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Assessment and mitigation of hydrological hazards in Sri-Lanka

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Abstract

In assessing Hydrological hazards emphasis be given to impact on land resources as it plays a very important role. Floods, water logging, acid sulphate conditions, iron toxicity, soil salinity, alkalinity, soil erosion, land slides and water pollution are the major hydrological hazards in Sri-Lanka.

Soil Erosion and land degradation is a very series aspect of hydrological disasters. Present day soil erosion is estimated for various land use categories and in certain categories like vegetables in mid and up country, tobacco in the mid country intermediate zone and slash and burn cultivation practices under low country dry zone it is alarmingly high. Monitoring is done in different catchments using absolute measurement estimation methods and cesium fallout method. Erosivity of rains decreases with increase in elevation of the country. Erodability of soil decreases in the following sequence. Red yellow latosolic soils or nitisols are the most stable followed by Red Yellow Podsolic soils(Ultisol), and Reddish Brown Earth soils(alfisol)

Land slides is another major aspect which cannot be disregarded. These are mostly activated by very heavy rains within very short time about 200 mm of rain within two days. Soil salinity and alkalinity is monitored in many tanks and in the command area of major irrigation projects in order to take necessary precautions.

Hydrological hazards can be minimized by educating rural people with awareness programmed and also to provide them with enough subsidies for results oriented active participation in this exercise.

INTRODUCTION

Water is an increasingly scarce and extremely valuable resource, without which sustainable development is highly impossible. At the same time it can become a disastrous member if not managed properly. Sri lanka is a very small country having 6.5 million hectares of land where almost half the work force is engaged in agriculture. Climate wise About 80% of the land is under dry and intermediate zones experiencing 500 - 1200 cm of rain in dry zone.

Though highly different figures have been given by different researchers, as a whole soil loss is alarmingly high in dry and intermediate zones under vegetables, tobacco and slash and burn land use categories. When the crop is not properly managed even under plantation crops there is appreciable amount of erosion. In mid country and up country during the last two decades the landslide intensities were alarmingly high.

In order to arrest soil erosion various practices are adopted, bunds and drains, terracing, mulching, cover crops and sloping agricultural land technique considered as the main measures. It is always advisable and economical to enlighten the people about the processes and consequences of erosion and steps that should be adopted to minimize soil erosion and land degradation than to spent enormous amounts to reclaim eroded lands.

In Sri Lanka land man ratio has changed from 2.7 ha to 0.3 ha during the past hundred years. Present arable land has to be protected from hydrological hazards that lead to soil erosion and degradation If special reference is given to management of water resources for sustainable land management it must not degrade the soil or significantly contaminate the environment while providing necessary support to human life.

FLOODING AND STAGNATION

Few decades ago flooding was a major hydrological hazard in wet zone of Sri Lanka. This was successfully arrested by constructing flood protection dams on either side of three major rivers. Construction of dams prevented flooding, at the same time reduce recharge of water table to a considerable extent. As a result during dry period people living in foot slopes of the lower peneplain faced with the problem of scarcity of water. This situation has aggravated due to extraction of sand from rivers for construction purposes leading to deepening of rivers and salinity intrusion along river beds.

Iron toxicity is another problem associated with paddy soils in narrow inland valleys. It is a frequent occurrence in low country wet zone when the associated soils are lateritic in origin. Concentration of iron is mainly by the sub surface flow and as a result of upwelling.

The acid sulphate or the potential acid sulphate condition is a common feature in low lands adjacent to the shore line in the wet zone of Sri Lanka. Large extents of paddy fields are abandoned as a result. The situation has created due to the formation of iron pyrites for which presence of salts from sea water, iron from surrounding highlands and presence of anaerobic condition become necessary. The pH values of these soils with 1:2.5 water and1M Kcl ranges from about 3.5 to 2.4.

SOIL SALINITY AND ALKALINITY

Salinity is a common hydrological hazard mostly confined to dry zone of Sri Lanka. During the recent past, when irrigation schemes were designed for the dry zone, designers were more concern to cater for the requirements of the politicians. In order to increase the command area the main channel was designed at a higher elevation. The development of water table and the dissolution of salts from the higher regions, lead to a subsequent enrichment of salts in the lower aspects of the command area. When there is no way to drain out the drainage water, during the dry period salts reach the surface due to surface tension forces and retain on the surface and gradually develop into a salt crust. The presence of Na+ lead to the destruction of favorable soil physical properties creating a hard layer due to a formation situation refer to a columnar structure in the sub surface. On reaching this condition it is extremely difficult to recover or reclaim the soil. So the best possible solution is to prevent this situation.

SOIL LOSS

Soil loss in tea areas

Tea is one of the major export crops in Sri Lanka. Tea growing areas are mostly located in up country, mid country and to a lesser extent in low country. The total extent is about 200,000 ha and out of which about 45% is managed by the small holders. Soil erosion is a major problem in tea areas where the management is not proper. As a result depletion of nutrients and organic matter from top layers are unavoidable.

Mid country wet zone - Reddish brown Latosol (Nitisol) (Krisnarajah, 1985)		
Old seedling tea - no conservation	40	t/ha/yr
Well managed tea - contour drains	0.24	
mixed home garden	0.05	
well managed VP tea on 30 - 40% slopes, 4 years measurements using 0.5 ha plots	0.3	t/ha.
Up-country Wet Zone - Red yellow podsolic soils (Ultisol)		
Bare clean weeded clonal tea	52.6	t/ha/yr
One year old clonal tea with mulch	0.07	t/ha/yr
Low country Wet Zone (El-Swaify et al, 1983)		
Low country tea	147	t/ha/yr

Soil loss from rubber areas

Most of the rubber plantations are located in low country wet zone area on lateritic landscape. These rubber growing soils have a good structural stability and their minimum infiltration rates exceed highest rainfall intensities. The total extent of rubber cultivation is around 200,000 ha and out of this about 65% are managed by small holders. Under a well managed rubber plantation erosion is usually absent.

soil loss in a rubber plantation		
clean weeded -	24	Mt / ha /yr
With a cover crop -	0.5	Mt / ha /yr

Rubber is a very sustainable soil and land management system.

Soil loss in tobacco areas

Tobacco is grown mainly in the intermediate and dry regions in Sri Lanka covering an extent about 10,000 ha. This crop fail to provide a good soil cover, as a result soil erosion is very high. Unlike other crops tobacco does not leave appreciable amount of organic matter at the end of the crop. Farmers usually uproot them before preparing for the next crop endangering the soil to major losses.

Mid country Intermediate Zone - Immature Brown loam		
Tobacco with no conservation (Krisnarajah, 1985)	70.0	t/ha/yr

field estimate, soil loss on red yellow
podsolic soils on 45% slope, approximated to 200 t/ha/yr.
(using growth node and roots exposure on plants 12 months old).

Soil loss under Chena cultivation

In mid country and low country chena cultivation is mostly confined to vegetables and pulses grown on sloping lands. The following figures show soil losses under different crops.

	Mid country		Low country (dry zone)	
	Capsicon	carrot	sorghum	cotton
no conservation	31	18	21.3	22.2
with mulch	-	-	3.9	2.8

using plots of 9m long with brick collection tanks on 20-40% slope.
Information from P.Krisnarajah

Mid country in Ratnapura district, the estimated mean annual loss over 40 yrs. 100 t/ha.in newly cleared chena plots on 45% slope. The technique used was exposure of roots and soil bulk density.

Sedimentation of reservoir

Hydrographic surveys conducted at four reservoirs along the main river Mahaweli reveal that the reservoirs are loosing their capacity at a fairly high rate.

Table 1. Reservoir sedimentation.

Reservoir name	Original Capacity $M^3 * 10^6$	Mth. & Year of Impound-ment	Surveyed Capacity $M^3 * 10^6$	Month & year of Survey	Capacity Lost upto date of Survey		capacity Loss/yr M^3*10^6
					M^3*10^6	Percent	
Kothmale	176.77	Aug1985	170.55	Aug 1995	6.22	3.52	0.62
Polgolla	4.68	Jan 1976	2.5 2.53	Jan 1993 Aug 1996	2.18 2.15	46.58 45.94	0.13 0.1
Victoria	717.53	Apr 1985	713.08	Aug 1993	4.45	0.62	0.54
Radenigala	860	Aug 1986	791.2	Feb 1996	68.8	8	7.24
Rantembe	10.95	1988	8.96 7	Feb 1993 Nov 1995	1.99 3.95	18.17 36.07	0.39 0.50

Source : MASL

Land Slides

Land slides are another major erosional event occur with increasing frequency in hilly terrain in Central Highlands in Sri Lanka. In Central, highlands most slides are reactivation of dormant slides that were in equilibrium. In Sri Lanka catastrophic land slides are slump flows, occur mostly on escarpments and scarp slopes. Dip slope failures are mostly minor slides. Most landslides are natural and may or may not be aggravated by land use.

Incessant heavy rains is the prime triggering factor for land slides. In the disastrous year 1986 had highest yearly rainfall over ten year period at four out of five stations. Most landslides in Nuwara eliya and Badulla, the frequent ly affected areas occur during mid October to mid January. Great majority of slides occur in slope range of 15 -40 ^{0}. The

abrupt drop in frequency above 40^0 reflect the fact that soil or colluvium generally do not occur on slopes steeper than about $38^{\mathbf{0}}$.

Relatively smaller areas have been mapped under land slide prone areas in Nuwara Eliya and badulla districts. and have compiled about 220 land slides. These were selected on the basis of damage to lives or buildings, destroyed transportation arteries or exceeded 150m in maximum dimension or 4000 m^2 in area.

Road cuts and construction sites

The construction sites and new road cuts located in mid country and in upcountry areas where the slopes are fairly high, presently considered to be the most hazardous in soil erosion compared with any other land use category in Sri Lanka.

Erosivity

Erosivity is a measure of erosive power of rainfall at a particular location. This is infact soil loss at that location due to rainfall alone. In Sri Lanka in the intermediate zone and in higher elevation of wet zone only a small fraction of the rainfall is erosive, where as in the dry zone most of the rains in the course of the year is erosive (Joshua, 1973)

Erodability

Erodability is a measure of susceptibility of soils to soil erosion. According to the method, developed by Wischmer et al (1971) the relative susceptibility of major great soil groups in Sri Lanka are as follows. regosol > non-calsic brown soils >red yellow latesols >reddish-brown earths > red-yellow podzolic soils > reddish-brown latosolic soils. The product of erosivity and erodability gives a mean to compare relative soil loss among locations as influenced by rainfall and soil alone.

MONITORING AND MAPPING OF EROSION HAZARDS

Erosion hazard maps

Presently this is being done by Land Use Division of the irrigation department using aerial photographs of 1:20,000 or 1:5,000 scale, but only on selected sites mostly on the request of an external organization. the criteria used in the demarcation of hazardous areas are soil slope, land cover, type of soil and the rainfall intensity. There is no national programma for this although this is of prime importance.

Mapping of landslide prone areas

There is a national programma for landslides funded by the UNDP conducted by the National Building Research Organization. They are in the process of compiling maps showing land slide prone areas selecting few districts in mid country and upcountry where the land slides are frequent during last two decades.

Use of Cs 137 method

McHenry and Ritchie (1975) described a technique using radioactive Cesium -137 (^{137}Cs) measurements to identify and quantify erosion and deposition areas. This method

was adopted in Sri Lanka to compare and monitor soil loss under different land use categories.

The fallout Cs-137 content was studied in soil profiles of two natural dense forest sites and four sites of different land uses on Reddish Brown Earth (Rhodustalf) soils in the Moneragala District The undisturbed sites from Yala National Park and Hambegamuwa showed the expected exponential decrease of Cs-137 with soil depth. Hambegamuwa natural forest site had higher Cs-137 in its profile compared to Yala site due high annual rainfall in Hambegamuwa area.

An undisturbed forest site from a national park in the dry zone has taken as the standard and this was compared with another forest site located closer to the area having a land slope of about 30%. The results indicated a soil loss from top soil. The shifting cultivation areas showed a marked loss of about 10 cm of top soil since 1950's. The lands under banana cultivation for the last five years and homestead for the last twenty years were comparable indicating the soil loss under banana cultivation is fairly high.

Table 2. Cs-137 concentrations m Bq/g soil.

Depth(cm)	Forest (Hambe-gamuwa)	Forest (Yala)	Upland annuals	Shifting cultivation	Banana	Homestead
0-1			2.6	1.4	1.8	1.7
1-2	7.5	5.5	2.7	1.4	1.8	1.5
2-3	7.0	5.9	-	1.8	2.1	2.0
3-4	5.6	5.7	4.0	1.7	2.1	-
4-5	5.2	5.6	3.4	1.6	2.5	2.52
5-6	3.8		3.5	1.0	2.5	2.37
6-7	2.9	4.2	3.2	1.2	-	-
7-8	2.6	3.3	2.8	1.0	2.4	-
8-9	2.3	-	2.2	0.9	2.2	-
9-10	1.7	3.0	1.9	0.6	1.9	-
10-11	1.6	2.2	1.3	-	-	-
11-12	1.5	1.2	1.4	-	1.9	1.5
12-13	1.0	-	-	-	1.7	1.8
13-14	0.7	0.9	1.0	-	1.6	1.5
14-15	0.4	1.1	-	-	1.5	-
15-16	0.6	0.7	-	-	1.4	0.7
16-17	0.5	-	-	-	0.8	1.5

SUSTAINABLE SOIL MANAGEMENT

Soil management for plantation crops

Cover crops provide a continuous cover to the ground and works through the interception of the energy of the raindrops, binds the soil together by the root system, breaks up the movement of water over the soil and keep the soil porous by the roots. This is widely practiced under rubber plantations in Sri Lanka, selected crops are creeping legumes. This type of erosion control does not bring any immediate economic returns. By introducing annuals at early stages of the rubber plantation cover can be maintained with a good economic return.

Widely used cover crop and their seed rate is given below:

Pueraria phaseoloides :	5.6 - 7.8 kg of seed/ hectare
Desmodium ovalifolium :	5.6 - 7.8 kg of seed/ hectare
Calopogonium mucunoids :	13.5 kg of seed/ hectare
Centroseme pubesoens :	26.9 kg of seed/ hectare

A proper drainage system will conserve the soil by reducing the rate of flow, increasing the infiltration and removing the surface runoff in the correct way. Main drains are improved using spill platform and splash cushions to reduce bank erosion. Main drains are mostly natural water ways covered by native grasses. Lateral drains are constructed along the contour with a slope of 1 in 120 and inserting silt traps. Spacing of these lateral drains are decided according to the slope of the land.

spaced 21.5 m for	1 in 20 and under
spaced 14.5 m for	between 1 in 20 and 1 in 4
spaced 7 m for	over 1 in 4

In rocky lands where continuous lateral drains are not possible stone terraces are used. To make the soil sustainable proper application of fertilizer is very essential.

In tea growing areas soon after uprooting and in early stages of growth, soil is prevented from erosion by spreading crop residues and dead organic matter on the surface of the soil. In most of the tea areas in Sri Lanka branches of Glyricidia shade trees use as a mulch for newly planted tea. Conservation of soil moisture is an added advantage in this method. Use of dead organic matter placed along the contour (Trash bunding) is another effective method. In rehabilitation of tea lands Gauthamala grass (Tripasacum laxum) or Mana (Cymbopogon conferti florus) is planted in close spacing on the contour. To replace lost nutrients application of fertilizer is essential, recommended by the tea research institute.

Terracing, contour drains and bunds,contour ploughing, green manuring and mulching and providing adequate drains to lead surplus water very slowly to the nearest main drainage channel are the practices that are carried out for the prevention of soil losses and conservation of moisture and nutrients under coconut lands. The absorption of runoff is enhanced by digging 2 feet deep contour drains on the contour. Contour bunds may also be build where ever possible with stone walling or husks. Green manuring and mulching make the crop land more absorptive.

Soil management for chena lands and upland farming

In dry zone most of these chena lands are located in the undulating and rolling region. The majority of the area is covered by reddish brown earth (Rhodustalf) group of soils. These soils which are not very stable when subjected to high rain fall intensities under monsoon rains are prone to soil erosion. The most effective way to minimize erosion is to use broad bunds along the slopes. Due to low infiltration rates and sealing effect it is rather difficult to control runoff during heavy rains as the amount of water is very high.

The chena cultivation in the intermediate zone and upland farming always associated with sloping lands. In this situation the best method by which the soil erosion is controlled is called sloping agricultural land technique (SALT) where a short hedge or two rows of Glyricidia branches planted in close proximity. The distance between these hedges are decided by the length and percent of slope.

Chena cultivation is normally practiced by poor farmers and the use of fertilizers is minimum. To regenerate lost nutrients it is necessary to keep these lands fallow for some time. Due to the competition for land by man fallow period is becoming more and more lesser. Some farmers are now beginning to use fertilizers for this type of cultivation, but with no soil conservation measures.

In tobacco growing lands the soil conservation measures are similar to that of chena cultivation in sloping lands, and the method is SALT system. To compensate for lost nutrients and minerals, fertilization and management is done under the guidance of agriculture department and the field staff attached to established tobacco companies.

Table 3. Estimate of soil erosion in few sites in Upper Mahaweli catchment

Place	Slope %	Rainfall mm (No.of rainy days)	Land Use	Condition of Soil Surface	Techniques	Period	Erosion Rate T/Ha/yr	
							Without SALT	With SALT
Mulgama	30	1035 (90)	Tomato Small holder mixed vegetables	Cultivated Plots	Demonstration plots with plastic sheet	5 months	48	1
		1373 (67)	Tomato	50% under	traps (Contour hedgrows of	6 months	20.1	2.2
		1878 (84)		grasses cultivated	Gliricidia & Casscia Spe)	6 months	60.0	14.0
Adikarigama	30	1573 (97)	Smallholder Tobacco	Cultivated Plots	-do -	5 months	22.4	6.7
Moragaha-mulla	45 – 50	1369 (74)	-do-	-do-	-do-	5 months	26.1	5.5
Mhaberiya-tenna MLDC Training Center	40 - 45	1432 (77)	Demonstra-tion models Tobacco	Grassland	-do-	5 months	43.7	8.0

Source : EFCD/MASL

Soil management for other problems

To control Iron toxicity a deep trench is made at the edge of the slope separating the paddy land from the high land, enabling safe disposal of water enriched with iron away from this area.

It is an extremely difficult task to neutralize the acid or potential acid condition in a soil. This is temporarily suppressed by maintaining the affected land under submerged condition, which is possible only if there is surplus water

The most recent schemes have understood the gravity of this situation and as a preventive measure dual canal system is employed. The area between the two canal are designed for upland crops which do not require so much water as that required for paddy. That will prevent salt coming and accumulating in the lower areas designed for paddy.

CONCLUSION AND RECOMMENDATIONS

Though some of these figures on soil loss from different land use categories are highly approximate, reflects the actual removal of soil from the field. This is a clear indication of the extreme danger of rainfed cropping on steep slopes in mid country, chena cultivation in low country and maintenance of ill managed plantation crops in any part of the island.

Most hydrological hazards are influenced by people. The amount of soil loss during one rainy season due to negligence may take ages to replace under normal soil forming processes.. The reclamation of lands need lot of inputs where an ordinary farmer cannot afford. If the people are enlightened, they become more concern about their future generation and realize the importance to protect the land.

The government must involve providing some sort of subsidy scheme to people who are engaged in slash and burn agriculture, where the soil erosion is very high, to use preventive measures for soil erosion and also to keep them away from clearing steeper lands.

At the moment there are number of organisation involved in work pertaining to mitigation of hydrological hazards. Lack of communication and proper coordination has lead to poor results.

By bringing all these organisations to work as a team, results oriented programme can be formulated to manage catchments.

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