CHAPTER – 4

Nature and Extent of Environmental Degradation in Darjeeling Hills

4:1 Introduction

Environmental degradation and its consequently deepening crisis of sheer magnitude have of late, altered many within this country. Thus, there is a serious concern for finding the right mitigative measures especially in dealing with the hilly environment. Whether, through ignorance or not, the fragile hill ecosystem has often been violated outrageously, impairing its delicate sub-systems which have a long term effects, jeopardizing the life-sustaining processes. The growing consciousness about the worsening situation compels the society today to make a rethinking, for halting the causes of grave injuries to the environment. While, it is admitted that the environment cannot be reverted to its original form, nor can it be intended to, it may not be beyond our conscious efforts to check or control such practices for arresting further deterioration, followed by protective measures for seeding-up the restorative processes in this fragile environment.

The Darjeeling Himalayan region is noteworthy for its wide variety of renewable and non-renewable resources. Of late, this repository of natural wealth has been subjected to virtual plunder. In consequence, the watershed ecosystems are fast loosing their resilience and regenerative capacity.

Since the British occupation, the physico-cultural set-up of this region has been seriously disturbed. Extensive heedless deforestation, tea plantation, haphazard construction, huge population influx induced illogical slope cultivation, inadequate drainage, in other words, unscientific and unplanned use of land has led to the establishment of vicious cycle of degradation. As a result, during heavy and concentrated rainfall, catastrophic soil erosion and innumerable landslips are caused, contributing huge sediment load to the rivers which are incapable of transporting the load efficiently under the existing hydrological conditions especially along their lower courses beyond the foothills. The river beds are rising, resulting in lessening of cross sectional area, which being incapable of arresting unusual monsoon discharge and cause devastating floods, endangering the vital line of communication, human habitations, farm lands and forests (Sarkar, 1991, 1996).

Implementation of various development schemes, construction of human settlement and road to cater the ever-increasing population, exploitation of forest produce to generate

work potential, boosting of agricultural growth, tourism, mining and quarrying, on the Himalayan immature geology trigger the disaster, huge and complex, never encountered before.

The situation was not so bleak even 100 years back. The hills were densely forested with very thin population and the harmonial relation between the upper and lower parts of the watersheds were well preserved. Extensive heedless deforestation, haphazard construction of roads and settlements, unscientific and illegal mining activities, inadequate drainage, in other words – unscientific and unplanned usage of land, has led to the establishment of vicious cycle of degradation.

During heavy and concentrated rainfall, catastrophic soil erosion and innumerable landslides are caused to transport huge amount of sediments from the upper part of the catchment to the parent river (Froehlich, Soja, & Sarkar, 2000; Patel, & Soja, 995; Starkel et. al., 1998, 2000; Starkel, & Sarkar, 2002). These rivers are incapable of transporting the load efficiently under the existing hydrological conditions, especially along their lower reaches. The river beds are thus elevating at many places at an alarming rate resulting in lessening of cross sectional areas. The reduced cross sections being incapable of arresting the unusual monsoon discharge caused devastating flood, causing heavy damage to the land and properties. It also endangered the priceless forest lands, wild life vis-à-vis bio-diversity and vital line of communication and strategic infrastructure.

Environmental degradation in Darjeeling hill areas has been increasing day by day. The Darjeeling hill areas are facing the worst ever crisis. The degradation damage is gradually extending into the comparative stable areas as well adjacent piedmont areas of North Bengal plains also. If the current illogical and so called development exercise is not arrested and/or be environment friendly the "*dooms day*" is far away for the entire Darjeeling hill area.

Among the major degradation processes active over the Darjeeling hills, deforestation is the single most important and also instrumental in releasing a chain of other kinds of degradation processes. Such as landslides, soil erosion, edaphic drought etc. are basically caused by the massive deforestation that had taken place during the past one and a half century.

4.2 Deforestation

It is already mentioned that the Darjeeling hills has been experiencing massive heedless deforestation since the British occupation. There are different causes of deforestation in Darjeeling hills of different dimensions. Although, the relative importance of such causes are more related to spatio-temporal variations yet all of them are in totality exerted detrimental impact to the once pristine environment of the Darjeeling hills (photo 4.1). The following are the important identifiable causes of deforestation in Darjeeling hills:

i) Deforestation due to establishment of development projects such as construction of dams, construction of roads establishment of railway link (from Sukna to Darjeeling railway line), urbanization, tea plantation and factories, quarry/mines etc. all in fact destroyed forests and disturbed delicate hill-slope hydro-geomorphic balance.
ii) Felling of trees for fuel for fuel wood by villages is a major cause of deforestation.
iii) Clearing of forest for agriculture to supply food for growing population is another reason.
iv) Industrial uses of timber for furniture, raw material, plywood industry etc.
v) Overgrazing by livestock especially introduced by villages inside forests and grasslands cause a great damage through the grazing of seedlings and saplings. This adversely affects the natural regeneration process.
vi) Inception of railway network in Darjeeling hill in the year 1881, steady supply of special variety of timber was needed for sleepers caused massive deforestation along the lower hills and piedmonts.
vii) Man induced forest fires have destroyed considerable forest area in different parts of the hill especially in some parts khashmahal forests of Kalimpong sub-division. Such grave activities have taken place as a result of unholy nexus between politician and timber smugglers. Natural forest fire also causes extensive damage to ground flora every year fire has caused extensive damage to young as well as old plantation in the hilly region of Darjeeling. The damaged of the older plantation was caused in Rimbik, Tonglu, Ghoom-Simana ranges of Darjeeling division. Fire has also caused damaged to the younger plantation especially in Tista valley and Darjeeling range of the division (table 4.1).
viii) Shifting cultivation is also a reason for deforestation in hill areas during early stage of British annexation of Darjeeling hills. This practice still continues as demands on agricultural land increases due to population influx, where more and more land is being brought under cultivation for which forests are cleared, grassland ploughed uneven unstable landslide prone areas are annexed thereby, causing further deforestation. It is

observed that even forest area are distributed among the landless families instead of redistributing un-utilised cultivable land.

ix) Fire wood collection from the forest has been a major occupation to the vast majority of rural population of hill areas not for their own sustenance but also for income generation till today. Fire wood is still today the only source of fuel for cooking and worming during chilly winter to the villagers and people living in small towns. Fire wood collection contributes much to the depletion of forest cover especially in localities which are lightly wooded, denser forest usually produce a lot of combustible material in the form of dead twigs and leaves, hardly any need of cutting down live trees. However, in the case of lightly wooded forest where the pressure of demand is usually higher a slow thinning of woodland occurs due to regular foraging of villagers.

Table 4.1 Forest area affected by fire in Darjeeling division.

Sl no.	Year of occurrence	Area in hectare
1	1991-92 April/ May	500.00
2	1995-1996	37.50
3	1997-1998	38.45
4	1998-1999	46.042
5	1999-2000	27.4
6	2000-2001	231.87
7	2001-2002	180.06
8	2002-2003	54.32
9	2003-2004	21.87
10	2004-2005	34.07
11	2005-2006	98.53
12	2006-2007	594.78
13	2007-2008	567.03
14	2008-2009	671.02

Source: Forest Deptt., Govt. Of West Bengal

x) Lumbering was an important economic activity in Darjeeling hills during the period of British occupation and still it is continuing. As a consequence, vast tracts of high natural forests are being mercilessly exploited. Logging or felling of forest trees for obtaining timber is an important cause of deforestation in this hilly region. Live trees with thick and straight trunks are felled and transported to commercial establishment elsewhere to consumers. The forest department also indulged clear felling in the name afforestation programme. The timber thus collected has been transported in different parts of the country for commercial purpose. Such activities are still in progress in areas under

Kalimpong Forest Corporation and practiced in Rongpu, Tarkhola, Manzang forest area and in Lava range of Kalimpong forest division (table 4.2). Thus large stretches of forest are damaged and the system which could have provided resources worth much more to the local people is disrupted. Profits from timber trade are normally enjoyed by the large companies and/or affluent contractor. Local people get a very small share in the benefits while axing their own resource base.

Table 4.2 Extent of forest degradation in Darjeeling hills

Forest Division	Forest Range	Blocks severely degraded > 40%	Blocks partly degraded 20-40%	% of the degradation as per total range area.
Darjeeling	Tista valley Takdah	Riyang Gayel Takdah west Pamong Lopchu	Pesok Sira	30 30 to 40
Kurseong	Bagdogra	Kalka, Dolka Kadam central Malta Tarabari Tirihana	Bagdogra	40 to 50
	Panighatta	Balasan Kalabari Mechi	Bangkolong Lohagarh	50 to 60
Kalimpong	Chel	Chunabhatti, Noam, Yamakum	Lish, Mangpong	20
	Neora	Mal, Sakam	Ambiok	20-30

4.2.1 Consequences of deforestation

The effects of contemporary forest degradation in the Darjeeling hills have been demonstrated by the ever increasing deterioration in the overall quality of land, air and water of the region concern. As a result, the overall quality of living in the Darjeeling hills is fast deteriorating putting a big question mark on the future of the region. Some of the striking effects are listed below:

- Edaphic drought ness
- Deterioration of surface water both quality and quantity
- Drying up of springs and *jhoras*
- Reduction of ground water recharge
- Deterioration of soil quality
- Increased frequency and magnitude of floods in the lower sections
- Increased frequency and magnitude of accelerated soil erosion and landslides and related slope movements

- River metamorphism vis-à-vis avulsion
- Enlargement of river valley
- Loss of forest resource including biodiversity
- Climate change

It would not be possible here to describe all details of these impacts. However, to visualize the magnitude of the possible threats of watershed degradation as visualized from the rising river beds has been shown in the present case. Increased frequency and magnitude of slope movement vis-à-vis landslides along with accelerated soil erosion in upper hilly section and increased frequency and magnitude of flood occurrences in lower sections of watersheds in the plains has already been demonstrated. Sarkar (2008) has demonstrated the effect of deforestation in upper catchments of Sub-Himalayan rivers as the alarming rate of river bed rising along the piedmont and plains in the following table (4.3).

Table 4.3 River bed rising in the Himalayan foreland

Rivers	Rising of bed level*	Location of measurement	Period of measurement
Tista	1.100	Jalpaiguri town	1985-2005
Jaldhaka	0.900	NH 31 Bridge, Gadhaierkuthi	1986-2005
Torsa	0.900	NH 31 Bridge, Madarihat	1985-2005
Sankosh	0.800	NH 31 Bridge	1987-2003
Balason	1.124	Near Matigara Tea Garden	1984-2006
Mahananda	1.980	NH 31 Bridge, Champasari	1984-2006
Kaljani	1.310	Near Alipurduar	1992-2002
Lish	2.490	Bagrakot	1982-2004
Gish	1.980	Odlabari	1982-2004
Diana	2.012	NH 31 Bridge	1990-2005
Rethi	2.410	Near Chamurchi	1990-2003
Dima	1.800	Near Rajabhatkhowa	1991-2003
Bala	2.145	Near Santalabari	1991-2004
Jainti	3.050	Jainti	1991-2004
Pagli	2.540	Near Makrapara	1993-2003

* *measured by the author.* *Source: Sarkar, S, 2008*

A chain of events is set into motion as the consequences of deforestation such as (a) soil degradation and erosion; (b) changes in climatic condition; (c) destruction of natural habitats and (d) destruction of valuable sink for environmental pollution.

(a) Soil degradation

Plants check rapid movement of air and water. Flowing water stay in the area for a longer duration during which time nutrients are re-absorbed and as water percolates down

ground water table is recharged plant cover keeps the ground surface humid. Trees with the help of deep root system are able to draw water from sub surface water. High humidity prevents excessive water loss and rapid desiccation and thus plants contribute organic matter which upon decomposition adds humus to the soil. Porosity helps in increasing water holding capacity and productivity of the soil. Organic matter binds the soil particles in soil crumbs which make it stable against forces of erosion.

Deforestation leaves the ground surface bare. In humid tropics a large portion of available mineral nutrients is taken away when the biomass is removed. Herbaceous plants and grasses are exposed to the sun, wind and rapidly flowing waters. There is further loss of mineral nutrients. Grazing may remove much of the organic matter with which the further loss of nutrients is even more rapid. All this further reduces the cover of small plants and grasses as well. Adequate plant cover keeps the soil temperature lower. At the depth up to 70 cm a higher temperature is observed in soil devoid of plant cover. Higher temperature speeds up mineralization of organic matter. This reduces the stability of soil crumb structure and the soil becomes easily erodible. It also loses its capacity to hold water, recycle mineral nutrients, nitrogen fixing capacity etc. and turn into a dead mass of silt clay and sand. With plant cover gone the battering action of wind and rain loosen the top soil which is thus carried along with water or air currents and deposited elsewhere.

(b) Change in climatic condition

Forests save natural environment and moderate local climatic condition. They maintain humidity, regulate temperatures, break wind velocities and influence precipitation. The extent up to which forests influence our natural environment is a controversial subject. However, it is almost certain that dense growth of green plants has moderating influences on local climatic condition and the global environment in a number of ways (a) maintenance of humidity (b) regulation of atmosphere temperature (c) moderation of wind velocity (d) enhancing precipitation. Today most scientists believe that perhaps increasing forest cover is the only solution to the ever increasing threat of adverse impact of climate change.

4.3 Edaphic Drought ness of hill slopes

Soil is considered one of the most important ecological factors. Plants depend for their nutrients water supply and anchorage upon the soil. Even for the free floating aquatic plants which derived their nutrients dissolved in the water medium around them, soil (mud) is

important as chief storage of all the nutrients which are made available to the water medium. Edaphic factors include the structure and composition of soil along with its physical and chemical characteristics. Soil system is indeed very complex and dynamic. The increasing edaphic drought condition has brought massive change in the soil of Darjeeling hill areas, and the rate of such changes being influenced by a number of other factors of the environment.

Due to physical and chemical condition of the soil under environmental degradation there have been massive change in plants and animal life in the Darjeeling Himalaya. As the deforestation adversely affect atmospheric humidity and in case of Darjeeling hills it was as high as 7% decrease during the past 100 years (Sarkar, 2012) the apparent soil desiccation is evident. Decreasing atmospheric humidity on the other hand leads to an increase in biological demand for water intake to the living organisms which further desiccate the soil moisture regime. As a result, many plants and animals including micro-organisms fail to survive which ultimately leads to species extinction an irreparable damage to the overall environment. It is seen that due to this reason the common and popular flower Marigold has been almost extinct from the Darjeeling hill area since 2005 and another important cash crops of Darjeeling hill area i.e. cardamom also has been facing serious threat of extinction from various parts of hill areas. Beside that many other less known plants of this hilly region also have been experienced either extinction or facing serious threat of possible extinction.

Perhaps, the increasing edaphic drought ness in the hill slopes of Darjeeling Himalaya has the most serious effect on the growth of shrubs and bushes including grass cover. Edaphic drought ness period now extending for over 7 months in year practically put death blow to many perennial plants and grass particularly along the southern and eastern aspects of the hill slopes. As a results, the forest floor and other hill slopes becomes bare which ultimately threaten the very existence of many small animals and ecologically invaluable microbes and insects. Animal like hare, fox, porcupine have been considered as threatened animal in the Darjeeling hill areas. It is also known that the environmental degradation has increased rate of soil erosion, further hampering food production, increase in rainfall has accelerated the rate of soil loss, reducing farm productivity even more. A further negative consequence of accelerated erosion has been increased sedimentation in stream and reservoir.

4.4 Landslides

Landslide and associated phenomena is the most pervasive of natural problems which has been accelerated by illogical human intervention vis-à-vis environmental degradation,

undermine the socio-economic development of the region. Darjeeling Himalayas occupy the lowest latitude of the entire Himalayan chain and highest permanent snow line. It is situated across the main pathways of the southwest monsoon winds from the Bay of Bengal and thus receives a fair amount of rainfall, which accelerates deep weathering. It occupies the major transverse structure of the Himalayas and exposes all the existing geological belts. Under such a geo-ecological background massive deforestation, unscientific construction, faulty land use pattern along and adjoining areas of the road, stream blocking due to non-disposable garbage dumping have made it unstable.

Earlier studies reveal that each landslide has its own peculiarities and its initiation is not due to any single factor (Bandopadhyay, 1980; Basu, 1969-70; Basu & Sarkar, 1984, 1985, 1987; Dutta, 1966; Ghosh, 1950; Nautiyal, 1951, 1966; Paul, 1973; Roy & Sensharma, 1967, 1986; Sarkar, 1990, 1995, 1999; 2010; Sinha et al, 1966). Of the various factors, water has the most deleterious effect. The toe erosion has admittedly caused some of the landslides. Many recent landslides are caused due to unscientific and unplanned usage of hill slopes and valleys. Every landslide is an individual problem, despite the fact that most of such cases have found to be initiated by common trigger mechanism. The solution to each problem has to be determined for individual site, though it may lie in combination of a few well established methods viz. retaining structure, drainage, afforestation, rock bolt, sheet pile, restriction of settlement and unplanned construction along the vulnerable hill slopes.

Landslide was a minor physical phenomenon in Darjeeling Himalaya a hundred and fifty years ago which has become rampant now-a-days leading to great loss of life and heavy damage to land and property. At present, therefore, suggestion of remedial measures and their active implementation is of vital concern for this extremely sensitive region. Today, in fact, landslide is the most pervasive of natural hazards that undermine the economic and cultural development of Darjeeling Himalaya. The diversity in slope components, geometry, site and situation, micro-regional susceptibility to degradation processes, micro-geology, micro-climate, depth of soil, its physical and chemical properties, vegetation with differential canopy and root system, unplanned growth of settlement, road and sewer systems, have led to recurring landslides.

With rapid modernization, the Darjeeling Himalaya at present is experiencing a phenomenal growth in population (456%) during last 100 years). To cater to such an overwhelming population, pressure on the land is ever increasing. Forests have gradually

been eliminated, steep slopes, generally unsuitable for human habitations and arable use have already been occupied and as a result Darjeeling Himalaya has of late turned into a highly vulnerable region without paying any heed to its ecological imbalance. Curiously, landslide, which was a minor physical phenomenon in Darjeeling a hundred and fifty years ago, has become quite rampant now-a-days leading to great loss of life and heavy damage to land and property. At present, therefore, suggestion of remedial measures and their active implementation is of vital concern for this extremely sensitive region.

4.4.1 The Landslide Occurrences

Historically speaking, a hundred and fifty years ago, land sliding in Darjeeling district was minor physical phenomenon. Ever since, the British occupation, the physio-cultural set up of this region had been seriously disturbed. Tea plantation, extensive and reckless deforestation, haphazard construction works and inadequate drainage, in other words; unscientific and unplanned uses of land have led to the establishment of the vicious cycle of denudation, heavy and concentrated rainfall aggravating soil erosion, landslides and associated phenomena.

From the available records, it may be said that the first disastrous landslip occurred on the 24th of September 1899; on the eastern side of Darjeeling town. The landslips were confined to the soil cap which from the Darjeeling ridge and their immediate causes was to excessive rainfall. This caused the loss of many lives (72 persons killed in Darjeeling town) and widespread destruction of houses, roads and properties. After the disaster, the govt. of Bengal had appointed a committee to enquire the causes of the slip and suggest preventive measures (Griesbach's Report, 1899-1900). The Committee had gone to show that the instability of the hill slides generally increased with the increase of saturation caused by absorption of moisture during a heavy shower and cutting the hill slopes by natural and artificial needs, future increased instability. The second major event of landslips in Darjeeling Himalayas took place on 15th January, 1934 due to Bihar -Nepal earthquake, which was responsible for widespread destruction through not of equal magnitude as was experienced during 1899. On 11th and 12th June 1950, the hill slopes in Darjeeling and Sikkim ware affected by disastrous landslips causing several deaths 'and heavy damage to roads, houses and public works due to heavy shower from 10 - 14 June. Apparent subsidence of Hill Cart Road near Paglajhora stretching for a length of about 500m was first recorded by K. K. Gupta in 1966.

Table 4.4: Incidences of major landslides in Darjeeling Himalaya

Major events and rainfall	Affected areas	Remarks
September 24-25, 1899	Darjeeling (Toongsoong, Singamari, Alubari, Station, Hermitage, Jalapahar); Kurseong, Kalimpong, Ghum, Tindharia, Bloomfield and Tukvor TGs.	72 lives lost in Darjeeling town. Houses along the En. Slope & Observatory hill mostly destroyed.
January 15, 1934; Bihar Earthquake.	Darjeeling town, Sonada, Sukhiapokri, Ghum and in Kurseong.	Little destruction was reported in Darjeeling.
June 11 and 12, 1950; Rainfall: 820.0 mm from June 11 to 13.	Darjeeling town (Jalapahar, Lebong, Katapahar, Bhutia busty, Hermitage), Happy Valley, Kalimpong, Mahanadi Paglajhora, Tindharia, Kurseong, Takdah, Glenburn etc. and the hilld remain cut-off from rest of Bengal for 5 days.	127 lives lost, thousands of people were homeless; slides breached roads and Siliguri Kalimpong. Rly. line lost forever. Paglajhora slump valley activated.
October 3 to 5, 1968. Rainfall: 1121.4 mm	Darjeeling town (Toongsoong, Kotwali, Rajbari, Kagjhora, Butcher busty, Manpari, Lebong, Ambutia, Kalimpong, Tista bazar, Rambi, Algara, Pesoke etc.	Hill Cart Road & NH 31 wiped out heavy loss of life and property. Ambutia landslide re-activated.
September 3 & 4 1980; Rainfall: 299.1mm	Rimbik, Lodhama, Bijanbari, Darjeeling Sukhiapokri, Ghum, Manebhunjang, Sonada, Lebong, Tukvor, Tindharia, Happy Valley, Ambutia etc.	Over 215 lives lost at Rimbik and Lodhama; property amounting Rs. 100 million destroyed.
September 16, 1991; 462.5 mm rainfall recorded from September 15 to 16.	Darjeeling town (North Point Toongsoong, Singamari), Ging, Tukvor, Bennockburn, Bloom- field, Paglajhora, Tindharia Rangtong, Chunbhati etc.	2 people killed. Rail connection between Siliguri and Darjeeling was snapped for five months.
July 13, 1993; Rainfall: 211.3 mm from July 11 to 13	Mongpo, Takdah, Pesoke, Rangtong, Tindharia, Pankhabari, Mahanadi, Gayabari, Ambutia, Darjeeling town etc	15 lives lost at Mongpoo.
April, 7, 2003	Sevoke area	240 mm in 24 hours
July, 8, 2003; 300mm rainfall in 24 hours	Gayabari, Puttung, Dudhia, Tindharia, Boxikhola, Giddhapahar also in NH 31.	17 died in Gayabari, Puttung and Pankhabari.
July, 8, 2005	West Point, Raniban, Krishnagram, Ging TG, Dunga in Darjeeling.	1 died; 8 houses destroyed; 300 people become homeless
July, 17, 2007: 175 mm in 24 hours	Darjeeling,	1 killed, 2 injured, 12 houses were destroyed
August 21, 09; 150 mm rain in 24 hours	Takling in Mirik, Kolbong at Algarah,	3 lives lost in Mirik and Kalimpong
May, 26, 2009; 171 mm rainfall in 24 hours	Aila induced cyclones caused massive landslides in Darjeeling hills between Darjeeling to Kurseong, 14 landslides recorded along the railway tracks.	30 lives lost, massive destruction of animal and property, hills remain cut-off for a long period.

August 16, 2009	Kurseong & Kalimpong: Gaurishankar TG, Sirubari, Nimbong, Paglajhora, Giddapahar area.	7 lives lost in Kurseong & Kalimpong, 500 houses destroyed, HC road & Rohini Road cut off.
June 16, 2010	27th Mile, Paglajhora, 400m road of NH 56 caved in. NH and DHR connection snapped for over a year.	Displaced material transported to the Sivkhola valley and blocked the drainage-way of the head stream of the Mahananda. An artificial lake was formed causing threat of flood further downstream.
September 18, 2011	Kalimpong, Kurseong, Darjeeling along the Roads	Earthquake of M-6.9 caused about 124 landslides of different dimension.

Evidences show that during 1950s, disastrous landslides, huge amount of debris were deposited below Hill Cart Road, along the main Paglajhora. Subsequently, the underground channel drains through joints of the existing bedrocks. Due to enlargement of underground passage through continuous fluvial erosion the basal support of the road is lost and thereby subsiding the Hill Cart road (photo 4.2).

Darjeeling town and its environs, Tista valley, Kalimpong area were again eclipsed with large-scale landslides owing to heavy rainfall that continued between 3 – 5October, 1968. The period between1969 to 1979 was relatively undisturbed. But heavy continuous rain on 27th August and 3rd to 4th September 1980 again triggered of widespread landslide in and around the township. The 1980s witnessed many cases of devastating landslide occurrences in the Darjeeling Himalaya particularly in and around Paglajhora, Tindharia, Darjeeling town, Kalimpong, along the Hill Cart Road and Sevok Gantak Highway. During 1993, there were heavy landslides in Bindu and Garubathan where about 15 persons were killed. During 1995, there was another heavy landslide in Pesok area where about 25 persons lost their lives. In September 2007 a number of landslides occurred in Kalimpong and Darjeeling triggered by high intensity rainstorm. Large scale destruction of land and property was reported in addition to loss of 5 lives in Kalimpong and 1 in Darjeeling. Since 1990 onwards, it has been found that almost every, year parts of Darjeeling Himalayas has been suffering from major or minor landslips, and thus, it has become an integral part of the life of the hill people (Photographs 4.2 - 4.12).

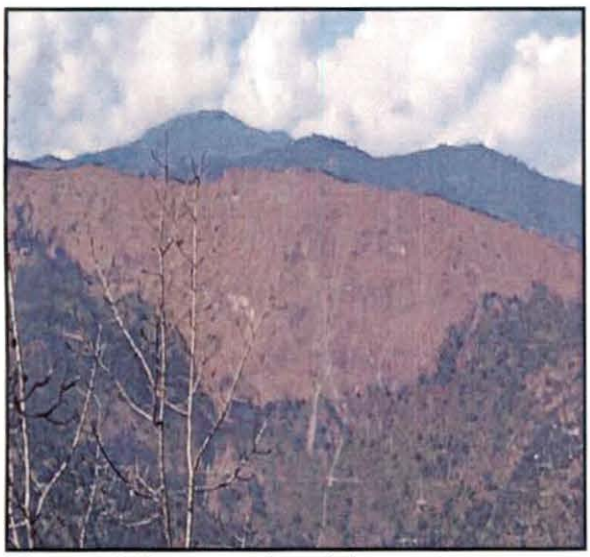

Photo 4.1 Near complete deforestation near Sikkim Darjeeling border.

Photo 4.2. Disruption of traffic: common scenario of roads of Darjeeling hill during monsoon months.

Figure 4.3. Victim of landslide near Kurseong, During the 2009 landslide.

Photo 4.4. Gigantic landslide along southern margin of the Himalaya.

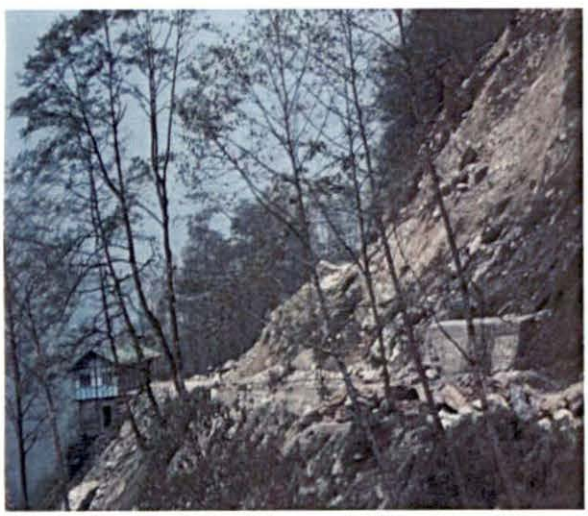

Photo 4.5. Debris slides near Kurseong

Photo 4.6 Slumping in Goomti Tea Garden, Kurseong

Photo 4.7. The Lower Paglajhora Landslide, 2010

Photo 4.8. NH-55 and Railway washed down at 17th Mile, hiking is the only option for local people in 2010

Photo 4.9 Photo 4.1. Debris slide: common form of Landslides in Darjeeling Hills.

Photo 4.10 The Paglajhora slump in 1998

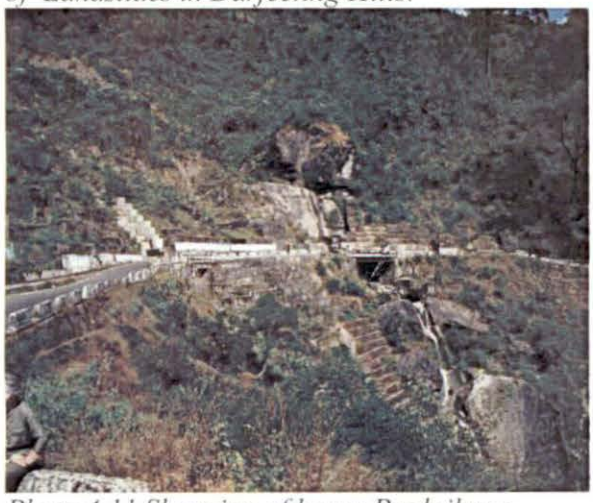

Photo 4.11 Slumping of lower Paglajhora

Photo 4.12. Tea Garden road induced soil erosion, Tindharia

4.4.2 Nature and Processes

Landslides occur in almost all types of slopes composed of various rocks in the Darjeeling Himalaya. Composite slides also take place involving soil or talus and underlying rocks. Slope failure is caused by shearing where the plane-of-shear, taking the form of an arc of a circle; in section leaving a parabolic outline of the slipped portion (Dutta, 1966). The most common occurrence of landslide is found along the spring (locally known as *Jhora*), where rock debris gets detached from their parent body along the slope and form channels. Later, such channels, while carrying drainage water are gradually widened by lateral erosion. Innumerable *nalas* (drainage channels) on hill slopes develop due to slope failure and many landslides in tea gardens and forests look like scars from a distance (Sarkar, 1999).

Landslides on rocky surfaces seem to be primarily influenced by the structural elements of the parent rock. Sliding also occurs in bedding and foliation in rocks with prominent joints and shear planes along the slope. Observations in the soil-covered slopes reveal that slopes having an angle below 30° were not generally affected by slides. The talus materials are formed due to weathering and loosening of rocks along the joints and foliation planes of the parent rocks. Such material, whether dry or in a permanently drained state, are stable at an angle of even 45° and the stability is not necessarily impaired by an occasional wet spell (Sarkar, 2000). Slope failure in such materials, however, occurs by seepage pressure of percolating water during heavy precipitation.

The tea garden slopes are generally formed of talus materials with a thin soil cover. Most of the slides have affected the materials but at some places, slides along the joints of the underlying rocks have also been observed. Generally, the displaced materials scour long channels down the slope, which are visible as scratched scars on hill slopes. The width of these scoured channels originally does not exceed more than 25 m or so but by subsequent erosion, they are further widened. Thus, once the slide has occurred, it generally remains a permanent feature and increases in dimension (Starkel etc.).

4.4.3 Landslide Prone Areas

Identification of landslide-prone areas has been performed with the help of "Check-List" where each separate and discrete slope unit has been classified according to their stability rating. Rating has been done according to a scale from stable through the degrees of potential instability to those slopes, which have already failed. Special attention has been paid

to the old slides, which could become re-activated. The excavation position and depth, drainage diversion across the hill, loading of the upper slope and valley, cutting of basal support, unscientific construction and land-use, deforestation, legacies from the past slope movement, relief, drainage, slope materials, etc. have been accounted for in the "Check-list". Sarkar (1999) has carried out such investigation through collection of direct field data from 65 sample sites as well as from secondary sources, and a map was prepared for identification of landslide-prone areas (figure 4.1).

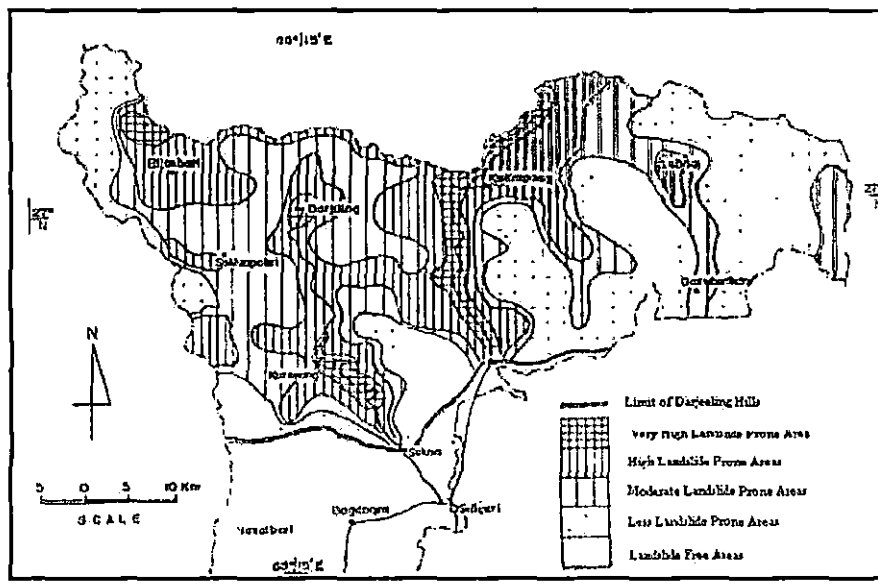

Figure 4.1: Landslide prone areas in Darjeeling hills (Source: Sarkar, 1999).

The map as represented in figure 4.1 shows some striking features such as some tracts of the study area, especially along the Tindharia-Paglajhora, Pankhabari, Rimbik-Lodhama, stretches along the river Tista, Bijanbari, in and around Darjeeling, Kurseong, Mahanadi, Ghum, Sonada, Sukhiapokri, etc., exhibit very high susceptibility. The ridges lower hills and the north facing slopes are showing moderate to moderately low susceptibility (figure 4.1).

Generally, deforested tracts, tea gardens, urban and other settle areas are more susceptible than the natural forested tracts. Geologically, the Daling rocks (phyllites, slates, schists, feldspar, etc.) and Damuda rocks (sandstones, shales etc.) are more susceptible to landslide. Table 2 shows the cases of major landslides, their topographic, geological and land use set-up in the study area.

Table 4.5: Landslides under different environmental set-up

Rocks types	No of Slide	Slope angle & Length	No of Slides	Land-use	No of Slides	Relief	No of Slide
Sandstone	12	> 50°& above 500m	30	Barren & rocky	0	Ridge	2
Shale	7	> 50°& less than 500m	15	Barren & talus	5	Spur (Upper)	27
Phyllite	39	40° – 50°& above 500m	53	Degraded grazing	16	Spur (Middle)	16
Schist	41	40° – 50°& above 500m	22	Grazing land	3	Spur (Lower)	6
Slate	13	30° – 40°& above 500m	3	Tea Garden	25	Valley (Upper)	8
Felspathic	6	30° – 40°& above 500m	15	Arable land	19	Valley (Middle)	19
Granite & Gneiss	24	20° – 30°& above 500m	14	Urban areas	14	Valley (Lower)	26
Complex	76	20° – 30°& above 500m	8	Semi-	16	Along Streams	76
Not Known	27	10° – 20°& above 500m	6	Rural	19	Complex	17
		10° – 20°& above 500m	3	Construction sites	73		
		Below 10°	1				

With the growth of tea and tourism industry in the area, the transport business has escalated tremendously. New roads are being constructed, new settlements are being created opened up and better infrastructural facilities are being provided in the older settlements. The National Highway 55, commonly referred to as the Hill Card Road was built by the British and is the main arterial link of all main hill towns as well as with the rest of the country. The other significant route is NH 31 that connects Siliguri and Kalimpong and the smaller Pankhabari Road (also built by the British) and the most recent route along Rohini built by the DGAHC in 2003. Since these roads have been constructed in the highly compressed and friable lithology prevalent in the region, it results in frequent occurrences of landslides.

Landslides are very common in the Hill Cart Road as well as along NH 31 towards Kalimpong between Likhuvir and 27 Mile. The roads are frequently blocked, sometimes for weeks together and the visitor are stranded and have to face many problems. The Hill Cart Road, connecting Siliguri with Darjeeling spans only 88 km but has been affected by flows,

slumps and slides at about 200 sites, (Basu and Starkel, 2000). This fear of landslips has adversely affected the tourist industry and residents of hill towns like Darjeeling, Mirik and Kalimpong, whose economy mainly rests on tourism, have begun to worry.

Effective insights can be drawn from a detailed study of the road section between Tindharia and Kurseong on the Hill Cart Road (NH 55). This region encompasses the Pagla Jhora environs that are notorious for its slump/ subsidence history that was first initiated in the 1950 landslides that took place in Darjeeling. Thereafter the incidence of slumping is a regular phenomenon and post 1990's, the Paglajhora slumps are causing complete disruption of transport and communication as shown in table 4.6.

Table 4.6: The Rate of Slumping at Lower Paglajhora

Years	Rate of slump (metre)	Years	Rate of slump (metre)
1983-1984	1.10	1987-1993	8.07
1984-1985	0.82	1993-2003	14.54
1985-1986	1.03	2003-2008	2.05
1986-1987	1.51	2008-2010	7.32

Source, S. Sarkar (2010)

4.4.4 Corrective and Preventive Measures

The stabilization on landslide and landslide prone areas must be executed according to a well throughout plan, which lists individual measures according to their urgency. This stabilization is usually difficult and expensive. Before going in for a corrective measure of the susceptible zone, one should have to consider the following points (Zauba & Manel 1982).

- The choice of the particular preventive measure change with the engineering geological conditions of the site.
- The choice of the techniques are to be applied for prevention of the slope movement which is also influenced by several aspects of economic character.
- The local conditions of the site play a dominating role in assuring the stability of potential slide prone areas.
- The importance of the project also influences the measures to be taken to tackle this problem
- It is also the task of designer to draw up a time schedule for implementing the various measures to be taken.

It is important to distinguish between those physical characteristics of a site that make landslide possible and the actual cause, i.e., the trigger mechanism that initiates movement through the increases of pore-water pressure. This is why landslide in the Darjeeling Himalaya almost perfectly correlates with the occasions of high intensity rainstorm. Potentially most unsuitable hill-slopes are also sensitive either to an increase in the load on the top or a decrease in the amount of support that they have at the toe. Recognizing which of these causative factor is in operation, can in itself suggest the cure.

Moreover, a long and often laborious process of investigation, static analysis and planning of the stabilization work should not delay the measures that obviously have to be taken as the treatment of an active landslide is always a context with time: a race against time. All corrective installations must be regularly checked and maintained. If regular maintenance for landslide protection measures has not adhered to, extensive and costly corrective measures may be useless and moreover, within a short period, new movement may start up. Thus the scheduled inspection and the maintenance work should be included in the overall planning of the corrective measures. Thus the principles to be observed in suggesting preventive measures would naturally depend upon the causes that lead to the failure of a slope. The following are the important preventive measures used against slope failures

1. Treatment of slope conformation
2. The drainage of landslides
3. Retaining walls and similar structures
4. Rock bolts and Rock Anchors
5. Stabilization of Landslide by Planting
6. Stabilization of landslides by piles and sheet-piles
7. The hardening of soils.
8. Restriction to settlement

1. Treatment of slope conformation

The slope of the ground surface plays an important role in causing slides of soil and talus material. Hence, theoretically the stability of slope can be increased by the reducing the slope angle, however, which is not possible to reduce the slope angle on natural slopes, except for small portions. This can be done at the cost of another portion, where the slope angle has to be correspondingly increased. The stability of a vulnerable slope may also be

increased either by reducing the volume at the head or by expanding the volume at the toe. Thus, the treatment of susceptible slopes should be done based on the local slope configuration and so it depends on the extent of the slope instability.

2. Drainage of landslides

The drainage plays the most crucial role in producing slope instability in the Darjeeling Himalayas. For the better representation the drainage of landslides may be further sub-divided (a) surface drainage, (b) sub-surface drainage and (c) prevention of percolation and seepage.

The **surface drainage** of any area is affected by landslides is generally uneven, hummocky and transgressed by deep fissures. In the depressions and fissures, water accumulate create wet- ground. Therefore, one of the first remedial measures is the surface drainage of landslide area. Although, surface drainage seldom sufficient to stabilize a slope which is in motion, but it can control landslides by drying ground surface.

First of all streams and temporary water courses are to be diverted from the treated area. Moreover, all springs issuing within the affected area, especially those at its head, must be contained and diverted away from the slide. For an immediate provisional diversion of flowing water and available pipes may be used. After partial stabilization of the landslides, open ditches of adequate dimensions and gradients are to be excavated for discharging rainwater. At the sometime, the ground surface is to be leveled and un-drained depressions filled along with all cracks so that a continuous run-off of surface water is ensured. During their operation, the grass cover must not be disturbed unnecessarily, because grass cover reduced the tendency of water to percolate down into the slope

Sub-surface drainage is one of the major causes of slope instability. Sub-surface drainage of an affected area should be dried up as an effective form of remedial treatment. The disadvantage of sub-surface drainage is that the drainage system cannot be designed until the geological and hydrological investigation has been completed. However, in talus slope, installation of deep drains may ensure protection against slides. For slopes occupied by rocks, drainage by drill holes may be installed as a preventive measure.

The stability of a hill slope can be increased by the prevention of the percolation from direct precipitation and run-off (Roy & Sen Sharma, 1967). Prevention of percolation may be ensured by covering up the portion of the slope to be protected by a layer of impervious

material like clay. However it would not be practicable to put such a layer for large areas of slope. It has been observed that turfed slopes remain stable up to a greater height than bare slopes (Sinha, Verma & Paul, 1975). Thus turfing should be encouraged on every bare soil slope. Afforestation is also beneficial as secretion form plant helps in formation of soil. The big roots, however, parking their way into the underlying material make the surface porous & allow quite a large amount of percolation. Hence, it is not entirely suitable. In fact, small shrubby undergrowth offer better protection against percolation. Rocky slopes with open joints can be made impervious by grunting although, it is an expensive method, but to protect Hill Cart Road near Tindharia, Paglajhora etc., it seems to be reasonable.

3. Retaining walls and similar structures

Retaining walls are sometime erected to bring greater stability to dangerous slopes, or to provide basal support to the existing landslide slopes. The construction of retaining walls requires a great deal of manual and skilled work and which is also highly expensive. Construction of retaining walls become necessary in slopes formed n clayey soil where it is difficult to ensure drainage due to the impermeability of the materials.

4. Rock bolts and rock anchors

The technique of stabilizing rock masses with rock bolts and rock anchors are found widespread in mining and tunneling. They are now also applied to the stabilization of soil slopes in association with other retaining structures (Zaruba & Manel, 1982). However, in the Darjeeling Himalayas, this method is used rarely because it is highly expensive and requires high technical skill.

5. Stabilization of landslides by afforestation

Slope movement generally disturbs the vegetation cover, including both the tree growth and grass cover. Afforestation of the disturbed slope in an important part of any corrective treatment, it is carried out during the latter stages of the work, invariably after at least some degree of stabilization of the landslides has been achieved. The planting of forest trees in landslide affected area should be undertaken after leveling and filling up the cracks. Tree planting, however, is an effective method of prevention only in the case of shallow street slides. Landslide with a deep scar cannot be controlled by development of vegetation, although this has an effect on slide-area by reducing infiltration of surface water. Thus, it is more advantageous to plant deciduous trees than to plant conifers which have a

comparatively low rate of transpiration. Sykora (1961) studies the influence of vegetation on sliding movements and suggested that in selecting suitable trees for sliding slopes, their effects on the structure of the soil should also be taken into consideration.

6. Stabilization of landslides by piles and sheet pile walls

Walls of piles often been used in place of retaining walls. The main advantage of piles is that this can be installed prior to excavation. Little place is needed and therefore, the amount of excavation work required is reduced. Piles decrease the danger of slope movements and also provide and effective means of stabilization. Protection against slope failure by piles and sheet pile wall have been found only a few places.

7. Hardening of soil

The impermeable soil often falls to stabilize the slopes by drainage. In such situation, method borrowed from foundation engineering and known as hardening of soil may be applied such as Electro-osmosis and Thermal Techniques (Litvinov 1955). These methods are expensive and highly technology centric.

8. Restriction to settlement

For a successful management of the susceptible tracts under study, it is wise restricted the existing population to the geologically and topographically more stable part in the hills setting apart the unsuitable areas which have to be carefully demarcated for afforestation by quick growing trees and grasses.

4.5 Soil Erosion

The rapid soil erosion has been a problem since man began cultivating the land. Natural soil erosion is the rate at which the land would normally be eroded without disturbances of human activities. Accelerated soil erosion is the increased rate of erosion that often arises when man alters the natural system by various land use practices. Thus, the problem of soil erosion is essentially the problem of accelerated erosion. Generally speaking, the soil particles are bonded to humus and sesquioxides gels that impart shear strength and resistance to movement. Stability is further aided by trees and shrub roots extending through the soil mantle into crevasses of bedrocks, acting as anchors. Hence in a well stock woodland with forest floor of several centimeter thick, surface erosion is less than 1mm/1000 years (Jenny, 1980), which is even less than that of the rate of soil formation. There are many

standard measures for assessing soil erosion of which sediment yield (Holeman, 1968) and soil loss (Wischmeier and Smith, 1965) are most widely used.

The Darjeeling Himalaya was truly a nature's domain, till the beginning of the nineteenth century. With very scanty population, these hilly tracts were densely covered by natural vegetation and thereby, had no major soil erosion problem. However, with the advent of British occupation, along with tea plantation, extensive heedless deforestation, unscientific terrace cultivation, haphazard construction work, inadequate drainage has led to the establishment of vicious cycle of soil degradation.

Methodology

The soil erosion of Darjeeling Himalaya has been assessed by the quantitative evaluation of the following diagnostic criteria (i) the climatic erosivity (R); (ii) the soil erodibility (K); (iii) the topographic erosivity (L.S) and (iv) the biological erosivity (C.P) based on the existing standard literatures and rating tables (Wischmeier and Smith, 1965; Fournier, 1972; FAO/UNEP, 1978; Arnoldus, 1980; Olson, 1984; Sarkar, 1987). The first three diagnostic criteria involved natural/physical factors and are used in assessing natural vulnerability. The biological factors include vegetation, land use and human interferences which permits the evaluation of actual and/or predicted erosion. The method itself is semi-quantitative in nature as rating value is assigned to each group of these factors in such a way that each group can influence the final result according to its own importance.

A detail assessment of soil loss by water erosion has been appended as "unit area" example from a site near Norbong Tea Garden. The quantitative assessment of the various diagnostic criteria has been described below:

12

i) The Rain erosivity or, $R = \sum_{1} Pr^2 10_{mm}/P$ 4.1

where, Pr_{10mm} is the average monthly rainfall of months having >10mm rainfall i.e., 389.88 mm, P is annual rainfall in mm i.e., 3140.0 mm and R is the rain erosivity i.e., 580.92.

ii) The Soil erodibility (K), has been estimated based on the USLE Nomograph. where, sand is 10.13%, silt and very fine sand content is 61.56%, organic matter content is 2.91%, soil structure has been identified as coarse granular and soil permeability has been identified as moderate to rapid. The K value has been estimated to be 0.28.

iii) The topographic erosivity (L.S) = $\sqrt{L/100(0.136+0.0097.S+0.0139.S^2}$ 4.2

Where, L is length of slope in meter i.e., 332 m, S is slope gradient in percent i.e., 28% and topographic erosivity has been estimated to be 37.533.

iv) The biological factor or C.P has been estimated based on the assigned parametric rating value i.e., 0.28 based on the table (4.6)

The potential soil erosion/loss may be assessed based on the following empirical equation:

Potential loss = RxKxL.S 4.3

Thus the potential soil loss has been estimated to be metric tons/hectare/year

The predicted or actual soil loss from the site may be assessed from the following equation

The Predicted/Actual Soil Loss = RxKxL.SxC.P 4.4

Thus, the actual soil loss from the sample site has been estimated to be 1709.41 ton/h^{-1}/y^{-1}.

4.5.1 Assessment of soil erosion

The assessment of soil loss has been done based on the quantitative estimation of the physical factors like rainfall erosivity (R), the soil erodibility (K), topographic erosivity (L.S) and biological erosivity (C.P) following the equation 4.4. An iso-erodent map has been prepared by interpolating the soil loss value estimated at 62 different sites within Darjeeling Himalaya (figure 4.2). It is evident the south-central part of south facing slopes near Tindharia, Paglajhora and lower Tista valley have been experiencing exceptionally high rate of soil loss estimated to be above 5000 tons/h^{-1}/y^{-1} or, above 300 mm/y^{-1}. Such unprecedented high rate of soil loss is perhaps caused by large scale mass movements that occurred in this area. Unscientific human occupation vis-à-vis land use, slope cuttings following heedless deforestation further aggravates the problem. The south-east and north-western parts of Darjeeling hills recorded low to negligible soil loss rate which is estimated to be less than 5 tons/h^{-1}/y^{-1} or, below 0.3 mm/y^{-1}. These areas in fact, are the least affected by human interferences and are mostly under the cover of natural forest.

In general, it is observed that the area traversed by transport network, settlements, agriculture use, tea garden and degraded pasture and forest yielded higher rate of soil loss. Even the urban areas of Darjeeling, Kalimpong and Kurseong also contribute considerable amount of soil loss. However, for the better understanding of the geographical distribution of soil erosion, the following classes of soil loss have been identified and shown in figure 4.2.

Table 4.7 Rating table for assigning parametric value for C.P factors

No	Major land use type	Coverage (%)	Rating Value
1	Virgin forest with thick vegetal matter on the surface	100	< 0.0005
2	Natural vegetation cover i.e., forest, bush, permanent pasture	100	0.001 - 0.0005
3	Natural vegetation cover i.e., forest, bush, permanent pasture	50 - 100	0.05 - 0.001
4	Tea garden	100	0.05
5	Degraded forests, rough pasture of perennial cover	> 30	0.05 - 0.5
6	Degraded or semi-degraded tea garden	± 50	0.1
7	Row crops, inter-tilled crop	< 30	0.05 - 0.8
8	Terraced cultivated field	20 - 50	0.05 - 0.8
9	Root crops, i.e., ginger, cardamom, potato etc.	± 50	0.9 - 1.0
10	Bare soil, cultivated fallow	0	1.0

Source: Modified from FAO/UNEP, 1978; Sarkar, 1987, 1993

Class I : Exceptionally high soil loss susceptible zone having estimated soil loss of above 5000 tons/h^{-1}/y^{-1} or, above 300 mm/y^{-1}.

Class II : Very high soil loss susceptible zone having estimated soil loss between 2500 to 5000 tons/h^{-1}/y^{-1}.

Class III : High soil loss susceptible zone having estimated soil loss between 500 to 5000 tons/h^{-1}/y^{-1}.

Class IV : Moderate soil loss susceptible zone having estimated soil loss between 50 to 500 tons/h^{-1}/y^{-1}.

Class V : Low soil loss susceptible zone having estimated soil loss between 5 to 50 tons/ h^{-1}/y^{-1}

Class VI : Very low susceptible zone having estimated soil loss between 1 to 5 tons/h^{-1}/y^{-1}

Class VII : None to negligible susceptible zone having estimated soil loss less than 1tons/ h^{-1}/y^{-1}

4.5.2 Strategies for soil conservation

The aim of soil conservation is to maintain soil loss below a threshold level which theoretically, permits the natural rate of soil formation to keep pace with the rate of soil erosion (Morgan, 1979). Of the various soil conservation measures effective for the present purpose may be divided into three major groups: (a) agronomic measures, (b) soil management and (c) mechanical measures.

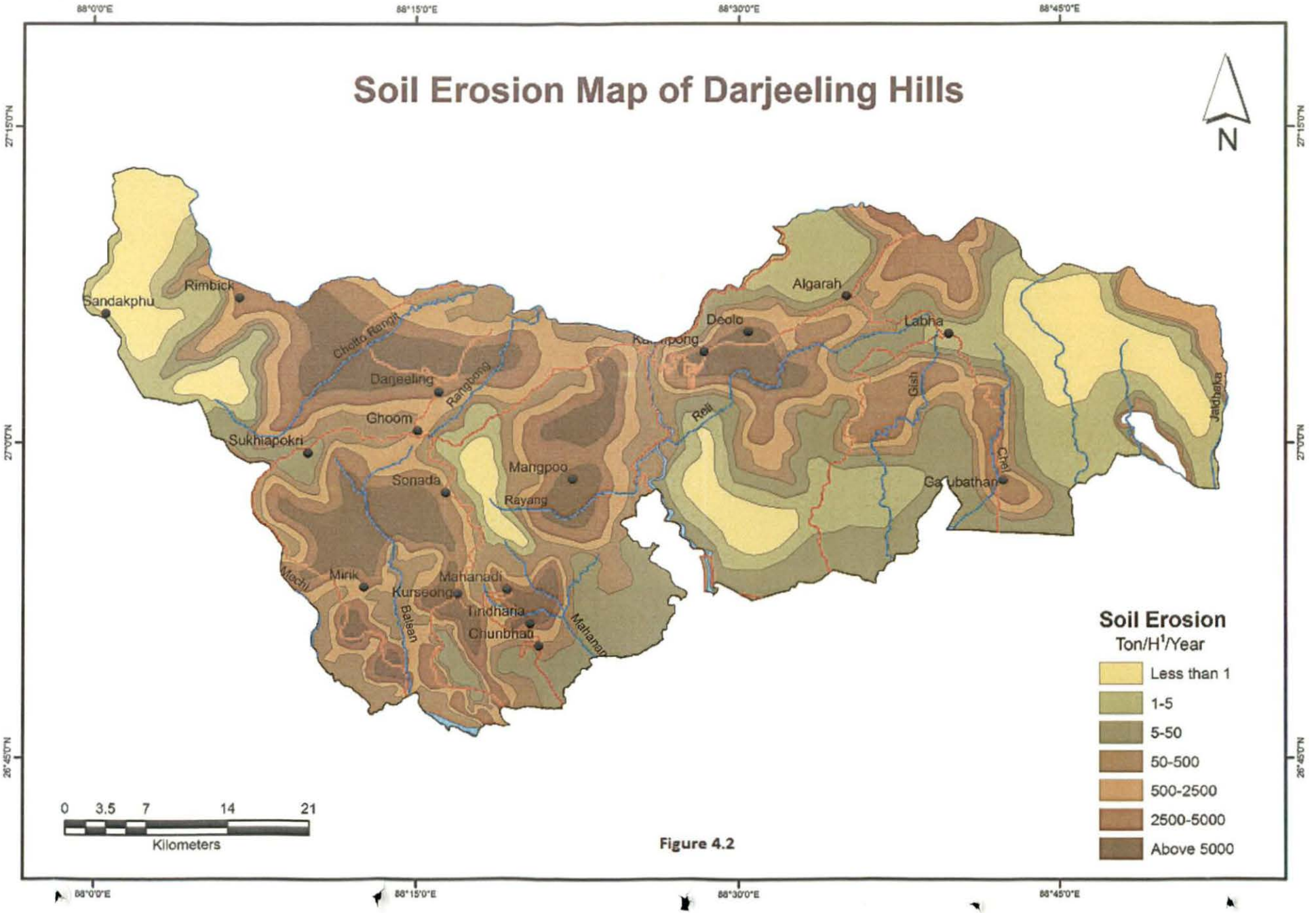
Soil Erosion Map of Darjeeling Hills
N
88°0'0"E
88°15'0"E
88°30'0"E
88°45'0"E
27°15'0"N
27°0'0"N
26°45'0"N
Sandakphu
Rimbick
Chotta Rangit
Darjeeling
Rangbong
Ghoom
Sukhiapokri
Sonada
Mangpoo
Rayang
Mirik
Mochi
Mahanadi
Kurseong
Balasan
Tindharia
Chunbhati
Mahanadi
Kalimpong
Deolo
Algarah
Labha
Reli
Gish
Chel
Gayabathan
Jaldhaka
0 3.5 7 14 21
Kilometers
Soil Erosion
Ton/H¹/Year
Less than 1
1-5
5-50
50-500
500-2500
2500-5000
Above 5000

Figure 4.2

(a) Agronomic measures

Plants differ in their effectiveness in protecting soil from erosion because of differences in their density and morphology. Generally, row crops are least effective and give rise to the more serious erosion hazards. In designing a conservative strategy based on agronomic measures, row crops must be combined with protection effective cover crops in a logical cropping pattern. Of the various agronomic measures, crop rotation, cover crops, strip cropping, and mulching are important and are recommended as protective measures against soil erosion in the Darjeeling hill area.

(b) Soil management

The aims of soil management are to maintain the fertility and structure of the soil because fertile soil results in high crop yield, good plant cover and therefore, in conditions which minimize the erosive effects of rain drops and run-off. In Darjeeling hilly area, a good fertile soil can be achieved by applying organic matter because, it improves the cohesiveness of the soil, increases its water retention capacity and also promotes a stable aggregate structure.

(c) Mechanical methods

The mechanical methods are used widely to control the movement of water and the decision which is to be adopted, depends on whether the objective is to reduce the velocity of run-off and increase surface water storage capacity or safely dispose off excess water. All mechanical methods should be employed in conjunction with agronomic measures. Of the various mechanical methods of soil conservation contouring, contour bunds, terraces and designed water-ways are recommended for the Darjeeling hills.

4.5.3 Proposed soil conservation plan for the Darjeeling Himalaya

Soil conservation strategies are aimed at reducing erosion to a tolerance level. Theoretically, such level is that at which the rates of soil loss and soil formation are balanced. However, in practice, it is difficult to recognize when this balance state exists and for this reason an alternative definition of an acceptable level is adopted i.e., soil fertility maintenance for a period of 20-25 years (Sarkar, 1993). A mean annual soil loss of 1.3kg/m^{-2} is generally accepted as the maximum permissible level but even lower value of 0.2 to 0.5 kg/m^{-2} are recommended for particularly sensitive areas like Darjeeling hills (Hudson, 1971).

The Darjeeling Himalaya exhibits higher erosion rate due to adverse environmental condition and on the other hand, favourable environmental conditions promote higher rate of soil formation. Keeping these in mind Sarkar in 1993, proposed a target of 0.5 kg/m^{-2} or, 5 tons/h^{-1}/y^{-1} of soil loss may be accepted as the uppermost limit.

Table 4.8 Proposed soil conservation plan for Darjeeling hills

No	Erosion Zone	Soil loss (kg/m^{-2}/y^{-1})	Recommended conservation measures
1	Zone I	< 0.5	No conservation measures are to be required
2	Zone II	0.5 - 5.0	Crop rotation, cover crop, strip cropping, contouring, contour bunds along with suitable waterways are recommended.
3	Zone III	5.0 - 50.0	Cover crops, mulching, organic matter application, contouring, retention and bench terraces, diversion channels, terrace channels and grass waterways etc. conservation measures are recommended.
4	Zone IV	50.0 - 250.0	Cover crops, mulching, organic matter application, bench terraces, suitable waterways along with some slope stabilization works.
5	Zone V	> 250.0	All possible agronomic, mechanical and soil management methods should be adopted simultaneously specially, cover crops, mulching, ladder terraces, adequate drainage and slope stabilization methods are recommended.

Although, the entire Darjeeling hilly area possesses high erosivity risk, yet an attempt has been made to categorize them under different classes depending on their degree of vulnerability. Thus with reference to figure 4.2 the proposed level of conservation measures needed to protect soil against degradation has been depicted in table 4.7.

4.6 Conclusion

The forest clad mountain of the Darjeeling Himalaya reveals man's heedless silvicultural activities that triggered mass movements and accelerated soil erosion along the hill slopes and valleys. Deforestation via-a-vis environmental degradation in the Darjeeling hills indeed plays the decisive role in contemporary increased frequency and magnitude of hazards. Vicious cycle of degradation has already been established in the sub-Himalayan watersheds. Perhaps, the only possibility to save the habitable environment lies into the pro-active watershed management. It is thus, our imperative duty to inform the people living in

threshold areas (prohibitive/restrictive zone) categorically about the hard reality of possible hardship during the different stages of watershed management processes.

The analysis of landslide in the Darjeeling Himalaya reveals that each of the slides has its own characteristics and is not induced by any single factor. Of the various factors, water has the most deleterious effect. Some of them have admittedly been caused by toe erosion of the drainage elements and the others due to the effects of unscientific and unplanned human interferences. The choice of remedial measures thus, should be made after careful analysis of the causative factors. The design of the preventive structures should depend on the geomorphologic, geo-hydrological and geo-technical framework of the site.

In view of the ever-increasing problem of landslide in Darjeeling Himalaya, man must be aware of the possible dangers that he is inviting, due to his careless dealing with nature. It is true that one has to make room for the growing population and in this pursuit he has to utilize every piece of land available. But the precautions that have to be adopted should not be neglected. In many places revetments are not maintained properly, the weep-holes are choked, the drains are dumped with garbage, restricting free drainage of water.

Moreover, the present land-use system should be properly evaluated. The construction of high-rise buildings should be stopped immediately. The people should be provided with alternative source of energy, may be through mini-hydel project, tapping the perennial springs, and perhaps this can be the only option to prevent them from cutting down more trees. It is of utmost priority to develop mass awareness among both local people and tourists, so that they become aware of the possible dangers that they are inviting by interfering with the natural laws.

Among the various conservation measures, the agronomic measures should be given preference because they are less expensive and deal directly with the reducing raindrop impact, increasing infiltration, reducing run-off volume and decreasing wind and water velocities. It is also easy to fit them into an existing farming system. The mechanical measures are largely ineffective on their own because they cannot prevent the detachment of soil particles. Their main role is in supplementary to agronomic measures, being used to control the flow of excess water.

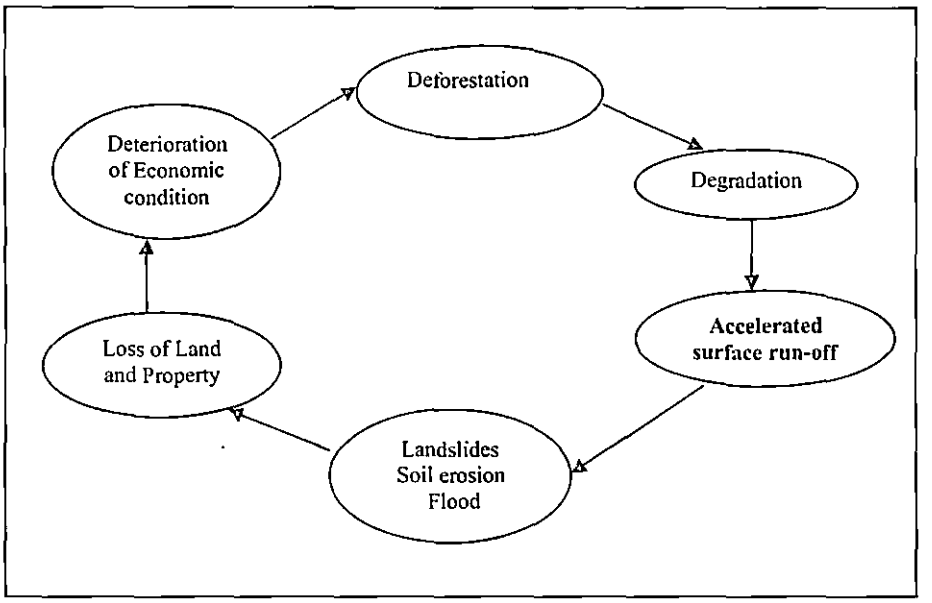

Figure 4.3 Deforestation-Flood Vicious Cycle: A Case of the Darjeeling hills

The conservation schemes must be well designed to reduce soil erosion effectively and their ultimate success depend on how well the measures are implemented. The willingness and the socio-economic background of the farmers and planters to adopt the techniques required by a particular strategy is also very important. Equally important is the strategy proposed should be clearly related to the problems involved. Hence, conservation design must be logically follow a thorough assessment of erosion risk of the area concern.

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