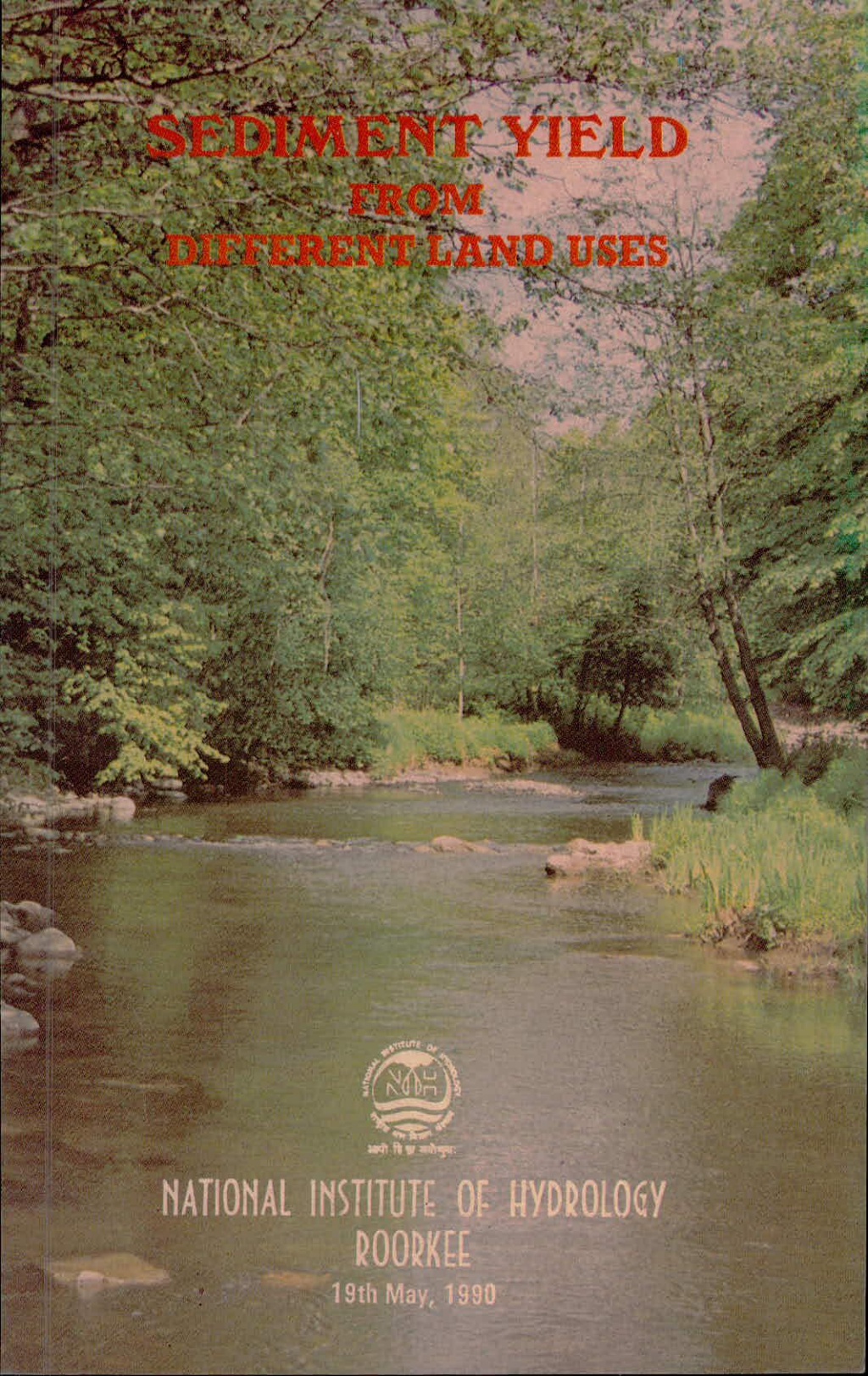
SEDIMENT YIELD FROM DIFFERENT LAND USES



NATIONAL INSTITUTE OF HYDROLOGY
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INTRODUCTION

Soil erosion is the removal of surface material by wind or water. When raindrop falls on a soil surface, the soil particles are splashed. Higher is the velocity of impact greater is the amount of soil splashed. Drop impact is more effective when a thin film of water covers the soil surface and the maximum dispersion of soil particles occur when the depth of water is about the same as diameter of raindrop. The detached soil particles are then carried further either by runoff or wind. This whole process is known as erosion.

When raindrop strikes vegetation, the energy of drop is dissipated and there is no direct impact on the soil surface. Some of the water is intercepted by vegetation and evaporates to atmosphere, the remainder drips or flows down into the soil. If runoff takes place in a vegetated area, leaves and roots of the plants inhibit movement of soil particles. Leaves form a rough surface, impetde flow, and reduce the velocity of flowing water and roots bind the soil. Runoff and erosion increases rapidly as the vegetal cover on soil surface gets thiner.

The soil erosion and sediment yield problems are important for India primarily because of varying topographical and geological conditions, pressures of human and animal population on the land resources and because of small land holdings. This is further aggrevated by improper land use and faulty land management practices being adopted in the upland watersheds. It is estimated that at present 150 million ha. (about 45% of total area of the country) of land under agriculture, forests, grass lands and other land uses is in need of soil conservation.

Studies carried out in India indicate that land use pattern is fast changing in the country. There is an urgent need to carry out studies of the effect of this land use change on erosion and subsequent sediment yield, as any long term or short term change in the land use definitely influences hydrological processes in the watershed. These influences are more severe if the top fertile soil is eroded.

The studies of sediment yield in our country have been concentrated on runoff plots and small watersheds. The results of small plot studies can be taken to be suggestive and indicative and cannot be extrapolated to large catchments.

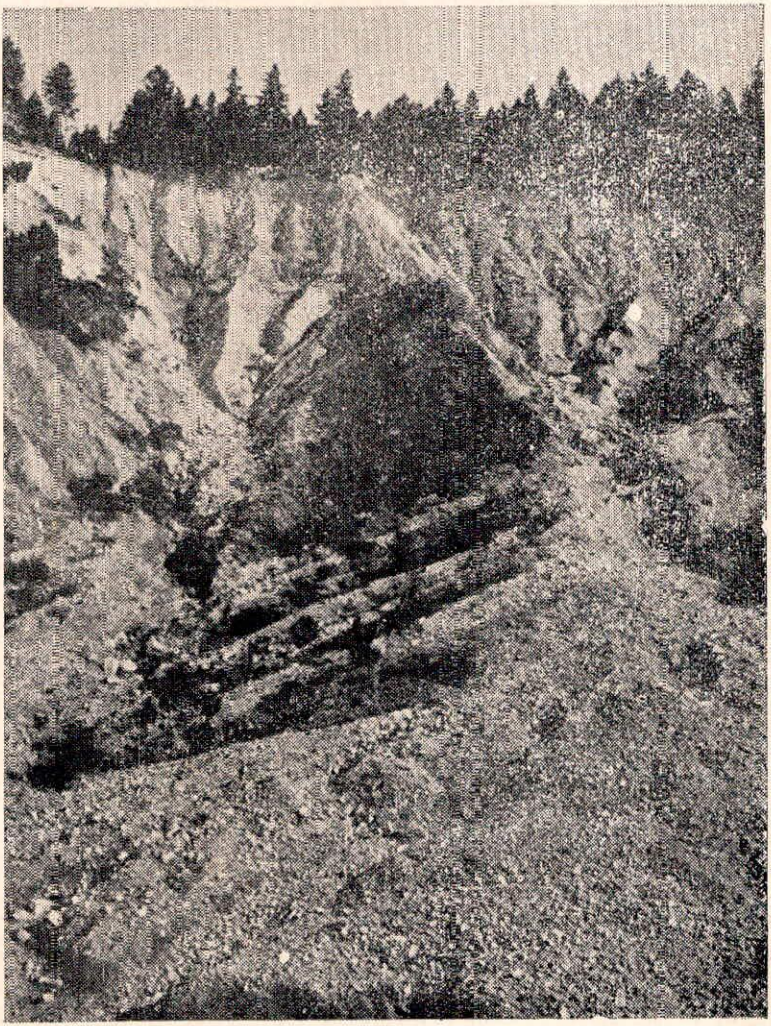
EFFECTS OF SEDIMENT YIELD

The process of sedimentation is a natural phenomenon which occurs whenever the flow of sediment carrying river is impounded by any kind of obstacle. This results in reduction in storage capacity, water supply capability, power generation, discharge control etc. of reservoirs, rivers/catchments. The erosion of catchments changes groundwater regime and results in lowering of water table at some places and rise at the other with the formation of arid zones and marshes respectively. The fertility of soil, its chemical composition also change sometimes due to catchment erosion.

FACTORS AFFECTING SEDIMENT YIELD

* Hydrology
  - — Rainfall
  - — Runoff

* Catchment characteristics
  - — Size of catchment
  - — Slope of catchment
  - — Length of overland flow



Erosion of a slope consisting of fluviological material of low resistance. Rapid growth of rills into gullies by channel of water.

* Soil characteristics
  —Soil erodibility
  —Soil transportibility
  —Soil texture & structure

* Land use cover
  —Plant canopy
  —Mulches
  —Plant residue

* Management practices
  —Tillage
  —Soil conservation structures
  —Terraces
  —Diversions
  —Bunds

Of all the factors listed above rainfall and runoff provide the basic energy input to drive the erosion process. Steepness of slope plays an important role in the process of erosion. Soil properties such as soil texture. structure and the land cover i.e. plant residue, mulches etc., have a major role in erosion process.

EFFECTS OF RESERVOIR SEDIMENTATION

The study of sediment yield from the catchment which in turn will be deposited in reservoirs is important for many reasons. Deposition of sediment in reservoirs reduces its capacity, thereby adversely affecting the water supply for irrigation, domestic and industrial uses and for power generation. It also causes problems in discharge control at reservoirs, navigational use of reservoirs, streams and stream channels. Other hazards of sedimentation such as choking of bottom outlets and damage to structures due to abrasive action of the sediment particles are indirectly related to sediment coming into the reservoirs from catchments. The eroded sediments from catchments may also be deposited on river beds and banks thereby causing the

braiding of river reach, submergence of flood plain of river during the floods and reduction of clearance below bridges. Thus the total benefits to be achieved from the reservoir system are greatly reduced. The status of reservoir sedimentation in India is given in the following table.

TABLE : Assumed (at the time of project formulation) and subsequent observed rate of sedimentation of some of the major reservoirs in India

Sl. no.	Name of reservoir	Year of reservoir filling	Annual rate of silting	
			Assumed ha.m/ 100 sq. km/ year	observed ha.m./100 sq km/year (year of reservoir survey)
1	2	3	4	5
1.	Bhakra	1958	4.29	5.93 (1973)
2.	Panchet (DVC)	1956	6.67	10.00 (1974)
3.	Maithon (DVC)	1955	9 05	12.38 (1979)
4.	Mayurakshi	1955	3.75	16.48 (1969)
5.	Tungabhadra	1953	4.29	6.03 (1961)
6.	Matatila	1956	1.33	3.82 (1974)
7.	Nizamsagar	1938	2.78	6.37 (1967)
8.	Shivajisagar (Koyna)	1961	6.67	15.25 (1971)
9.	Hirakud	1957	2.52	6,82 (1982)
10.	Gandhisagar	1960	3.61	9.64 (1975)
11.	Lower Bhawani	1953	—	3.56 (1977)
12.	Girna	1965	0.56	8.03 (1979)

(Source : Ministry of Water Resources, 1986)

SEDIMENT PRODUCED BY CATCHMENT UNDER DIFFERENT LAND USES

The effects of land use on sediment yield are closely linked to those of climate and physiography, since the later may exert a major control on land use practice. Where it's effect can be isolated, it is clear that the major contrasts in sediment yield may be attributed to the influence of land use.

A useful general perspective on the influence of human activity in increasing sediment yields above a natural base line can be obtained by considering the various parameters employed in well known Universal Soil Loss Equation (USLE) where, cover and management factor C, expresses the influence of land use practice. This value of C is the main factor responsible for extended sediment yield. Besides this, soil degradation (K) could itself cause detrimental changes in soil character, which has been generally assumed a constant and therefore further increases the soil loss. Other factors of USLE also do not remain constant since increased erosion may initiate a change in drainage density and therefore a change in the topographic factors like length of flow (L) and slope (s).

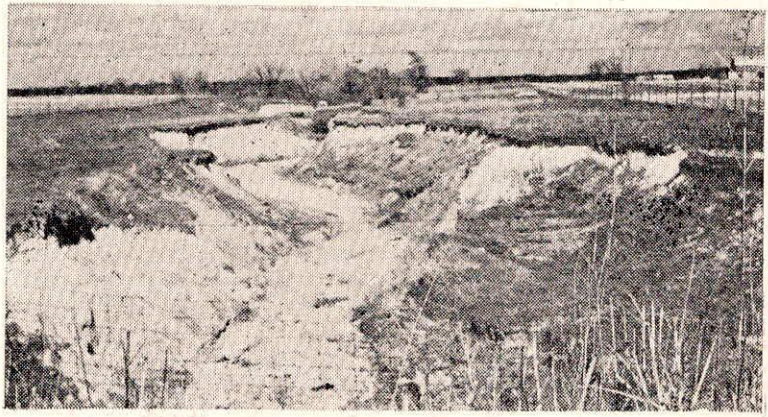
Factors such as climate, local soil and tarrain character, forestry and farming practices will exert an important influence on the precise magnitude of the increased sediment yield that will occur in particular area as a result of land use activities.

When studying the effects of land use on sediment yield, the temporal dimension must also be considered. The precise sequence and timing of land use change within a basin will exert a strong control on the resultant pattern of sediment yield. But, one thing laking is that, the absence of long term records of sediment yield generally precludes detailed analysis of the effects of (a documented history of) land use change on sediment yields.

The global studies on sediment yield due to land use changes reveal that—

* The change from virgin grassland to cultivated land produces an increase in the soil loss 10 folds whereas, the conversion of natural forest produces an increase of 100 fold.

* The soil loss is now 5.5 times than that occuring during preagricultural period and that this could increase a further 1.9 times as reserves of tillable land are brought into cultivation. Thus a total increase in soil loss will be about 24 fold over the preagriculture period.



Soil erosion resulting from heavy grazing by cattle.

RESULTS OF STUDIES CARRIED OUT IN INDIA

Forests :

Scientific studies have been conducted on experimental watersheds to study the effects of forests on the soil loss. The studies indicated that .....

* In north west Himalayan region of 100% sal forest (dense and well managed) the soil loss was 0.90 t/ha/yr.

* In the same region of 82% forest with 18% agriculture (well protected) the soil loss was 0.40 t/ha/yr.

* In the same region for 100% sal forest (protected) the soil loss was 0.06% t/ha/yr.

* In the north eastern hill region of bamboo forest, the soil loss was 0.29% t/ha/yr.

* In the southern hill region for well managed forest and ill managed forest the soil loss was 0.06 and 20-60 t/ha/yr. respectively.

Bedrock completely denuded by erosion on slopes once covered by forests

Grass Land

The studies carried out to consider the effect of grazing on production of sediment yield revealed that.....

* Land covered with dub grass produced maximum sediment of 2.1 t/ha/yr at 11% slope.

* The perennial legumes like Kudzu have been found to produce maximum soil loss, of the order of 0.11 t/ha/yr at a slope of 11%.

* Thin grasses of red soil region produced 0.68 t/ha/yr. of soil loss at a slope of 5%.

* Protected grass cover of southern hill regions have no soil loss at a slope of 16%.

Agricultural Land

The soil loss studies carried out on agricultural lands for different agronomic practices indicate that.....

* The cultivated legumes in general provide better cover and hence better protection to cultivated land against erosion.

* Pulses, cowpeas are important crops for producing less soil loss.

* Potato, wheat, maize etc. produce relatively more soil loss, of the order of 39.3 t/ha on 25% slope, 21.3 t/ha on 8% slope and 23.6 t/ha on 5% slope respectively.

* For a given agricultural land use, the contour cultivation reduces soil loss in watershed considerably to the extent of 33% to 67%.

* Application of mulch at a rate of 27 t/ha has produced 66% reduction in the soil loss.

* The channel terraces with grade and furrows produced a maximum sediment yield of the order of 2.3 t/ha/year at a slope of 4%.
* Bunding reduces sediment yield by about 90%.
* In the north-east hill region on steep slope of 40%, the agricultural watersheds treated with bench terraces produced sediment yield of 2.3 t/ha/year as against 41 t/ha/year produced in conventional practice of shifting cultivation.

Fallow Land

The effect of various land uses with reference to fallow lands on sediment yield have shown that.....

* Cultivated fallow lands of north-east Rajasthan having 4% slope produced soil loss of 3.4% t/ha/yr.
* Cultivated fallow lands of Gujarat alluvial and upper Gangetic plains have produced 5.16 t/ha/yr & 15.67 t/ha/yr of soil loss at a slope percentage of 2%.
* In northern Himalaya the soil loss of 42.2 t/ha/yr and 70.7 t/ha/hr were observed for bare fallow (9% slope) and cultivated fallow (8% slope) respectively.

Ravine Land

The experimental studies conducted in the ravines of Yamuna rivers at Agra, Chambal and Mahi reveal that.....

* Denuded ravines give 10 to 20 tons of soil loss per ha. per year.
* Protected ravines give 0.5 to 5 tons of soil loss per ha. per year.

Bare Rock

In case of bare rocks, the rate of erosion depends upon parent material, intensity, duration and amount of rainfall. For some parent material, studies reported (in foreign literature) claims that.....

* Lime stone erosion takes place at a rate of 1mm/yr.

* For metamorphic rock/igneous rock the erosion takes place at the rate of 1mm/1000 yr.

* For volcanic ash the erosion is nil.

Horiculture Land

For the silt produced for different horticultural lands at it has been reported that.....

* Silt production from mixed land use (agriculture-horticulture) at Shillong is measured to be 2.96 t/ha/year.

* At Dehradun the soil loss with strawberry with weeds, pineapple with weeds, strawberry clan, pineapple clan, cultivated fallow has been observed as 4.99, 1.69, 23.07 8.44 and 18.46 t/ha/year respectively.

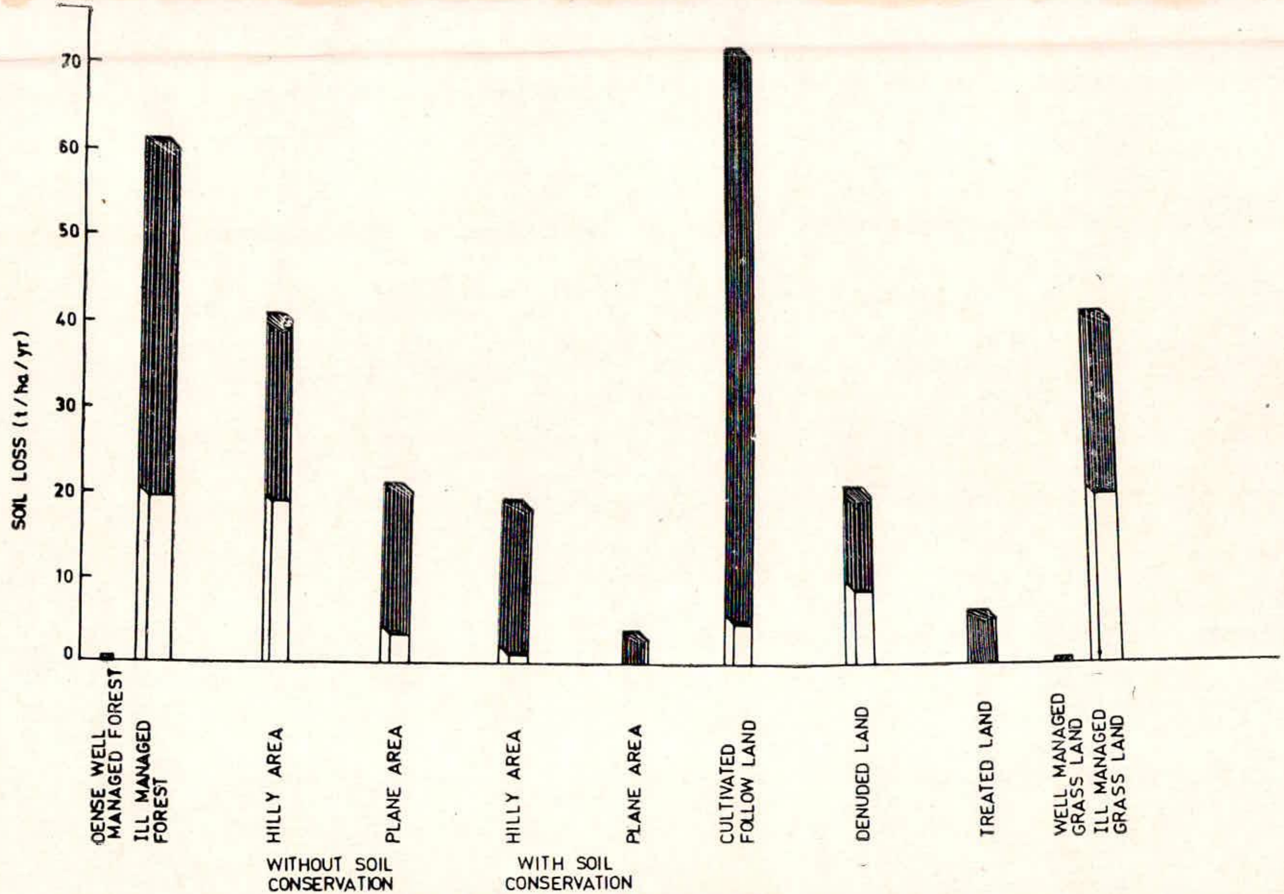
Ranges of soil loss from different land uses have been given in the following table and the bar chart at the end of this brochure gives these ranges which are shown by filled up black bars.

Note : The information / statistics presented in the brochure have been extracted from the published literature and all authors are hereby acknowledged.

SUMMARY TABLE*

Sl. No.	Land Use	Soil Loss (t/ha/Year)
1.	Forest	
	a) Dense, Well Managed	0.05 to 0.90
	b) Ill Managed-(denuded lands)	20.0 to 60.0
2.	Agricultural Lands	
	a) Without soil conservation	
	i) Hilly areas	20 0 to 40.0
	ii) Plain areas	5.0 to 20.0
	b) With soil conservation (varying from simple agronomic practices to engineering measures)	
	i) Hilly areas	1.0 to 19.0
	ii) Plain areas	0.0 to 3.0
3.	Cultivated Fallow Lands (1% to 9% slope)	4.0 to 70.7
4.	Ravine Lands	
	i) Denuded lands	10.0 to 20.0
	ii) Treated lands	0.5 to 5.0
5.	Grass Lands	
	i) Well managed	0.0 to 1.0
	ii) Ill managed	20.0 to 40.0

* This table has been derived from results of various studies conducted in India at various places for various slopes, for different rainfalls, for different soils etc. Ranges are being presented here to give a general idea for the soil loss from a particular land use.



SOIL LOSS FROM DIFFERENT LAND USE