following categories. Landslides tend to have following features which help to distinguish them from other types of mass movements;

Landslides represent one category of phenomena included under the general heading of mass movements.

1. In both, gravity is the principal force involved.
2. Movement must be moderately rapid, because creep is too slow to be included as land sliding.
3. Movement may include falling, sliding and flowing.
4. The plane or zone of movement is not identical with a fault.
5. Movement should be down and out with a free face, thus excluding subsidence.
6. The displaced material has well defined boundaries and usually involves only limited portions of the hill slide
7. The displaced material may include parts of the regolith and / or bed rock.

The Mass Movements are classified according to different methods and one of the most accepted methods is the 'Wyoming Classification Scheme'. The Geologic Hazards Section at the Wyoming State Geological Survey developed this Mass movement classification system modified from Varnes (1978) and Campbell (1985). According to this classification there are five basic types of Mass Movements that occur in three types of material. Falls, topples, slides, lateral spreads, and flows can occur in bedrock, debris, or earth.

Hazard, Vulnerability and Risk of Mass Movements

Mass Movement hazard refers to the natural conditions of an area potentially subject to slope movements. It is defined as the probability of occurrence of a Mass Movement of a given magnitude, in a pre-defined period of time, and in a given area (Varnes and IAEG, 1984).

Vulnerability is defined as the level of population, property, economic activity, including public services, etc., at risk in a given area resulting from the occurrence of a Mass Movement of a given type (Department of Regional Development and Environment, Executive Secretariat for Economic and Social Affairs Organization of American States, 1991).

Risk or specific risk expresses the economic and social dimension of mass movement. It is generally considered to be equal to the likelihood of death or injury, or to the expected monetary loss due to the occurrence of a Mass Movement. Mass Movement risk is usually defined as the product of Mass Movement hazard and vulnerability (Varnes and IAEG, 1984; Fell and Hartford, 1997).

Specific Risk = Hazard * Vulnerability

The present study has utilized satellite remote sensing and image analysing software to predict the mass movement hazard. It explored the feasibility of utilizing these techniques in the assessment of land use dynamics and ultimately the environmental sustainability associated with regional development programs. But due to resource constraints, whole spectrum of environmental sustainability such as water quality could not be assessed.

MFWORKS and Multispec W32, software were used for the satellite image analysis of this study. MFWORKS is raster based Geographical Information System (GIS) software which is suited for Loss and Gain analysis in detecting land use dynamics, unlike vector based GIS software systems. MultiSpec is a data analysis software system which is intended for the analysis of multi-spectral image data, such as that from the Landsat series of Earth observational Satellites. Thus Multispec W32 was used to define and determine the different categories in satellite images, according to their spectrum.

Objectives

Objective of the study was to analyze the hazard of mass movements in the Kothmale Reservoir surroundings and to identify the land use dynamics in the region. The land use dynamics included the contribution of the Reservoir and other land use factors such as anthropogenic factors and forest cover changes which interact and combine in complexity to influence the mass movements in the study area. Ultimately it assessed the extent of environment sustainability as measured by hazard of mass movements and extent of land use dynamics.

Methodology

One hundred square kilometres of the surroundings of Kothmale Reservoir with most complex land use types and concentrated sites of mass movements was selected as the study area after a pilot field exploration. Geology, Soil, Land Use, Slope and Hydrological parameters were utilized to analyse mass movement hazard.

The study utilized field observations and existing maps (Geology, Soil) of the area along with Landsat ETN satellite images (Landsat ETN - 1992. 02.10→ 141-55 92 02 10 K and 2001. 03 14 →141-55 01 03 14).

Satellite images of the study area were correlated with the topographical maps from the Survey Department of Sri Lanka, taken as the reference material (Topographical Maps of 1: 50000 of Gampola, Nuwaraeliya and Badulla produced in 1999 by Survey Department of Sri Lanka). Satellite Images of the study area were subsequently corrected for geometry as Longitude - Latitude Coordinate System using MF Works.

- Classification of Land Use and Creation of Land Use Maps

These images were transferred into images in the Multispec W32 and land use classifications were done for 1992 and 2001 satellite images.

- Creation of Digital Elevation Model

Digital Elevation Model of the study area was created for 1992 and 2001, using the 'Fill Dem' facility in MF Works. It was subsequently classified into Slope Gradient classes; Maximum Slope, High Slope, Moderate Slope, Lower Slope and Minimum Slope using the Multispec W32.

- Creation of Geology Map of the Study Area

The study area was demarcated in the geological map (Geological Map of 1:10000 of Kandy - Hanguranketha produced by the Geological Survey and Mines Bureau in 1996). This map was transferred to Tiff Format in Adobe Illustrator and resolutions and size of the map were corrected in reference to the 2001 Satellite Image of the study area.

The map was transferred to Multispec W32 and classified into geology classes and they were; Garnet Biotite Gneiss, Charnockeitic Gneiss, Quartzite and others. It was then transferred into MFworks with geometric corrections.

- Creation of Surface Soil Cover Map of the Study Area

The study area was demarcated using the Surface Soil Cover Map (1: 50,000) produced by the National Building Research Organization. This demarcation was subsequently transferred to Tiff Format in Adobe Illustrator and resolutions and size of the map were corrected with reference to the 2001 Satellite Image.

It was then transferred to Multispec W32 and spectrally classified into Soil Cover Classes, Colluvium Overburden, Thick Soil, Thin Soil, Bed Rock and Mountainous Soil. This map was transferred into MFworks and with geometric corrections used for subsequent analysis.

- Creation of Distance Zones from the Reservoir

Using the Adobe Illustrator and overlaying a grid network over the 2001 Satellite Image, zones were identified at 0.75 Km distance. This grid map was classified using Multispec W32 and analysis was done using MFworks.

Finally these maps were analysed in step wise manner as indicated below.

- Combination of Slope Gradient and Land Use - Using 1992 Data
- Combination of Slope Gradient and Land Use - Using 2001 Data
- Combination of Slope Gradient, Land Use, Soil Cover & Geology
- Combination of Slope Gradient, Land Use, Distance to Reservoir & Geology
- Combination of Slope Gradient, Land Use, Soil Cover, Geology & Distance to Reservoir

The land use and slope gradient classes were given a weight according to their susceptibility to Mass Movement and this was decided through the observations made in the course of the field survey.

Table 1 Weight for the Mass Movement Hazard Map - Land Use & Slope

Slope / Land Use		Moderate Slope	Maximum Slope	High Slope	Lower slope	Minimum Slope
		5	4	3	2	1
Home Gardens	5	25	20	15	10	5
Paddy	4	20	16	12	8	4
Tea	3	15	12	9	6	3
Scattered Forest	2	10	8	6	4	2
Dense Forest	1	5	4	3	2	1

Source: Based on the data obtained through field observations

These weights were then classified and the following Hazard classes were assigned to the respective range of weight. Subsequently using the 'Combine' option of MF WORKS, DEM and Land Use map was combined to create the Mass Movement Hazard Map. It was classified using the given in Table 2.

Table 2 Weight Range and Hazard Classes

Weight Range – Obtained from Table 1	Hazard Classes
0 – 4 →	Minimum Hazard
5 – 9 →	Low Hazard
10 – 14 →	Moderate Hazard
15 – 19 →	High Hazard
20 – 25 →	Maximum Hazard

Source: Based on the data obtained through field observations and Secondary Data

Subsequently this Hazard map was further improved through 'Combine' option by combining Land Use Map of 2001, Digital Elevation Model, Geology Map of the study area and Distance to Reservoir Zonation Map to produce an improved Mass Movement Hazard Map. The combinations obtained were given weights depending on their susceptibility to Mass Movements and the respective weights for each class have been indicated in Table 3.

Weights for Land Use, Slope Gradient and Distance to Reservoir were given based on observed data and data obtained from the field investigations during the study. For example, majority of Mass Movements occurred on moderate slopes, close to the reservoir, in home gardens and thus these categories were given the highest weights. The vice versa applied to the minimum slopes, far from the reservoir, in dense forests and were given the lowest values.

Weights for the Surface Soil Cover were theoretical formulation. In areas where there is colluvium, there will obviously be high incidence of Mass Movements and the opposite in true of areas where there is an exposure of bed rock. Regarding thick soil and thin soil, in a region where gentle slopes are seen as in Kothmale reservoir surroundings, thick soil regions are highly susceptible to Mass Movements. Thin soil is less susceptible. Thus, sequence of soil cover classes in order of increasing susceptibility to Mass Movement are; Bed Rock, Thin Soil, Thick Soil and Colluvium.

Weights for Geological Classes were given using the research done by the National Building Research Organization in 1995 - "Landslides Hazard Zonation Mapping Process". According to NBRO research the sequence of Geological classes in order of increasing susceptibility to Mass Movement are; Marble, Weathered Rock, Garnet Biotite Gneiss, Charnokeitic Gneiss, and Quartzite.

Each cell of the grid network thus had a specific value of Hazard (Hazard Score) and this was obtained by adding each class numbers of each parameter. The subsequent analysis was done by classifying these Hazard Scores into Hazard Classes as indicated in table 3.

Table 3 Weights for the Mass Movement Hazard Maps for All Categories

Geology Classes		Present Land Use Classes		Slope Classes		Distance to Reservoir Classes		Soil Cover Classes	
Quartzite	6	Home Gardens & Settlements	5	Moderate Slope	6	Less than 0.75 Km.	6	Colluvium	5
Charnockeitic Gneiss	5	Paddy	4	Maximum Slope	5	0.75 – 1.5 Km.	5	Thick Soil	4
Garnet Biotite Gneiss	4	Tea	3	High Slope	4	1.5 – 2.25 Km.	4	Thin Soil	3
Weathered Rock	3	Scattered Forest	2	Lower Slope	3	2.25 – 3.0 Km.	3	Not analyzed Soil	2
Marble	2	Dense Forest	1	Minimum Slope	2	3.0 – 3.75 Km.	2	Bed Rock	1
Others	1			Flat Regions	1	More than 3.75 Km.	1		

Source: Based on the data obtained through field observations and Secondary Data

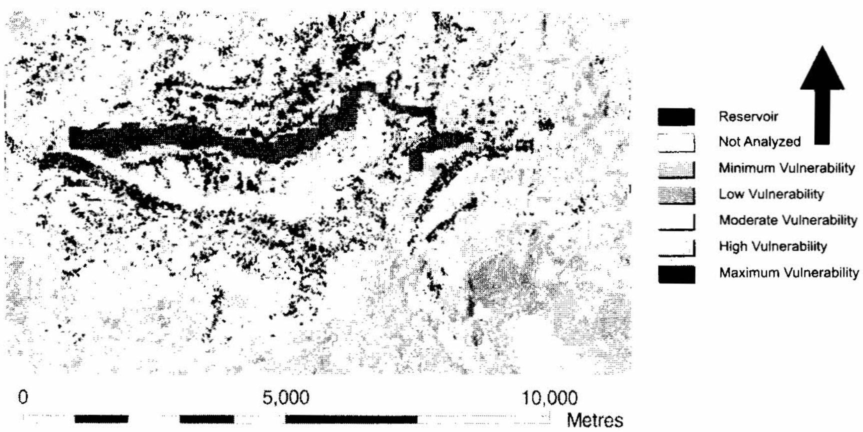
Table 4 Hazard Score for Creation of Hazard Maps for All Categories

Hazard Score – Obtained from Table 4		Hazard Classes
Without Soil Cover Class	With Soil Cover Class	
0 – 9	0 – 4	Minimum Hazard
10 – 12	5 – 10	Low Hazard
13 – 15	11 – 16	Moderate Hazard
16 – 18	17 – 22	High Hazard
19 – 23	23 – 28	Maximum Hazard

Source: Based on the data obtained through field observations and Secondary Data

Results and Discussion

MAP 1 Combination of Slope Gradient, Land Use, Distance to Reservoir & Geology



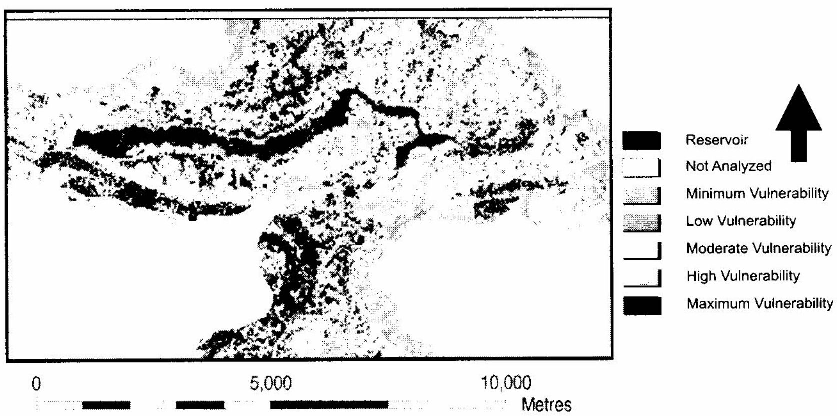
Source: Landsat ETN 2001. 03. 14, Geological Maps (1:10000) (1997) produced by Geological Survey and Mines Bureau.

Table 5 Comparison of Hazard with and without the Effect of the Reservoir

Hazard Zones	Without Reservoir (Percentage of Area)	With Reservoir (Percentage of Area)	Change (With – Without)	Percentage of Change
Reservoir	3.5	3.5	0	0
Not Analyzed	45	45	0	0
Minimum	0.44	0.13	- 0.31	-238 %
Low	3.04	1.35	- 1.69	-125 %
Moderate	14.38	12.29	- 2.09	-17 %
High	26.35	27.64	1.29	4.6 %
Maximum	7.29	10.09	2.8	27.8 %

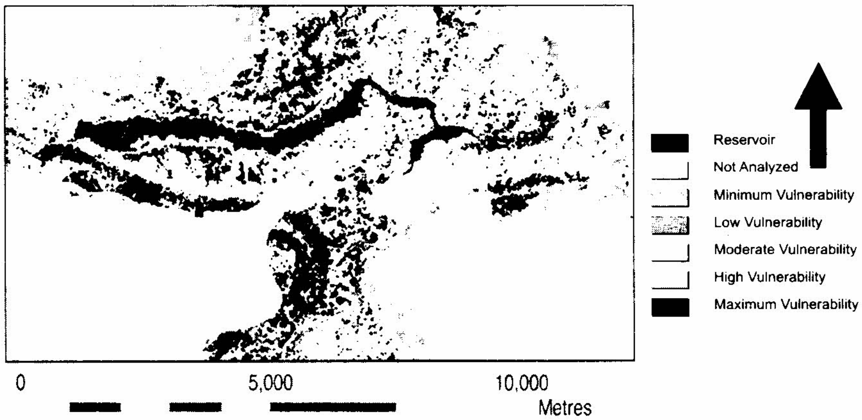
When comparing the hazard with and without the effect of the Reservoir, results shown in Table 5 (Map 2 and 3) were obtained. Even without the effects of the reservoir, 33% of the study area was either 'maximum' or 'high' hazardous to mass movements. It was evident that there was a considerable decrease in the minimum and low hazard zones and conversely a notable increase in the maximum and high hazard zones, with the construction of the reservoir. What the reservoir has done is to contribute further to the causation of Mass Movements and the high hazard region had increased to 38% (with 15% increase) purely due to the addition of the reservoir.

MAP 2-Combination of Slope Gradient, Land Use, Geology and Soil Cover



Source: Landsat ETN 2001. 03. 14, Geological Maps (1:10000) (1997) produced by Geological Survey and Mines Bureau, Soil Cover Map produced by National Building Research Organization (2001).

MAP 3 Combination of Slope Gradient, Land Use, Geology Soil Cover and Distance to Reservoir



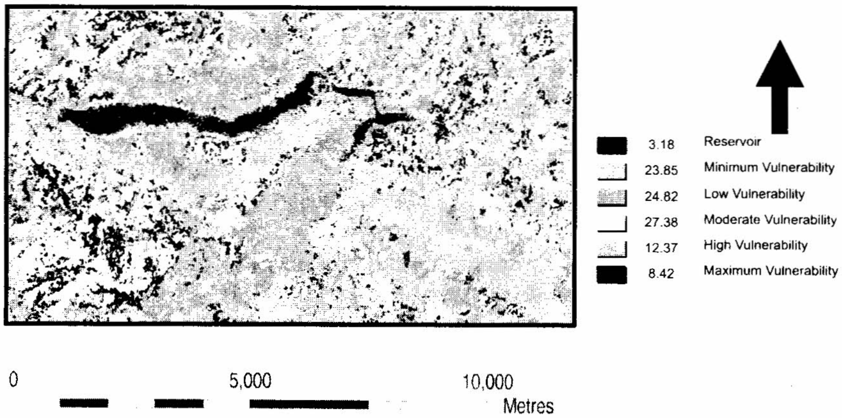
Source: Landsat ETN 2001. 03. 14, Geological Maps (1:10000) (1997) produced by Geological Survey and Mines Bureau, Soil Cover Map produced by National Building Research Organization (2001).

But the burden of Mass Movements in this region had increased not only due to the reservoir. Lack of measures to regulate the dynamics of land use in this fragile environment has further worsened this scenario. For example, there was an increase in the high hazard zones when comparing the Hazard Maps of 1992 and 2001 (Map 4 and 5). Two Hazard Maps in respect of 1992 and 2001 were made based on changes in land use and the slope gradient, to compare the situation between the two years. It was assumed that the proportion of all the other factors (Geology, Soil and Distance to the Reservoir) between these two periods were similar.

Table 6 Comparison of Hazard between 1992 and 2001

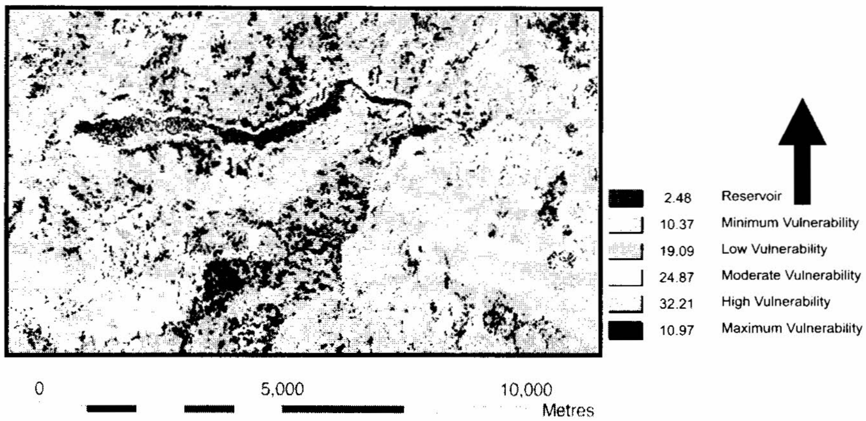
Hazard Zones	1992 Percentage	2001 Percentage
Minimum	23.85	10.37
Low	24.82	19.09
Moderate	27.38	24.87
High	12.37	32.21
Maximum	8.42	10.97

MAP 4 - Combination of Slope Gradient and Land Use - Using 1992 Data



Source: Landsat ETN 1992. 02. 10 → 141-55 92 02 10 K

MAP 5 - Combination of Slope Gradient and Land Use - Using 2001 Data



Source: Landsat ETN 2001. 03. 14 → 141-55 01 03 14

When comparing the Hazard Maps of 1992 and 2001, there was an increase in the high hazard zones with the time. The least hazard zones (Minimum and Low Zones) which accounted for almost 50% of the total area had been reduced to 30% by the 2001, and conversely high Hazard zones (High and Maximum) had doubled their share of land occupation from 21 % to almost 43%.

According to the above maps the main variability is seen in respect to the land use pattern while the slope gradient makes very little contribution. The reservoir surroundings, especially the right bank, has changed its land use pattern considerably with a significant reduction in the forested areas and subsequent increase in tea cultivations and home gardens. This is also evident towards the eastern edge of the reservoir.

There was a reduction of forest regions (28% to 11.5%) with an increase of areas under home gardens (23% to 32%) as shown by the Table 7 between the two years. This was due to the occupation of marginal and reserve lands and forested regions by the second generation evacuees, creating home gardens including small scale tea lands and paddy fields.

Table 7 Dynamics of Land Use 1992 - 2001

	Land Use Classes	1992 Percentage	2001 percentage
1	Reservoir	3.75	2.60
2	Tea	41.42	41.80
3	Scattered Forest	24.53	8.80
4	Dense Forest	3.40	2.70
5	Paddy	3.72	11.90
6	Home gardens	23.18	32.20
	Total	100	100

Source: Landsat ETN satellite images - 1992. 02.10 and 2001. 03.14

This fact was visible even during the field survey. Twenty one sites of mass movements were identified during the field survey in the surroundings of the Kothmale Reservoir and almost all of these sites were situated in the high or maximum hazardous areas as depicted in the above maps.

In the field survey it was noted that, there was resettlement of the forest reserves surrounding the reservoir by the second generation evacuees. Although the evacuees were given lands during the impoundment of the reservoir, they were again resettling in the reserve areas due to poor maintenance of these reserves and due to inadequate space and economic futility of working the given lands. These dynamics of land use in high and maximum hazard zones in the *Kothmale Oya* catchment will definitely have serious effects on the future sustainability of the Kothmale reservoir by increasing the incidence of Mass Movements which are already intent.

Conclusions and Recommendations

It could be concluded that, the area surrounding the Kothmale Reservoir was a hazardous region for Mass Movements even without the reservoir. The hazard of mass movements has further worsened due to non consideration of this fact prior to the reservoir construction and non implementation of measures to ensure environmental sustainability by stabilizing the land use dynamics of the region. The high hazardous areas of Mass Movements in the Kothmale reservoir surroundings could be classified into four major zones as follows.

Table 8 Identified Hazard Zones of Mass Movements

Zone	Situation in Relation to the Reservoir
Zone 1	Left bank of the Reservoir
Zone 2	Right Bank of the Reservoir
Zone 3	Area situated at the eastern edge of the Kothmale Reservoir
Zone 4	Right Bank of the *Kothmale Oya* before its confluence with Reservoir & Puna Oya

As the Kothmale reservoir is already constructed, nothing significant could be done to repeal its effects on the environment of the reservoir surroundings. But it illustrates the importance of vigilant examination, evaluation and monitoring of the sensitive environmental factors when planning major regional development programmes in a fragile environment such as *Kothmale Oya* Catchment, to ensure its sustainability.

Considerable changes in land use dynamics have occurred in the region in the past 9 years and these have adversely contributed to the causation of Mass Movements, by destabilizing the environment. Thus minimizing the negative effects of land use dynamics is mandatory for the people to realize the potential benefits of the Kothmale Hydropower Project. Environmentally sustainable measures through stabilization of land use are necessary to minimize these effects.

Identified Hazard Zones should be made strict reserves with minimal human interferences and people in the hazardous areas should also be relocated as a mass movement mitigation strategy. People already occupying these areas should be given economically productive lands for resettlement. At the same time authorities should take necessary action to prevent progressive and further occupation of these reserve areas which disharmonize environmental sustainability. Already damaged areas should be improved with reforestation after evacuating people. These stabilization techniques of the land use dynamics and environmental sustainability will be of prime importance to reduce the hazard of Mass Movements in the Kothmale Reservoir Surroundings. It will also ensure the future sustainability of the Kothmale Hydropower Project.

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