Himalayan erosion is discussed here under B) Surface Erosion and C) Mass Wasting.

The inability to appreciate the differences between these two distinct processes has resulted in considerable confusion when implementing soil conservation programmes. It is important to determine which erosion processes man can effectively moderate through appropriate land use techniques.

B. SURFACE EROSION

Surface erosion is less visually apparent than mass wasting but it is much more damaging to the livelihood of the people of Nepal. Loss of topsoil by surface erosion is the direct result of heavy rains pounding unprotected soils. Many of man's activities cause the soil to become less protected than it would be in a natural state. (See Photo I.)

The loss of one or two millimeters of topsoil every year may not make a spectacular visual impact, but the cummulative effect is the impoverishment of the soil base. Topsoil has the highest levels of nitrogen, phosphorous and organic matter and is more productive for plant growth than lower soil horizons. Because of the insidious nature of surface erosion, it is necessary to develop a method whereby surface erosion can be quantified.

1. Factors Contributing To Surface Erosion

Scientists have developed a number of regional assessments characterizing soil erosion throughout Nepal. Such exercises are difficult to carry out because of the extreme variability found throughout the country. Rainfall erosivity, wind velocity, aspect, slope, bedrock type and characteristics, land use, forest type and condition must all be considered in the prediction of surface erosion. Surface or topsoil erosion caused by rainfall can be investigated by the use of the Universal Soil Loss Equation (U.S.L.E.) (Wischmeier and Smith 1978) whereas mass wasting events are virtually unpredictable without very expensive on site investigation.

Briefly the U.S.L.E. is A = RKLSCP

Where A = the amount of soil loss in tons per ha
R = Rainfall erosivity
K = Soil erodibility
LS = Slope length and steepness
C = Cropping management
P = Erosion control measures

The Universal Soil Loss Equation was developed for gently sloping agricultural land in America and direct applicability to the mountainous regions of Nepal cannot be assured. It does however provide some insight into the quantification of topsoil erosion. The factors considered in soil erosion prediction are given below.

a) Rainfall Erosivity (R)

The magnitude of surface soil erosion is directly related to the intensity of precipitation. Since rainfall intensity data is very scarce in Nepal, direct assessment of rainfall intensity throughout the country is impossible. Backed by existing Kathmandu weather station data, Fetzer and Jung, (1978) calculated a moderately low rainfall intensity (R = 70; World values range between 10 and 1000.) It is commonly acknowledged that rainfall intensity decreases with increasing elevation; areas on the Terai have relatively higher rainfall intensity while areas in the High Himal have a relatively lower rainfall intensity. A slope on the Terai or in the Siwaliks experiences more erosive storms than a slope in the High Mountains. Consequently, farmers in Jumla or Solu can cultivate unterraced, 15 degree slopes with only minor apparent damage. The same slope in the Siwaliks would be badly eroded after one monsoon season.

b) Soil Erodibility (K)

Soil characteristics including texture, percentage of organic matter, structure, and rate of infiltration can markedly affect erodibility of soil. In general terms, the less the proportion of fine sand or silt, the higher the organic matter content, the more developed the soil structure and the higher the infiltration, the less erodible the soil will be. Red soils in Nepal are notorious for sheet and gully erosion because of the low infiltration rates, and tendency toward surface crusting. Overgrazing and burning on red soils results in severe soil degradation. Structureless, very fine sands such as excavated in the new Kathmandu airport construction at Gauchaur are also extremely erodible and even low intensity storms result in tremendous surface soil movement. During one storm event in July 1984 over 250 tons per hectare of such material was eroded.

c) Slope Length And Steepness (L,S)

As slopes become steeper and longer the potential for surface soil erosion increases. The higher the velocity and the greater the concentration of water, the greater sheet and rill erosion. Slope steepness is a key factor used when mapping soil erosion hazard and many land managers classify erosion hazard based on slope alone. However, at slopes greater than 30 degrees, mass movements begin to outweigh the effect of surface erosion. On very steep slopes surface erosion rates drop because all unconsolidated material has long since washed away.

d) Cropping Factor (C) (including natural vegetation)

The cushioning of bare soil by crops or vegetation protects the soil from eroding during rainfall events. The greater the density of vegetation, the less is the erosion of the soil surface. Overgrazed lands result in the most severe surface erosion while multistoried forests have the lowest levels of topsoil erosion. Researchers in Nepal tend to overestimate the value of trees and underestimate the value of ground cover in reducing surface erosion.

There has been general discussion on the value of the forest in proper watershed management. However, there is a tendency to stress tree planting and protection while ignoring the fact that trees are only one component of a healthy forest. The primal forest includes trees, shrubs, herbs, grasses and forest litter. The ability to resist erosion caused by the monsoon rains is largely dependant on the percent cover and vigor of vegetation at ground level, the herbs, grasses and litter. Healthy trees alone do not ensure protection from soil erosion. In the heavily used forests of Nepal, Pine and Sal are noted for the scarcity of growth in their understory. In spite of complete Sal or Pine tree cover there can still be severe damage to the soil surface. At the same time, areas demarcated as badly degraded forest, if they have adequate ground cover can provide excellent cover for soil conservation management. The presence or absence of trees alone cannot be linked to rates of topsoil erosion.

e) Erosion Control Factors (P)

By reworking hill slopes into bench terraces, and maintaining lined or vegetated waterways with adequate drop structures, man can achieve positive changes on a cultivated slope. The Nepalese farmer, by constructing and maintaining bench terraces has developed a very stable agricultural system for his cultivated crops.

The area of most severe damage to the land resource is occurring on over-utilized communal grazing and forested land where the individual villager has no motivation for improving management.

2. Wind Erosion

Although rainfall erosion is the major topsoil degrading process occurring in Nepal, wind erosion plays a significant role on certain landscapes associated with cultivation. In general, throughout the Middle Mountains, wind erosion is of minor importance because the soils have medium textures and good structures so they are able to resist wind erosion. Overgrazed and badly compacted sites experience very little wind erosion, although rainfall erosion on these same sites can be severe. Further, cultivated soils are in stubble fallow in April and May when the winds are strongest.

Dust storms occur on, and adjacent to, all major dry river beds, which comprise 1.6 percent of Nepal. Unvegetated, structureless riverbed sediments are easily windborn and can be carried for long distances. Little of the observed dust is actually coming from agricultural lands. The net result is loess deposition on forested and cultivated land, particularly in the Terai and Siwaliks, because the majority of dry river beds are found there. Aeolian sediments can be traced from as far away as the Rajastan desert, brought during the strong winds of April and May. These windborn sediments may have had a net positive contribution to the soils of Nepal by the deposition of silt, often of a calcareous nature.

Wind erosion is significant in areas of semi-arid and arid climate, common in the deep valleys of the High Himalayan Region, particularly in Dolpa, Mustang and Manang. The Kali Gandaki, at Jomsom, experiences tremendous winds daily. These winds are strong enough to move coarse sand along the valley floor. The area is so dry that vegetation is restricted to scattered thorny scrub growing on bare soil. Over time, the removal of fine surface soil materials by wind erosion has left behind a stone pavement, which if left undisturbed, protects the soil from further wind erosion. Obviously any activity in this area that opens the soil must be combined with good erosion management including wind breaks, surface mulches and irrigation to minimize topsoil loss.

Where mechanized cultivation is feasible, particularly in the Terai and in the Dun Valleys of the Siwaliks, there is cause for concern upon the introduction of heavy farm machinery that is capable of working dry, hard soils. Traditional ploughing required that the soil be wetted to field capacity in order to restore the soil to a workable state. Heavy equipment (including chisel ploughs, harrows and rotovators) in the process of making a seed bed on dry soil can create a powdery soil surface that is vulnerable to wind erosion. If harrowing is done during April and May in anticipation of the first rains, severe wind erosion may result. Agronomists must consider the wind erosion hazard in rainfed cultivation if new cropping patterns are introduced.

Wind erosion is a problem on the sandy textured active alluvial terraces of the Terai. Sandy soils are relatively easy to plough, even when dry, and in their ploughed state are susceptible to blowing. The planting of windbreaks with trees such as Dalbergia sissoo can significantly reduce surface wind speeds and thus reduce soil loss. Farmers on the Terai adjacent to major river systems are beginning to use sissoo hedge rows. Riverine forest plantations can be more economic than annual cropping and much more suited for wind erosion control.

In spite of its localized importance, wind erosion is not discussed further in this paper as its significance to Nepalese Himalayan geomorphology is small.

3. Topsoil Erosion Assessment for a Watershed

By an empirical study of erosion on a typical watershed, an attempt can be made to estimate how much topsoil is actually leaving any landscape. One can appreciate the magnitude of rainfall erosion, by actually measuring the soil loss during various types of land use on a given landscape. Literature accumulated by Laban (1978) provides us with a rough estimate of surface soil loss from specific land use types for an otherwise uniform slope. The following soil loss figures are given for a typical watershed in the Middle Mountains of Nepal.

TABLE I ESTIMATED SOIL LOSS FOR DIFFERENT LAND USES (Laban 1978)

Type of Land	Soil Loss (Tons/ha/yr)
Well managed forest land	5 - 10
Well managed rice terraces (bunded)	5 - 10
Well managed maize terraces	5 - 15
Poorly managed sloping terraces	20 - 100
Degraded range land	40 - 200

However these figures are not usually measured data, but estimated, based on known sediment loads of streams. They most likely overestimate surface soil erosion based on the assumption that sediment production is largely a function of land use. Topsoil losses in many areas may not have exceeded 0.5 tons per hectare. These estimates have probably included various forms of mass wasting in the assessment of surface erosion. This complication will be considered in the section on mass wasting.

4. Topsoil Erosion and Soil Fertility Management

Throughout the hill regions of Nepal, soil erosion losses on cultivated and grazing lands are a major factor in soil fertility management. Any techniques used to enhance productivity must consider soil conservation measures. Conversely, any techniques used to reduce soil erosion must consider land productivity. In Table II the magnitude of nutrient losses through soil erosion on different land uses is presented. Well managed irrigated and rainfed terraces experience only minor soil loss which can be matched by compost and fertilizer additions. With land uses such as shifting cultivation, the loss of nutrients obviously cannot be maintained and so fertility declines.

The decline of soil fertility through topsoil erosion is one of the major ecological crises facing Nepal today and it is in this area that soil conservation programmes have an important role to play.

TABLE II ESTIMATED SOIL AND NUTRIENT LOSSES BY RAINFALL EROSION ASSOCIATED WITH DIFFERENT LAND USES*

	Irrigated Rice Land	Level Terraces	Sloping Terraces	Shifting Cultivation
Soil Loss Depth	0.0 mm	0.4 mm	1.6 mm	8.0 mm
Soil Loss (Kg/ha/yr)	0	5,000	20,000	100,000
Organic Matter Loss (Kg/ha/yr)	0	150	600	3,000
Nitrogen Loss (Kg/ha/yr)	0	7.5	30	150
Phosphorus Loss (Kg/ha/yr)	0	5.0	20	100
Potassium loss (Kg/ha/yr)	0	10	40	200

*Based on a topsoil with the following analyses.

Organic Matter	3.00%
Nitrogen	0.15%
Phosphorus	0.10%
Potassium	0.20%
Bulk density	1.3 g/cm