SR-7

SEDIMENT YIELD FROM DIFFERENT LAND USES

SATISH CHANDRA
DIRECTOR

STUDY GROUP

K K S BHATIA

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667

1985-86

CONTENTS

LIST OF TABLES

LIST OF APPENDICES

ABSTRACT

Sediment yield studies have undergone a major change in the last three decades. In India, the studies concerning the effect of land use changes on sediment yield are limited and are mostly on the experimental watersheds. Very few attempts have been made to study the effect of land use changes on the sediment production for large catchments.

The problems of erosion and subsequent sediment yield are very wide spread and are of great concern to hydrologists and water resources engineers. The phenomena of sedimentation affects the reservoirs, lakes,rivers and other water bodies. This sedimentation would, in a big way, depend upon the soil loss or silt production in the catchment. The silt production soil loss would largely depend upon the land use pattern and land management practices.

In this report, an attempt has been made to present the results of various experimental studies conducted by researchers in India for the amount of soil loss/sediment yield from different land uses. The results are presented for various land uses e.g. forests, grass lands, agricultural lands , fallow lands, ravine lands, bare rocks, horticultural lands. From the results of various studies a summary table has been derived which specifies ranges of sediment yield for each land use.

1.0 INTRODUCTION

1.1 Scope of the Problem

The problems of erosion and subsequent sediment yield are wide spread and of great concern to hydrologists and water resources engineers. The movement and/or deposition of sediments in water bodies is of interest to water resources engineers as it influences the downstream hydrology causing sedimentation in reservoirs; lakes, rivers, water quality problems etc. Changes in sediment transport rate or volume can produce changes in the flow conditions in the channels, changes in geometry of channels, changes in river regime, degradation and aggradation and meandering.

The soil erosion and sediment yield problems are important for India primarily because of varying topographical and geologic conditions, pressures of human and animal population on the land resources and because of small land holdings. This is further aggravated 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.

Das (1982) has given the comparison of the land use statistics for the year 1950-51 and those of 1978-79, from which is becomes evident that land use pattern is changing in a significant manner. The land use pattern is being changed at such rapid rate that there is a definite need to carry out studies of the effects of this change on erosion and subsequent sediment yield. Man's activities on or within a watershed can accelerate erosion and can affect the operation of water control structures.

Watersheds may have single land use e.g. agriculture, forests, grasslands, wastelands or a combination of these. Any long term or short term changes in land use are definite to influence the hydrological process in the watershed. These influences become a great cause of concern if they affect the rich top soil or lead to soil erosion. Subsequent to erosion, the problem of sediment yield also takes on a new dimension.

1.2 Factors Affecting Erosion

The major factors affecting erosion/sedimentation are:

1. Hydrology: Rainfall and runoff provide the basic energy input to drive the erosion process. Erosivity of rainfall which governs the potential ability of rain to cause erosion is a function of rainfall characteristics which include intensity and kinetic energy of rainfall.
2. Catchment Characteristics: Erosion is a function of slope, catchment size and shape, length of overland flow,channel geometry. Steepness of slope plays an important role in the process of soil erosion as it affects the velocity of flow and thus the carrying capacity of the detached particles.

3. Soil Characteristics:

a. Soil Erodibility: It is the resistance of soil to both detachment, and transport. Some of the more important properties of the soil those influence erodibility are soil texture, stability of soil structure, permeability, infiltration, organic and chemical content of the soil. Thus, soil erodibility is different for different soils. Usually deep,permeable,coarse sands are the least erosive. Erodibility cań change over time depending upon the land management practices.

b. Soil transportability: It is the ease with which detached soil particles can be transported. The transportability will depend on the size, shape and specific gravity of the soil particles.

4. Land Use Cover: Cover including a plant canopy, mulches, plant residue or densely growing plant in direct contact with soil surface has a greater impact on erosion than any single factor. The canopy intercepts raindrops,and it is close to the ground, water dripping off the leaves has much less energy than unhindred raindrops. However, many canopies have open spaces that allow raindrops to strike the soil surface directly and detach soil particles. Material in contact with the soil surface reduces erosion more effectively that canopy. No detachment occurs by raindrops where the soil surface is covered because there is no fall distance for drops to regain energy. Also, such material slows the runoff , thus increasing the flow depth which in turn provides a

cushioning effect for falling raindrops thus reducing detachment. Erosion at a time depends on the previous management history. A freshly plowed field is much less erodible than one continuously tilled.

5. Management practices:

a. Tillage: Tillage is sometimes a detachment mechanism that creates a ready supply of detached aggregates. Tillage seems to increase rill erosion in a big way than interrill erosion. Repeated drying, wetting and compacting (because of traffic) causes the aggregate to form bonds and the soil becomes less erodible. A soil that has not been tilled for 6 years was only 40% as erodible as it was immediately after its last tillage.

b. Soil Conservation Structures: The field practices like contour bunding, and engineering measures like terraces, diversions, bunds etc. reduce the length of slope, and hence the total amount of slopes. Sediment yield from terraced fields is further reduced by deposition in low gradient terraces and diversion channels.

1.3 Types of Erosion

1. Sheet erosion

Sheet erosion is the removal of thin layers of soil by water acting over the whole soil surface. Raindrop splash and surface flow cause sheet erosion with splash providing most of the detaching energy and flow providing most of the transporting capacity . Soil loss by sheet erosion is insidious because it is so difficult to see or measure. One is seldom aware of soil loss until fields begin to change over as subsoil becomes mixed with topsoil. Sheet erosion can occur on any part of a slope but becomes apparent first on the convex upper portions.

2. Rill Erosion

Rills are erosion channels small enough to be obliterated by normal tillage operations. Most rill erosion occurs on recently cultivated soils where runoff water concentrates in streamlets as it passes downhill. This water has greater scouring action than sheet flow and it removes soil from the edges and beds of the streamlets. Rills frequently occur in relatively straight lines between crop rows or along tillage marks. After somoothing by tillage, the long-term effect of rill erosion is similar to that of sheet erosion, but because it is more obvious, action is more likely to be taken to control it.

3. Gully Erosion

Erosion channels that are too large to be erased by ordinary tillage are called gullies. The slope of the gully walls depends on the angle or response characteristics of the material. Deep, relatively straight-sided channels develop where the soil material is uniformly friable throughout the profile. In deep loess soils the walls are almost vertical, forming U-shaped channels, but most other soils have less steep side slopes. Broad

V-shaped channels often develop where cohesive tight subsoil that resists cutting, underlies friable surface soil. Gullies are considered to be active as long as erosion keeps the sides bare of vegetation and inactive when they have been stabilized by vegetation. Gullies are further described as small,medium or large according to depth, with medium sized gullies being between 1 and 5 m deep.

4. Streambank Erosion

Sheet,rill and gully erosion are active only during or immediately after rainstorms. Erosion along the banks of perennial streams occurs both during and between rainstorms.

Although the actual area damaged by streambank erosion is small compared to the area affected by other types of water erosion, it is very important because bottom-land soils damaged by this type of erosion are usually more productive than any other soils in the area , and because soil picked up by streams is carried completely away, with little or no chance for deposition close to the original site. Streambank erosion is usually most intense along the outside of bends. Inside river meanders can be very intensively scoured during severe floods. Bank erosion often damages or destroys the approaches to bridges, culverts. Stream bed erosion also causes bridge failures by removing material that serves as footing.

5. **Land Slides:**

It is mass movement by slippage. These are important accessory to the soil erosion process. Downward and upward movement of slope forming materials composed of natural rocks, soils, artificial fills, or combination of these material is called land slides.

1.4 Need for Studies

In India the studies of erosion and sediment yield have mostly been concentrated on runoff plots and small watersheds only. Very rarely the studies have been directed towards large catchments. The soil loss and silt production data from various land uses and land management practices are being collected since 1950 in India from experimental plots located in various regions. The results of small plot studies can be taken to be suggestive and indicative and can not be extrapolated to large catchments.

In view of this, efforts have been made in this report to highlight the problems of erosion and subsequent sediment yield as they are affected by various land uses. Results of soil loss/ sediment yield for experimental small watersheds for various landuses like Agricultural lands (crops, agronomic practices, fallow lands), Grass lands, Forests, Horticulture etc. are presented. Finally the results of experimental studies on small watersheds have been summarised in a table. This table gives the ranges of sediment yield/erosion for various land uses. However, this table does not consider slope,region in which studies were conducted, rainfall characteristics etc. Hence the values given in the table can be taken to be indicative for a particular type of land use. For details a reference can be made to the results of that particular land use which are given separately in the report.

2.0 RESULTS OF STUDIES CARRIED OUT IN INDIA

In India, the soil loss and silt production studies from different land uses, land use management practices are being conducted since 1950. The main organisations carrying out such studies are Central Soil and Water Conservation Research and Training Institute,Dehradun and its regional centres, Forest Research Institute; Dehradun,Central Water Commission;Delhi, Central Water and Power Research Station; Poona,Damodar Valley Corporation,Soil Conservation Departments of various States, and various Universities. It is to be noted that most of the studies have been conducted on experimental plots or small watersheds only. Microwatersheds have been studied to compare soil loss from different land uses and vegetative covers under different slope ranges, soil and climatic conditions in various land resources regions of the country. The main objectives of these studies are :

1. To evaluate the effect of various land uses and vegetative covers on soil loss.
2. To develop sediment yield relationships for small watersheds and
3. To identify, suitable crops, agronomic practices, field practices, biotic species for soil conservation.

The significance of soil loss studies was reported by Dhruvanarayana and Rambabu (1983) while estimating annual soil loss from water erosion in India, they indicated that the erosion is taking place at a rate of 16.35 t/ha/annum which is more than permissible value of 4.5-11.2 t/ha/annum. It was also indicated that nearly 10% of this gets deposited in reservoirs as silt. Taking into account the importance of soil erosion and subsequent sedimentation, the effect of various land uses and vegetal covers on soil loss/silt production has been studied and results of such studies have been given in the subsequent section. The results of the experimental studies conducted at different places in India for the following land uses are given in this report.

1) Forests
2) Grass lands
3) Agricultural lands
4) Fallow lands
5) Ravine lands
6) Bare rocks
7) Horticultural lands

2.1 Forests

Scientific studies have been conducted on experimental watersheds to study the effects of forests on the soil loss. The data of few selected studies on forested watersheds(Sal forests) at Dehradun have shown 38.5% less sediment yield (Ghosh & Subbarao,1979). The experimental forested watershed at Dehradun (Coppice Sal forest) produced average soil loss of 0.9 ton/ha/year (Subbarao et.al.1973). Similar decreasing trend in sediment yield as observed in other forested watersheds in various regions of India are summarised in Table 1.

Table - 1
Sediment Yield from Forested Watersheds

S.No.	Land Use	Region	Soil	Soil loss (t/ha/year)	Remarks
1.	100% Sal Forest (dense well managed)	N-W Himalayan Region	Silty clay loam	0.90	i) Average of 4 years. ii) Watershed size 6.5 (Subbarao et al.1973)
2.	82% Forest + 18% Agriculture (Well protected)	N-W Himalayan Region	Silty clay loam	0.40	i) Average of 18 years. ii) Watershed size 83.4 ha. iii) Slope-2 to 6% (Source-Dhruvanarayana et al. 1985)
3.	100% Sal Forest (Protected)	N-W Himalayan Region	Silty clay loam	0.06	i) Average of 9 years. ii) Watershed size 0.45 ha
4.	Bamboo Forest (Well managed)	N-E Hill Region	-	0.29	i) Average of 2 years (Source-Dhruvanarayana et al.,1985)
5.	a) Well managed Forest	Southern Hill Region	-	< 0.06	(Chinnamani,1985)
	b) Ill Managed Forest	"	-	20-60	-do-

2.2 Grass Lands

Number of studies have been carried out on small plots and small watersheds to evaluate the effects of different grass species on soil loss in various regions of India. The studies have also been carried out to consider the effect of grazing on production of sediment yield. The studies carried out by Tejwani et.al.(1973) reveal that the land covered with dub grass produced maximum of 2.1 t/ha soil loss at 9% slope whereas Bhabhar grass produced 0.29 t/ha of soil loss at 11% slope. The perennial legumes like kudzu have been found to produce maximum soil loss, of the order of 0.11 t/ha/year at a slope of 11%. Table 2 shows the results of such soil loss studies.

Table -2

Sediment Yield from Grass Lands

S.No.	Land Use	Region	Soil Loss (t/h/y)	Slope	Remarks
1.	Grass	N-W Himalayan Region	1-2.1	2% to 9%	i) Silty clay loam ii) 1250 mm rain fall iii) For Monsoon rains (Tejwani et al.1975)
2.	Protected Grass Cover	Southern Hill Regions	Nil	16%	i) 1340 mm rain fall (Hukam Singh,1985)
3.	a) Thin Grass	Red Soil	0.68	5%	i) 1302 mm rain fall (Hukam Singh,1985)
	b) Giant Grass	Regions	0.57	5%	

Studies on the management of grass lands which were conducted at Deochanda (DVC) from 1955-60 show that overgrazing not only reduces grass cover but also deteriorates the top soil by animal hoofs. The details are given in Table 3.

Table - 3

Soil Loss as Affected by Grass Land Management(Singh,1985)

S.No.	Land Use/Management	Soil Loss (t/ha/y)
1.	Over grazed	2.37
2.	Properly grazed	0.79
3.	Not Grazed	0.40

2.3 Agricultural Lands

In the agricultural lands soil loss studies under various crops, soils, climatic conditions have been conducted at various places. The soil loss studies have also been carried out on agricultural lands for different agronomic practices and engineering field measures e.g. bunding, terracing, etc. Therefore, it becomes necessary to make a mention of the supporting conservation practice also in the agricultural land use.

a. Silt production under Different Crop Covers

The cultivated legumes in general provide better cover and hence better protection to cultivated land against erosion and silt production than clean cultivated crops. The soil loss recorded under different crop covers at various places is given in Appendix I(a). Among the legumes, in agricultural watersheds, pulses, cowpeas have proved to be important crops for producing relatively less soil loss. Whereas potato,maize, wheat etc. produce relatively more soil loss.Potato (up and down cultivation i.e. along the slope) produces maximum soil loss of 39.3 t/ha on 25% land slope followed by maize producing 23.6 t/ha on 5% land slope and 21.3% on 8% land slope(Tejwani et.al 1975,Tejwani 1980).

b. Silt production Under Different Agronomic Practices

In the agricultural lands, effect of agronomic practices like contour cultivation, strip cropping, minimum tillage, and mulches has been studied to evaluate the silt production from agricultural watersheds. The practice of contour cultivation (i.e. cultivating against the contours) gives better results against traditional up and down cultivation (i.e. along the slope) as far as soil erosion control is concerned. The experimental result obtained from various studies at different places is given in Appendix-I(b). It has been observed that in a given agricultural land use, the contour cultivation reduces soil loss in watershed considerably, to the extent of 33% to 67%. It clearly indicates that for a given land use and cropping pattern the supporting practice alone plays a vital role in checking silt production from a watershed. It has been observed by Khybri (Anon.1983) that mulch applied even @ 27 t/h has produced considerably less soil loss (a reduction of 66%).

c. Silt production under different Engineering Measures

The soil loss and consequent silt production from a given agricultural watershed depends upon the type of engineering or mechanical conservation practices adopted in the watershed. These measures include contour bunding, terracing, graded bunding bench terracing, peurtoricon type terraces, grassed waterways, check dams etc. The effect of such measures on sediment yield has been studied in India for various regions and suitable measures have been suggested for different terrains, climates and crops. The results of some of these studies are given in Appendix I (c). Most of these experimental studies are based on the data of small plots and small watersheds. At Dehradun the channel terraces (at 1.5 times usual spacing) with grade and furrows produced minimum sediment yield (2.3 t/ha/year) at a slope of 4%. The normal soil loss is around 6-10 t/ha/year. The studies conducted on agricultural watersheds (54.6 ha) at Dehradun indicated that the bunding reduces the sediment yield by about 90% (Dhruvanarayana et.al.1985). At Chandigarh, bunding reduced the soil loss and conserved 2.5 tonnes of soil /ha/hr in runoff plot studies at 1.5% slope. The experimental studies in N-E hill region on steep slopes of 40% have shown that the agricultural watersheds treated with bench terraces produced sediment yield of 2.3 t/ha as against 41 t/ha produced in conventional practice of shifting cultivation(Singh et.al. 1981).

2.4 Fallow Lands

Experimental plot studies have been conducted by various investigators to quantify the effects of various land uses with reference to fallow lands on the sediment yield. The results presented in the Table-4 are for small watersheds.

Table -4

Silt Production from Fallow Lands

Sl.No.	Land Use	Region	Slope	Soil loss (t/ha/y)	Remarks
1.	Cultivated fallow	N-E Rajasthan	4%	3.4	i) Average of 3 years (Anon.1983)
2.	Cultivated fallow	Gujarat Alluvial	2%	5.16	(Anon.1976)
3.	Cultivated fallow	Upper Gangetic Plane	2%	15.67	i) Average of 3 years (Bhushan & Prakash,1983)
4.	Cultivated fallow	Southern Region	3%	5.0	i) Average of 4 years (Shri Niwas, 1980)
5.	Bare fallow	Northern Himalaya	9%	42.2	i) Average of 2 years (Singh,1985)
6.	Cultivated fallow	Northern Himalaya	8%	70.7	-do-

2.5 Ravine Lands

The experimental studies have been conducted in the ravinous lands of Yamuna ravines at Agra,Chambal ravines-Kota and Mahi ravines at Vasad (Gujarat). The studies have been conducted both under natural cover and treated ravines. Some of the results are presented in Appendix II. In the ravines of Mahi,Chambal and Yamuna denuded ravines give 10 to 20 tons of soil loss per ha per year and after they are brought under protected natural grass land/ forests after 10 to 30 years of protection give 0.5 to 5 tons/ha/year. In red soils protected forested watersheds have produced less than 1 ton/ha of sediment yield.

2.6 Bare Rock

In case of bare rock, the rate of erosion or weathering would largely depend upon the parent material of which the rock is formed. The erosion in such case would also depend upon intensity, duration and amount of rainfall. However Table-5 gives some data for erosion/ weathering of some of the rocks.

Table - 5

Erosion of Bare Rock

S.No.	Parent/Material	Weathering/Erosion	Remarks
1.	Lime stone	1 mm/year	Kaye (1959)
2.	Metamorphic rock/ igneous rock	1 mm/500 to 1000 year	Young (1969)
3.	Volcanic ash	nil	Dorokohina (1980)
4.	Lime stone	40 mm/1000 year	Corbel (1959)

2.7 Horticulture Lands

The silt productions from different horticultural land uses have been studied at Shillong and Dehradun. The silt production from mixed land use (Agriculture-horticulture) at Shillong is measured to be 2.96 t/ha. At Dehradun, the studies indicated relatively more soil loss for clean crop as compared to pineapple and pomegranate. The results of such experiments are given in Appendix-III.

2.8 Other Studies

The hydrological studies have been carried out by Pathak et.al.(1984) on six forested sites in microwatersheds of 25 m^2 in Kumaon, Himalaya. The sediment yield was maximum about (57.2 kg/ha) for sal forest and minimum (15.3 kg/ha) for mixed oak forest with average value of 32.5 kg/ha for all the six different forest sites. These results are obtained from very small plots, however, their application on watersheds basis may be doubtful.

The data of an experimental watershed (80 ha, predominantly covered with forest) at Khandala for years 1979-81 have been analysed by Saxena et.al.(undated) to establish the relationship between discharge and sediment yield. A sediment rating curve relating suspended sediment discharge and water discharge has also been established for the purpose of estimating suspended sediment load for periods during which data were not collected. But the established relationship is based on few observations hence it has a limited application.

Studies on experimental runoff plots at Nurpur (H.P.) also showed increased runoff and soil loss from regularly grazed areas as compared to the areas under shrub and grass cover (Singh,1975, cited from Lal and Subba Rao,1981). The phenomenal extension of torrents (Chos) in Punjab from 194 km^2 (1852) to 2000 km^2 (1939) was attributed to large scale deforestation on the hill slope (Kaith et.al.1948, cited from Das and Singh,1979).

In the River Valley Projects at number of sites, hydrological monitoring is being done to evaluate the effect of soil conservation and watershed management in checking the sediment inflow to the reservoirs. Hydrologic and sediment monitoring of small watersheds is being done by the Min. of Agriculture, Soil and Water Conservation Division,New Delhi with a view to:

1) Identify priority watersheds contributing high volumes of sediments.
2) Develop appropriate methods for predicting runoff and sediment yield from ungauged watersheds and
3) Determine the effects of soil conservation methods.

The analysis of data by the Central Unit of Soil Conservation (Govt. of India) has revealed a decreasing trend of sediment production in respect of Bhakra,Maithon,Panchet, Machkund and Hirakud . The decrease in sediment production rate ranged from 13.11% to 31.95% (Das et al.,1984). Small watershed data in respect of Chambal (Rajasthan),Hirakud (Orissa), Damodar -Bharakar (DVC), Machkund (Andhra Pradesh and Orissa),Mayurkashi(Bihar) and Tungabhadra (Karnataka) have been analysed by the Central unit. The trend analysis made in Chambal watersheds showed that watershed treatments could moderate the sediment production rate in the range of 0.62 to 1.65 ha/100 sq.km/year. By using progressive annual average series, it could be detected that the sediment yield was reduced by 50.23% from a watershed in Damodar catchment. Similar trends have been observed in respect of other watersheds also. In watershed management programmes, the afforestating and bunding measures have been considered as effective measures in areas where major contribution of sediment is in the form of sheet erosion. Hydrological monitoring of Sukhna lake catchment at Kansal,Ghareri and Nepli (from 1979 onwards) have shown considerable reduction in sediment yield due to afforestation and other watershed measures. The hydrological data collected by the Kalagarh Project Authority before and after the commencement of soil conservation works in the catchment (307,644 ha) was recorded as 0.1795 ha m/sq.km (1958-62) and 0.1444 ha m/sq.km (1967-71) which means a reduction in silt load of 0.0351 ha m/sq.km of the catchment (Pathak,1974). The reduction in silt load mostly appears to be due to afforestation as the cultivated area treated was comparatively very less till then. Recently CWC,New Delhi also sponsored a project in collaboration with G.B.Pant University,Pantnagar and I.I.T.,Delhi to evaluate the effects of soil conservation measures on hydrology and sedimentation of the Ramganga river. The data adequacy reports are yet to be completed and reviewed before making any conclusions (Shah,1985,Personal Communication)

3.0 SUMMARY

The foregoing review of the results of limited studies conducted on runoff plots and small experimental watersheds in India brings out that watershed research is an important aspect of integrated watershed management. There is a need to gain a better understanding of the various land uses as they affect the sediment yield from large watersheds. This would help to estimate erosion and subsequent sedimentation because of various land uses. Extensive research efforts are being made in India for sediment yield studies but these are mostly aimed at small, experimental watersheds and runoff plots. These studies have been focussed on effect of land use change on hydrological regimes and conservation measures that can effectively be used to control erosion but such studies are not directed towards large catchments.

The concept of representative basins may give answers to many vital questions and may provide data for sediment yield as it is affected by various land uses, for large catchments.

Summary of various results of studies is presented in Table-6. This table is derived from results of various experiments and a range has been given for sediment yield from various land uses. As this table gives a range, it would be useful to consider the slope, the rainfall, the soil types etc.,while using this table. However, the table would be useful to get a general idea of the sediment yield/soil loss from different land uses.

For details and specific location, slope, watershed sizes etc., a reference can be made to tables given earlier.

TABLE - 6
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) Plane 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) Plane 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 rainfall, for different soils etc. Ranges are being presented here to give a general idea for the soil loss from a particular land use. For details a reference can be made to Tables given elsewhere, in this report.

REFERENCES

1. Anonymous (1973) to (1983),' Annual Reports of Central Soil and Water Conservation Research and Training Institute,Dehradun'.

2. Anonymous (1982),' 25 Years of Research on Soil and Water Conservation,Research Centre,Ooty'.

3. Bhatia,K.S. and Chaudhary,H.P.(1977),' Runoff and erosion losses and crop yields from slopy and eroded alluvial soils of Uttar Pradesh in relation to contour farming and fertilization', Soil Conservation Digest, 5(2),pp.16-22.

4. Bhushan,L.S. and Omprakash(1983),' Runoff and Soil loss under different cropping systems on 2% slope', CSWCRTI,Dehradun'.

5. Corbel,J.(1959),' Erosion en terrains calciers',Ann. Greogr. Vol.68,pp97-120.

6. Chinnamani,S.,(1985),' Forest,grassland and agroforestry and its impact on water resources development in India', Proc. Int. Seminar on Env.Impact Assessment of Water Resources Projects,12-14 Dec.1985,at Roorkee,pp.93-105.

7. Chinamani,S.,S.K.Gupta and P.K.Thomas (1965),' Runoff and Soil Loss Studies under Different Vegetative cover', Ind.For.,Vol.91, pp.672-682.

8. Das,D.C. and S.Singh (1979),' Soil Conservation for Moderation of Flood and Sedimentation- A Review', Hydrology Review- A publication of INC for IHP,Vol.5 (1-4),pp.36-47.

9. Das,D.C.,Y.P.Bail and R.N.Kaul (1981),' Soil Conservation in Multipurpose River Valley Catchments-Problems Programme,Approach and Effectiveness', Ind.J.Soil Cons. Vol.9 (1),pp.6-26.

10. Das,D.C.(1982),' National Land Resources Conservation and Development Commission' ,Report of the Committee of Experts, Ministry of Agriculture (1984).

11. Das, D.C., Subramaniayan, S.C.Samuel and Ramasesha,C.S., (1984),' Guidelines and status of Hydrologic and Sedimentmonitoring of watersheds in Selected River Valley

Catchments', Technical Series No.1/H and S/1984,Ministry of Agriculture,New Delhi p. 175.

12. Dhruvanarayana,V.V. and Ram Babu(1983),' Estimation of Soil Erosion in India', Journal of Irrigation and Drainage Engineering, ASCE,109 (4): 419-434.

13. Dhruvanarayana,V.V.,Ram Babu and C.Venkataraman,(1985), ' Soil erosion under different agro-climatic condition in India', Presented in the National Seminar on Soil Conservation and Watershed Management,Ministry of Agr. and Rural Development,Sept.17-18,1985.

14. Dorokhina,S.V.(1980),' Weathering of voleanic ash in a cold,humid climate', Moscow Univ. Soil Ses.Bulletin 35 ,p.52.

15. Ghosh,R.C. and B.K.Subbarao (1979),' Forests and Floods', Ind. For,105,pp.249-257.

16. Hukam Singh,(1985),' Status of grasses in soil conservation and integrated watershed management', Lead Paper in National Seminar on Soil Conservation and Watershed Management,Sept.17-18,1985 at Delhi,pp.164-180.

17. Kaye,(1954),' Shoreline features and quaternary shoreline charge', Pouerto Rico,USGS Paper No.317-B,p.49-140.

18. Mirachandani,P.M.(1958),' Runoff-soil loss studies at Deochanda Expt.Station', J.Soil Water Conservation India 6(3),pp.125-132.

19. Pathak,S.(1974),' Role of forest in soil conservation with special reference to Ramganga watershed', Soil Cons. Digest, Vol.2(1),pp.44-47.

20. Pathak,P.C.,A.N.Pandey and J.S.Singh(1984),' Overland flow,sediment output and Nutrient Loss from Certain Forested Sites in the Central Himalaya(India)', Jour. of Hydrology,Vol.71,pp.237-251.

21. Saxena,P.C.,K.S.Rajagopalan,K.K.Patil and C.Ramesh (Undated),'Sediment Yield from an Experimental Watershed' CWPRS,Poona.

22. Shah,(1985),Personal Communication,CWC, New Delhi

23. Sharda,V.N.,L.S.Bhusan and Raghuvir (1982),' Hydrological behaviour of ravinous watersheds under different land uses', Proc. Int.Symp. on Hydrology of Mountaneous Watersheds,Roorkee.

24. Shri Niwas,Gupta,P.D. and Das,S.K.,(1980),' Runoff and soil loss studies on red 'Chalka' Soil at Hyderabad', Presented at National Symposium on Soil Conservation

and Water Management in 1980's at Dehradun,March 12-13, 1980.

25 Singh,G.,Ram Babu and S.Chandra,(1981),' Soil loss prediction research in India',Bulletin No.T-12/D-9, Central Soil and Water Conservation Research and Training Institute,Dehradun p.70.

26. Subbarao,B.K.,B.G.Dabral and B.C.Ramola (1973),' Quality of water from forested watersheds', Ind.For.,99(12).

27. Tejwani,K.G.,S.K.Gupta and H.N.Mathur(1975),' Soil and Water conservation research,1956-1971',ICAR Publication.

28. Vasudevaiah,R.D,Singh,T., and D.P.Guba,(1965),'Runoff soil loss determination studies at Deochanda Expt. Station II', J.Soil Water Conservation India,13:3,pp. 36-46.

29. Verma,B.,Tejwani,K.G.Kale,M.V. and A.P.Patel,(1968), ' Evaluation of different cropping patterns for runoff and soil loss in ravine lands', J. Ind.Soc. Agron,13,pp.262-270.

30. Young (1969),' Present rate of land erosion',Nature, 224,p.851.

APPENDIX - I (a)

Soil loss as influenced by crops and cropping systems

S.No.	Treatment	Soil loss (Tonnes/ha)
1.	Alluvial soil-2% slope-(rainfall,June to March 791 mm-rainfall causing runoff 205.9 mm-Vasad)- Average of 7 years (Verma,et.al.1968)	
	Bajra-fallow	2.3
	Bajra-mung strips(3:1 ratio)fallow	2.2
	Bidi tabacco-fallow	4.8
	Sannhemp (cover green manure crop)	14.4
	Bidi tobacco-fallow	4.83
2.	Cotton local method	
	Black soil - 1% slope-Annual rainfall 606mm,Kota,Average of 4 years (Singh et al.,1967)	
	Groundnut	1.9
	Black gram	2.1
	Jowar	2.4
3.	Red Soil-2% slope monsoon rainfall 1002 mm Deochanda(DVC) average of 3 years (Mirchandani, et al.1958)	
	Maize	3.3
	Maize and Urd(for seed)intercropped	3.0
	Maize and Urd(for green manure) intercropped	2.9
	Maize and Arhar intercropped	2.5
	Maize and Arhar (maize stalks stubble mulched) intercropped	3.3
4.	Red Soil - 5% slope monsoon rainfall 1129 mm - DeocHanda (DVC-average of 3 years (Vasudevaiah,et al 1965)	
	Maize	23.6
	Urd	47.8
	Groundnut	13.9
	Gora paddy	21.1

APPENDIX - I (b)

Soil loss(t/ha) from various agronomic practices

S.No.	Crop and place	Soil Loss (t/ha/year) Up & down cultivation	Contour cultivation	Remarks
1.	Potato at 25% slope (Ootacamund)	39.3	14.9	(Tejwani et.al.,1975)
2.	Maize-wheat at 8% slope(Dehradun)	28.5	19.3	(Tejwani et.al,1975)
3.	Maize (Mulch)@ 2 t/ha (Dehradun)	-	7.2	(Khybri,1983)
4.	Jowar at 2.2% slope (Kanpur)	14.1	5.5	(Bhatia and Chaudhary, 1977)
5.	Maize at 5% slope (Hazari bagh-red soils)	17.57	5.34	(Singh et.al 1981)
6.	Sorghum at 1% slope (Kota-Clay soils) Average of 3 years	1.4	0.9	(Singh et.al 1981)

APPENDIX - I (c)

Effect of engineering practices on silt production from agricultural land use

Place	Land use		soil loss (t/ha)	Remarks
Dehradun (on 4% slope)	Agril.	Up and down channel terrace	6.06	i) large plots (100 x 20 m)
		" with contour farming	2.53	
		Channel terraces(at 1.5 time usual spacing with graded furrows)	2.32	ii)Av. of 3 years (Tejwani et.al., 1975)
	Agril. Water-shed (54.6 ha)	Untreated watershed	2.3	i)Av. of 9 yrs. (Dhruvanarayana et.al.1985)
		Treated with field bunds	0.1	
Chandi-garh	Agril. Maize-in run-off plots (at 1.5% slope)	Unbunded	3.51	i)Av. of 5 years.
		bunded	0.97	(Anon.1977)
Ootaca-mund	Agril. Potato on 25% slope (in run-off plots)	Up and down	39.3	i)Av. of years
		Bench terraces	1.0	(Tejwani et.al,1975
		Peurtoricon type terraces with mechanical barrier	2.9	
		-do- with vegetative barrier		
Shilong	Agril. (Jhum-ing) i.e. Shifting cultivation food crops	(40% land slope)	40.95	Av. of 2 years (Dhruvanarayana et.al.1985)
		Bench terrac-ing	2.3	Av. of 4 years
		Peurtoricon type Terrace(contour bounds)	20.98	-do-
	-do-			
	Agri-horti-cultural	Bench terracing	2.98	-do-

Agra	Agril. Water-shed (9.6 ha)	Untreated	1.4	(Anon.,1984)
		Treated with land levelling and field bunds	0.6	-do-
	Agril. + Grassland (8.5 ha)	Untreated	4.5	-do-
		Treated grassed waterways and check dams	0.8	-do-

APPENDIX- II

Soil Loss in Ravine Lands

Place	Cover	Soil Loss (t/ha)	Remarks
1. Agra (Ravines of Yamuna)	a. Bare fallow	3.8	i) Average of 5 years. (Singh et.al.1981)
	Cultivated fallow (2% slope)	15.67	i) Average of 3 years. (Bhushan and Prakash, 1980)
	b. i) Grass (2% slope)	1.8	i) Runoff plot (1 year)
	ii) Dichanthium annulatum	0.53	ii) Average of y years (Singh et.al,1981)
	iii) Grass land (9% slope)	Nil	i) Area 0.21 ha (Anon,1980)
	iv) Mixed landuse (Natural grass+ sisham(8.5% slope)	Nil	i) Area 0.29 ha
2. Kota (Chambal- Ravines - Black soil)	a. Cultivated fallow (1% slope)	3.4	i) Average of 3 years. (Anon,1983)
	b. i) Natural cover (1% slope)	4.8	i) Runoff plot
	ii) D Annulation Watershed Studies	0.10	ii) Average of 3 years.
	iii) Grassland	0.43	iii) Area 0.4 to 1.45 ha.
	iv) Mixed land use (Grass + trees)	1.15	
	v) Agricultural Watershed	3.83	
3. Vasad -Mahi (Alluvial Soil)	a. Cultivated fallow (2% slope)	5.16	(Anon,1976)
	b. Grass cover (2% slope)	Nil	i) Runoff plots (Bonde et al.,1976)

APPENDIX-III

Silt Production from Horticulture land use(Singh,1985)

Sl.No.	Place	Land use	Soil loss (t/ha)	Remarks
1.	Shillong	Mixed land use(Agri-horticulture on bench terrace)	2.96	i) Av. of 2 years
2.	Dehradun	Strawberry with weeds	4.99	i) Plots on 11% slope
		Pineapple with weeds	1.69	ii) Av. of 2 years
		Pomegrante with weeds	1.39	
		Strawberry clan	23.07	
		Pineapple clean	8.44	
		Pomegranate clean	16.39	
		Cultivated fallow	18.46	