Chapter - III

SOIL LOSS BY WATER EROSION

A. INTRODUCTION

The rapid soil erosion has been a problem since man began cultivating the land. Natural erosion is the rate at which the land would normally be eroded without disturbances by human activity. Accelerated erosion is the increased rate of erosion that often arises when man alters the natural system by various land-use practices and as such it falls squarely into the subject of environmental management. Thus, the "Problem of soil erosion" is really the problem of accelerated erosion, (Hardin 1968, Eckholm 1976). The rate of soil erosion varies greatly from place to place and from time to time depending on a number of environmental variables. There are many standard measures for measuring the rate of erosion of which sediment yield (Holeman 1968, Douglas 1976) and soil loss (Wischmeier and Smith, 1965) are most widely used.

The Darjiling Himalaya was truely a nature's domain, till the British occupation. These steep hill slopes and valleys with a very scanty population (approximately 100 persons during 1800 in and around the present Darjiling town) was densely covered by natural vegetation and thereby, had no major soil erosion problem. The cutting of trees, creating open-land mainly for tea plantations and construction curtails transpiration and the unspent water feeds the run-off and infiltration. It invites the drying up of many springs, accelerated soil erosion, mass-movements and landslips.

1. Aims

An attempt has been made in this chapter to apprehend the major processes and mechanisms involved in soil erosion. The author has also tried to assess the potential and predicted soil loss quantitatively in order to recommend the best possible strategies for soil-erosion control in the study area. Finally, a formula for proposed conservation plan has also been presented to protect the extremely vulnerable soil against erosion.

B. ASSESSMENT OF SOIL LOSS BY WATER EROSION

The assessment of erosion hazard is a specialised form of land resource evaluation, the objective of which is to identify those areas of land where the maximum sustained productivity from a given land-use is threatened by excessive soil loss. The assessment aims at dividing a land area into regions with similar intensity of erosional hazard, as a basis for planning soil conservation work (Sarkar 1987). The potential soil loss is the diminution of current or potential productivity, resulting in the action of physical factors such as climate, soil and topography but without the intervention of biotic factors. Biological activities, however, modify the natural/potential soil loss and lead to the actual rate of soil loss (Requier 1980).

1. Diagonstic Criteria

There are innumerable factors that affect the rate of soil loss. Quantification of some factors may be possible readily, such as climate, topography, soil etc. While, others like land management and human interference may not be readily available (Riquier 1980). However, when a criteria or factor is lacking, it is possible to substitute it by another (FAO/UNEP, 1978). The factors affecting soil loss may be placed into four groups :

i) Climatic Factor (R);

ii) Soil Factor (K);

iii) Topographic Factor (L.S.) and

iv) Biological Factor (C.P.)

2. Methodology

The soil loss by water erosion of the study area has been assessed by the quantitative evaluation of the various above mentioned diagnoistic criteria, based on the existing standard literatures and rating tables (Wischmeir and Smith 1965, 1978, Fournier 1972, FAO/UNEP 1978, Arnoldus 1980 and Riquier 1980) with necessary modifications. Rating value is assigned to each group of these factors in such a way that it can influence the final result according to its own importance (FAO/UNEP 1978). A detailed assessment of potential and predicted soil loss has been put forward as an example of 'unit area'. The site near the main gate of St. Paul's School, Jalapahar has been chosen for this purpose and the following diagonistic criteria have been employed for the assessment:

i) Climatic Erosivity

$$R = \sum_{1}^{12} Pr^2{}_{10mm}/p. \qquad ...3.1$$

where $Pr^2{}_{10mm}$ is the average monthly rainfall of months having >10 mm rain in a single rainfall event i.e. 312.0; P is the annual rainfall in mm i.e. 3272 mm; R is the climatic erosivity i.e. 357.0.

ii) Soil Erodibility (K), has been calculated based on the USLE Nomograph, where sand (0.10 to 2.00 mm) content is 48%, silt and very fine sand (0.002 to 0.10 mm) content is 32%, organic matter content is 3.4%, soil structure has been identify as coarse granular; soil permeability is slow and hence the K value has been calculated to be 0.22 (Fig.3.2).

iii) Topographic Erosivity (L.S.)

$$L.S = \sqrt{\frac{L}{100}}\,(0.136 + 0.0097.S + 0.0139.S^2) \qquad \ldots\ 3.2$$

where L is the length of the dominant slope in meter, i.e. 650 m, S is the slope gradient in % i.e. 17% and L.S is the topographic erosivity, i.e. 14.81.

iv) Biological Factor

C.P. has been calculated based on the assigned parametric rating value i.e. 0.08.

The potential and predicted soil loss by water erosion has been assessed from the following empirical formula :

i) Potential Soil Loss = R.K.L.S ...3.3
i.e. 1163.18 tons/h^{-1}/y^{-1}.

ii) Predicted/Actual Soil Loss = R.K.L.S.C.P ...3.4
i.e. 93.05 tons/h^{-1}/y^{-1}.

a. Climatic Erosivity/Rain erosivity

Soil erosion is closely related to rainfall, partly through the detaching power of raindrops striking the soil surface and partly through the contribution of rain to run-off (Morgan 1979). The erosivity of a rainstorm is a function of its intensity and duration, and of the mass, diameter and velocity of raindrops. Based on the work of Laws and Pearsons (1943) Wischmeier and Smith (1962) obtained the equations :

$$K.E. = 13.32 + 8.78 \log. 10^{I} \qquad ...3.5$$

where I is the rainfall intensity (mm/h^{-1}) and K.E. is the Kinetic energy ($Jm^{-2}mm^{-1}$).

But, the methods require a continuous rainfall data which are not available from the present recording stations, thus, the investigator could not use the method .

An index that requires little imput of data and that can easily be calculated effectively within the limitations of insufficient rainfall records is that of Fournier's index (1972).

$$R = Pm^{2}/P \qquad ...3.6$$

This index is very popular due to its simplicity, but a correlation study between the Fournier's index (Equation 3.6) and EI_{30} for 164 stations in U.S.A. and 14 in West Africa show that the Fournier's index can be hardly used to approximate the R factor of the USLE (Arnoldus, 1980).

The FAO/UNEP experts, (1978) have tried to modify the Fournier's index (Equation 3.7) in such a way that not only the month that receive the highest rainfall but also the average monthly rainfall plays the critical role in the evaluation of the R factor such as :

$$R = \sum_{1}^{12} p^2/P \qquad ...3.7$$

where p is the monthly rainfall and P is the annual rainfall in mm. But, in this index only the total amount of rainfall plays the important role while, another very important factor i.e. the rainfall intensity has less part to play. To overcome this problem, Sarkar (1988) has tried to modify the Fournier's and FAO/UNEP index (Equation 3.8) in such a way that the amount of rainfall as well as its intensity can play the role simultaneously in the evaluation of R factor, in studying the rain erosivity of the Darjiling Himalaya, such as :

$$R = \sum_{1}^{12} pr^2{}_{10mm}/P \qquad ...3.8$$

This equation suits best as an effective alternative of the existing standard index for the evaluation of rain erosivity (R) index for the study area.

An iso-erodent map of the study area has been prepared based on interpolation method (Fig.3.1). Broadly speaking, the northern and western parts of Darjiling town show a comparatively low R value while the eastern and southern part exhibit a higher rate of R value. However, for a better understanding of the geographical distribution of rain-erosivity, the following classes are put forward :

<u>Class I</u> : High rain-erosivity zone, (R= >400) found along the eastern spur of Katapahar-Jalapahar ridge.

RAIN – EROSIVITY MAP OF DARJILING TOWN AND ITS ENVIRONS

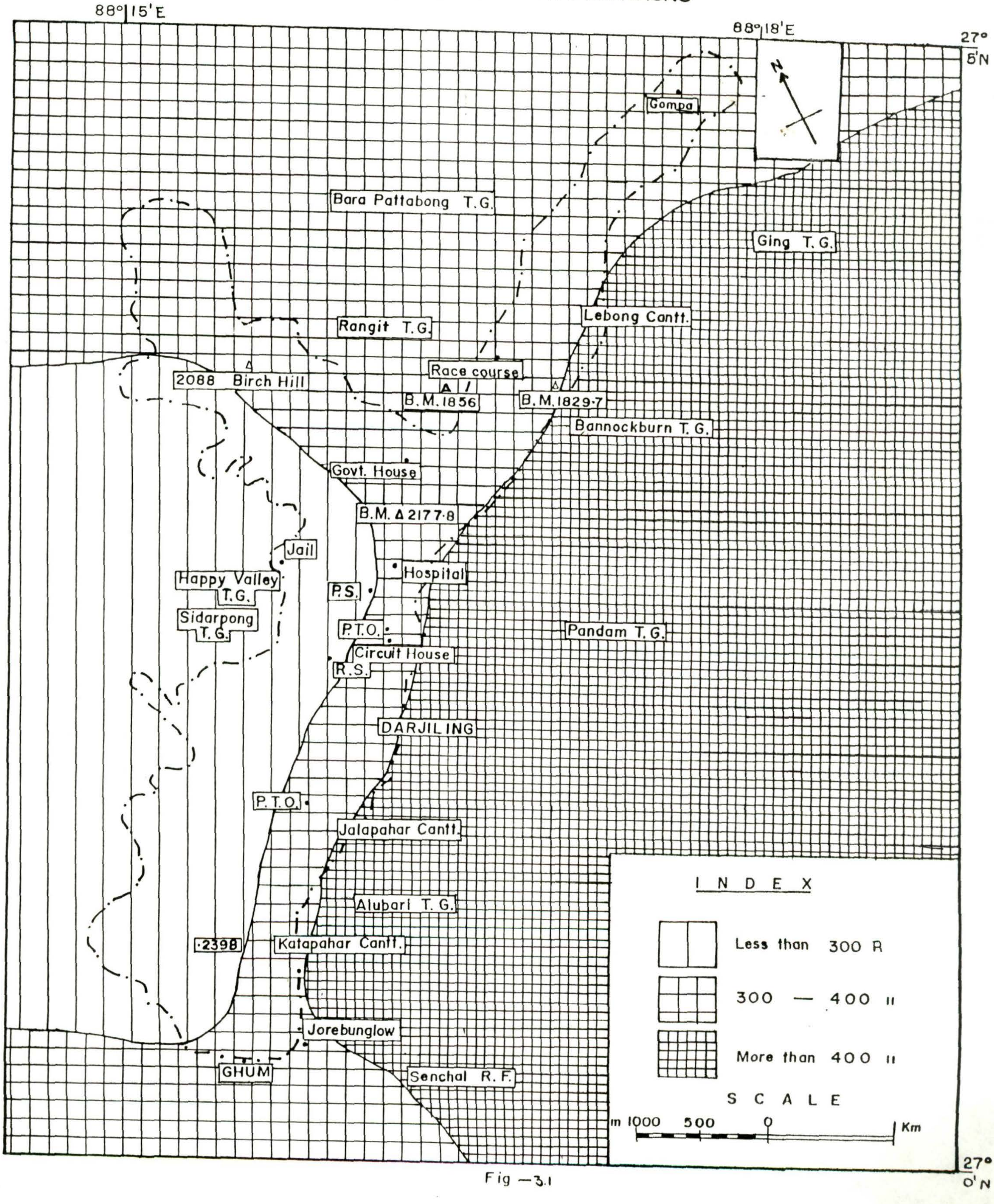


Fig —3.1

Class II : Moderate rain-erosivity zone, (R= 300-400) noticed along the southern spur of Birch Hill and Lebong ridge upto the Tukvar spur.

Class III : Low rain-erosivity (R= <300) has been identified in and around the western spur of the town along the Happy Valley tea garden area.

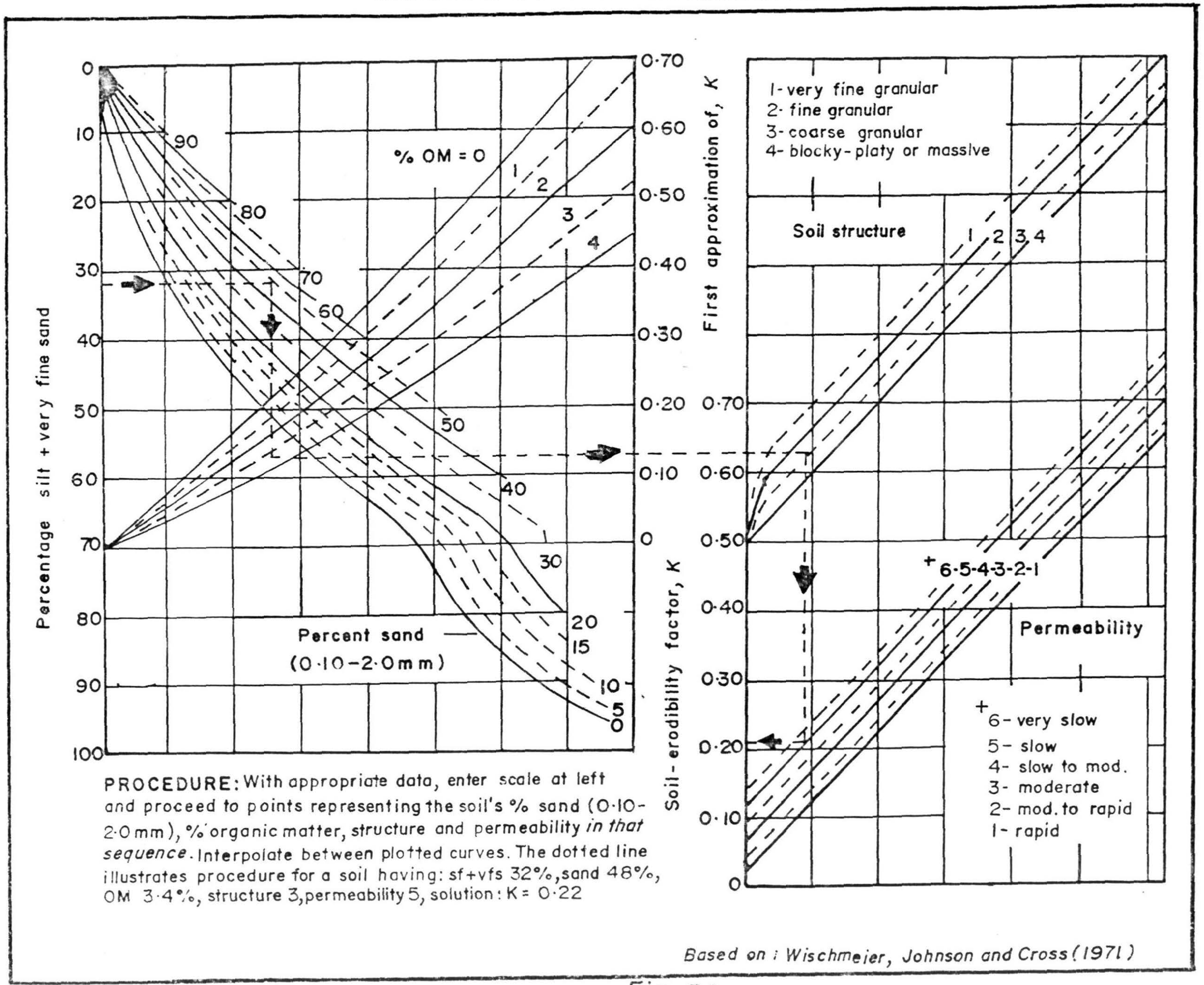
b. Soil Erodibility (K)

Soil erodibility defines the resistance of soil in relation to both detachment and transport. It depends on the factors like texture, structure, permeability and organic matter content. For the assessment of soil erodibility in and around Darjiling town, the investigator has applied the soil erodibility nomograph (Fig.3.2) of the USLE (Wischmeier, Johnson and Cross 1971), based on the following :

(i) the percentage of sand, silt, and very fine sand; (ii) the organic matter content in percent; (iii) the soil structure and (iv) the profile permeability.

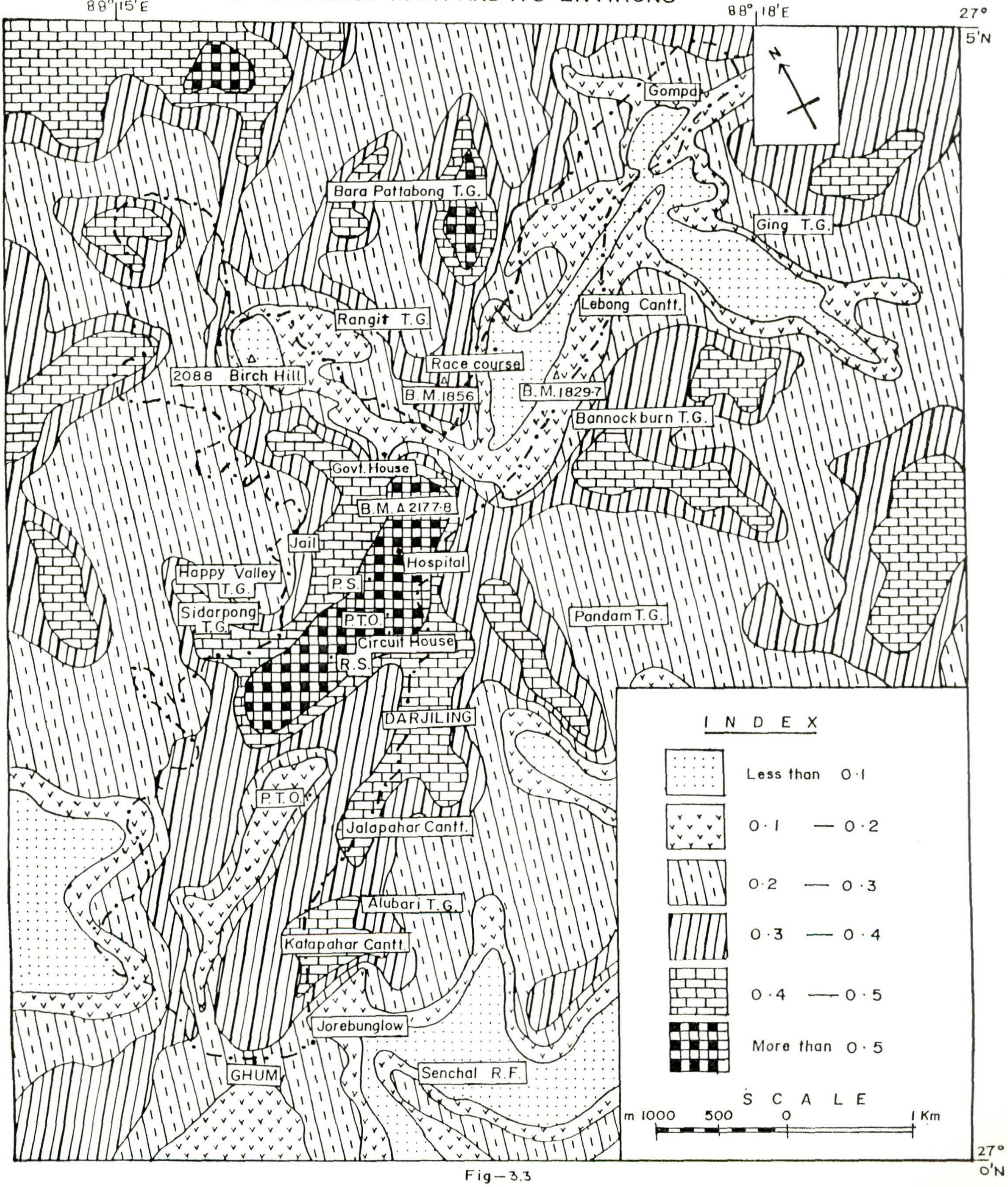
A soil erodibility map has been prepared based on the available K value (Fig.3.3). It has been found from the analysis that the K value varies from 0.04 to 0.68. A very low soil erodibility (<0.1) has been detected along the south-eastern, south-western and along the ridges of Jorebunglow-Katapahar-Jalapahar-Birch Hill and along the Lebong spur, which are densely covered by natural forests. While, the extreme north-eastern, east-central and the core zone of the town possess a relatively high soil erodibility, (K= >0.5). Along the eastern, western and the northern

SOIL ERODIBILITY NOMOGRAPH



Fig–3.2

SOIL ERODIBILITY MAP (K) OF DARJILING TOWN AND ITS ENVIRONS



Fig—3.3

spur of the Darjiling ridge the soil erodibility is moderate, where the K value varies from 0.1 to 0.5 (Fig.3.3).

c. Topographic Factors (L.S)

The topographic factor specially of slope gradient and its length play an important role in the assessment of soil loss by water. Soil erosion would normally be expected to increase with the increase in slope steepness and length as a result of respective increase in velocity and volume of surface run-off.

To evaluate the topographic factor (L.S.) of soil loss, the author has employed the soil Erodibility Nomograph (Wischmeier, Johnson and Cross 1971) which is based on the following equation :

$$L.S. = \sqrt{\frac{L}{100}} \, (0.136 + 0.0097.S + 0.0139.S^2 \qquad ...3.9$$

Based on the calculated L.S value, a topographic erosivity map has been drawn (Fig.4.4). The topographic erosivity value (126.54) has been found to be highest along the eastern slope of the Jalapahar-Katapahar ridge, while, the lowest (5.97) has been identified on the top of the Jalapahar ridge (near the old military meteorological observatory). Generally speaking, the Senchal-Jorebunglow-Katapahar, Jalapahar-Birch Hill-Lebong ridge exhibit a relatively low to moderate L.S factor which varies from 20 to below 10, mainly due to less slope steepness. While, the L.S factor is found to be moderate to high (20-80) along the spurs and valleys of the study area. Very high topographic erosivity (>80) has been identified along the eastern slope of the Jalapahar-Katapahar ridge, along the valley of Rangnu Khola, and along the northern slope of

TOPOGRAPHIC EROSIVITY MAP (L.S.) OF DARJILING TOWN AND ITS ENVIRONS

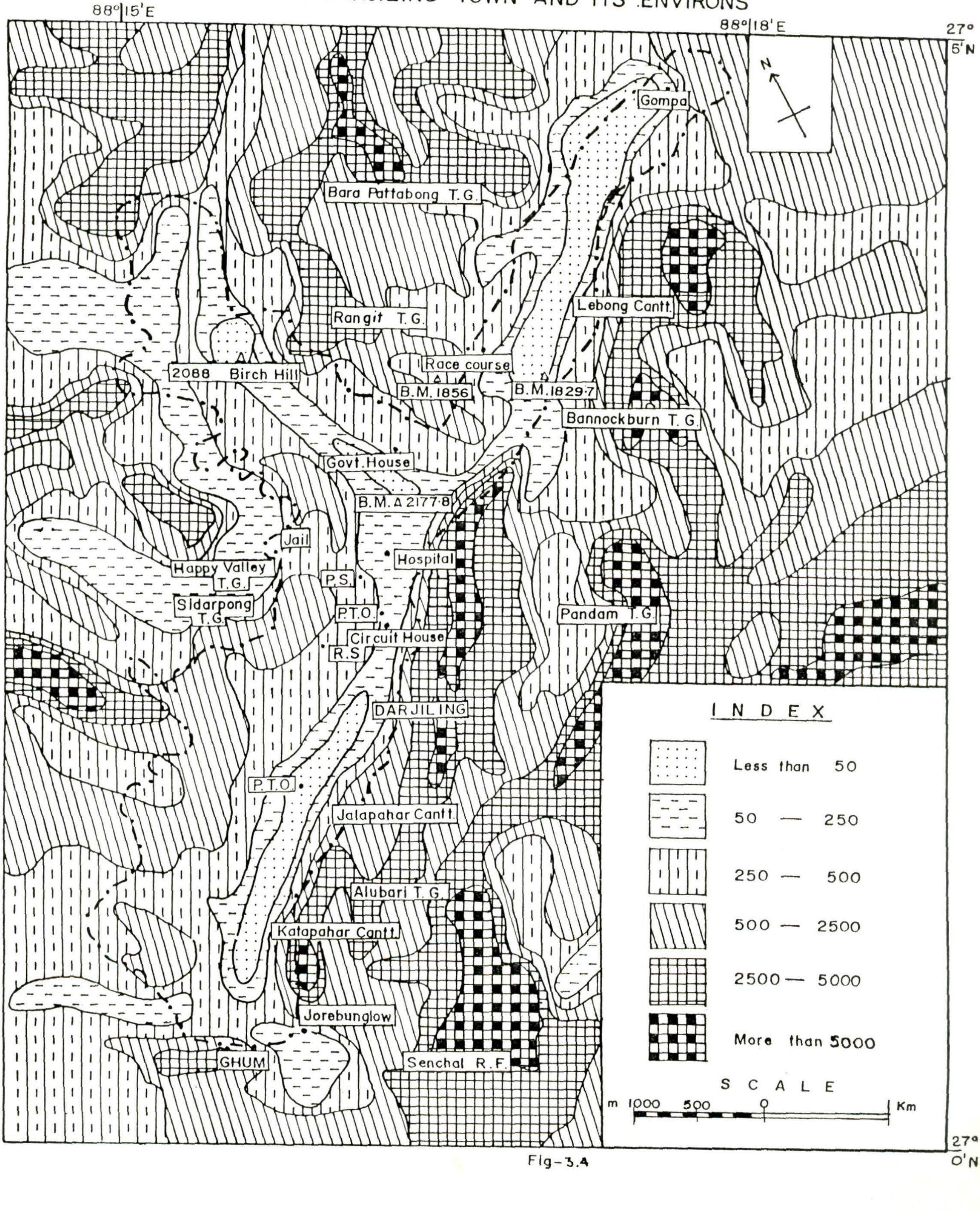


Fig-3.4

the Birch Hill (Fig.4.4).

d. Biological Factors (C.P)

The biological factors, particularly land-use, soil management and cultural practices have many and varied effects and the generalisation and quantification of these effects of an area are often difficult and complicated (FAO/UNEP 1978). To determine the biological factor (C.P.) along with human interference of soil loss, the investigator has tried to quantify the same depending on the assigned parametric rating values of each different types of land-use (Table 3.1). Since, the land-use types and patterns, ultimately depend on the complex physio-biological processes and it reflects, the human level of interference in the natural eco-system (FAO/UNEP 1978). A biological erosivity (C.P) map has been prepared (Fig.3.5) from the available C.P index, which also includes C and P co-efficients of the USLE (Sarkar 1987).

It has been found from the map, that the C.P co-efficient is directly dependent on the existing land-use pattern. The highest C.P has been found in several small pockets along the north-western part of the study area, where it varies from 0.5 to 0.8, due to extensive urban and other human activities. Patches of very high C.P, have also been found along the eastern spur of the Jalapahar-Katapahar ridges i.e. around Alubari busti, Bhutia busti, Manpari busti and Toongsoong. Here vulnerable slopes have been most extensively utilized by low to very low income group of urban people. A low C.P value (<0.01) has been noticed along the forested tracts of the eastern and western valleys and along the Senchal-Katapahar-Jalapahar-Birch Hill and Lebong spur. The urban centre is

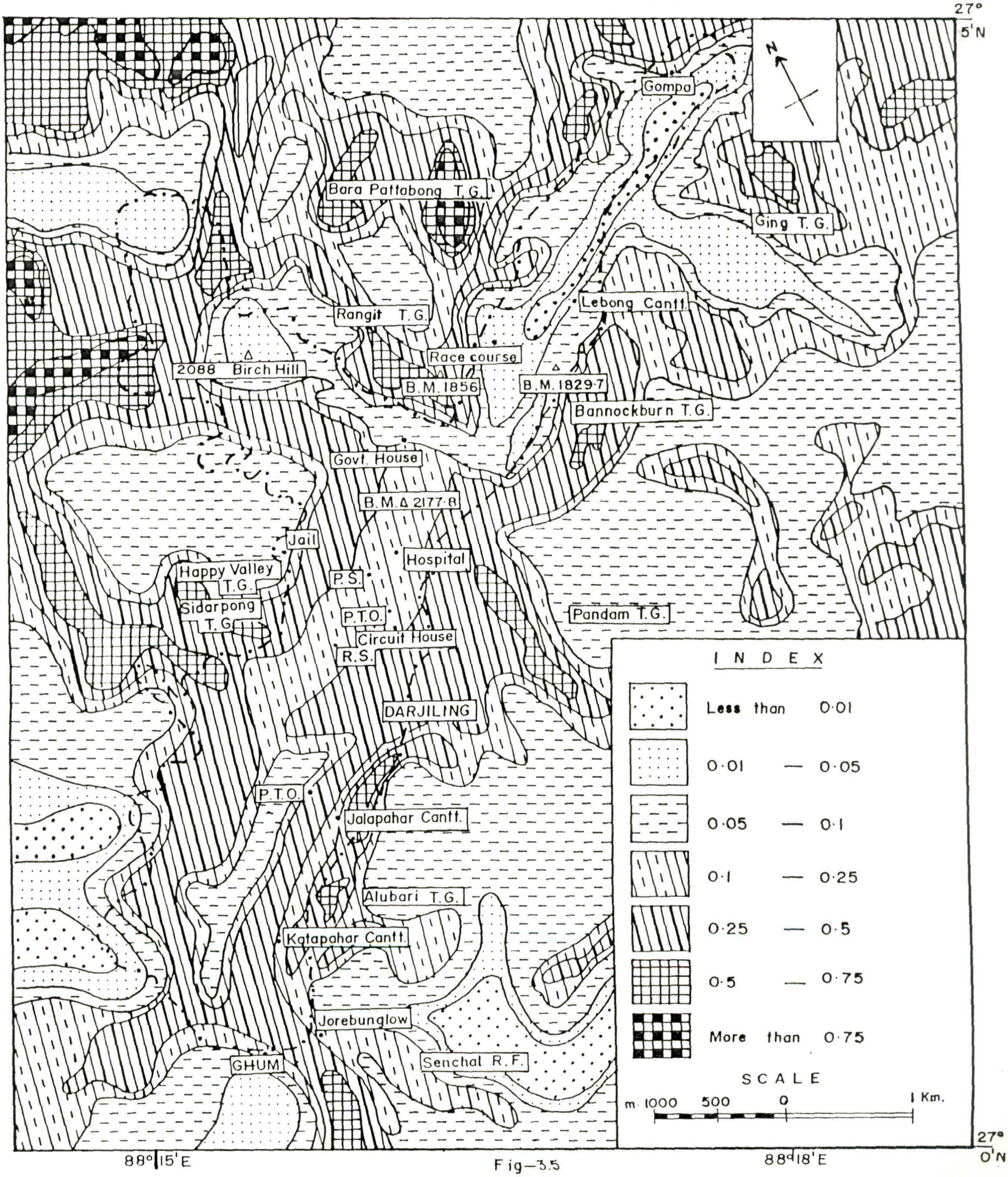
Table 3.1

Rating Table for the Parametric Values of C.P.

Sl. No.	Major Land-use types	Percentage coverage	Rating values
1.	Virgin forest with a thick vegétal matter on the surface	100%	<0.0005
2.	Natural vegetation cover i.e. forest, bush, parmanent pasture etc.	100%	0.001-0.0005
3.	Natural vegetation cover i.e. forest, bush, shrubs and permanent grass land	50-100%	0.05-0.001
4.	Degraded forest rough grazing, perennial cover	>30%	0.05-0.5
5.	Tea Garden	100%	0.05
6.	Degraded tea gardens	±50%	0.1
7.	Terrace field/Horticulture etc.	20-50%	0.5-0.8
8.	Built-up areas, completely paved	100%	0.001
9.	Built-up area, paved partially	50%	0.01-0.001
10.	Urban slums without or only partial drainage or sewer facilities		0.5-0.9
11.	Bare slopes, cultivated or cultural fallows	100%	0.1
12.	Protected tracts i.e. Cantonments etc. ±75% natural forests and ±25 built up areas with proper drainage facilities		0.01-0.05

Based on FAO/UNFP, 1978; Sarkar, 1987

BIOLOGICAL EROSIVITY MAP (C.P.) OF DARJILING TOWN AND ITS ENVIRONS



Fig—3.5

bounded by tea gardens - some of the most flourishing tea estates of the world, where the C.P value has been assumed between 0.1 to 0.05. Although paved surfaces of the area i.e. the central urban quarter have lost the natural soil structure along with its cohesiveness, yet, due to impermeability and artificial supports provided by the urban people it is rated between 0.25 to 0.1 by the present investigator.

3. **Potential Soil Loss by water erosion**

The potential soil degradation is the diminution of current or potential productivity or suitability which results from the action of physical factors (climate, soil and topography) without the intervention of human factors and without the protection of natural vegetation (Eiquier 1980). A potential erosivity map (Fig.3.6) of Darjiling town and its environs has been prepared from the available quantitative information, based on the equation

$$Pe = R \times K \times L.S \qquad \ldots 3.10$$

Although, the entire study area possesses a high degree of potential soil loss (mainly due to topographic configuration) yet, their spatial variation seems to be striking. For a better geographical explanation the following gradation has been put forward (Fig.3.6).

<u>Class I</u> : Exceptionally high potential erosivity zone; where the potential soil loss has been estimated to be more than 15,000 tons/h^{-1}/y^{-1} or$>$900 mm/y^{-1}; found along a number of tracts of the eastern and western slopes of the central ridge.

<u>Class II</u> : Very high potential erosivity, varying from 10,000 to 15,000 tons/h^{-1}/y^{-1} is to be ascertained along the eastern, northern and western slopes of the study area.

<u>Class III</u> : High potential erosivity zone, where the rate of potential soil loss has been found to be between 5,000 to 10,000 tons/h^{-1}/y^{-1} or 300 to 600 mm/y^{-1}; found extensively along the north-eastern, south-western and south-eastern part of the town.

<u>Class IV</u> : Moderate potential erosivity has been noticed along the north-western and eastern slope of the Tukvar spur and the northern slope of the Ghum-Sukhia Pokhari ridge, where the potential soil loss has been estimated to be between 2,500 to 5,000 tons/ $h^{-1}y^{-1}$.

<u>Class V</u> : Moderately low potential erosivity zone is found along the margins of the central ridge of the town, where the potential soil loss has been estimated to be between 1,000 to 2,500 tons/h^{-1}/y^{-1} or 60 to 150 mm/y^{-1}.

<u>Class VI</u> : Low potential erosivity i.e. below 1,000 tons/h^{-1}/ y^{-1} or $<$60 mm/y^{-1} has been found along the central Darjiling ridge i.e. Ghum-Katapahar-Jalapahar.

The potential erosivity map (Fig.3.6) of Darjiling town and its environs provide a basic inventory for calculation of the actual or predicted soil loss. This will also provide an appropriate tool for the future land-use planning and conservation practices.

POTENTIAL EROSIVITY (Pe = R. K. L. S)
OF DARJILING TOWN AND ITS ENVIRONS

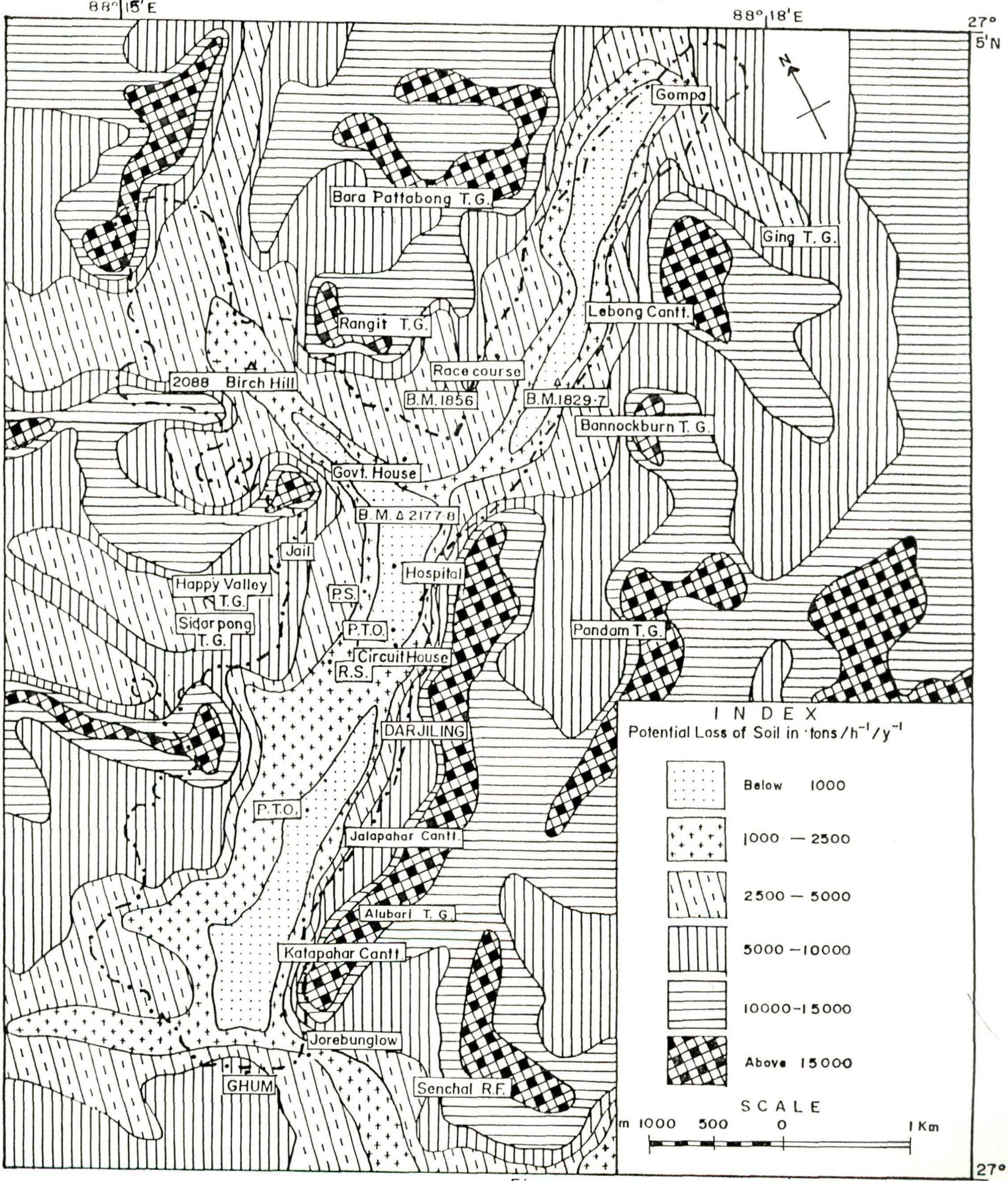


Fig - 3.6

4. Predicted Soil Loss by Water Erosion

The predicted or the actual soil loss has been calculated based on the potential erosivity and the biological factors of soil degradation by using the equation

$$Pi = R \times K \times L.S \times C.P \qquad ...3.11$$

An isoerodent map has been prepared by interpolating the predicted soil loss (Fig.3.7). The eastern slope of the Jalapahar-Katapahar ridge, the northern Birch-Hill, north-western Tukvar spur and the Chotta Rangit Valley, experience an exceptionally high rate of predicted soil loss (>2,500 tons/h^{-1}/y^{-1} or >150 mm/y^{-1}). While, the Ghum-Katapahar-Jalapahar-Birch Hill and Lebong spur i.e. the central ridge, experiences a low to very low predicted soil loss (below 250 tons/p^{-1}/y^{-1} or <15 mm/y^{-1}). Incidentally, these are the zones which the British chose for the development of this hilly township.

However, for the better understanding of the geographical distribution of the predicted soil loss by water erosion, the following classes of erosion - susceptibility and hazard have been made (Fig.3.7).

<u>Class I</u> : Exceptionally high susceptibility, (>5,000 tons/h^{-1}/y^{-1} or >300 mm/y^{-1}) has been found along the eastern slope of Jalapahar and Katapahar, north of Birch Hill, Chotta Rangit Valley and east of Lebong spur.

<u>Class II</u> : Very high susceptibiity (2,500 to 5,000 tons/h^{-1}/y^{-1} or 150 to 300 mm/y^{-1}) has been identified along the eastern

slope of the Jalapahar-Katapahar ridge, north of Birch Hill, north of Tukvar spur, Chotta Rangit Valley, eastern and western slope of the Lebong spur.

Class III : High susceptibility (500 to 2500 tons/h^{-1}/y^{-1} or 30 to 150 mm/y^{-1}) identified along the eastern, northern and western slopes of the central ridges.

Class IV : Moderate susceptibility, where the rate of predicted soil loss has been estimated to be between 250 to 500 tons/h^{-1}/y^{-1} or 15 to 30 mm/y^{-1} and has been identified mainly along the margin of Ghum-Katapahar-Jalapahar, Birch Hill , Tukvar and Lebong spur.

Class V : Very low susceptibility (50 to 250 tons/h^{-1}/y^{-1} or 3 to 30 mm/y^{-1}) has been found mainly along the Darjiling ridges. In fact most of the pre-independent urban growth were concentrated along these tracts.

Class VI : None to negligible erosivity, where the predicted soil loss has been estimated to be below 50 tons/h^{-1}/y^{-1} or below 3 mm/y^{-1}, found in three pockets i.e. Jalapahar-Katapahar Birch Hill and Lebong spur. Incidentally these are the most stable parts of Darjiling town.

In the present study two types of soil losses are differentiated and estimated such as the potential soil loss or natural vulnerability and the predicted or actual soil loss. Both types of losses are found to be exceptionally high in few pockets i.e. eastern slope of the Jalapahar-Katapahar ridge, northern part

PREDICTED SOIL LOSS
OF DARJILING TOWN AND ITS ENVIRONS

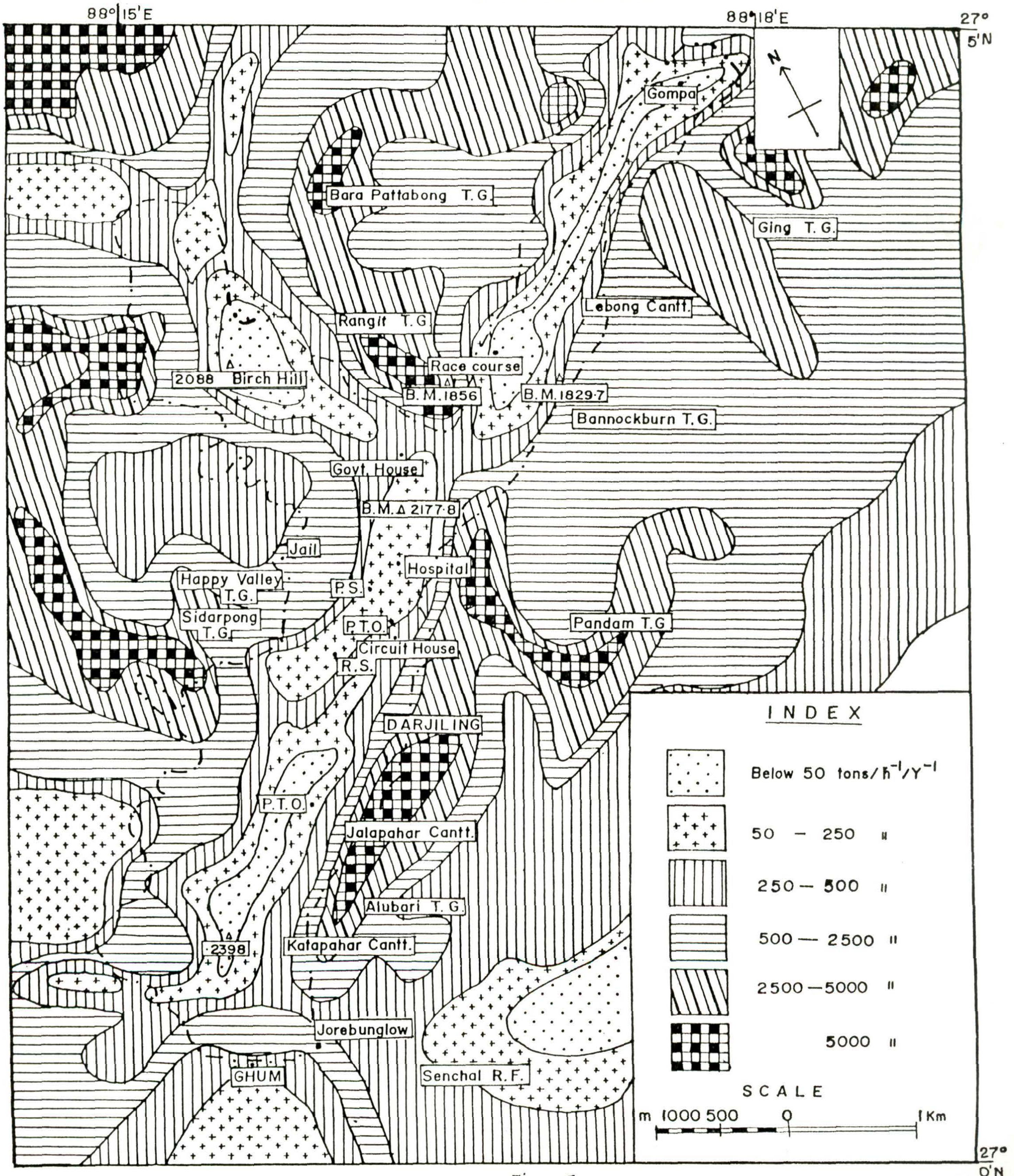


Fig – 3.7

of the Birch Hill and along the Chotta Rangit Valley where the rate of potential and predicted soil loss has been estimated to be >15,000 and 5,000 tons/h^{-1}/y^{-1} respectively. These are the worst affected tracts and the unprece dented high rate of soil erosion is due to the various types of mass movement and in particular land slips. While, the ridge top and western spur show a low to moderate potential and predicted soil loss which have been estimated to be below 2,500 and<250 tons/h^{-1}/y^{-1} respectively. These are the least affected tracts, covered by either paved urban structure or by Dhupi tree (Chyptomeria japonica).

C. STRATEGIES FOR SOIL EROSION CONTROLS

The aim of soil erosion control 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.

The area under study is predominantly a built-up area, as a result the conventional measures of erosion control seem to be less effective and sometime inoperative. Thus, the investigator has suggested the following important conservation measures.

1. Contouring

Slope utilisation such as construction of various urban structures and related uses can reduce soil loss from sloping land upto 50% compared to other usages across the slope. Although built-up areas in Darjiling town generally follow the principle of contouring but their spacing is not laid down scientifically. For the best protection against soil loss the following critical lengths per dominant slope angles have been recommended i.e. 180 m or more at 1°; 30-50 m at 5.5°; 20-30 m at 8.5°; 10-20 m at 11°; 5-10 m at 15°; 3-5 m at 20°; 2-3 m at 25°; 1-3 m at 30° and below 1 m at 40° angle.

2. Terraces

Terraces are perhaps the most common and widely used methods in the study area. The most common method of terrace construction is 'cut-and-fill'. Almost all constructions including buildings, roads, railways and municipal water supply lines are situated on such cut-and-fill terraces. Among the different types of terraces, retention terraces and bench terraces are most common in the present study area. However, such terraces remain ineffective in case of the ground slope having an angle more than 35°. Retention terraces (sometimes known as retaining wall) also hold back much water on the hill sides so that the soil becomes saturated during monsoon and may induced catastrophic erosion.

3. Water-ways

The purpose of water-ways in a conservation system is to convey run-off at a non-erosive velocity to a suitable disposal point. The water-ways in the study area should be constructed in such a dimension so as to provide sufficient capacity to confine the peak run-off from the rain storm with a 20 year return period and to promote a complete surface water disposal system. First of which is the <u>diversion channel</u>, which should be placed up slope to intercept water running off the slope above and divert it across the slope to

3.1

An example of well maintained, cemented sewage outlet.

a grass waterways or natural waterways. Secondly, the terrace channel should be constructed to intercept run-off from the inter-terraced areas and convey it across the slope to a grass water or natural waterways. Finally, the existing natural water-ways should be designed and reinforced to serve, (a) storm water disposal mainly during high intensity rain storms and (b) regular sewer and waste disposal system.

Thus, these natural water ways should be paved with a series of terraces of different dimensions depending on the gradient of the channel (Photo 3.1). These steps are designed mainly to reduce the run-off and the acceleration velocity. The main channels like Hospital Jhora, Victoria Falls, Kagjhora, Kotwali Jhora, Kahil Jhora, Barbatia Jhora should be paved and covered by impervious structures to check soil erosion and mass movement.

4. Proposed Conservation Plan for the Study Area

(Fig.3.8 and Table 3.2)

Soil conservation strategies are aimed at reducing erosion to an acceptable level. Theoretically, the level is the rates at which the soil loss and soil formation are balanced. However, in practice, it is difficult to recognise when this balanced state exist and for this reason, an alternate definition of an acceptable level is adopted, i.e. the level at which the soil texture, structure etc. can be maintained over a longer period (50-100 years) Sarkar has proposed a mean annual soil loss of 1.3 kg/m^{-2} is recommended for particularly sensitive areas, where soils are thin or highly erodible. The study area shows an overall high erosion rate due to

PROPOSED GENERALISED CONSERVATION SCHEME FOR DARJILING TOWN AND ITS ENVIRONS

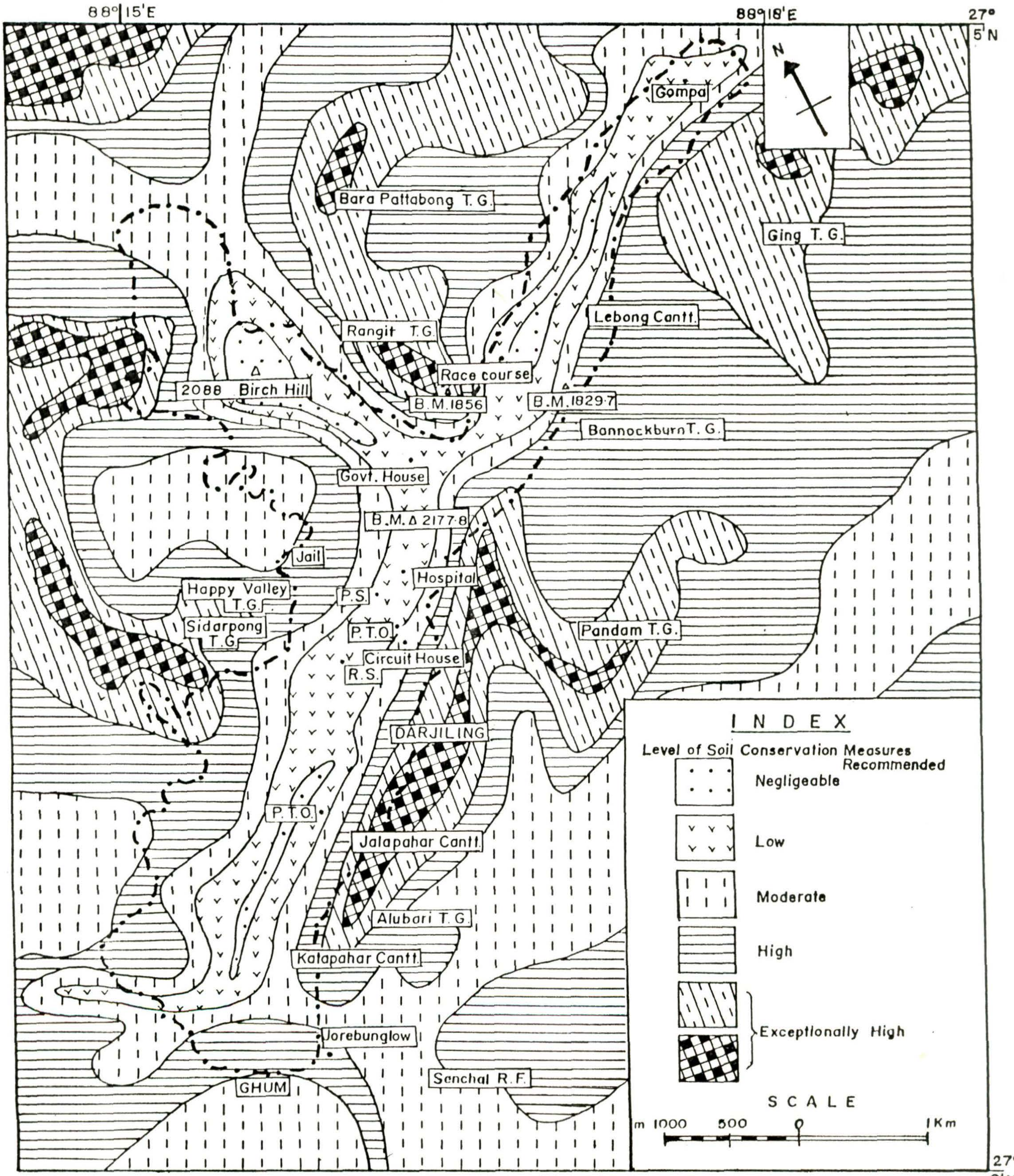


Fig-3.8

adverse environmental conditions. But it has been observed that due to favourable conditions tha rate of soil formation is rather high. Keeping these two points in mind the researcher of this study has proposed a target of 0.5 $kg/m^{-2}/y^{-1}$ or 5 $tons/h^{-1}/y^{-1}$ or 0.3 mm/y^{-1} of soil loss may generally be accepted as the upper most limit.

Although, the entire study area possess a high erosivity risk yet, the researcher has identified some highly vulnerable areas which needs an immediate conservation measures. The researcher has presented the map (Fig.3.8) of the proposed level of conservation measures required to protect soil against erosion. The various erosion classes, their rate of soil loss and the recommended conservation measures have been presented in tabular form in Table 3.2.

D. CONCLUSION

The hilly urban-ecosystem of Darjiling is a good example of man's interaction with nature. Complete severance of soil and forest from bed rock is visible in this area and the once lush green mountain and valley slopes are becoming barren and de-populated, along with these, the urban centre is registering more and more incidences of slope failures (Photo 4.11 & 4.12).

The worst affected tracts are the eastern slope of the Jalapahar-Katapahar ridge, and northern Birch Hill and Tukvar Spur, which are mostly deforested, along with a skeletal soil and a very steep slope that needs an immediate conservational measures as mentioned in Table 3.2. Special attention should be taken along the

Table 3.2

Proposed Conservation Model For The Study Area

Major Erosion Class	Rate of Soil Loss	Recommended Conservation Measures
Class I :	<0.5 $kg/m^{-2}/y^{-1}$ or, 5 $ton/h^{-1}/y^{-1}$	No conservation measure required for urban structure or, for any other urban use.
Class II :	0.5 to 5 $kg/m^{-2}/y^{-1}$ or, 5 to 50 $ton/h^{-1}/y^{-1}$	Very little conservation measures required for urban use which includes, cover crops along with suitable water ways and proper waste-water disposal system.
Class III :	5 to 50 $kg/m^{-2}/y^{-1}$ or, 50 to 500 $ton/h^{-1}/y^{-1}$	Moderate conservational practices are recommended for urban use i.e. drainage particularly peak flood waterways and sewer system. While in retention and bench terraces, terrace channels of grass water-ways are recommended for intensive urban agriculture/horti-culture.
Class IV :	50 to 250 $kg/m^{-2}/y^{-1}$ or, 500 to 2500 $ton/h^{-1}/y^{-1}$	Careful conservation measures are re-commended i.e. retaining walls, minimum cut-and-fill along with very careful drainage are required. Open spaces should remain under natural cover.
Class V :	250 to 500 m^{-2}/y^{-1} or, 2500 to 5000 $ton/h^{-1}/y^{-1}$	These tracts should not be disturbed except in special cases, it requires a good number of stabilising structures and paved water-ways for urban use. Un-used tracts should remain under forest cover.
Class VI :	>500 $kg/m^{-2}/y^{-1}$ or, >5000 $ton/h^{-1}/y^{-1}$	These are the extreme vulnerable tracts and should not be used for any kind of use.

roads, railways, slums (busties) and various other urban structures in the town. Large scale afforestation, turfing, paving, reinforcement of the existing retention walls and drainage facilities are necessary in these settled tracts to check this large scale soil degradation. Care should be also taken to provide an adequate drainage facilities to allow peak discharge during high intensity rain storms. Perhaps the most stable part (from the point of view of soil erosion) of the urban centre is the Katapahar-Jalapahar ridge that extends towards Birch Hill and Lebong spur, (below 50 tons/h^{-1}/y^{-1}) is due to a gentle topography and dense vegetative cover. These areas are mainly occupied by the Army Installations since the inception of Darjiling Town 1848. Although these areas have no immediate visible degradational danger, yet they need to be brought under the conservational measures, keeping in mind the long term consequences of soil erosion.

Among the various soil conservational measures described in the previous paragraphs, the concrete peak flood-water disposal systems with slope breaks, concrete natural disposal systems and proper waste water sewer disposal systems are important. In other words, erection and maintenance of proper drainage system is in fact the key to all conservational measures for Darjiling town and its environs.

The conservation schemes must be well designed to reduce soil erosion effectively and their ultimate success depends upon how well the measures are implemented. The willingness and the socio-economic background of the urban people to adopt the techniques required by a particular strategy, is also very important. Equally important is the fact that the strategy proposed should be clearly related to the problem involved. Thus, conservation design must logically follow a thorough assessment of erosion risk.

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