Chapter 4

GEOMORPHOLOGICAL CHARACTERISTICS

4.1 Land Forming Processes

Land forming processes consist of both erosional and depositional process. Different types of weathering, erosion and deposition are the important factors in the development of landscape in south-western Midnapur.

Diverse erosional agents such as water, groundwater, etc. play a vital role in landform development in different environmental situation (plateau fringe and plain). It may be mentioned that, weathering, erosion and deposition are the continuously acting processes which are responsible for dynamicities in the landscape of the area under study.

4.1.1 Erosional and Depositional Processes

In the present context erosional and depositional processes include both physical and non-physical factors responsible for the development of landforms.

Weathering

The role of weathering especially in the development of soil in the area is very important. Weathered parent material is an essential condition for the development of soil. Weather-
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ing loosens the rock structures by disintegration and decomposition and broadens the way for erosional process. Continuous removal and transfer of weathered materials through erosional agents (rainfall, running water) gives rise to gradual reduction in the amplitude of relief in the area under investigation.

Geomorphologic processes can affect rocks and soils of any geological age and human activities often induce change or accelerate the process of change. Weathering and denudation are the natural processes that affect the geomorphic environment of the area concerned. The environment maintains a delicate equilibrium between various forms of changes. An improper treatment of any component not only accelerates many natural processes but may introduce new hazards to the area.

Weathering process alters the physical or chemical state of rocks at or near the surface with eroding or transporting products of alternation. Mechanical disintegration and chemical decomposition are the two important weathering processes. The chemical weathering is more important than the mechanical weathering in the area. The minerals of surface rocks tend to be weathered by exothermic chemical reaction resulting new compound of greater volume and low density. The physico-chemical process and its resultant rock are responsible for the present surface mantle of the study area.

Running Water

Running water is the most widespread exogenetic erosional agents in the study area. The characteristic landforms arising out of fluvial erosion include meanders, river terraces etc.

Soil Erosion

Soil erosion is a comprehensive process of wearing down of loosened land surface through natural agents such as running water, groundwater, sea waves, glaciers, winds etc. Broadly speaking, there are two types of soil erosion i.e. (i) soil erosion by natural agents and (ii) man-induced soil erosion.

Natural soil erosion is common almost everywhere in the area under study. Soil re-
moved by the natural agents (running water, rainfall etc.) in almost every parts of the area. Sometimes, negligible amount of finer soil or colloids also move down within the soil profile and are deposited in the lower horizon.

During heavy downpours soil erosion reaches maximum in the study area. Water erosion is mostly severe during rainy season. Soil erosion by rain has three harmful effects i.e. (i) it detaches the soil, (ii) its beating effect destroys granulations and (iii) its splash displaces soil. Soil through gullies is most harmful to land utilisation in S-W Midnapur. Besides natural erosion, intense human activation lead to severe erosion. As a result of compaction, smearing, excessive working, pulverisation etc. through human activities fertile upper soil layers are removed faster. As a result, soil organic matter declines and consequently physico-chemical properties of soils are changed. Man-induced soil erosion is mostly common in the area due to extensive forest clearance, removal of grassland, overgrazing for livestock and boulder extraction at an alarming rate. However, soil erosion whether natural or man-induced affect the scale of use of land (De & Jana, 1997) [98].

River Bank Erosion

The rivers by nature erode their banks. They change their courses by eroding one bank and depositing the eroded materials to the other. Generally stream bank erosion gets momentum during rainy season when discharge of water in the channel bed increases. Most of the rivers in this part of West Bengal are engaged in stream-bank erosion (De & Jana, 1997) [98].

The principal river of the area is the R.Subarnarekha and Dulung is the main tributary. In the lower reaches of the Subarnarekha, deposition is found to be maximum. Some erosional hazards are found in the upper part where altitude is comparatively higher. The river bank erosion creates ecological imbalance by damaging crop fields, settlement sites, soil as well as natural vegetation (De & Jana, 1995) [96].
Leaching

Leaching is a process by which soluble materials such as, mineral salts and organic matter are washed out from the upper layer of soil into the lower horizon by percolating rainwater. In the study area less leaching takes place during the prolonged summer season. During the south-west monsoon the area receives heavy rainfall which causes thorough leaching within the soil profile. Consequently, the soluble materials are removed. High temperature and heavy downpours favour the degree of decomposition of rocks. As a result, the bases are leached out easily because of precipitation. High temperature and high moisture accelerate the process of humification and mineralization which keep the surface low in organic matter thereby land use is affected (De & Jana, 1995) [96].

Fluctuating Underground Water

Underground water table is one of the most important parameter of environmental situation. The soil character is influenced to some extent by the depth of water table. The process of laterization which is predominant in the area is largely influenced by the depth of water table. The seasonal fluctuations of the ground water table in summer and rainy seasons are in a large measure responsible for environmental deterioration. In a sample survey at Gopiballavpur village (Gopiballavpur-I), the author has measured the depth of some wells. It is interesting to point out that in a small village like Gopiballavpur, the depth varies considerably 6.75m, 6.30m, 6.25m, 5.75m, 5.60m and 4.50m. The average recorded depth during three seasons vary from 6.50m in summer, 5.75m in winter to 3.80m in rainy season respectively (Based on observations of more than 40 wells).

In Kharikamathani village (Nayagram Block) the water table depth varies from 4.80m, 5.00m to 10.35m in winter season. A remarkable variation in the depth of underground water table is observed within the village. In the south-eastern part the water table lies as below as 10m from the surface whereas in the west and north western part it lies between 1.50 to 2.00m from the surface (Recorded in December, 1991).

Fluctuations in the underground water table affect the concerned environment. The
less moisture content of the upper surficial material (Gopiballavpur, Nayagram, Sankrail, Keshiary) due to impervious honey-comb lateritic soil develops hard iron pan on the surface as well as the prolonged drought before and after rainy season.

The state of underground water in the alluvial tract, however, is comparatively better. So, no evidence can be found here in favour of such landform changes due to underground water fluctuations (De & Jana, 1995) [96].

Boulder Extraction

Boulder is generally used for road construction and house building purposes. In Keshiary and Sankrail areas boulder extraction on a large scale is found. In these places a number of excavated hollows are seen. To get quality boulder the builders extract it on a commercial basis neglecting the environment or at the cost of the environment. After the extraction of boulders the excavated hollows cause severe environmental problems such as soil erosion, land degradation as well as it leads to immaturity in the development of soil profile.

Deforestation

Deforestation plays an important role in the landforming processes in the lateritic tract of the area under study. In the present context the author has done a detailed vegetation survey and noted the depletion of vegetal cover. It has been observed that the Nayagram - Gopiballavpur route is covered with dense jungles consisting of Sal, Sishu, Mahua, Neem etc. The width of the jungle is about one & half kilometre. It has been reported that the jungles were much more denser formerly, but in recent years it has been cleared by the unscrupulous timber traders. Moreover, the forest is also depleted to some extent for meeting the local fuel needs.

The sample survey at Gopiballavpur revealed that, the surroundings were once densely covered with vegetation. The former dense jungles have been cut down by the local people (for domestic use as fuel) as well as by the timber smugglers. Because of deforestation, the Gopiballavpur village has now been affected by the recurrent floods.
In another survey point at Kharikamathani village a dense bushes of Sal is observed. According to a local villager, the present bush was a dense jungle of Sal trees formerly. After the rigorous cutting down of big Sal trees the forest has been cleared. The saplings of present Sal trees are now comming up. Another interesting feature is to be observed that 75% of the people present in a village market were in a drunken condition with Mahua liquor. Obviously question arises in mind that there must be the availability of Mahua forest nearby. As per the local villagers, previously there was a dense forested tract of Mahua. Because of the continuous exploitation as mentioned above it is now found to be scattered. This is a strong evidence in favour of deforestation in the area.

In the field survey the Sal bushes have been observed in the north western part of Keshtiyaria. It is reported that the whole northern part was once a dense forested tract which has subsequently been destroyed by the continuous exploitation of valuable Sal trees. However, some of the deforested tracts are now under social forestry while others are still lying as vacant. The consequences of deforestation are clearly seen in the area.

Owing to continuous depletion of vegetal cover the environment being affected severely. In the last ten years a notable climatic change in the study area is observed. It is interesting to note that the region is going towards drought conditions. The state of underground water is going to be worsened day by day only due to the vagaries of monsoon. Sediments in the bed of R.Subarnarekha have increased. Soil erosion in the deforested part of the lateritic tract is a regular phenomena.

River Deposition

Generally in the lower course, the rivers deposit their loads brought down by the concerned rivers from the upper catchment. The R.Subarnarekha flows in a zig-zag direction through the area under study which indicates the sluggish nature of the river. The vast amount of river-bourne sediments coming from the upland in the west affect the channel depth causing flood (Dantan and Keshtiyaria area) in the rainy season due to over discharge of water thereby flood alluviation takes place. The R.Subarnarekha in different parts of its courses deposits sediments of different grades thus contributes various aggradational
landforms such as sand banks, natural levees, floodplains, sandbars etc.

4.2 Morphometric Analysis

Morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface as well as the shapes and dimensions of its landforms. In morphometric analysis topographic maps on which the surface relief is portrayed by the contours, provide a valuable tool for the geomorphologists. Morphometric analysis provides sufficient clues to visualize and reconstruct the analysis of regional morpho-units. This analysis helps to pinpoint those parts of the area where relief, drainage and slope aspects need intensive investigations.

In the present context, different morphometric attributes (i.e. average relief, relative relief, dissection index, ruggedness index, slope, stream frequency, drainage density) have been applied to represent the nature of topography and its relevant relationship with land utilisation.

4.2.1 Relief Analysis

A landscape is composed of variations in altitude forming the relief of a region. Thus relief analysis forms an essential part of the landform system analysis. The term relief may be defined as the differences in the elevation of any part of the earth's surface. But there have been considerable differences among the geomorphologists regarding the definition of relief. Relief is a concept intended to describe the vertical extension of landscape feature without reference of absolute relief, relative relief, relief profiles, area-height relations and dissection index.

Relief analysis of a region is interrelated with slopes. Both slope angle and sediment loss (hence, rate of change in slope) are greatest where relief is at a maximum. Relief is indicative of the potential energy of a drainage system, by virtue of elevation above a given datum.
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The relief aspects in the present context have been considered as some of the specific components for the terrain classification and their evaluation for agricultural land use. These aspects have been taken into account as the relief, through its manifold bearings upon soil formation, soil erosion, run-off and static and dynamics of drainage exerts collective natural influence on the inherently potential, potentially vital and socio-economically viable land attributes of agriculture. Relief, as a geomorphological factor, greatly affects the grade and alignment of agricultural plots, their locations and accessibility, field channels and feasibility of different modes of irrigation and methods of cultivation (Patnaik, 1993) [206]. Therefore, it is essential to investigate the important elements of relief such as average relief, relative relief, dissection index and ruggedness index.

Average Relief

The concept of average relief is associated with the idea of having a very simple measure of the general altitude of any given unit of area on the earth’s surface. This exercise should not be taken as something outstanding on very significant when considered as an independent method, but even on the basis of such a method some findings are made which may be of sufficient significance not from the conventional viewpoint of geomorphology but from some specific angle of enquiry. On the basis of average relief, some sort of zonal classification of terrain becomes possible.

The term ‘average relief’ is an expression of a projected workability of relief intensity in regard to any land use type. It is calculated as an average of maximum and minimum height-values within a purposefully specified unit area. Average relief, therefore, is an average amplitude of a two-dimensional relief within a well-defined area conspicuous by it relative altitudinal significance for the user’s three dimensional needs more particularly in the field of agriculture. It, thus provides a projected potential base for further diagnostic survey of the terrain relief for generating/evolving a significant number of more potential micro-terrain units at a time when a more detailed evaluation for agricultural land use in the study area requires a rigorous analysis of its terrain.
The dynamic potentiality of a terrain is not truely assessed by the absolute and relative relief for their methodological limitation, but appears to be more expressive and computative in the method of average relief (a significant mid-value component of a two-dimensional sharpness between maximum and minimum heights of a unit area). Average relief, thus serves as an index of reference in bringing closer its upper and lower values to an apparently central value within a reasonable natural limit to diminish the unworkable amplitude of available relief and dissection for increasing the intensity and potentiality of agricultural land.

The active and adverse mutuality of relative relief and slope in their cause and effect inter-relationship is therefore, pacified by the forceful field application of the average relief measures. The average relief, in its sharp and contrasting uniqueness, is an expression of a simple relief mean of a unit area. If put to an effective field test, it points towards the necessity of an areal extent of land-levelling in a given unit of productive space in possible negotiation with the orographical projections of the same unit if any.

It is an undeniable fact that the study of average relief, whether intensive or extensive, will not turn a highly dissected and rough terrain to a flat land, but surely it will enable an applied geomorphologist in his pursuit of agricultural studies to learn how to put a given amplitude of available relief within each unit of his study area to the most effective in terms of agriculture. (Patnaik, 1993) [206].

In the present context, the author has adopted the technique of average relief in order to categorize the study area into several average relief zones (Table 4.1) and to assess the degree of local relief sharpness for utilisation purpose with due consideration to lithological, geological and surface elevational aspects (Fig.12).

Very Low Average Relief Zone

It lies in the southern part of Keshiary, southern half of Narayangarh, whole of Dantan-I & II. This category covers an area of about 27.35% having the dominance of alluvial soil which is a prospective agricultural tract.
Table 4.1: Distribution of Average Relief

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Size class</th>
<th>Category</th>
<th>Frequency</th>
<th>Cumulative frequency</th>
<th>Frequency (%)</th>
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<td>180</td>
<td>27.35</td>
<td>27.35</td>
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<tr>
<td>2</td>
<td>30-60</td>
<td>Low</td>
<td>373</td>
<td>553</td>
<td>56.68</td>
<td>84.03</td>
</tr>
<tr>
<td>3</td>
<td>60-90</td>
<td>Moderate</td>
<td>105</td>
<td>658</td>
<td>15.95</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Low Average Relief Zone

Occupying an area of about 56.68% the zone covers the northern half of Narayangarh, whole of Sankrail (*except a patch in the extreme north*) and Gopiballavpur-II, major parts of Keshiary and Nayagram. These identified zones are little bit undulating with erosional nature having lateritic and older alluvial soils which are not fully suitable for optimum agricultural land utilisation.

Moderate Average Relief Zone

Covering an area of about 15.95% the zone occupies the western part of Nayagram, and whole of Gopiballavpur-I having lateritic and new gravelly soils and erosional topography with the gullies. The zone besides agriculture are enriched with dense forest cover.

Relative Relief

The term ‘relative relief’ denotes actual variations between the highest and lowest hieghts in a unit area with its local base level. It has been differently termed as ‘amplitude of relief’ or ‘local relief’ because ‘it ascertains the amplitude of available relief to relate the altitude of the highest and the lowest points of any particular area’ (Prasad, 1985) [212]. In examining the changes in relief to measure the amplitude in terms of relative values to find out the uniformities or discontinuities in the gradient of change. From the relative relief map we may assume the nature of topography or terrain whether it is plain, plateau or hilly country.
Keeping in view the greater magnitude of unevenness in the sequence of surface continuity, it may be mentioned that a relative relief map enumerates physical regionalism implying regional comparison for which it has a definite edge over the technique of absolute relief in visualising the properties of terrain in proper perspective. Both these elements of relief, however, establish a close correlation for all practical purposes including an evaluation-oriented terrain classification relating to agricultural land use (Patnaik, 1993) [206].

According to Singh (1988) [261] relative relief ‘overcomes the difficulty of presenting the three-dimensional relief characteristics with the help of two-dimensional maps.’

Because of its close association with slope, the relative relief is more expressive and useful in understanding classes of natural phenomena including relief dessection and surface ruggedness (Patnaik, 1993) [206]. Thus, ‘the more is the local relative relief, the more is the roughness and there is manifold decrease in the effective value of terrain for arable farming’ (Singh & Dhillon, 1984) [260].

It may be mentioned further that ‘the relative relief enumerates that the steeper the slope the higher the surface above its base’ (Kumar & Pandey, 1981) [164]. Therefore, the greatest advantage of the technique of relative relief is that the sharpness of relief as visualized by it can not be expressed singularly by any graphical representation including surface elevation, profiles and area-height relation curves.

Despite some limitations, the method of relative relief has widely been used by the researchers and planners both for theoretical deductions (such as determination of stages of landscape evolution) and practical purposes (such as terrain evaluation and classification for land utilisation). This method has attained popularity for its simplicity in procedure, objectivity in height determination and clarity in result. In addition, this method can be applied to map of any type of contour pattern. In some specific cases where there is no contour in a particular grid, the maximum and minimum heights can be determined by interpolation (Patnaik, 1993) [206].

To show varying amplitude of relief over the area Smith’s method (1935) [265] has
been followed. It is obtained by calculating the vertical differences between the highest and lowest points in each grid of 4sq.km (4cm x 4cm grid having 4sq.km area).

The relative relief map (Fig 13) shows that there is no such abrupt variations in relative relief in the study area, although the western lateritic undulating tract reflects some changes. Three major categories of relative relief have been identified in the present context for analytical interpretation (Table 4.2).

The table 4.2 illustrates that the study region covers maximum area (86.90%) under extremely low relative relief. The details description are given below:

### Extremely Low Relative Relief Zone

Maximum area falls under this category (86.90%). Occupying the whole area of Datan I & II, major parts of Narayangarh, Keshiary, Sankrail and Gopiballavpur II, considerable area of Nayagram and parts of Gopiballavpur I. This category covers continuous stretches of alluvium in the east, along the Subarbaranmarekha basin, scattered patches of alluvium in the west (although lateritic soil is predominant).

### Moderately Low & Low Relative Relief Zones

These occupy parts of Keshiary, Sankrail considerable parts of Nayagram and major areas of Gopiballavpur I having undulations (alternate low ridges and depressions) which hindrance smooth optimum land utilisation. These cover an area of about 10.86% and 2.24% respectively.

<table>
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<th>Frequency (%)</th>
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<td>86.90</td>
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<td>97.76</td>
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<td>580</td>
<td>2.24</td>
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Dissection Index

From the geomorphological viewpoint the consideration of dissection index is very important in understanding the terrain characteristics of an area. It indicates the stages of evolution of the landform. Such a map of dissection index becomes more meaningful when is taken into consideration. For example, the higher relief is the result of gneissic rock whereas the valley region shows the deposits of newer alluvium thereby developing a subdued relief. Such relief always reflects greater amount of dissection due to higher elevation from the base level of erosion. Greater amount of slope resulting an increase in the erosive power of the agencies in sculpturing those parts.

The word 'dissection' refers to the mechanism and magnitude of relief incision in response to an area's geology, lithology, surface elevation, angularity and amplitude of available relief under a given meteorological framework. It may be pointed out that absolute relief and relative relief - the two attributes of morphometry are inadequate to express the sharpness of the terrain characteristics of the area individually. As Dou Nir (1957) [201] stated that as a criterion of relief energy the concept of relative altitude is not entirely satisfactory. Equal relative altitudes are not always of equal importance, since their absolute altitude may differ. The picture gained from relative altitudes only is static, for it fails to take into erosion base, i.e. the dynamic potential of area studied.

Dissection Index is the ratio of the two variables of morphometry i.e. relative relief and absolute relief within a definite area, to express even the dynamic potential of the area as its vertical distance from the erosion base. Emphasizing the importance of dissection index he stated that it is the index of the degree to which the dissection has advanced, which always lies between '0' and '1' which denoted complete absence of dissection and vertical cliffs respectively, certainly this is an advancement in the expression of the landscape.

The dissection index (a more potential relief element of a diagnostic terrain study) is the product of a ratio of absolute and relative relief within a well-defined unit area. The index of dissection indicates the intensity of effectiveness of relief intensity for achieving an apparent inability of an areal unit especially in terms of agriculture. An investigation
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Table 4.3: Distribution of Dissection Index

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Size class</th>
<th>Category</th>
<th>Frequency</th>
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<th>Frequency (%)</th>
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<tr>
<td>1</td>
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<td>Low</td>
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<td>220</td>
<td>41.67</td>
<td>41.67</td>
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<tr>
<td>2</td>
<td>0.2-0.3</td>
<td>Moderate</td>
<td>205</td>
<td>425</td>
<td>38.83</td>
<td>80.50</td>
</tr>
<tr>
<td>3</td>
<td>Above 0.3</td>
<td>Moderately High</td>
<td>103</td>
<td>528</td>
<td>19.50</td>
<td>100.00</td>
</tr>
</tbody>
</table>

of an areal differentiation of this ratio affords an appropriate estimation of the vertical balance of erosion within a specified unit area. Therefore, the dissection index appears to be quite helpful in understanding the nature of terrain relief better than either absolute or relative relief. Due to its manifold expositions of complex surface expressions it is also helpful for further classification and investigation of terrain units and their more scientific evaluation for agricultural land use (Patnaik 1993) [206].

To prepare the map of dissection index, 4sq.km grid patterns are used and grid-wise values of amount of dissection are obtained by the equation: Maximum height-Minimum height/Maximum height. Then the values thus calculated are plotted at centre of each respective grid and isopleths are interpolated (extrapolated wherever necessary) resulting in the present dissection map.

On the basis of dissection index the study area has been divided into three major categories viz. low, moderate and moderately high (Fig 14) (Table 4.3):

Table 4.3 illustrates that major part of the area falls under the categories of low and moderate dissection. The intra-regional variations of the nature of dissection are as follows:

Low Dissection Zone

This zone occupies considerable areas of Narayangarh, Keshiary and Sankaril, parts of Gopiballavpur I & II and Nayagram (both sides of R. Subarnarekha), almost all areas of Dantan I & II where altitudinal variation is not so significant. This category covers an area of about 41.67% and offers physical possibilities for agricultural land utilisation.
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Moderate Dissection Zone

Covering an area of about 38.83% this zone occupies the northern part of Narayangarh (where undulation is present), considerable parts of Keshiary and Sankrail, small parts of Gopiballavpur-II, significant areas of Nayagram and Gopiballavpur-I.

Moderately High Dissection Zone

This zone covers the major areas of Gopiballavpur I and Nayagram, a small parts of Narayangarh and Sankrail which reflect variation in surface elevation and creates hindrance to agriculture. The areas of Gopiballavpur-I and Nayagram exhibit erosional surfaces. This zone covers an area of about 19.50%.

Ruggedness Index

The ruggedness index is a measure of surface unevenness under a given lithological basement complex. The technique expresses different degrees of surface resistance or submission to either manual or mechanical land use operations. It is a derivative of long-standing interaction between the available sharpness of the local relief and the amplitude of available drainage density. Moreover, other physical environmental parameters such as slope, precipitation, weathering, soil texture, natural vegetation, etc. are partially responsible for the ruggedness of a surface (Patnaik, 1993) [206].

Chorley (1972) devised the method of ruggedness index (number) for measuring the extent of dissection by taking into account both relief and drainage. It may further be pointed out that the nature of dissection can accurately be measured not considering only relative relief and other variables but drainage texture also. The author in the present context feels it necessary to apply the method devised by Chorley which incorporates relative relief and drainage density in the form of product. The method of ruggedness index is calculated by the formula: Relative relief and Drainage density /1000 * (constant). (* the length of one side of the squared grid : 2km) (Fig.17).
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Table 4.4: Distribution of Ruggedness Index

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Size class</th>
<th>Category</th>
<th>Frequency</th>
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<tbody>
<tr>
<td>1</td>
<td>Below 0.02</td>
<td>Low</td>
<td>616</td>
<td>616</td>
<td>95.06</td>
<td>95.06</td>
</tr>
<tr>
<td>2</td>
<td>Above 0.02</td>
<td>Moderate</td>
<td>32</td>
<td>648</td>
<td>4.94</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Based on the ruggedness index the study area has been divided into two major categories (viz. low and moderate) to assess the nature and magnitude of ruggedness for practical purposes (Fig 15, Table 4.4):

It is evident from the table 4.4 that almost the major part of the area reflect low dissection index except some patches. The intra-regional variations of ruggedness are as follows:

Low Ruggedness Zone

This zone covers the entire eastern part (Dantan I&II, Narayangarh), both sides of the R. Subarnarekha and major parts of Nayagram and parts of Gopiballavpur I. The area under this category (index value 0.01) is characterised by older and newer alluvial soils, very low drainage frequency and density offering possibilities for agricultural development. The area under index value 0.02 reflect older alluvial and lateritic soils, low drainage frequency and density, moderate suitability for land utilisation. The category of low ruggedness covers an area of about 95.06%.

Moderate Ruggedness Zone

Covering an area of about 4.94% this zone occupies considerable parts of Nayagram, Gopiballavpur-I, small parts of Keshiary, Sankrail and Gopiballavpur-II which are characterised by lateritic, red gravelly soils, moderate stream frequency and medium drainage density reflecting comparatively less suitability for land utilisation.
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Average Slope

The term 'slope' commonly refers to 'some small element or area of the land surface which is inclined from the horizontal' (Strahler, 1968) [279]. Slope, an element of inclined relief expresses the relief from the horizontal or local base level in a unit and is shown often in degrees. Slope is a product of exogenetic and endogenetic forces such as lithology, surface material, surface elevation, relative heights, climate, vegetal cover, magnitude of weathering and erosion and other numerous factors. Slope thus defined is 'a function of structure, process, time and tectonics' (Ahmad, 1985) [2]. Shukla (1975) pointed out that the slope in the valley is a function of lithostratigraphy.

Slope may be designated as 'mountain slope', 'hill slope', 'valley side slope' and other inclined surfaces with reference to any plane, tangential to the surface base at any point. In fact the slopes are the 'upward or downward inclinations resulting from the form of the natural landscape' (Harry, 1969) [131] and the tangent of gradient is the first derivate of relative altitude, i.e. the rate of change in height with distance.

'Slope is specifically most powerful physical determinant in agricultural land utilisation, affecting the existence, depth, structure, texture and stability of soil; possibilities and pattern of irrigation, field pattern, distribution and size of holding; cropping pattern, agricultural output and efficiency, agricultural transport, etc.' (Ahmad, 1985) [2].

Systematic and scientific studies of slope have been done by S. Finster Walder, Rich (1916), Wentworth (1930), Raisz and Henry (1937), Smith (1938), Robinson (1948), Strahler (1956), Miller et al. (1960), and Eyles (1965) [224, 298, 217, 266, 225, 277, 181, 108]. S. Finster Walder, the father of slope analysis devised a quantitative method of 'average slope' determination which paved the way to the future workers like Wentworth, Smith, Henry, Raisz, Miller and others. Wentworth's method is found most suitable and applicable due to its lucid approach.

The Wentworth's method of slope analysis is a 'general' and 'random' method of average slope determination from a contour map based on the following formula:
S-W MIDNAPUR
AVERAGE SLOPE (in Degree)
(After Wentworth)

LEGEND
- Level (below 1°)
- Very Gentle (1° - 2°)
- Gentle (above 2°)

Grid Size : 4 km²
1, 2, 3 etc are grid Numbers.
N.B: All grids have not been given numbers.

 fig. 16

 fig. 17
Chapter 4. Geomorphological Characteristics

Table 4.5: Distribution of Average Slope

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Size Class</th>
<th>Slope Category</th>
<th>Frequency</th>
<th>Cumulative Frequency</th>
<th>Frequency (%)</th>
<th>Cumulative Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Below $1^\circ$</td>
<td>Level(almost)</td>
<td>449</td>
<td>449</td>
<td>81.04</td>
<td>81.04</td>
</tr>
<tr>
<td>2</td>
<td>$1^\circ - 2^\circ$</td>
<td>Very gentle</td>
<td>94</td>
<td>543</td>
<td>16.97</td>
<td>98.01</td>
</tr>
<tr>
<td>3</td>
<td>Above $2^\circ$</td>
<td>Gentle</td>
<td>11</td>
<td>554</td>
<td>1.99</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Average Slope = (Average number of contour crossings per unit side of a square grid × contour interval) / (Length of one side of the grid in unit of contour interval × 0.6366).

It has already been mentioned that the study area is the transitional zone between Chotonagpur plateau fringe and alluvial plain. The area is traversed by the R. Subarnarekha, its tributary Dulung and the Keleghai river. Some parts are covered with lateritic and red gravelly soils. For the occurrence of such surface configuration and natural actions of these rivers the average slope is not so significant although intra-regional variations are there. The area has been divided into three categories for assessing the intra-regional capability and limitations for agricultural development (Table 4.5, Fig 16):

The table 4.5 illustrates that the major parts of the area are under level category (81.04%). Very gentle and gentle slope are found in some parts of Sankrail, Gopiballavpur-II and considerable parts of Nayagram and Gopiballavpur-I covering an area of about 16.97% and 1.99% respectively. Thus, the level ground (slope) in the alluvial tract offers physical possibilities for agricultural land utilisation.

4.2.2 Drainage Texture

Drainage texture is an indicator of the spacing of the stream. The texture of the area is the product of number of contour crenulation and the length of the basin perimeter so frequency of crenulation indicates the closeness of channel spacing. The texture ratio can be computed by the following equation: $T = \frac{N}{P}$ where $T$ means texture, $N$ is the number of contour crenulations and $P$ is the length of the perimeter.
Drainage texture refers to the relative spacing of total number of stream segments of a given length per unit area. Thus, it is a bilateral index manifesting drainage density / stream length and stream number/stream frequency with respect to their relative spacings in a given areal unit. It represents varying regional scales of textural fineness, medium texture and textural coarseness emphasizing thereupon the extent of agricultural land use development in a specified unit area. These generally accepted relatively quantitative usages of drainage texture as fine, medium and coarse are seemingly situation specific in their areal applications without indicating a rigid adherence to any arbitrary definition or all-too flexible textural scales. Further, the varying grades of drainage texture do not refer to such factors as steepness of slope, amount of relief or stage in the geomorphic cycle because 'we may have fine or coarse drainage texture in regions of low or high relief, in regions of gentle or steep slopes, or in young or old age topography' (Thornbury, 1954) [285].

Whatever may be its morphometric conspicuity, the drainage texture, however, lays a theoretical stress upon a significant critical natural limit. It is indicative of an inter-terranean or intra-terranean imbalance in terms of agricultural land use. It specifies either a productive space in respect of potentially rich water availability or physically possible usability or an unproductive barren space devoid of potential water or excessively drained area. The texture of drainage emphasizes upon different grades of topographical incision and relief contortions which affect the relative ease of tillage in a well-defined terrain unit. In addition, the texture of drainage, through its binomial covariants of stream frequency and density, draws out significantly forceful natural implications of its varying grades with reference to an interaction of its regional geolithology with permeability, vegetation, and human behaviour apart from referring to the frequency, amount and effectiveness of precipitation. It also accounts for a complex regional fluvial dynamics in terms of its volume and velocity accentuating the further complexities of a terrain relief in response to the topographical sharpness and associated factors. Thus, the author aptly considers the texture of drainage as an essentially purposeful physical determinant of a terrain type and class of facets, each representing a distinct class of phenomena and therefore, leading
CHAPTER 4. GEOMORPHOLOGICAL CHARACTERISTICS

It is noted that there are many technical exaggerations and misleading conclusions in respect of a definite textural ratio relationship between the stream frequency and drainage density. There may be conspicuous non-representation of stream segments on a generalised topographic map for obvious reasons of scale limitations particularly the first order stream segments (Patnaik, 1993) [206]. In order to tide over several such mapping limitations with regard to some topographical maps published by the Survey of India; as well as in order to adopt methods relating to the computation, interpretation and conclusions in respect of drainage texture, the author has, thus, diligently taken recourse to field observation, field measurement and incorporation of drainage phenomena consisting of length and frequency of streams that are missing from the details of the Survey of India toposheets of South-Western Midnapur.

On the basis of the topographical maps and field observations the two properties of drainage texture, viz. stream frequency and drainage density have been determined separately (Figs.18 & 19). First of all, the whole area has been subdivided into small micro units (each of 4 square km)(Fig 17) and then the number and length of streams per sq.km. have been counted and measured respectively. These values helped in drawing isopleths at suitable intervals.

It has been done in view of a perspective presentation of facts relating to drainage density and stream numbers per unit area separately for their individual, comparative and collective assessment in order of their variation on space with respect to their distribution and interrelationship. This attempt facilitates in expressing major and minor orders of terrain differentiation and evaluation of agricultural land use in the area under investigation.

Stream Frequency

Stream frequency is defined as the number of stream segments per unit area. It is controlled by various factors viz. climate, underlying rock and vegetation.
Stream frequency is one of the most potent natural indices in determining the magnitude and amplitude of the texture of a terrain and its water potentials. It is a helpful natural indicator in assessing soil loss or soil gain within a specified land unit as well as in augmenting or desicating the units' productive space in terms of available water by its functional interaction with its terrain space expressing the rate of infiltration and surface runoff and so on (Patnaik, 1993) [206].

Therefore, the author feels it purposefully essential to present the organizational and distributional phenomena of stream frequency because this textural component of drainage helps to establish a harmonious blend of several significant geomorphic relationships and interrelationships with respect to the texture of the terrain and agrogeomorphology of the South-Western Midnapur. Thus the number of streams per unit area has been calculated for the present study by Strahler's method taking a unit of 4 sq.kms. The formula is:

\[ \text{Stream frequency} = \frac{\Sigma N}{A} \]

where \( \Sigma N \) = total number of streams in the unit area, and \( A \) = area of the unit. After the calculation, the stream frequency in each uniform unit area has been traversed by the lines of equal value at suitable intervals expressing relative abundance, structural adjustment and general tendency of stream segments in scaling the possibilities relating to agricultural land use such as, the relative ease of tillage, usability, utility and neutrality in terms of available water for the potential productive tracts/terrains of the South-Western Midnapur.

It may further be pointed out that the stream frequency is governed by rainfall intensity, erosional proportionality factor, evaporation, infiltration rate, characteristics of rock and run-off (Hironi, 1991) [135].

The range of stream frequency in the area under study has been divided into four categories viz. very low, low, medium and high (Table 4.6):

Table 4.6 illustrates that most of the frequencies are concentrated in the very low
Table 4.6: Stream Frequency Distribution

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Size Class</th>
<th>Category</th>
<th>Frequency</th>
<th>Cumulative frequency</th>
<th>Frequency (%)</th>
<th>Cumulative frequency(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Below 0.5</td>
<td>Very Low (very coarse)</td>
<td>360</td>
<td>360</td>
<td>55.81</td>
<td>55.81</td>
</tr>
<tr>
<td>2</td>
<td>0.5 – 1.00</td>
<td>Low(coarse)</td>
<td>181</td>
<td>541</td>
<td>28.06</td>
<td>88.87</td>
</tr>
<tr>
<td>3</td>
<td>1.00 – 2.00</td>
<td>Medium (moderate)</td>
<td>88</td>
<td>629</td>
<td>13.64</td>
<td>97.51</td>
</tr>
<tr>
<td>4</td>
<td>Above 2.00</td>
<td>High(fine)</td>
<td>16</td>
<td>645</td>
<td>2.48</td>
<td>100.00</td>
</tr>
</tbody>
</table>

category. The detail description of stream frequency distribution is given in the following paragraph (Fig 18):

The Areas of Very Low Frequency

The areas of very low stream frequency (0 - 0.5) lies mainly in the major parts of Keshiary & Narayangrah, parts of Sankrail, whole of Dantan I & II covering significant area of about 55.81% of the total area. It reveals an important fact that this category covers the maximum area and mostly occurs on the plains of alluvial origin.

The Areas of Low Frequency

Covering an area of about 28.06% the areas of low stream frequency (0.5 - 1.00) lies in the extreme northern part of Sankrail, Gopiballavpur-II, parts of the western and southern side of Gopiballavpur-I, major parts of Nayagram and parts along the course of R. Subarnarekha which are underlain by older alluvium (false bedded lenticular layers of sandy and clayey deposits with pebble beds) and newer alluvium respectively.

The Areas of Medium Frequency

The areas of medium stream frequency (1.00 - 2.00) occur in the central part of Sankrail and Gopiballavpur-II, major parts of Gopiballavpur-I and in the northern parts of Nayagram (i.e. along the R. Subarnarekha). This category covers an area of about 13.64% of
S-W MIDNAPUR
STREAM FREQUENCY

LEGEND
No. of Streams/km

- Very Coarse (Below 0.5)
- Coarse (0.5 - 1.0)
- Moderate (1.0 - 2.0)
- High (Above 2.0)

S-W MIDNAPUR
DRAINAGE DENSITY

LEGEND
Length of Streams (km)/km

- Very Low (Below 0.5)
- Low (0.5 - 1.0)
- Medium (Above 1.0)

Fig. 18

Fig. 19
the total area having lateritic, older & newer alluvial soils.

The Areas of High frequency

This category covers an area of about 2.48% of the total area occurring in the parts of Gopiballavpur-I and Sankrail (undulating lateritic tract).

Drainage Density

Drainage density is an important geomorphic concept which means the relative spacing of drainage density (Strahler, 1964; Thornbury, 1954) \[ \text{Dd} = \frac{\Sigma L}{A} \]

where Dd = Drainage density, $\Sigma L$ = Total length of stream channels in a unit area, and A = Area of the unit. The study denotes a sharp spatial variation in the extent of agricultural land use in South-Western Midnapur.
CHAPTER 4. GEOMORPHOLOGICAL CHARACTERISTICS

Table 4.7: Distribution of Drainage Density

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Size Class</th>
<th>Category</th>
<th>Frequency</th>
<th>Cumulative Frequency</th>
<th>Frequency (%)</th>
<th>Cumulative Frequency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Below 0.5</td>
<td>Very Low</td>
<td>245</td>
<td>245</td>
<td>44.95</td>
<td>44.95</td>
</tr>
<tr>
<td>2</td>
<td>0.5 – 1.00</td>
<td>Low</td>
<td>180</td>
<td>425</td>
<td>33.02</td>
<td>77.97</td>
</tr>
<tr>
<td>3</td>
<td>Above 1.00</td>
<td>Medium</td>
<td>120</td>
<td>545</td>
<td>22.01</td>
<td>100.00</td>
</tr>
</tbody>
</table>

In the area medium drainage density (relatively high in the area) is found in the Subarnarekha basin followed by Dulung basin and Keleghai basin.

The range of drainage density in South-Western Midnapur has been divided into three categories viz. very low, low and medium (Table 4.7).

Table 4.7 shows that most of the frequencies are concentrated in the very low category. The details of drainage density distribution are as follows (Fig 19).

The Areas of Very Low Drainage Density

The areas of very low drainage density are found in parts of Sankrail and Gopiballavpur-I, major parts of Keshiary and Narayangarh, considerable parts of Nayagram and maximum of Dantan-I & II. This category covers an area of about 44.95% of the total area. Very low drainage density areas are mainly alluvial tracts.

The Areas of Low Drainage Density

Covering an area of about 33.02% the areas of low drainage density occur in the southern parts of Gopiballavpur-I and Nayagram, northern parts of Gopiballavpur-II, Sankrail and Keshiary as well as both sides of the R. Subarnarekha and Dulung having lateritic and red gravelly soils.

The Areas of Medium Drainage Density

The areas of medium drainage density are found along the R. Subarnarekha, Dulung, Keleghai and the adjoining tracts with newer alluvium and red gravelly soils. This cate-
gory covers an area of about 22.01%.

4.3 Nature of Underground Water

Ground water influences the land use pattern of a region. The seasonal fluctuations of underground water in summer and in rain are in a large measure responsible for diverse land use patterns.

It may be mentioned that the lateritic tracts are intimately linked with the oscillation of ground water table. The ground water table oscillates between the monsoon and dry season which apparently corresponds with the periods of leaching and capillary actions respectively. The ferrallitic soils, result of ground water actions, are not always conducive for agricultural land use, while in the alluvial tract ground water contributes saturated soil and favours large scale cropping practice.

Underground water is used as an alternative to surface water. In most parts of India, the present day vagaries of monsoon have compelled the land users to extract huge amount of underground water by different methods. Besides, the multiple uses of land solely depend on the ground water potential. Extraction of underground water resources and their judicious use forms a major aspect of water resource management and ultimately the land use pattern (De & Jana, 1997) [98].

To assess the ground water conditions the detail study of hydrogeology of the area is essential. It is difficult to group the hydrogeological units systematically due to heterogeneous terrain which are controlled by the diverse geological and geomorphological conditions depending upon definite lithological characters and sedimentary facies as well as their arrangement in space and time alongwith the pattern of palaeo - drainage system. Keeping in view these parameters, the study area can broadly be demarcated into two hydrogeological zones viz. Platform zone and Alluvial zone (Fig.20) (Central Ground Water Board).

1. Platform Zone: This zone forms the southern, northern and western part of the study
area. It consists of Mio-Pliocene sediments with cappings of laterite and older alluvium. The laterite cover overlies the Mio-Pliocene sediments of dark grey sequence of sands, silts and clays which acts as regional aquitared. This clay bed is not encountered in the western crystalline undulating region. This confirms the possibility of occurrence of interconnected aquifer system receiving recharge from the upland region.

In the undulating lateritic upland groundwater occurs both in unconfined and confined conditions. Groundwater under unconfined condition generally occurs in the lateritic profile, while the same under confined condition occurs in the deeper aquifers. Generally laterite is highly porous which is quickly recharged as well as quickly discharged. The deeper waterlevels are generally confined in the pockets of thick laterisation, whereas the shallower ones are observed in areas of limited thickness of laterite. Where the groundwater exists under watertable/unconfined condition, dugwells are effectively used to withdraw the water but where the groundwater occurs in the deeper aquifers, water is withdrawn by tubewells. Deep tubewells are used where the water levels fall below 11m and above from the ground and shallow tubewells where water level remains within 8m.

A number of free flowing tubewells (locally known as ‘auto-flow wells’) has been observed in Belda area of Dulung sub-basin, Gopiballavpur in Subarnarekha basin etc. which seems to be controlled mainly by the structural pattern of the aquifers.

It may be pointed out that the free flow discharge is widely variable but shows significant increase in yield during the monsoon season, which almost ceases during January-February (Sar, 1975-76) [234].

The chemical analysis of the water ($P_H : 6.5$ to $8.5$, chloride : $10-80$ ppm, bicarbonate : $22-213$ ppm, total hardness : $30-220$ ppm) shows that it is suitable for agricultural purposes (Surface Water Investigation Directorate, West Bengal).

2. Alluvial Zone: Small patches of recent alluvium are found in the southern and the entire eastern part of the study area as well as along the river channels. Generally these areas are covered by a blanket of clay. Groundwater under confined condition
occurs in the aquifers underlying the clay. These aquifers continue inland and the areas capped by laterites are underlain by some aquifers which are depositories of groundwater in the undulating lateritic terrain *(Central Ground Water Board)*.

The chemical analysis of the water *(\(P_H:7.1-8.4\), chloride : 9-60ppm, bicarbonate : 16-320ppm, total hardness : 10-240ppm)* shows that the quality of groundwater in the alluvial terrain is also of good quality and suitable for agricultural purposes *(Surface Water Investigation Directorate, West Bengal)*.

**4.3.1 Groundwater Fluctuation Scenario**

In the laterised platform the depth of watertable experiences a substantial variation from 2 to 15m below ground level. It may be more in the drought-prone areas. The water level depths at Sankrail and Rohini are 11.62m and 5.07m below ground level respectively. The seasonal fluctuations range from 1 to 8m in the southern part of the upland near R.Subarnarekha. The groundwater in this terrain is tapped by open dugwells. During the summer months the amount of seasonal fluctuations is greater as the waterlevel continuously falls *(Sharp falls)*. In the alluvial zone the depth of water level varies between 2m and 20m below ground level. The Table 4.8 represents the waterlevel fluctuations in the area under study *(Figs 21 & 22)*:
S-W MIDNAPUR

PRE-MONSOON DEPTH OF WATER TABLE (m)

Depth Below Ground Surface (m)

I > 7
D 5-7
E < 5

Source: S.W.I.D. West Bengal

S-W MIDNAPUR

POST-MONSOON DEPTH OF WATER TABLE (m)

Depth Below Ground Surface (m)

I > 5
D 3-5
E 1-3

Source: S.W.I.D. West Bengal
Table 4.8: Waterlevel Fluctuation Data in the Study area (B.G.L.), 1990

<table>
<thead>
<tr>
<th>Location of selected well</th>
<th>Well type</th>
<th>Nature of the water bearing formation</th>
<th>Depth of water level below ground level (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pre monsoon (Apr/May)</td>
</tr>
<tr>
<td>Gopiballavpur-I Baranganga</td>
<td>Dug</td>
<td>Laterite</td>
<td>4.73</td>
</tr>
<tr>
<td>Gopiballavpur-II Topsia</td>
<td>do</td>
<td>Laterite</td>
<td>5.48</td>
</tr>
<tr>
<td>Nayagram</td>
<td>do</td>
<td>Lateritic soil</td>
<td>10.90</td>
</tr>
<tr>
<td>Chandavilla</td>
<td>do</td>
<td>Laterite</td>
<td>18.43</td>
</tr>
<tr>
<td>Khairamathani</td>
<td>do</td>
<td>Laterite</td>
<td>11.40</td>
</tr>
<tr>
<td>Baligeria</td>
<td>do</td>
<td>Laterite</td>
<td>7.34</td>
</tr>
<tr>
<td>Dumaria</td>
<td>do</td>
<td>Laterite</td>
<td>18.43</td>
</tr>
<tr>
<td>Sankrail</td>
<td>do</td>
<td>Laterite</td>
<td>11.62</td>
</tr>
<tr>
<td>Rohini</td>
<td>do</td>
<td>Laterite</td>
<td>5.07</td>
</tr>
<tr>
<td>Bankra</td>
<td>do</td>
<td>Laterite</td>
<td>2.80</td>
</tr>
<tr>
<td>Jordiha</td>
<td>do</td>
<td>Laterite</td>
<td>3.20</td>
</tr>
<tr>
<td>Nehar</td>
<td>do</td>
<td>Residual soil</td>
<td>9.93</td>
</tr>
<tr>
<td>Ranjitpur</td>
<td>do</td>
<td>Laterite</td>
<td>8.76</td>
</tr>
<tr>
<td>Keshiary</td>
<td>do</td>
<td>Older Alluvium</td>
<td>9.48</td>
</tr>
<tr>
<td>Bhasraghat</td>
<td>do</td>
<td>Alluvium</td>
<td>5.62</td>
</tr>
<tr>
<td>Hatigera</td>
<td>do</td>
<td>Lateritic soil</td>
<td>3.88</td>
</tr>
</tbody>
</table>

Source: S.W.I.D., Midnapur.

4.3.2 Groundwater Recharge

In the undulating upland, lateritic soil, is quite sandy and gravelly in nature which permits some recharge by the infiltration of rain water to the deeper aquifers. This recharge of the deeper aquifers at higher altitudes results in free flowing auto-flow wells along the river valleys at several places in the upland terrain. It may further be pointed out that the thick valley-fill sediments occurring along the major river courses of the area form a potential zone of recharge (Roy Chowdhuri, 1970-71).
CHAPTER 4. GEOMORPHOLOGICAL CHARACTERISTICS

Table 4.9: Annual Recharge of Groundwater in Selected Blocks

<table>
<thead>
<tr>
<th>Name of the Block</th>
<th>Annual recharge ($M^3$)</th>
<th>Water available for irrigation (80% of annual recharge) ($M^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gopiballavpur I&amp;II</td>
<td>211.28</td>
<td>169.02</td>
</tr>
<tr>
<td>Nayagram</td>
<td>182.96</td>
<td>146.36</td>
</tr>
<tr>
<td>Sankrail</td>
<td>111.83</td>
<td>89.46</td>
</tr>
<tr>
<td>Keshiary</td>
<td>117.20</td>
<td>93.76</td>
</tr>
</tbody>
</table>

The Table 4.9 gives the annual recharge of groundwater in selected Blocks, using the norms laid down by the Central Ground Water Board (C.G.W.B.), using water table fluctuation method.

It is quite interesting to note that Blockwise total groundwater recharge, as calculated by the Central Ground Water Board (C.G.W.B) by using the water table fluctuation method, can be compared fairly well with the calculation of water surplus (which goes as groundwater storage) from the Thornthwaite's method, though the meteorological data do not cover a long period, but are based on only six years of observations.

For the entire area, water surplus (storage) can be taken as 0.25$m$ as calculated for water budget. The study area occupies 2392.88sq.km. (i.e. 2392.88 x 10^6 $m^2$). Therefore, the total ground water storage is 0.25$m$ x 2392.88 x 10^6 $m^2$ = 598.22$M^3$ (million cubic metre). The Table 4.10 gives additional information about the ground water conditions in the area.

From the following table it is evident that the pronounced seasonal fluctuation of water table is the main constraint of water use for land utilisation. The Summer months experience drought condition when the extraction of groundwater becomes quite difficult (Das, 1993) [70].
Table 4.10: Groundwater Information in the Area

<table>
<thead>
<tr>
<th>Depth range below land surface (m)</th>
<th>Open wells %</th>
<th>Water bearing zone</th>
<th>DTWL (m) Winter</th>
<th>Seasonal fluctuation (m) Summer</th>
<th>Seasonal fluctuation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td>12</td>
<td>Primary laterite</td>
<td>1.50-7.50</td>
<td>3.88-10.00</td>
<td>2.5</td>
</tr>
<tr>
<td>10-15</td>
<td>16</td>
<td>do</td>
<td>1.80-9.00</td>
<td>2.80-15.00</td>
<td>1.00-6.00</td>
</tr>
<tr>
<td>15-20</td>
<td>2</td>
<td>do</td>
<td>2.80-8.80</td>
<td>5.70-13.80</td>
<td>3.00-5.00</td>
</tr>
<tr>
<td>5-10</td>
<td>12</td>
<td>Secondary laterite</td>
<td>1.50-7.76</td>
<td>4.00-10.00</td>
<td>2.00-2.50</td>
</tr>
<tr>
<td>10-15</td>
<td>50</td>
<td>do</td>
<td>2.20-9.00</td>
<td>3.15-15.00</td>
<td>1.00-6.00</td>
</tr>
<tr>
<td>15-20</td>
<td>8</td>
<td>do</td>
<td>2.80-7.80</td>
<td>11.00-18.00</td>
<td>8.00-10.00</td>
</tr>
</tbody>
</table>


4.4 Soil Forming Factors and Processes

Soil is the product of parent material, climate, relief, biosphere and time. At any specific location on the surface of the earth, the development of soil depends mainly upon the following factors: (i) parent material, (ii) climate, (iii) topography, (iv) biotic components (flora and fauna), and (v) time.

H. Jenny (1941) [147] has expressed the relationship between soil properties and pedogenetic factors in the general form: \( S = f(cl, o, r, p, t, ...) \) where \( S \) = Any Soil property, \( f \) = Function of or dependent upon, \( cl \) = Climate, \( o \) = Organisms perhaps including man, \( r \) = Relief (topography), \( p \) = Parent material, \( t \) = Time (age). Thus any soil property is a function of the collective effect of all the soil forming factors. Jenny specified temperature and rainfall as climate; flora and fauna as biospheric organisms; elevation, slope, and depth of water table as relief. In this way, he could thus analyze quantitatively in young soils the effect of one of the factors on soil formation when that particular factor was dominant in relation to others. Similarly this happens in old soils, which have developed over a long time. Some of the factors, such as climate, relief etc. have changed during the course of soil formation and such analysis is not possible. The laterite cappings as observed are undoubtedly the relics of a past humid climate.
Parent Material

Parent material refers to the unconsolidated mass from which the solum develops. The parent material has been defined by Jenny (1941) [147] as, "The state of soil system at time zero of soil formation". The parent material (i) may be formed in situ by weathering of rocks, (ii) may be transported from the place of their origin and redeposited either before they become subject to modification by soil formers or during the process of modifications or by organic deposits.

The parent material must be regarded as a participating factor which is passively involved in soil formation. Parent material is the result of the weathering processes on the parent rock, which thus becomes the ultimate passive participant in soil formation. In some cases, the nature of the parent rock determining the character of the parent material, can decisively affect the character of the final product. Generally the effect of parent material on soil is stronger in the early stages of soil formation. With excessive leaching and advanced development, the influence of the parent material on soil character gradually decreases.

Different parent materials give rise to the same kind or type of soil whenever the principal factors of soil formation are the same. A corollary of this principle, is that similar parent materials give rise to different kinds or types of soil, provided the principal factors are dissimilar. For example, acid igneous rocks, quartz, grits and sand stones usually weather slowly and give rise to coarse sandy soils with low base status, a kaolinite type of clay and infertile soil. Most of the basic igneous rock and sedimentary rocks normally weather to finer textured soils with high base status and fertile soils.

Some times parent materials indicate the soil characteristics. The texture of the parent material determines, to a large extent, the depth of soil profile. The finer the texture the higher the rate of soil reaction. Generally it has been found that soils are deeper on light textured parent material as compared to heavy textured parent material. The chemical composition of soils, to a great extent, depend on the types of rock on which they have developed and their mineralogical composition (Biswas and Mukherjee, 1989) [29].
CHAPTER 4. GEOMORPHOLOGICAL CHARACTERISTICS

Parent materials have a great influence on the soils of South-Western Midnapur. The significant characteristic formations of the area are older alluvium and newer alluvium. It is found that older alluvium has resulted in the lateritic and older alluvial soils, whereas newer alluvium has resulted in the formation of newer alluvial soil especially in the river valleys.

The parent material of these soils (lateritic and alluvial) being the product of age long processes is in an advanced stage of weathering. By contrast with parent materials and parent rock the climatic factor must be regarded as the most active agent in soil formation.

Climate

Soil can be regarded as the mirror of climate. Soil, which formed under different climatic conditions differs considerably one from the other in all their characteristics and properties.

The climate influences the process of soil formation directly and indirectly. Directly, the two primary elements of climate i.e. precipitation and temperature, supply water and heat to react with the parent material. Indirectly, the climate determines fauna and flora (the biosphere) which furnish sources of energy in the form of organic matter. This energy acts on the rock and mineral material by means of acids and salts released in the processes of organic matter decomposition. To appreciate the role of climate in soil formation one must have to study its individual elements.

As parent material determines the character of the resultant soil, climate and other factors operate both in the stages of weathering and profile development, and in correlating in certain soil property with a particular factor it is desirable to decide at which stage it is operative.

B.M. Crowther from a consideration of the effect of temperature and rainfall on leaching as shown by the Silica-Alumina ratio of the clay fraction found that to maintain constant intensity of leaching, a rise of 1°C in temperature must be accompanied by in-
crease of 3.3 cm in rainfall. He thus derives a measure of leaching termed the leaching factor which is \( R - 3.3T \), where \( R \) is the mean annual rainfall in cm. and \( T \) is the mean annual temperature in \( ^0C \). This means that with a mean annual rainfall of 75 cm or a little less than 30 inches and a mean annual temperature of about \( 23^0C \), the leaching factor would be zero. Leached soils could thus be defined as soils with a positive leaching factor, incompletely leached soils as soils with a negative leaching factor.

Temperature affects soil formation firstly by modifying the effectiveness of rainfall, secondly, all chemical processes in the soil also all biological processes including both the growth of higher plants and activity of micro-organism within the soil.

The nitrogen and organic matter increases with rainfall, the effect of rising temperature is opposite, partly through its effect in diminishing the efficiency of rainfall and partly through its effect in increasing the rate of decomposition.

The organic matter and nitrogen contents in soil decreases with increasing temperature, reflecting the increase in chemical weathering. With this increase in clay content there is a tendency of molecular \( Si/Al \) and \( Si/R_2O_3 \) ratio to decrease so that under tropical conditions the typical clay will be of the ferrallitic type.

The area under study lies within the monsoonal belt. It receives the major amount of rainfall during the period of south-west monsoon.

There are greater variations in natural configuration and topography which are highly correlated with the climatic changes in north-west to the south-eastern part of the area under study. The climate of the north-western part is hot and dry whereas in the south-eastern part it appears to be warm and humid.

The area receives very little leaching during the prolonged summer season (mean temperature 32.25 \( ^0C \) in May and rainfall about 109.4 mm). During the south-west monsoon, the area receives heavy rainfall causing thorough leaching (rainfall about 290 mm, temperature about 29.6 \( ^0C \)) within the soil profile, removing the soluble material downwards. High temperature and heavy downpours favour the degree of decomposition of rocks. As a result the bases are released and upper horizons become gradually rich in iron and
aluminium while other bases are leached out easily. High temperature and high moisture content in the area accelerate the process of humification and mineralization thus keeping the surface low in organic matter.

Laterization is the predominant process of soil formation. Lateritic and red gravelly soils which developed on laterite and granite-gneissic parent material have occupied a considerable part in the area. Alluvial soil covering significant part develops on alluvium. The development of these soils are mainly due to climate and parent material, but the maturity of profile depends on the topographic situation, time, etc.

Topography

The classical exposition of soil forming factors termed as 'relief' is regarded as static. Relief influences soil formation through its effects on drainage, runoff, soil erosion and micro climate i.e. exposure of land surface to sun and wind.

Jenny, (1941) [147] implied that soil climate is largely related to the water table which in turn is dependent on relief. He considered truncated soils on slopes and buried soils at the foot of slopes as a toposquence. Quoting Marbut he referred to the concept of 'normal' soil development on undulating topography and to 'not normal' soil development on level topography for some horizons are over developed for example clay-pans. Other soils on steep slope are 'abnormal' for they lack some of the horizons that is to be in normal soils.

Topography affects temperature through elevation (there is approximately a fall of $1^\circ F$ for every 300 feet increase in altitude), aspect and surface relief. The elevation factor is reflected in a lower mean temperature, a shorter growing season. According to aspect, one can observe, south slopes naturally receive more solar radiation and are therefore to that extent warmer. Aspect is often reflected in the type of vegetation and in the type of profile development. The most obvious effect of relief is in basin-shaped areas, although these may be of considerable importance for agriculture and horticulture.

The effect of topography on the moisture air regime in the soil is twofold, namely as
affecting the actual rainfall and also as affecting its disposal. The rainfall has a general tendency to increase with altitude.

The principal effect of topography, however, is on drainage condition. In passing from a lowland to the adjoining upland the water table tends to recede from the surface, or near the valley bottoms the water table is nearer the surface and dominates the water-air regime. We may thus have a paradox that whilst the air climate is wetter in the upland, the soil climate is wetter in the lowland.

The effect of topography on erosion is most marked where the climate and character of the soil are such to favour this process. Slope is an important factor in determining both the character of the soil profile and its behaviour under cultivation. Surface relief has an important effect on soil depth, which is greater in lowlands and areas of flat and concave relief than in uplands and local areas of convex relief. Apart from the effect of relief on depth of profile, there is also an effect on leaching processes which are more intense with the shallower profiles. It is, also, possible that some of the leaching may be down the slope instead of vertical.

Topography has markedly affected the soils of the study area. Western part has comparatively higher elevation (70m - 100m) than the eastern portion. General slope of this area is towards east and south east. The upland area of convex topography is strongly leached and easily eroded. This has a truncated or immature soil profile. Owing to free drainage the colour of the soil is dark red and are inevitably lateritic while the lowlands with a concave topography, where there is impeded drainage, develop dark brown ferralic.

Micro relief of the western part i.e. convex undulations have greater evaporation which hinders the development of mature and deeper profile. The general slope of the area is above $2m/km$.

In eastern part the general slope is below $1.5m/km$. The area here receives comparatively low temperature and high rainfall and as a result greater amount of water for percolation.
Organisms

Organisms which include flora and fauna in general and man in particular play the important role in soil formation. The plant roots penetrate the parent material and make channels which induce drainage of water and provide favourable environmental conditions for biological activity. The following paragraphs highlight the form and amount of plant life acting in or on the soil.

Flora: The amount of solar energy used by the plant in $CO_2$-assimilation is only 0.01% of the total solar energy reacting the earth. This means light energy is converted into chemical energy and the elements in the atmosphere are brought in the soil. The basis of all life on earth, therefore, is the process: $6CO_2 + 6H_2O + (708 \text{ kg/cal.energy}) = C_6H_{12}O_6 + 6O_2$. The sugars produced from cellulose and other complex substances of the plant dry matter and by respiration, plants extend their roots by oxidizing carbohydrates: $COOH + O_2 \rightarrow CO_2 + H_2O +$ energy, to obtain nitrates and mineral nutrients from the soil. Living plants of all sizes achieve mechanical and biochemical effects by this energy transfer. On death (decomposition) they deliver a considerable amount of material to the soil which has four effects: (i) it helps sustain other forms of life, (ii) it changes the appearance of surface soil, (iii) it accelerates the weathering of minerals, and (iv) it promotes the process of soil formation.

Correlation between vegetation and soil is so intimate that the principal soil groups can almost be completely defined according to the type of vegetation under which they occur. Broadly speaking the character of natural vegetation expresses the summation of the climatic factors under which it grows. Thus, it is observed that the organic matter profile of coniferous forest soil differs from that of deciduous forest soil. In one case, there is a sharply defined raw humus layer with a strongly acid reaction overlying mineral soil i.e. relatively poor in organic matter. In other case there is a moderate content of neutral or only slightly acid, organic matter which decreases gradually in amount from the surface.
The study area contains a variety of soil and vegetation. Soils, here, until they are cultivated may contain appreciable proportion of organic matter particularly where the natural vegetation forms a close association. But in regions particularly where the natural vegetation cover has been removed as a preliminary to cultivation, immature profiles have developed (e.g. north Sankrail and part of the eastern region). The organic matter is very low in this area as the natural vegetation cover is too poor and the insolation too high to add humus to the soil.

It is generally an established fact that the tract enriched with vegetation contributes organic matter in significant amount. In the lateritic tract, despite the presence of rich vegetation, the organic matter content is very low because of oxidization of organic matter due to high temperature whereas in the alluvial tract the organic matter is comparatively high.

Fauna: The activities of soil flora and fauna are so interrelated that it is rather difficult to study them independently. Various soil organisms are involved in the degradation of higher plant tissue, even in the growing stage of plants they are subject to attack by soil organisms known as herbivores (Brady, 1989) [34]. Some fauna, harbouring soil, dig into the soil body and mix the materials of different horizons. The earthworms play an important role in soil granulation. Fauna also contribute to the biomass of soil, but is insignificant and less in amount. The appreciable influence in soil formation is made by ants, termites and rodents. Ants and termites carry materials from the lower depths upwards and even to the surface. The burrowing rodents may affect the soil forming processes (Biswas and Mukherjee, 1989) [29].

The study area inherits two predominant types of soil viz. lateritic (older alluvium) and alluvial. In the lateritic soil where formation of sesquioxides and development of leaching within the profile are the conspicuous features, the role of fauna in the soil formation seems to be insignificant, while in the alluvial tract the burrowing animals contribute significantly in the soil formation.
Man: It is also of a great interest to think that the human being can take part in the modification of soil or can be soil forming factor. This interference has operated mainly through the conversion of soils under natural vegetation into agricultural land. In other areas the changes has been from natural to artificial forest or from forest to scrub.

The effect of human interference in producing accelerated soil erosion by deforestation hinders the profile development. On the other hand, if forestation helps in the development of profile.

Agricultural practices including the application of liming materials and other fertilisers, may alter the general character of profile development.

The organic matter status of soils varies with cultivation where forest has been replaced by grassland the organic matter status is raised. On the other hand, conversion of steppe land to cultivable land decrease the organic matter status.

Fundamental changes in soil profile are made by such treatments as drainage, irrigation and flooding. Drainage changes a profile with impediment leaching to leached profile.

Irrigation can have different effects on the soil according to the character of the irrigation water and the way in which it is used.

Flooding accompanied by deposition of silt from flood water builds up an artificial soil profile.

Human interference is highly marked in the eastern part of the area. Intensive cultivation and use of artificial manure hinder the normal profile development. Irrigation and drainage system of the area help to develop leached and low salt content soil.

Deforestation in the western part accelerate soil erosion and hinders the development of deep and mature profile (Bandopadhyay, 1974) [12].

Time (Age of the Land): A soil body at any point of time reflects the combined influence of soil forming factors and processes. The span of period from the inception of
soil development to the present stage is termed 'age'. Jenny (1941) [147] expressed soil age in terms of the pedogenic factor, 'time', t. Soil formation is a very slow process and the time required may vary from a mere few years to several thousand years (Biswa & Mukherjee, 1989) [29].

The actual length of time that materials have been subjected to weathering plays significant role in soil formation. But the length of time required for a soil to develop horizons depends upon many interrelated factors, such as, climate, nature of parent material, burrowing animals and relief. Horizons tends to develop faster under cool humid forested conditions.

Certain soils are termed mature and immature which give some idea of the time factor. But soil maturity is not mainly dependent upon weathering time. A mature soil reflects dynamic equilibrium with its environments. Mohr and Van Baren (1959) [191] recognised five stages of development of tropical soils:

i) Initial stage: unweathered parent material,

ii) Juvenile stage: starting of weathering, but much of the original material is still unweathered,

iii) Virile stage: decomposition of easily weatherable minerals for the greater part, the clay content is increased and a certain mellowness is discernible, content of soil components less vulnerable to weathering is still appreciable,

iv) Senile stage: decomposition reaches at a final stage and only the most resistant minerals survive,

v) Final stage: completion of soil development and experiences fully weathered parent material (Biswa & Mukherjee, 1989) [29].

It may be pointed out that time and degree of maturity are factors used in many systems of soil classification, e.g. classification of zonal, intra-zonal and azonal soils. In India, soils in the alluvial regions are classified on the basis of old alluvium and young alluvium.
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Time has influenced the soil development in the area (S-W Midnapur) to some extent. Alluvial soils of eastern Midnapur receive continuous supply of silt due to inundation of river water. The alluvial soil of this portion is of comparatively recent age.

In western part wind and water erosion wash off the upper layer continuously which hinders the development of normal mature profile. As a result, truncation of profiles are met with locally.

Thus it may be mentioned that the character of the soil is determined by the operation of processes dependant on climate and modified by topography. The processes act both directly and indirectly on a given parent material itself the result of the action of weathering and of the soil forming processes takes place in time, which thus affects, although not casually the final result.

4.5 Pedological Variations

Dokuchaev stated that, "Soil is the result of the combined activity and reciprocal influence of parent material, plant and animal organisms, climate, age of land, topography". "Soil is a natural body of minerals and organic constituents differentiated into horizons, of variable depth which differs from the material below in morphology, physical make-up, chemical properties and composition and biological characteristics" (Joffe, 1949) [151]. Soil may be defined as "a collection of natural bodies occupying portions of the earth surface that support land, plant and that have properties due to the integrated effect of climate, living matter and human activity, acting upon parent material, as conditioned by relief, over periods of time" (U.S.D.A, 1975).

In the sense of an individual a soil is three dimensional piece of land that supports plant. Soils have various physical, chemical and biological characteristics which can be learnt through intensive investigations in the field and in the laboratory. The influence of any one characteristics upon soil behaviour or a variation in any one, depends upon the others in the combination (Sarkar, 1988) [236].
Soils of the area under study are classified as (i) lateritic, (ii) red gravelly, (iii) older alluvial and (iv) newer alluvial (Fig.23).

i) Lateritic soils: The north-eastern part and the south-western part of the area are covered by lateritic soils. The soils (roughly lying between 50m to 120m contour lines) are found in parts of the area covering mainly Gopiballavpur, Nayagram, Sankrail, Keshiary and Narayangarh Blocks. This type of soil is mainly derived from the laterites (older alluvium) which contains quartz, pebbles, and other rock fragments. The soils are mainly loam to sandy loam of reddish-brown colour. Iron concretions are present in these soils. These are dry and completely bleached. Water table varies between summer (Tm and above) and rain (3m - 5m). Soils are moderately acidic in reaction and $P_H$ ranges from 5.5 to 6.0. Content of $Fe_2O_3$ and $Al_2O_3(R_2O_3)$ are not high in this soil. Iron-oxide content is mainly below 3%. Most of the areas have $Al_2O_3$ below 5%, Nitrogen, $K_2O$, $P_2O_5$ contents are 0.05%, 0.5% and 0.05% respectively. Organic matter varies from 0.1% - 0.5%. Salt content is very low (below 0.05%). The land is undulating with tiny rivulets and the soils are highly eroded. It is less fertile than the alluvial tract.

ii) Red gravelly soils: These soils are found in the extreme western part of the study area. These soils are generally lying between 100m - 120m contours and mainly developed on older as well as on newer alluvium. The colour of the soil ranges between brown and grey brown. The texture of the soil mainly sandy loam to clay loam and clay. The water table fluctuates between summer (> 7m) and rain (3m - 5m). The soils vary in depth and occur with or without occasional lime concretions in the profile. Chemical properties of the soils vary from place to place depending on the topographic situation. The soil $P_H$ varies between 5.5 and 6.5. Iron-oxide content is mainly below 3%, but in some cases it is found to vary between 3% and 6%. Aluminium-oxide is higher than that in the lateritic tract. It varies between 5% and 10%. Nitrogen content is also slightly higher than lateritic soil (i.e. below 0.05% - 0.1%). $K_2O$ and $P_2O_5$ is below 0.5% and 0.01%-0.1% respectively. Organic matter content varies between 0.1%-0.5%. Salt content is low, i.e. below
**PROFILE CHARACTERISTICS**

**LATERITIC SOIL**
Profile Site at: Hathibari (J.L. No. 1) Gopiballavpur - I
- Light brown, sandy loam, dry, roots present upto 6", globular concretions, brittle, air dry moisture - 1.20%, acidic (pH 5.2), \( R_{2}O_{3} \) - 6.06%, CaO - 0.05%.
- Light brown, sandy clay loam, less dry, globular concretions, brittle, roots absent, air dry moisture - 1.93%, acidic (pH 5.4), \( R_{2}O_{3} \) - 9.15%, CaO - 0.12%.
- Light brown, sandy clay loam, less moist, globular concretions, soft, roots absent, air dry moisture - 3.27%, acidic (pH 5.6), \( R_{2}O_{3} \) - 15.27%, CaO - 0.166%.
- Light reddish brown, sandy clay loam, dry, moist, globular concretions, roots absent, air dry moisture - 3.56%, slightly acidic (pH 5.8), \( R_{2}O_{3} \) - 18.74%, CaO - 0.204%.

**RED GRAVELLY SOIL**
Profile Site at: Bhola (J.L. No. 212) Gopiballavpur - I
- Brownish yellow, sandy loam, brittle, roots present, air dry moisture - 1.46%, slightly acidic (pH 6.3), \( R_{2}O_{3} \) - 5.88%, CaO - 0.203%.
- Brownish yellow, sandy, roots present upto 16", loose, air dry moisture - 0.40%, pH - 6.5, \( R_{2}O_{3} \) - 2.38%, CaO - 0.084%.
- Yellowish brown, sandy loam, loose, roots absent, air dry moisture - 2.14%, slightly acidic (pH 6.5), \( R_{2}O_{3} \) - 8.38%, CaO - 0.287%.

**ALLUVIAL SOIL**
Profile Site at: Sorrong (J.L. No. 213) Dantan - I
- Grey, roots present upto 7", brittle, air dry moisture - 3.98%, pH - 6.5, CaO - 0.84%.
- Dark grey, less brittle, pH - 7.0, CaO-0.854%, air dry moisture - 6.27%.
- Grey, soft, air dry moisture - 6.88%, pH - 7.0, CaO - 0.60%.
- Grey, a few nodular Fe concretions present, soft, pH 7.2, CaO-1.22%, air dry moisture - 7.0%.

Legend:
- Fe/Al concretions
- Boulders & coarse sand
- Fine sand
- Silt & clay

Fig 24
0.05%. Air dry moisture varies between 1% and 3% generally, but in some places up to 5% can be found.

iii) Alluvial soils (older): These soils are found in the central part as well as in the south-eastern and the north-western parts of the area. The alluvial soils are mainly of Vindhya family and is derived from the alluvium brought down from the Rajmahal hills and the Chotanagpur plateau. The soils are mainly brown to grey brown to olive-brown. Soil texture varies from clay loam to clay and in some places sandy-clay-loam. Ground water table ranges from < 5m (summer) to 1m - 3m (rainy). The soil reaction is slightly acidic (i.e. $P_H$ ranges between 5.8-6.8). The percentage of $Fe_2O_3$ and $Al_2O_3$ are 3% - 6% and 5% - 10% respectively. Sesquioxide content is higher than that of the lateritic and red soil. Nitrogen, $K_2O$, $P_2O_5$ are 0.05% - 0.1%, 0.1% - 0.6% and 0.05% - 0.1% respectively. Organic matter content 0.75% - 1.0%. Salt content is below 0.05% but 0.09% locally. Air dry moisture is higher than the former types (3.0% - 5.8%).

iv) Alluvial soils (newer): These soils are found along the valleys of R. Subarnarekha. Soils are mainly developed on newer alluvium of recent origin. Colour is brown to grey brown and texture varies from sandy-clay-loam to clay loam. Soils are slightly acidic in reaction ($P_H$ : 5.8 - 6.8). Organic matter content is high (0.75% - 1.0%). Other elements are more or less same as that of older alluvial soils.

The profile characteristics of three different soil zones are seen in the Fig.24.

4.6 Soil Fertility

Soil fertility is the quality that enables the soil to provide proper compounds in proper amounte and in the proper balance for the growth of specified plants, when other factors, such as light, temperature, moisture and the physical conditions of the soil are favourable. It is thus the capability of soil of producing a plant yield under defined conditions.

By superimposing the different soil properties (Figs. 25 & 26) a fertility map (Fig 27)
has been prepared in the present context (low, low to medium, medium and high).

4.7 Geomorphological Regions

By superimposing the maps of different land attributes (geology, average relief, relative relief, average slope, depth of watertable, dissection index, reggedness index, stream frequency, drainage density, soil etc. etc) a final map showing geomorphological regions is prepared. It may, however, be pointed out that almost all the individual attributes (mentioned above) more or less coincide with each other thereby conforming their intricate relationship between themselves (Fig.28)

The area under study may thus be divided into two broad geomorphological regions which are further classified into units(Fig.28) as follows:

1 Plateau Fringe (Degradational Surface).
   1. Upper Degradational Surface.
   2. Lower Degradational Surface.

II Gently Sloping Flat Plain (Aggradational Surface).
   1. Upper Subarnarekha Valley (older & newer alluvial tract).
   2. Lower Subarnarekha Valley (older & newer alluvial tract).

Plateau Fringe(Fig.29): It is a degradational surface which experiences accelerated soil erosion mainly caused by gullying, leaching and human interference in the form of deforestation. Covering a major part of the study area the region is confined to the extreme northern, north-western, southern and south-western part. It is covered by older alluvium (lateritic) with moderate average relief (60m-100m), moderately
PLATEAU FRINGE

GENTLY SLOPING FLAT PLAIN

1. Upper Subarnarekha Valley
2. Lower Subarnarekha Valley
3. Keleghai Basin
4. Murli Basin
low (10m - 30m) to low (above 30m) relative relief, gentle (above $2^\circ$) to very gentle ($1^\circ - 2^\circ$) average slope, moderately high (0.3-0.4) to moderate (0.2-0.3) dissection index, moderate (above 0.02) to low (below 0.02) ruggedness index, high (above 2.00) to medium (1.00-2.00) and low (0.5-1.00) stream frequency, medium (above 1.00) to low (0.5-1.00) drainage density, deforested, lateritic and red gravelly soil.

The soil is relatively mature with moderate to low fertility and has fair to poor potentiality for agriculture and agro-forestry. Considering the geomorphological attributes, it may, however, be pointed out that the lower degradational surface has got comparatively much more potentiality for land utilisation than the upper one which is confined to the extreme south-west.

**Gently Sloping Flat Plain (Fig.30):** The region is an aggradational tract confined mainly to the eastern and south-eastern parts as well as along the river valleys of the area under study. It is an outcome of the deposition of sediments brought down by the flowing rivers. The region experiences very low (below 30m) to low (30m-60m) average relief, extremely low (below 10m) to moderately low (10m - 30m) relative relief, level (below $1^\circ$) to very gentle ($1^\circ - 2^\circ$) average slope, low (below 0.2) to moderate (0.2-0.3) dissection index, low (below 0.02) ruggedness index, very low (below 0.5) to low (0.5-1.00) and medium (1.00-2.00) stream frequency, very low (below 0.5) to low (0.5-1.00) and medium (above 1.00) drainage density, older and newer alluvial tract and it is younger along the river valleys. Rivers in general are sluggish in nature.

The upper and lower Subarnarekha valleys as well as Keleghai and Murli basins although are included under aggradational tract, experience river bank erosion.

Owing to level slope, availability of surface and underground water, periodic renewal of alluvial soils through siltation by occasional flooding this geomorphological region offers favourable conditions for agricultural land utilisation.