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Soil studies between Ganga and Yamuna rivers of Siwalik range of Uttarakhand: Emphasis on their depletion and remedial measures for their conservation

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Abstract
This study region lies between Ganga & Yamuna Rivers in N.E. & S.W. direction and then indogangetic plane in the South and doon gravels in the North with the reference to capital Dehradun (U.K.).
The present study aims to investigate the geomorphology & geology of the above region so that the soil of the region can be studied under classification, origin, depletion and remedial measures.
The study region is sloping towards North, maximum height of the Siwalik ranges upto 3000 ft., the area to Ganga is NS and Yamuna in NW is traversed longitudinally by Suswa & Asan rivers confluansing with the Ganga & Yamuna. These two rivers are separated by Dehradun Asarori Mussoori water divide more of less at the centre.
Geologically these are consist of Middle Shiwalik and upper Shiwalik with recent Alluvium.
Geomorphological the morphounits includes hills of the structural origin, hills of denudation origin and units of fluvial origin.
The soil materials of the study region have been derived mainly from Shiwalik ranges consisting of boulders, cobbles, pebbles sand, silt and clay minerals. The article describes them origin.
The soil so generated is depleted by biotic and abiotic causes like weathering, erosion by water, run off over plounging, over grazing and deforestation. The present article suggest the conservation measures for the soil for the betterment of the population of the study region to proper utilization of the precious material resources available to them.

Keywords: Soil studies, Ganga, Yamuna rivers, Siwalik range

Introduction
This geomorphology of the Himalaya, along with the study of geotectonics, has been a popular subject. The area between Ganga and Yamuna rivers (Siwalik formation) forms a unique geomorphic unit in the Garhwal Himalaya. Geomorphological this area is drained by the spring fed perennial rivers- the Suswa and Asan which contribute to the Ganga and the Yamuna forming the eastern and western part respectfully.
The geomorphic surface of the area has been described by the on the basis of the altitude and red soil cover and relates them with four glacial and interglacial stages of the Himalayan glaciations. The gravel deposits have been formed by the superimposition of the alternate erosional and depositional phases caused by climate and crustal movements.
The area being enriched with various land natural resources like soils, present an example of the haphazard use and misuse of these resources. The maximum rainfall is 210 cm per annum and the fast flowing perennial streams with higher gradients in the region are not properly used for agriculture on account of misuse of gradient and excessive flow of the running water.
The present study of the soils of the entire Siwalik formation between Ganga and Yamuna rivers aims to evaluate the geomorphological features and their interferences upon the terrain morphology as influenced by the drainage network and them with abrupt changes in the physiographic and climate conditions. Further, it is proposed to mark out the intensity of the land depletion in geomorphic region by geographic factors viz; severe soil erosion as stimulated by the excess of the ecological imbalances.

Some ecological measures shell be suggested to treat the geomorphic regions from the said geocatastrophic factors

Geoidentity

In the Himalaya region, the dun and dwarfs are significant, the area traversely crossed by the antecedent rivers Ganga and Yamuna forming open gorges in the shiwalik at Hardwar and pontadwar (Saxena, Anantharaman and Pandey, 1979)[28].

The area is gridled with the Doon gravel in the north and siwalik formations in the south and traversely bordered by the antecedent holy river the Ganga in SE and Yamuna in NW (Fig 1A). The drainage of the eastern and western parts of the area is determined by Suswa and Asian rivers respectively. The Suswa and Asian rivers are are demarcated by a low water divide namely Dehra-Asarori water passing through Mohand (Saxena Anantharaman and Pandey, 1979)[28].

Precisely, the study region is located with 29˚ 55´ to 30˚ 30´ N latitudes and 77˚ 35' to 78˚ 5' E longitudes ranging between 300 to 733 meters above m.s.l. in height. The shape of the area constitutes a rectangle. The area is bounded by districts pauri-Gharwal in south-east, Saharanpur in south, Chakrata in the North-west and Himachal Pradesh states in the south-west. The exact location and surroundings of the area is depicted in key plan of the area (Fig 1 A)

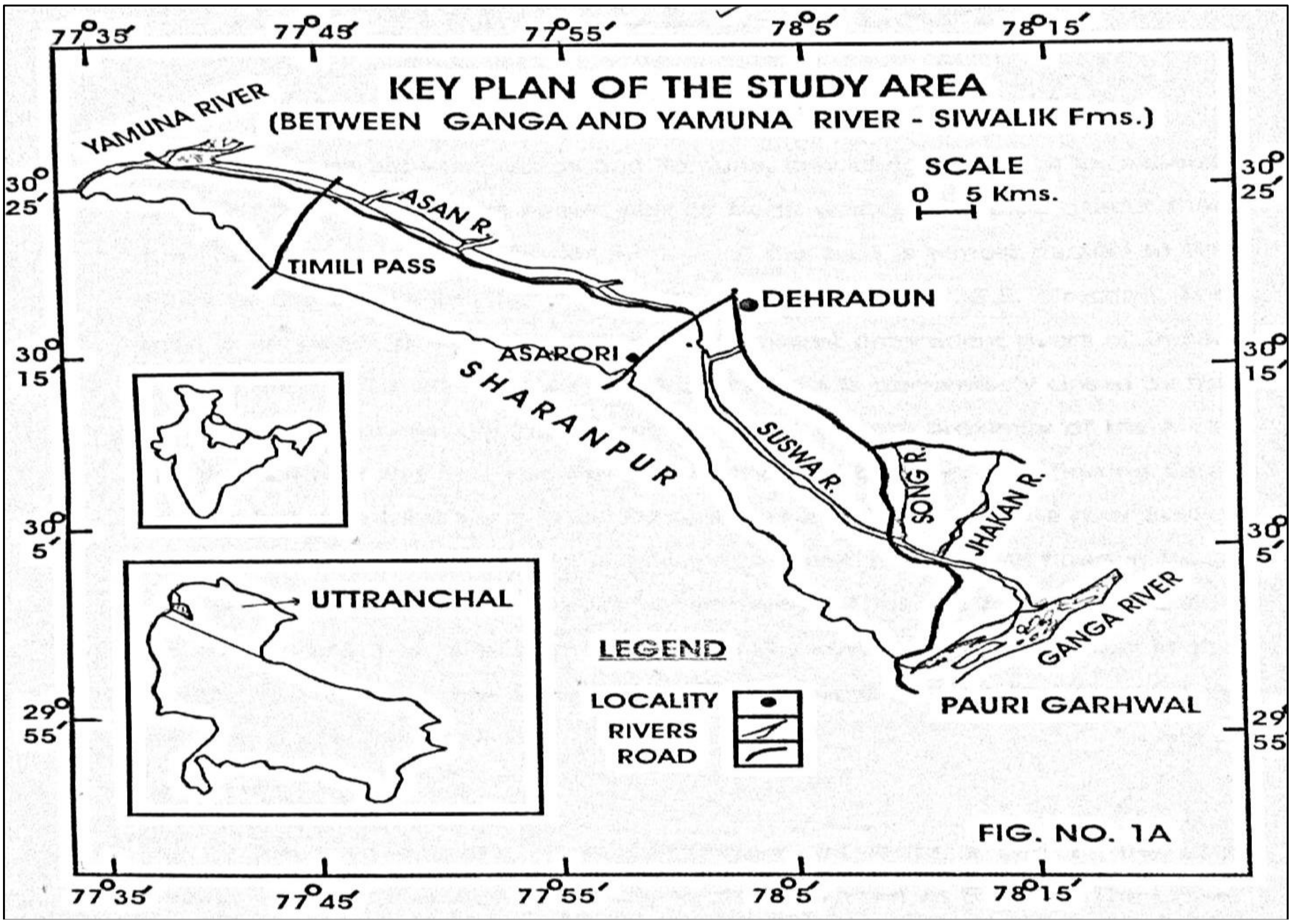

Fig1: a, b Key plan of the study area

Geographically, the crest line of the Siwalik may be taken as the southern boundary of the region. For demarcation, this line is observed from the Siwalik peak, 733 meters above the m.s.l. near amwala, and 3.2 kms south of nahan. The line runs eastward through Khala-Amsote forest. The state boundaries of H.P. and U.A. meet here. This point is located 3.2 kms south of the confluence of rivers the bata and Yamuna.

Following the administrative boundaries of the Saharanpur and Dehradun districts, the line touches amsote peak, 951.5 meters above m.s.l. thus, the area proper exists in the shiwalik ranges, followed by a flat bottomed parallelogram shaped tectonic synclinal trough nearly bounded by the Dun-iso-aquifer line

The physical infra-structural aspect of the area reveals that the antecedent drainage pattern develops in the region of the Ganga and the Yamuna, near the crossing of the Siwalik with "Draws" (Haridwar and ponta sahib). These rivers form south-east and the north-west boundaries of the area respectively.

The parallel water-parting lines of the of the Siwalik ranges from a parallel network of rivers valley which result in rectangular drainage (Fig 1) Dendritic drainage is most common form, developed by the main streams, its tributaries and their effluents in the mountain above the area proper. The tract of paired terraces, fanglomerated spurs and ridges reveals that the area has undergone intermitted upheavals four times and produced a complex terrain.

The physique of the terrain reveals varied characteristics in the basins of Suswa and the Asan forming the administrative blocks units of the eastern western part of the area.

The central part of the area towards north is diversified by isolated hill called Nagsidh. The Nagsidh hill an offshoot of the Siwalik. The hill is incised by the Suswa River. The eastern part of the hill consists of swampy Suswa terrain which is thickly covered by with forest. Further south of this

swampy terrain, the prosperous alluvial of the Ganga river exists with flat terraces.
The physique of the western part consist of the three well defined tracts. The first tract comprises an upland on the Asarori water parting line up which the Dehradun city stands. The second tract consist of the riverine patch of the Asarori and the effuents. The third is the triangular tract of the Yamuna dhang (Saxena, 1975) [27]. The tract is deeply incised by the rapid flow of the local torrents forming entrenched and ingrowned meanders.

Previous Litrature
The Dehradun valley, of which the study area is the southern boundary has been attracting the attention of various workers since the middle of 19th century. suggested that the origin of sediment for siwalik was from the Himalaya in the form of alluvial fans. The present day structure according to him, due to foothill orogeny during Pleistocene period. Further, the antecedent nature of the Ganga and Yamuna was suggested by himafter his study of flat topped terraces suggested the following hill top surface, upper dun surface, middle dun surface, lower dun surface, higher, middle and lower river terraces, recent alluvial fans, present day river bed and flood plains.
analyzed the shape of the quartz grains of the middle and upper siwalik sandstone of the area. Shukla and Verma (1976) has studies of the grain shape characteristic of siwalik sediment, slopes and sedimentological studies in a part of the area.
Prakash and Sharma (1980) worked on molasses sediments shed by collision of continental plates. Geology of Doon valley – Neotectonics and colluvial deposition with fault propagation was studies by Thakur in 1995.
resources, Anantharaman and Ravat (1988) had done precise study of terraces of Dehradun valley. Ananatharaman, have studies the soil of Dehradun valley. Pooja sharma and anantharaman have studies of Mohand area,

Methodology
The origin, nature and distribution of soils have been discussed and is depicted in the map. The soil constituents analysis based on the literature on the soil conservation center have been depicted in the triangular graph. On the basis of the soil productivity, management under prevailing geographical factors, the soil capability classification has been made with the support of earlier work done (Saxena 1975)[27] and confirmed by "Landsat" imagery.

Relief
The area under investigation is apparently a single slop hill structure belonging to the great river system of the Ganga in the south-east and the Yamuna in the north-west. The area is drained by the system of longitudinal tributaries to Suswa and the Asan contributing to Ganga and Yamuna respectively. The region is demarcated by the Dehra-Asarori low water divide with gradient varying from 10.3metres/1.6kms 12.7metres/kms (34"/mile to 32"/mile). Owning to considerable elevation varying from 318 meters (1050") to 2424 meters (8000") above m.s.l., the swift drainage has inclined the area evolving the dissected and ravined topography.

Table1: Pair Wise Relationship –Hight and Area

Height in feet (metres)	Siwalik [area in sq. miles (sq. kms)]
1000-1250 (303-378)	19 (49.4)
1250-1500 (378-454)	30 (78)
1500-1750 (454-530)	69 (179.4)
1750-2000 (530-606)	63 (163.8)
2000-2500 (606-757)	54 (140.4)
≥ 3000 (909)	-
TOTAL	248 (644.8)

The unique trend of the altitudinal pattern of the area exhibits the changes in land use and geonomics structure which occurs from low lying area to the upland. The altitudinal belts depict a clear cut physiographic influence on the geonomics resources of the area.
Geonomic-geology +nomic economy

The tectonic succession of the region[1] can be summarized as noted below:
Lower Siwalik
Middle Siwalik
Upper Siwalik

The main boundary thrust, the Nahan Thrust and the Mohand Thrust are well defined and differentiated on the basis of fossils evidences which not occurring in the present region but are found in the neighboring area to the east and the west.

Geology
The regional study of the geology has been carried out by conducting a number of transverses in the valley including (i) Ponta Saheb-Timli, (ii) Timli-Clement Town-Motichur-haridwar, (iii) Haridwar-Chandi Devi Temple (iv) Mansa Devi temple, (v) Raipur-gullerghati, (vi) Bindal river, (vii) Sakumbari Devi temple (viii) Dat Devi temple and (ix) Ponta saheb sections, besides others.

Siwalik group Sequences
The Siwalik group has been classified into lower, middle and upper formations on the basis of the lithostratigraph (Auden, 1937; [10]. They are exposed in the west and eastern part of the region.

Lower Siwalik formation[2]
The lower Siwalik formation has a thickness of 1700 meters (5610') consisting of thick, hard, and purple coloured sandstone and maroon clay.

Middle Siwalik formation
It consist of massive gray, soft and micaceous sandstone and the estimated thickness is 2000 meters (6600'). The feature of middle Siwalik is the presence of 'Ferryballs' i.e., rounded pebbles of sandstone in the sandstone bands (Pandey, 1975)[21].

Upper Siwalik formation
The middle Siwalik grade upward into 1250 meters (4125') thick massive beds of the sand, grit, brown clay and poorly bedded conglomerates and boulders.
The best studies section in the region is the Mohand area. Here the stratigraphic succession is as follow; (Pandey, Verma and Anantharaman, 1983)[19].

Table 1:C Geological Succession in type area-Mohand

Age	Division	Subdivision	Lithology
Post Cromerian	Dun-gravel and alluvium	-	Unconsolidated pebbles of quartzite, granite, Siwalik sandstones etc. interbedded with clay.
Cromerian to Astian	Upper Siwalik	Mohand-6	Conglomerates interbedded with sands, siltstones and reddish to yellowish brown clays.
		Mohand-5	Conglomerates, cobbles interbedded with soft friable micaceous, coarse grained sandstone and deep red clays.
		Mohand-4	Massive, micaceous, coarse to medium grained sandstones interbedded with thin beds of conglomerates
			reddish brown to maroon coloured clays and calcareous sandstones.
Sarmation to Potian	Middle Siwalik	Mohand-3	Soft, friable coarse to medium grained sandstones interbedded with reddish brown clays, pebbles and concretions, pockets of lignite and clays.
		Mohand-2	Thick, massive, compact medium grained sandstones interbedded with reddish brown, silty and micacerous clays and calcareous concretions
		Mohand-1	Massive, micacerous, medium to find grained sandstones interbedded with clays and calcareouys concretions.

Era	Age Period	Formation	Rock types
Quarternary	Present day	Alluvium Recent deposits	Alluvium Gravels, sand, alluvium
	Holocene	Holocene terraces	Loose boulders, coffles, pebbles gravels sand, clay
	Late Pleistocene	Pleistocene terraces	Consolidated boulders, pebbles, conglomerates, clay
Tertiary	Mid-Pleistocene	Upper Siwalik Fm	Sandstones, clay, conglomerates
	Mid-Miocene	Middle Siwalik Fm	Sandstones, shales and clay

Morphounits of Structural Origin

Ridge consisting of sandstone

This sandstone unit is present in the south-west and south-eastern part of the region. They belongs to middle and upper Siwalik formations. They are affected by numbers of tectonic movements resulting in folding and faulting. The relief of this part is subdued with the few fan deposits.

In the southern part of the middle and upper Siwalik conglomerates, sandstone, shale and clay constitute this unit (Pandey, Verma and Ananatharaman, 1983)[19]. The beds are steeply dipping and they form the southern limb of the Dehradun syncline. The slope is moderate to steep and highly dissected with broad and less intrenched streams with coarse drainage texture.

Structural hill (Nagsidh hill)

This hill is an offshoot of Siwalik formation upries from the dun gravels to 818 m (2700’) above m.s.l. and is situated in lacchiwala in the east and clement town in the west, river Suswa in the south. Gullies are frequent in the foothills. The slop are subjected to denudational agencies In the north-western part of the hill, the scrap section exhibits a lower unit of 1.2 m (4’) thick reddish brown iron clay, a middle middle unit of 1.8 m (6’) thick coarse sandstone and silt and upper unit of 1.5 m (5’) thick loose gravels and conglomerates. The bed show faint stratification. The conglomerates are composed of poorly sorted sub-rounded grains, Medlicott (1864), Auden (1937)[10], and included the Nagsidh hill in the Siwalik formations. The author includes this hill in upper region of the siwalik as the characters exhibited by the conglomerates in the scarp section is similar to the characters exhibited by the upper Siwalik conglomerates of Mohand region, south west of the Dehradun (Pandey, 1975)[21].

Morphounit of Denudational Origin

Siwalik pediments

South-west Siwalik pediments

South-east Siwalik pediments

Pediment is defined as the degradational slopes cutting the structure of the formation cutting with the veneer of gravelly debris The pediments in the region occur all along the upper Siwalik formations of the southern part. The bed rock is composed of conglomerates in sandy and silty matrix and they are observed as gentle to moderate steep slopes cutting the rock surface with thin layer of pebbles and gravels strewn all over near Sabhawala, Parwal, Bajawala, Karwapani, S-W of nagsidh hill and Kansrao. They occur both in the south-western and south-eastern parts of the region on the uniform dip slops of Siwalik in the Asan and Suswa valleys. (Fig. 6). Pediments may have been originated due to (i) erosion by mountain streams under certain climatic conditions during the break in the mountain uplift, (ii) Subsidence of the base level of the erosion in the fore-land, and (iii) parallel retreat of slopes due to slope denudation.

Erosion relict levels

These are recognized the basis of lithology level (I) occurs between 757 m and 727 m (2500’ and 2400’), level (II) occurs between 727 m and 697 m (2400’ and 2300’), and of level (III) occurs between 666 m and 636 m (2200’ and 2100’). The flat levels are covered with red loamy soil with a gentle slope to north. They indicate polycyclic development. The relict levels at various altitude of plantation surfaces are of different ages due to upliftment by tectonic movements (Ananantharaman and Pooja Sharma 2003)[8].

Denudation slopes with slump and rock slips

Rock slips and the slumps occur along denudational slopes in Siwalik formation in the south and along the southern slopes of nagsidh hill. There are referred to as erosional foot slope carved in bed rocks by weathering and erosional process and are veneered with debris (Ananatharaman and Pooja Sharma, 2003)[8]. They occur between the foot of the mountain and the adjoining valley bottom over the slopes. On the basis of erosional process and slope stability the denudational slopes has been classified into (i) denudational slopes controlled by the dip slopes, (ii) denudational slopes resulting from superficial mass movements. The former, which occurs in the Siwalik formations of southern part has been subjected to slopes which occur around 727.2 m (2400’) and 424.2 m (1400’) above m.s.l. These slopes are formed by the fluvial erosion. Weathering and rain-wash are dominant process. These slopes are concave and gentle to moderately steep indicating slow rate of uplifting (Penk, 1953). Occurrence of alluvial fans at the bottom of these slopes is a common feature in the study region. The latter occurs in the southern and south-eastern flank of the Nagsidh foot hill. The slope is caused by rill and gully erosion and is covered by reddish soil creep.

Morphounits of Fluvial Origin

Flood plains

These are the youngest geomorphic units and include landforms like sand bars, Channel Island, natural bay, meanders, abandoned river channels and recent river borne sediment sediments like boulders, pebbles and silt. They are flat, lying adjacent to the streams. The deposits are poorly consolidated and loose thus enabling migration of the river channels. Channels Island and sand bars are formed due to vertical accretion of silt, clay, cobbles and are caused by the flooding streams The flood plains are classified into low and high flood plains on the basis of relief and susceptibility (Ananatharaman and Rawat, 1988)[7, 9].

(i) Low flood plains

These are susceptible to flood through mostly they occur above active channel (I.I.P. Dehradun- a survey Doon valley- A report, 1971). The Asan River leaves low flood plains at 439 m (1450') and 844.8 m (1600') above m.s.l. Near Sabhawala and partipur the low flood plains is adjacent to a recent terrace cut into the denudational slope of Siwalik Hills. Old channels are observed in these parts. Low flood plains are observed in Lacchiwala. In the south-western part at Asan basis flood plains and alluvial fans have also been observed on the uniform concave slope of Siwalik. Similar structure of flood plains have been recorded in Asan river basin where the thickness of fine alluvial material ranges from 15.1 m to 30.3 m (50' to 100'). In Suswa basin on the base of concave slope flood plains are formed. The base is made of pebbly sand. In Asan basin the flood plains where the sandy material have been deposited in a considerable thickness.

(ii) High flood plains

These are flat stable, occurs at higher level and they are in the form of unconsolidated gravels, pebbles and sand. They are isolated from active channels and therefore, not affected by flood. In the Yamuna River it is 6 meters (20') at higher level. The high flood plain on Asan occurs between 515 m and 545 m (1700 and 1800) above m.s.l. and is composed of 3 meters (10') thick well rounded stratified pebbles and cobbles in sandy matrix. The high flood plains are incised by many streams The plain is composed of 3 m (10') thick sub angular gravels and pebbles covered by 90 m (3') thick reddish brown silt clay. Abandoned channels are exposed in a 1.8 m (6') thick exposure indicating recent movements.

At the Song-Suswa confluence, the Song leaves a high flood plains

Island (Anantharaman and Pooja Sharma, 2003)[8]. A mixed high flood plains of Song-Suswa is exposed between Lacchiwala and Banbasa (409 m – 484 mm. i.e., 1350'-1600' above m.s.l.).Song-Suswa at Satyanarayan leaves at high flood plain on the western bank from Bhogpur to confluence (3636 m – 606 m i.e., 1200'- 2000'' above m.s.l.). Between Bhogpur and fatehpur several old channel scars are noticed and this indicates recent uplifting.

Himalayan Ganga-Yamuna terraces

Suswa-Asan river terraces

The river terraces occurring between the Himalayan Ganga-Yamuna terraces are termed as the Suswa river terraces in eastern dun and the Asan river terraces in the western dun after the major rivers in the area. These terraces persist throughout the region, occurring between 318 m and 848 m (1050' and 2800') above m.s.l.

i. **Suswa river** terrace are observed at Lacchiwala-Raipur, Fatehpur, Thano, Song (near Gobindwala), and Motichur. Their thickness ranges is from 6 m to 30.3 m (20' to 100 ') and they slope toward south-east direction with 1° to 8° slope angle.
ii. **Asan river terraces t**hese terraces possess a thickness ranges from 6 m to 30.3 m (20' to 100') and they are almost flat or gentle sloping at angle between 1° to 8° towards south-west direction. These terraces are of fluvial origin and they are exposed as scarp sections in field. These are old flood plains incised by streams which are very gently inclined broad surface. These plains represent former level of the valley Leopold, or flood plains. The terraces deposits are well stratified and comprise of two facies, viz. (i) flood plain facies (red to brown ferruginous clay), and (ii) river bed facies (loose pebbles, cobbles and sand). The old flood plain levels have undergone uplifting to give rise to these terraces. The terraces in the foot hill regions show that the streams are responsible for the formation of these terraces.

Salient Geomorphological Features

The Dehradun-Asarori water divide

It is an important geomorphic feature in the region and it divides the region into eastern and western parts. It runs from Asarori to Landaur Cantn through Dehradun Rajpur and Mussoorie

Fluvial and Denudational surface

Fluvial fans are formed by the streams where braiding takes place. The denudational surface are constructed by streams where gradient remains high and streams are so powerful to erode the flat top of the spurs and hillocks which generally occurs in courses.

Escarpments

Steep escarpment are observed from the south-west to south-east in Siwalik formation of the region at Chandi Devi mandir and Shakumbri Devi mandir, Haridwar, Mohand, Dat kali Devi mandir and Shakumbri Devi mandir among the others parts of the study region. The escarpment are formed due to texture, structure and composition of the rock and also due to the influence of the denudational agencies and tectonic movements.

Alluvial fans

These are bodies of detrical sediment build up at the mountain bae by mountain streams. These are formed where the gradient streams lessens abruptly, i.e., when the stream enter in a region from mountain slope. Their surface are sandy. They have bold relief and they are formed due to sheet flood and stream flood. The fans has four parts viz., apex (courses particles), fan head, mid fan and base (fine particles). In the Siwalik foothills in the south-eastern and south-western parts number of alluvial fans occur. The fans in the south-western part occur on the south of the Asan channel between Dehradun and Dakhrani. They were formed under the humid conditions. The fan materials are made up of cobbles and pebbles which are poorly sorted. Some of these fans are deeply incised. The overlapping fans are observed at Aglikhala are known as telescopic structures, and indicates neo-tectonic upliftment. Similar fans are observed on the eastern bank of Song and near Lachiwala.

Tulas cones

These are structures which are made of broken and angular rocks particles coming down the steep slopes due to gravity and spread out as cones. They are observed at the base of Gullies along escarpment and they are formed due to neotectonic activity.

Gullies

When clay is eroded from the rocks/terrace horizon gullies are formed and they are commonly found in the morphounits of the fluvial origin.

Dry channels

These are streams channels in the Siwalik formations which remain dry except during rainy season.

Abandoned channels

These are associated with inactive flood plains under streams do not flow in these channels.

Intermittent channels

These are those channels in which water appears at some places and disappears in others places.

Neotectonic Features

These are slow tectonic movements which are contemporary or of recent origin. The neotectonic features like faults, knickpoints and Crestline are depicted in the geomorphological map (Fig. 6A, 6B) in details The term neotectonism is used for those crustal movements which took place from later tertiary period and have played a decisive role in the formation of contemporary topography (Fairbridge, 1968)[14]. The composition of sediments, structures and geomorphological features reveal the neotectonic movements (Hill, 1961). In region important neotectonic activities are: Siwalik anticline, Dehradun syncline, Ganga fault, Nagsidh hill upliftment, and fault near Suswa. Dholani fault, Motichur fault, effects in the course of the river Yamuna and its tributaries towards west due to relative upliftment of landmass (Babu,1972) [12] incised valley, asymmetrical river terraces, waterfalls, rapid, differentially uplifted block, talus cones and alluvial fans (In Siwalik slopes).

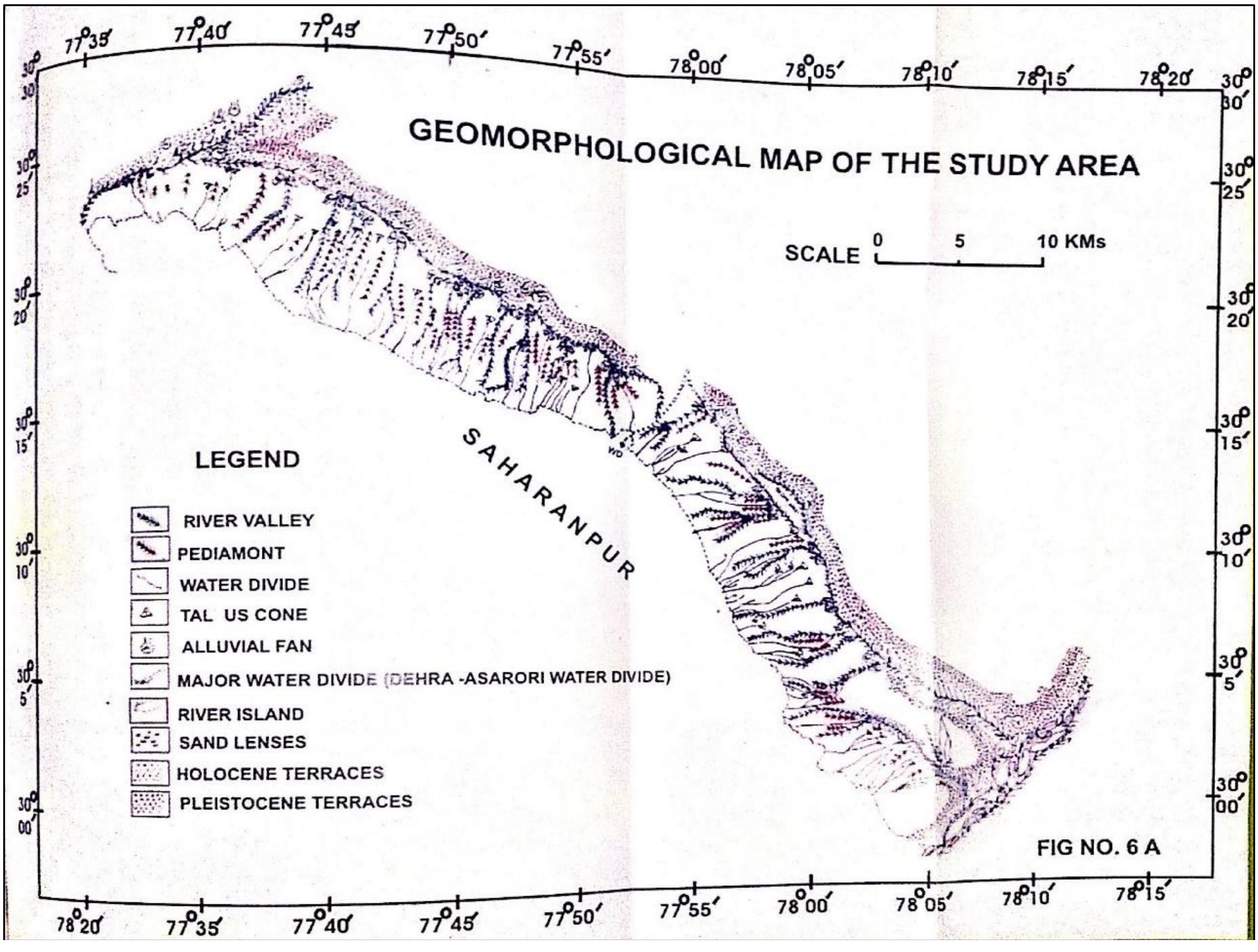

Fig 2: A geomorphological map of the study area.

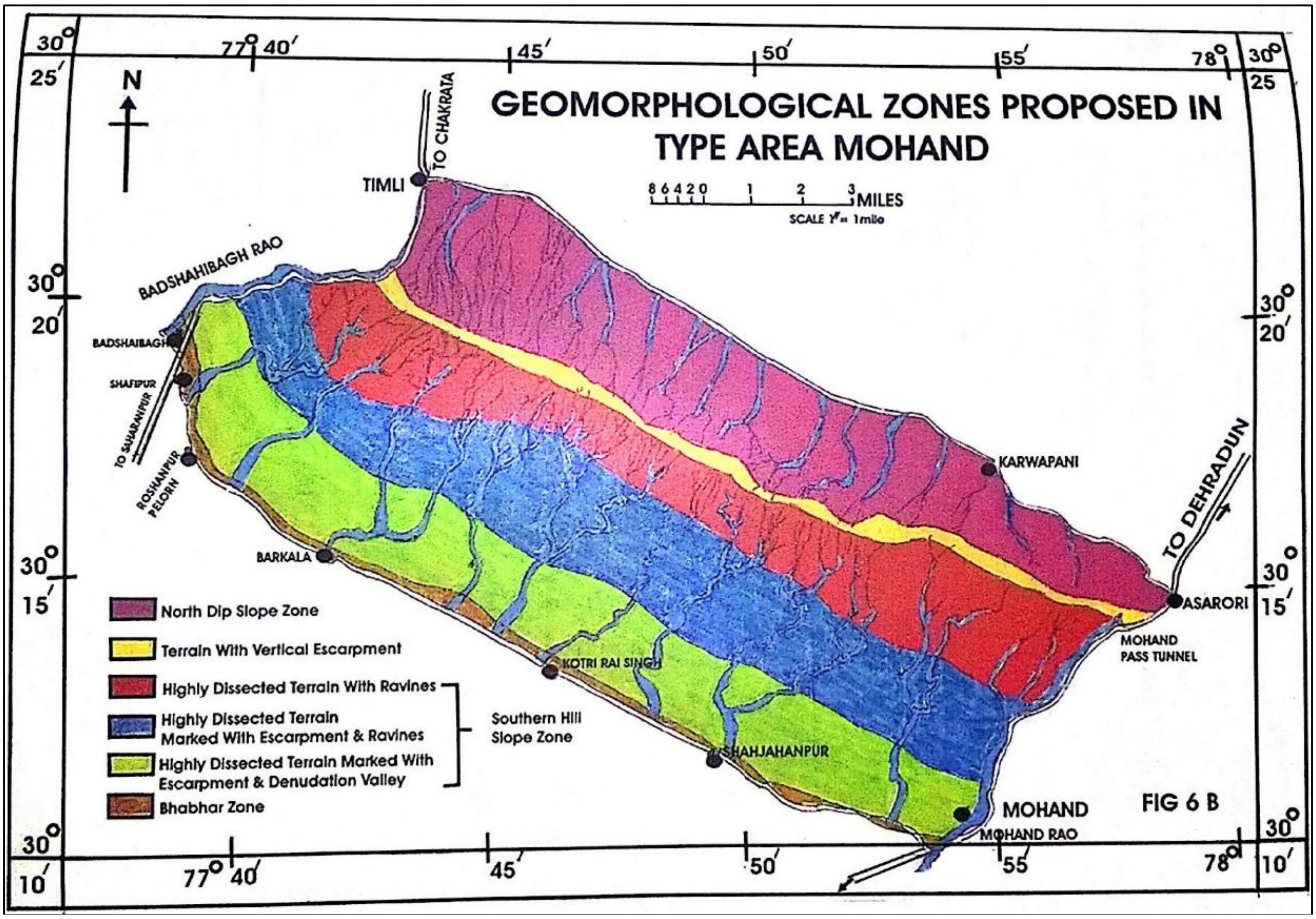

Fig 3: b Geomorphological zones proposed in type area Mohand.

The mountain of the region which have developed from the main Himalayan orogeny are characterized by an inherited sequential development The tectonic movement that are reflected in the valley are predominantly parts of those affecting a larger region. Many local features have developed due to the exogenic processes. Denudation is prominent in the area and the relief is controlled by lithology and structure. Gravel slopes having steep surface gradient are present all along the foothill. They are the result of coarse deposits brought down by the older streams. The present day stream have cut to these and on a lower gradient than the general slope of the gravel surface. There has been a general tilting of the surface and uplift The study of interaction between tectonic movements and exogenic processes in the area of the uplift and depression indicates in the relief of intensity of the region uplift. The intensity of relief formation is directly proportional to the speed of the local tectonic movements

The region is syncline, situated in anticline in the Siwalik range and the overturned anticline in the Massoorie range which is affected by the M.B.F. and other thrust. This suggest that the region is faulted controlled. The Himalayas, during Miocene times might have created a younger mountain system, the erosion of which contributed to Siwalik sediments During middle Pleistocene to main orogenic Himalayan phase produced the upper Siwalik deposits The first major glaciation begin during the Pleistocene and the overturning of the Siwalik was followed by fluid-glacial deposition. This produced boulders larger than of the upper Siwalik conglomerates. The formation of such boulders contained into Holocene gravels and terraces and related to the last marked and still active morphogenic uplift of the main ranges (Friedman, 1961 and Fuches, 1968)[15, 16].

Structural Unit	Denudational Unit	Fluvial Unit	Stratigraphical Unit	Lithounit	Climate (Krishnan, 2003)	Age (Auden, 1937)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
-	Talus cones	Braided river bed	-	Boulders, pebbles sand, silt and clay	Subtropic	Present day
-	-	Alluvial fans	-	Boulders, pebbles sand silt and clay	Subtropic	Present day
-	-	High and low flood plains	Recent	Boulders, pebbles sand, silt and clay	Fluctuating	Late Holecene
-	Younger terraces	-	Holocene terraces	Loose pebbles, cobbles, gravels sand and clay	Fluctuating	Early Holocene
-	Colluvial terraces	-	-	Loose pebbles, cobbles, gravels sand and clay	Fluctuating	Late Pleistocene
Para Unconformity						
-	Older terraces	-	Pleistocene terraces	Consolidated boulders, pebbles, cobbles and gravels	-	Upper Pleistocene
Angular Unconformity						
-	Erosion relict level III	-	-	-	-	Upper Pleistocene
-	-	Ganga Yamuna terraces	-	-	-	

(1)	(2)	(3)	(4)	(5)	(6)	(7)
-	E.R.L. II	-	-	-	-	Upper Pleistocene
-	-	Assan-Suswa terraces	-	-	-	Upper Pleistocene
Structural hill	E.R.L.I.	-	-	-	-	Upper Pleistocene
Dip shope	-	-	-	-	IV Glaciaton	Upper Pleistocene
Structural hill	denudational slope	-	-	-	Intergiacial period	Upper Pleistocene
Structural hill	-	-	Upper Siwalik	Boalder Conglomerate pebble	III Glaciation	Mild Pleistocene
Sandstone ridge	-	-	Upper Siwalik	Conglomerate and sandstones	Interglacial period	Mild Pleistocene
Sandstone ridge	Siwalik pediments	-	Upper Siwalik	Clay, silt, sand	II glaciation	Mild Pleistocene
	Siwalik pediments	-	Mid-Siwalik	Sandstone, clay, shale	Inter glacial period	Mild Pleistocene

SOIL

In the area under investigation the geomorphic processes are conspicuously responsible for the varied types of weathering of rocks under humid conditions (2B,2C) resulting in the formation of diversified soils.

Soils is the natural body of mineral and organic constituents, differentiated into horizons, which differ among themselves as well as from the underlying material in morphology, physical makeup, chemical composition biological characteristics.

Soil is the result of soil forming processes, representing an intricate exchange of radiant energy and matter, a complex of prolonged interactions between lithosphere, biosphere and the environment including topography, parental material, climatic and geographical situation (space and time). The soil function are (1) to act as physical support to vegetation, (2) serve as a medium for sorting water to be used by roots of plants and (3) to supply a small but an essential percentage of the materials which are converted into plant food by photosynthesis.

(i) Geological structures of soils

Geologically, the soil of the area are composed of heterogeneous and unconsolidated alluvial deposits in various geological belt (Fig, 2B and 2C) given below:

Boulder belt

This part includes the boulders shingles and gravels of great thickness. The soil cover is sandy and poor in clay. The soil are feebly leached and are less acidic in nature. The process of infiltration, in action with upper piedmont slopes and braided river bed in Suswa leading to the formation of hydromorphic soil in the lower terraces and the lower reached of Suswa River.

Siwalik Belt

The belt is characterized by conglomerates, sandstones and thick bands of clay (Pandey, verma and anantharaman, 1983) [19]. The soil resulting from these rocks are sandy loam with a large proportion of clay i.e., 50% (Saxena, 1975, Figs, 2B & 2C)[27]. On the higher slopes the soil cover is very thin and on the lower slopes it becomes thick. It is observed that the outer dip slopes of the Siwalik belt, dun consist of clayey soil (Figs. 2B & 2C). The Motichur syncline is covered by the soil. The lower colluvail slopes have coarser textured and gravelly soil. Lower Siwalik and Nnahan sandstones produce fine silt and clay.

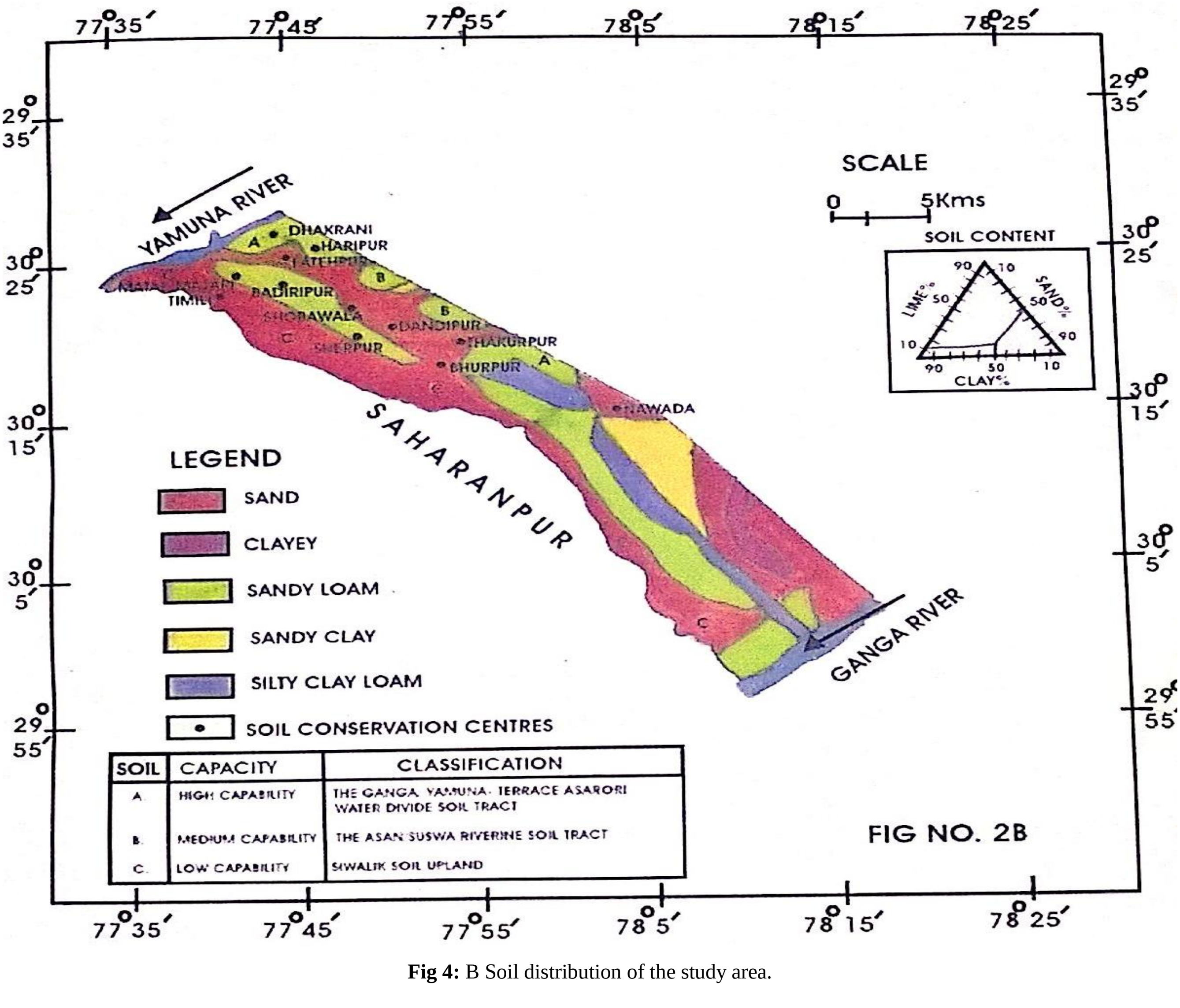

Fig 4: B Soil distribution of the study area.

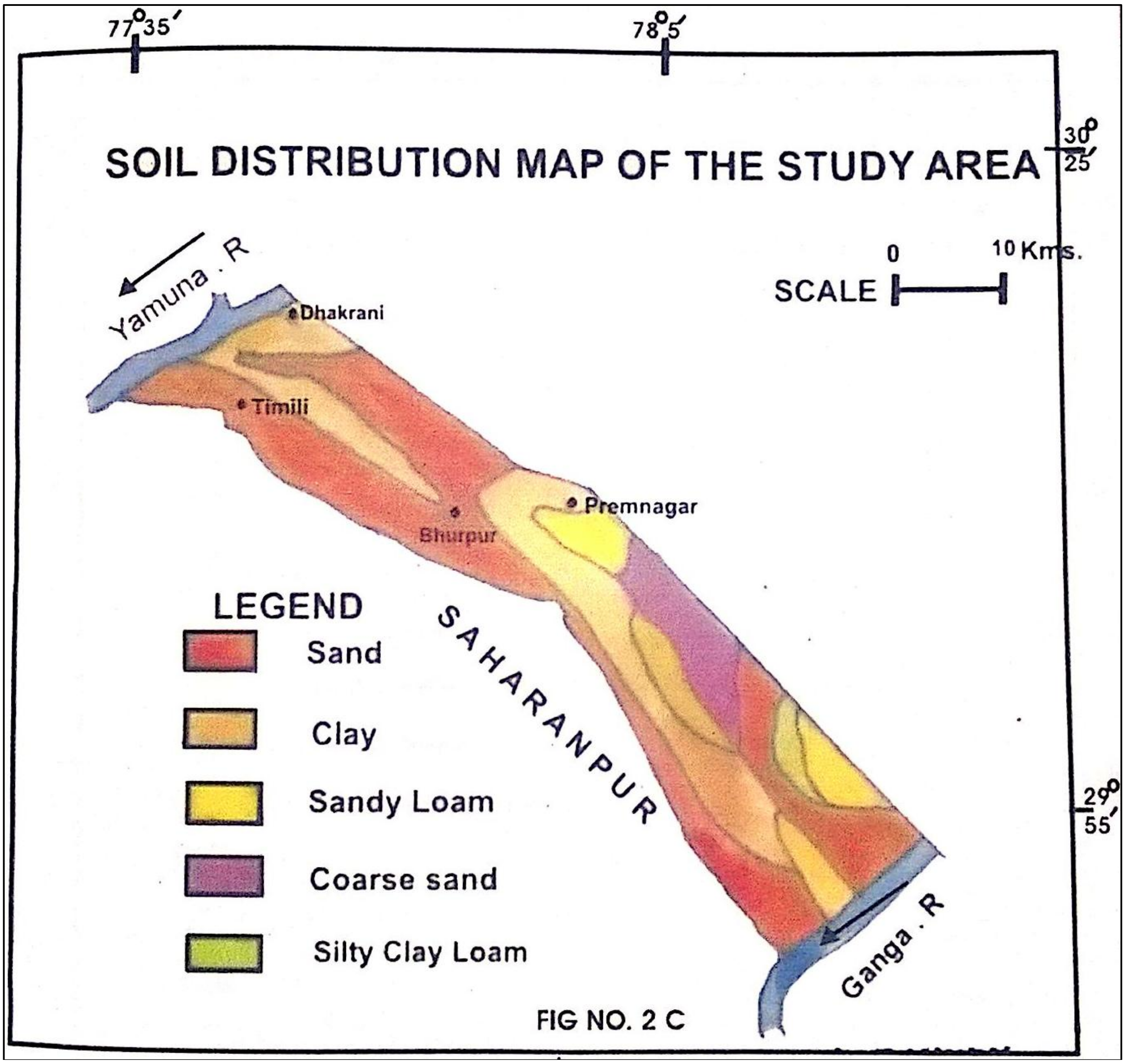

Fig 5:C Soil distribution map of the study area.

The classification of the soil of the area is as follows:-

Goyand: it is very good clayey friable, fertile soil devoid of pebbles and stones. It is deposited below the spurs.

Rausli: it is medium sandy soil consisting of some pebbles.

Dakra: it is good, brownish, clayey soil and is found in lowlands.

Sankra: it is the fertile soil in the area. The soil capability given below is based on chemical composition of the surface soil with depth slope, erosion, soil moisture infiltration and present land use (Saxena, 1975)[27].

High Capability: the Ganga-Yamuna terraces and water divide soil tract. The soil is rich in human and the slope is between 7.5 and 15 meters/1.6 km (25'-50'/mile).

Medium Capability: Asan-Suswa riverine soil tract-Mostly the alluvial material is completely spread over the riverine, old beds of Song, Suswa and Asan and also the Holocene fans. It is medium soil with 20 to 30 % of clay. The soil is coarse textured and brownish in colour.

Low Capability: Siwalik soil upload –the soil of this group is sandy loam. The gradient is between 151 and 303 meters/1.6 km (500'-1000'/mile) and the soil cover is very thin.

Soil Resources depletion

The increasing pressure on the land distribute the natural balance between soil formation and soil conservation on the one hand and soil erosion on the other hand It is the function of soil and water conservation.

Geomorphic Processes

The topography of the area is much responsible for the existing properties of the soil. The soil of the region are all alluvial and their properties are determined by various geomorphic processes.

Regional uplift:

The rejuvenation caused the incisions in the river valley like ingrowned and entrenched meanders of the Dun, resulting in the formation of the terraces. On the basis of the age of the terraces, the soil may from calcareous and pavements, through leached inceptisol and alfisol. The colour of this chronosequence vary (from young to old) from grey through grayish, yellowish brown to yellowish red and red.

Differential uplift

This type of uplifting is visualized between the Siwalik Hills and the alluvial cover of the Dun, and it has caused varying steepness in the gradient of the river and small streams. This has greatly influenced the texture of the soil. For instance, the river Ganga has deposited coarse material on its banks (dhang), while the river Yamuna has deposited fine textural alluvium on its terraces. The central part of Dun, consisting of the finer material, deposited by the river Suswa and Asan, forms a flat to gently sloping old plain of 10 meters (33') thick find silty and clayed soil on which old clay soils with textural and B horizon have formed.

Block Faulting
It has been a process to bring a change in parental rock of the soil with the result, the older surface have been raised out of the later sediment. The surface being relatively higher from the local base level consist of old soil. The monodnacks of the old piedmont fan surfaces are found as sedimentary caps of overlying hills of Siwalik core. The incision of the streams due to the regional uplifting of block faulting gives rise to widespread erosion which removes the humus rich top soil under forests. Sometimes the extremely of the erosion prevents the formation of the textural and B horizon.

Phytogeographic Factors
The region is more or less well covered with natural dense and scrubby types of vegetation and forests. The dun gravels (the boulder belt) present a very thin coverage of vegetation. Consequently, it has a little amount of humas compared to the Siwalik in the south of the Dun. The present study reveals that the land covered with scrubby and forest vegetation has generally clayey and dark coloured vegetation, gradually become sandy and sandy loam in nature.

Genetic Factors
The catchment area of various streams have an influence directly on the properties of the various sediment deposits by them. The rivers Ganga and Yamuna bring micaceous materials, streams from laser Himalayan drainage line produce calcareous materials in the Dun, while the streams from the Siwalik drainage line bring down siliceous materials.
Similarly there is great difference in piedmont fan material in the Himalayan belt and Siwalik belt. The piedmont material from the former is composed of coarse fraction of platy shales, slates and latter consists of pebbles, cobbles and gravels at varying depth below the soil surface. The genetic relation and petrological studies show that soils of the region falls in two main belt viz. the Boulder belt and Siwalik belt 3. Soil erosion due to over grazing: It is one of the constant factors responsible for the causation of soil erosion in the region. The cultivated land adjacent to the forest roads is generally decomposed by the movements of animals and this decomposed layer of soil is badly washed out during rains. The total land under soil erosion by grazing is about 7 sq. kms. (4.4 miles) in region.

4. Soil depletion and quarrying: Quarrying of massive sandstones in one of the most prominent geo-factors of soils erosion.

Depending on inclination of the strata the following intensity of erosion has been recorded on various slopes[1]:

1. Weak erosion tales place in regions with a gradient of 250'/mile (175.7), meters/1.6 km) 0-3^0.
2. Medium erosion takes place in regions with a gradient of 500'/mile (151 meter/1.6 kms). 3^0-5^0.
3. Pronounced erosion takes place in regions with a gradient of 1500'/miles (454 meters/1.6 kms) 5^0-7^0 and
4. Very pronounced erosion takes place in regions with a gradient of 2500'/mile (757 meters/1.6 kms) 7^0-10^0.

The erosion is more pronounced on the northern slopes and convex slopes as compared to the southern slopes and concave slopes. This is because the steepness increase down the slopes in convex slopes and slops and steepness decreases down the slope in concave slopes.

Soil Resource Conservation
The devices against erosion should be mainly directed to the removal of its causes and not to its consequences. The measures against the soil erosion should be based on a harmonious complex comprising forest reclamation, agrotechnical and hyrotechnical measures within the framework of the scientific management of the land This complex and systems of measures should be on the fight against stream.
Erosion, involving the immediate protection of the soils of the whole catchment basins through the creation of belts and grazing strips and the control of cultural micro relief as well as through the undertaking of engineering works i.e., ditches, embarkments, terraces, dikes, drainage and water absorbing installations so as to redistribute the surface runoff and elements the ablation of the soil. The soil conservation measures are classified into two parts viz., biotic measures and mechanical measures. The biotic measures check the soil erosion indirectly and the mechanical measures check the soil erosion.

(A) Biotic Measures

1. **Nature of crop cover:** Cultivated legumes in general provide better cover hence better protection to cultivated land against the erosion than the cultivated bare fallow-land (Fig.8 B).
2. **Intensity of Ploughing:** it has been observed that too many unnecessary titling operations are harmful to land and accelerates soil erosion[2] due to runoff. Further, they reduce production also. Three ploughings are sufficient for maximum yield of maize grains and grains in the region.
3. **Change in crop rotation:** Of most important with regards to the fight against soil erosion is the choice or correct rotation, taking into account the time during which the soil is protected from erosion by agricultural crop, Good crop rotation, under maize-peas and malze-wheat rotation, can yield higher return and effectively check soil erosion in the region.

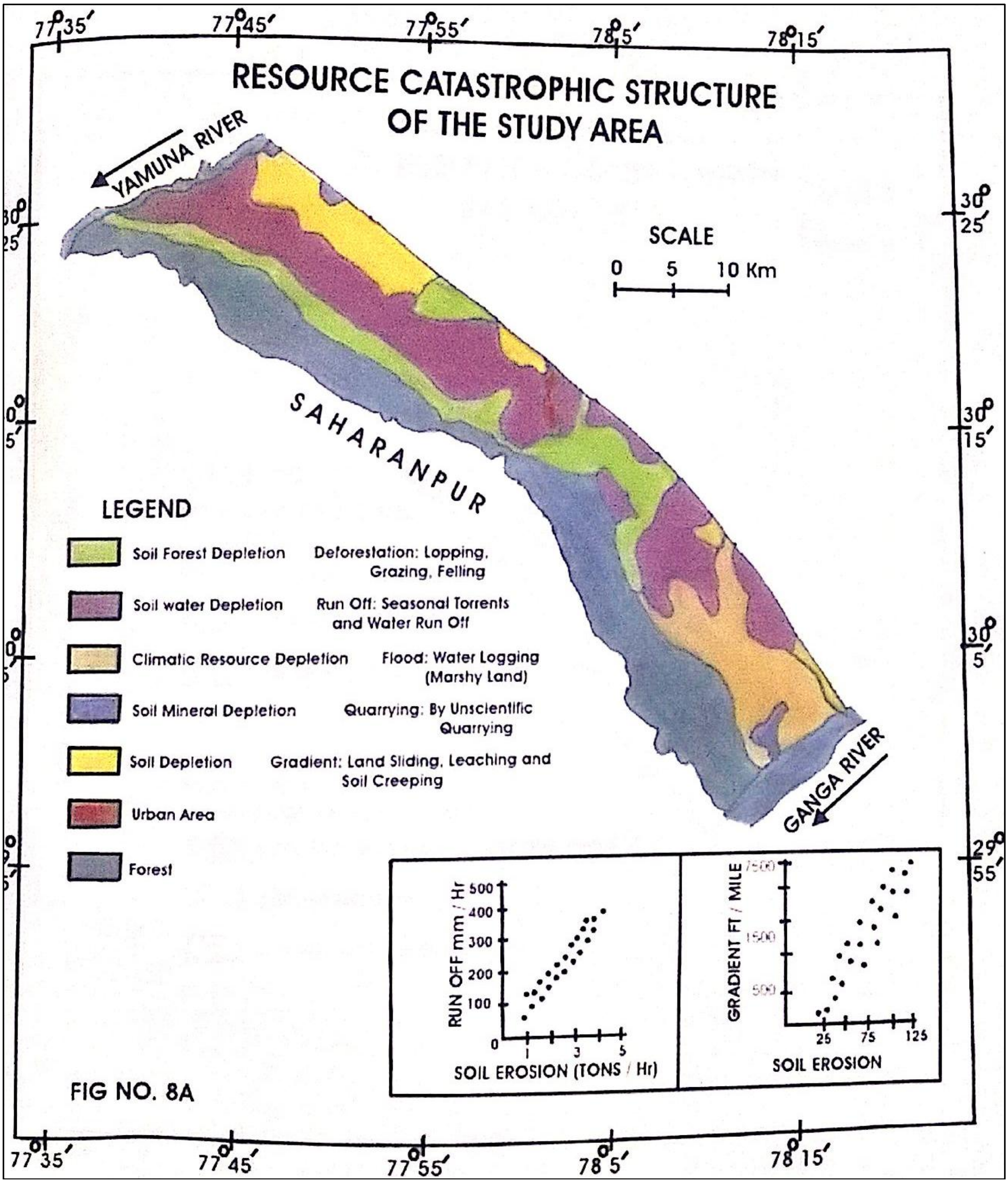

Fig 6: A Resources catastrophic structure of the study area.

4. Afforestation: Protective forestation in the region constitutes one of the most important measures for guarding soils against the harmful effects of droughts, ablation and scouring, therefore, one should resort to afforestation wherever the soil is in need of such protection On the hill slopes the ploughing should be restricted to slopes with gradients $10^0 – 15^0$ for saving the soil from erosion Forest belts combined with grass and soft fruits strips on terraces (Fig. 8B) and other water retaining measures should be adopted. Measures to restore and maintain this balance (Ananthraman, 1984; and Ananthraman, Saxena and Pandey, 1984) [2]. The region is constantly subjected to severe soil erosion due to deforestation, quarrying, flood, water logging, runoff, land sliding, leaching and soil creeping and these lead to the depletion of soil, water forest, mineral and climatic resources.

In the region the area affected by the soil erosion is enormous. The main causes of soil erosion are discussed in the following paragraphs:

1. Soil depletion and runoff: The region which is under well-defined drainage has maximum runoff during rainy season causing severe erosion.

Evaluation of any conservational practice necessitates measurements of soil loss and runoff (Fig. 8 a & C). The details related to dissected portion of the region[1] are given in table No. 16 which after the figure 8C.

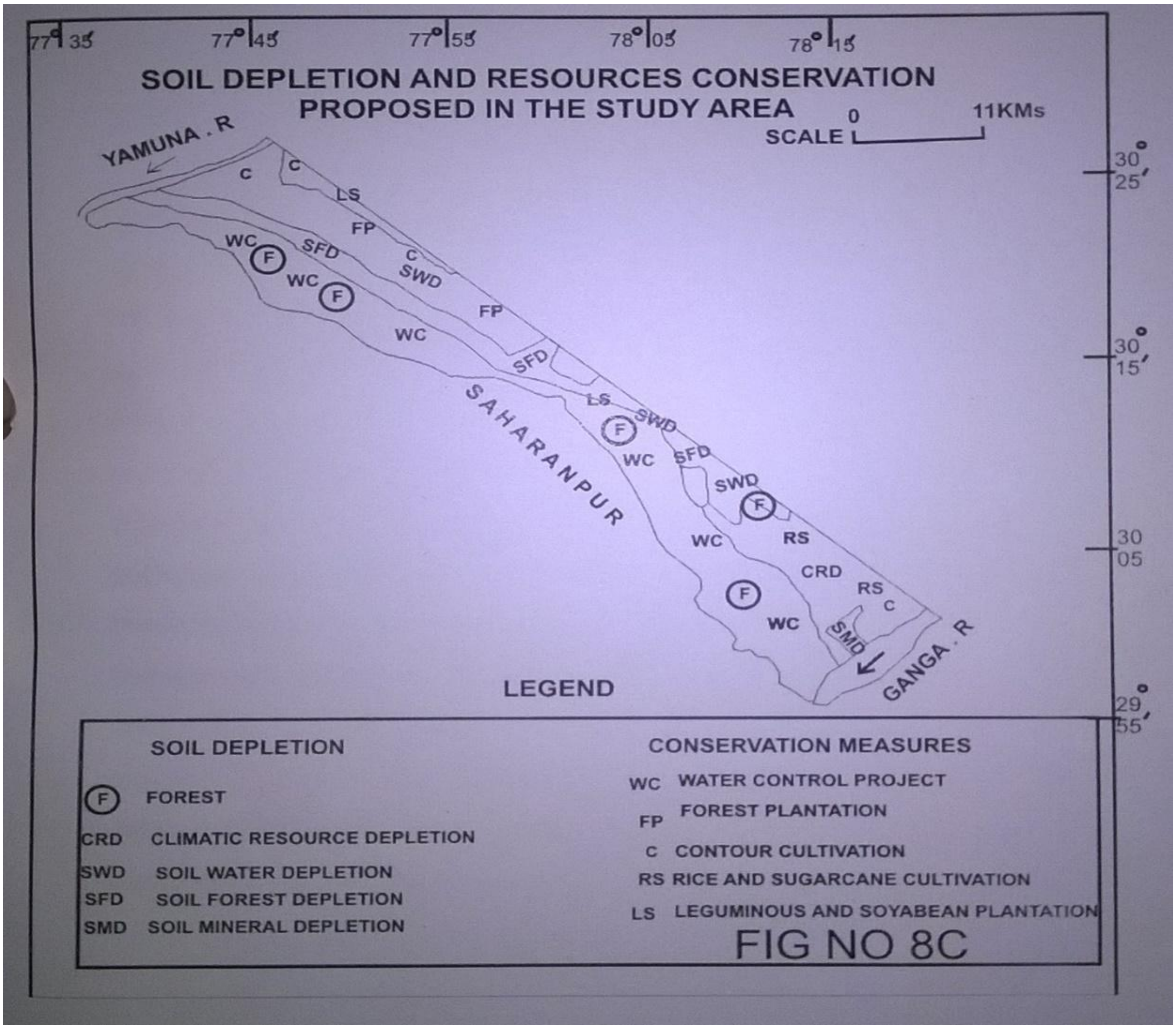

Fig 7

Table 16: Soil loss and runoff in the study area.

Treatment	Between June - October			Between November – March		
	Rainfall in mm	Waterloss as % of rainfall	Soil loss due to soil erosion tons/hr*	Rainfall in mm	Waterloss as % of rainfall	Soil loss due to soil erosion tons/hr*
Fodder graze	1250	27.1	1.10	173	11.4	1.10
Bare fallow	1250	71.1	42.4	173	58.7	3.55
Bare ploughed	1250	59.6	55.95	173	45.6	5.77
Natural grass	1250	21.2	1.0	173	4.1	0.03

From the table No. 16, it is observed that the maximum water loss occurs bare fallow plot, whereas maximum soil erosion is associated with bare ploughed plot. The soil erosion remain low under grass cover. This proves the effectiveness of grasses as soil and water conservation media.

Soil depletion and over fallowing and over plughing under different crop combination with various systems are as follows:

Maximum soil erosion occurs when giant star grass is grown on bare land, but on cultivated land, the contour cultivation system with maize and wheat crop combination result with maize and wheat crop combination result in minimum loss It may, therefore, be concluded that the land need not be left bare follow.

2. **Soil erosion and deforestation:** The practice of deforestation prevails in the forest villages of the region. Towards Siwalik slopes deforestation also occurs on account of flow of rain water which washes the decomposed layer of silts, pebbles and weakness the roots due to which trees fall down. Along the Ganga and Dehradun-Haridwar railway line deforestation is due to increase of settlement areas.

(B) Mechanical Measures

These play very important role in soil erosion control. The mechanical measures include graded bending or channel terraces, contour cultivation, contour strip farming, bench terracing and buffer strip cropping.

1. The channel terraces: Reduce soil loss by decreasing the length of the slope. The method should be used in areas having annual rainfall more than 200 cm. In this method, a portion of water is allowed to be impounded to infiltrate the soil and divert some water to one side of the field. This method should be applied in the lower terraces.
2. Contour Cultivation: Each ridge of the contour furrow formed by contour farming serves as a dam and each depression as a diversation ditch. The water is allowed to enter the soil body and to percolate through it, rather than runoff the surface and carry away the fertile cover of the soil.
3. Contour Strip Cropping: In this method bands of crops are grown on the contour at right angle to the natural slopes of the land. This is also effective to control water erosion.
4. Bench terracing: It is one of the most important mechanical soil conservation practices. Bench terracing is constructed by half cutting and folds. Filling and the original ground slope is converted into level step like folds. This practice is suggested in villages located along the water divide and spurs.
5. Buffer strip cropping: In this method, on steep badly eroded areas of a slope strip grass or legume crops are land out between stripes of crops in regular rotation.

Economic Planning

The most urgent problem of the region is the severe soil erosion which bring out in its wake the decline in cultivated area. In the region afforestation and fruit groves belts should the encouraged on the scarp ridges of the ingrown and entrenched meanders of the rivers.

In the piedmont colluvial tract, the cultivated areas of the spur villages should be protected by bending and contour terracing. Grassy water courses for checking soil erosion be introduced in the settlements along the spring lines where the flow of water is not very swift like chanderbani, Banjarawala and Bhupalpani. This spring line lies in the flat to gently sloping run gravels. In the siwalik structural and denudational hills, the forest ranges of kansrao and Asarori in the Eastern part and Jhajra, Malhan and Timli.

Conclusion

The study area that is southern part of Dehradun valley is composed of Shiwalik sediments between Ganga and Yamuna rivers in the North West and south east respectively as the source material is of arenuaous & argillauous in nature the resultant soil reflect the same the soil classified as. Boulder bed and shiwalik belt according to the composition and on the basis of their properties, they are classified as Goy, Rausli, Dakra, Sankra, and on the basis of their capability they classified high medium low.

The soil resources depletion is mainly due to the regional uplift, differenicial uplift, block faulting and abiotic factors.

The soil conservation method include the biotic measures such as crop cover, plunging, crop rotation, forestation, contour cultivation.

Keyword

1* Survey of doon valley by IIP Dehradun faculty paper, fifth int. sem. Promation & training aspect of integrated survey by ITC- UNESCO centre, India, 1971. P.p 6-7.

2* this formation is not exposed in the study area but is observed along Western bank of Yamuna river which form the boundary of the area.

3*IPI 1971 Survey of doon valley, P 27.

4*Dhang – Raised land mass near river bank is known as Dhang in Local dialent.

5* As adapted by central soil and water conservation and research Centre Dehradun.

6* soil samples are from soil conservation Centre.

7* soil sample are from C.S.W.R.C. Dehradun.

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