# SOIL RATING STATUS IN DIFFERENT ECOLOGICAL ZONE
# A FIELD BASED STUDY OF
# WEST KHASI HILLS DISTRICT OF MEGHALAYA

ABSTRACT

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Dissertation submitted in partial fulfilment of the requirements for the Degree of

**MASTER OF PHILOSOPHY**

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SHILLONG, MEGHALAYA

1987

## I. Statement of the Problem

The physical environment of man consists of landforms, climate, water, soil, natural vegetation and native animal life etc. This resource complex is necessary for human existence. It provides him with living space, with food and with a vast variety of raw materials used in the satisfaction of human wants.

Land resource plays a vital role in the determination of man's economic, social and cultural progress which could be easily seen and clearly understood through reference to economic development of different countries. In many parts of the world, the soil has been so damaged by mismanagement and abuse that it will never again be able to sustain a viable food production system. Nearly, 50 per cent of the world population depends directly or indirectly on land and land based resources for living. Therefore, the assessment, management, preservation and maintenance of land resources is the most important task to the present civilization.

The mismanagement of land has led to soil erosion on a vast scale, or top soil, the most vital part necessary for healthy plant growth. Under the natural conditions, it requires from 300 to 1000 years or more to generate an inch of top soil.

In case of India, it has been noticed that the good soils have been degraded due to climatic factors, its improper management and misuse. Deforestation is a major cause of soil erosion. The extent of annual deforestation of rain forests in India is about 80,000 to 1,00,000 sq.km. (FAO, Soil Bulletin No. 30, 1977-78). The scale of deforestation, not only makes ecological imbalance in our country but also causes the soil erosion and degradation. In India, one-third (NRSA, 1983) of the arable land is threatened with total loss of top soil.

The main casuality of this process of deforestation is the hill areas of North East India, where the soil is being washed by its faulty use pattern. It has about 4.94 per cent of closed forest (NRSA, 1983) cover. It is estimated that about 5.5 thousand sq.km. of additional forest is cleared every year in the region (50 per cent of which is Primary forest) due to slash and burn practices (P.S. Ramakrishnan, 1985). At this rate, the primary vegetation would vanish from this region within a span of 25-30 years. This will distort not only the ecology in this region but also will degrade the soil fertility.

The pressure of population (at 3 per cent per annum) on the land and land based resources is increasingly tremendously in the region and as a result the tropical rainforest ecology is being converted to degraded grassland ecology, a transformation both in the structure and as well as the functions of the system. The gentler slopes and spurs which come usually under first stage shifting cultivation (Jhumming) have been severely degraded with the parent materials exposed and soil cover eroded due to shortening of the 'Jhumming cycle' to less than 10 years. It is now the steeper slopes and crests of hills, which are under severe strain of 'slash and burn'. The gentler slopes are normally more fertile and have a greater soil retention capacity. The steep slopes and the crests ecologies are most 'vulnerable' and if not protected, get degraded after one or two of the shortened shifting cycles.

This, particularly, is true in case of West Khasi Hills District of Meghalaya. A large areas of this district is totally deforested and has given way to extensive degraded grassland vegetation with little hope of reversal.

There are also no accurate information available on these processes:

a) the extent of erosion of soil;
b) the pattern and quality of soil at different stages of degradation and the quality of soil at different slopes, valley bottom and crest lands.

II. Objectives

Keeping the significance of the problems to be investigated in mind, the objectives of the proposed study could be stated as follows:

a) To prepare a detailed soil map of the district on the basis of ecological land units and various degrees of slopes and stages of degradation,

b) To analyse the physical characteristics like – texture, structure, colour etc. and chemical characteristics like – NPK status, pH value, organic carbon etc. which have been measured from sample collections covering selected samples, and

c) Finally, to prepare a soil rating index in different ecological zones and preparation of the soil map of the district indicating degraded areas for their suitable management.

Besides these objectives, the following hypotheses have been proposed and tested in the study.

i) That clearing and cultivation of steeper slopes ($>15^{o}$) and crest lands lead to quicker removal of top soil and fall in fertility status of the soils.

ii) That the progressive desertification of the slope-ecology may lead to sharp degradation of the valley-bottom ecology and the cultivation practices.

iii) That arrested jhum cycles (5-10 years) and shortened cycles ($<5$ years) allow for large nutrients loss from the soil, and distort the soil characteristics.

## III. Methodology

The plan of work has been divided into three parts:

a) Maps.

b) Analysis of soil - i) Soil Sampling.
ii) Physical Characteristics.
iii) Chemical Characteristics.

c) Soil Rating Index and Soil Classification and Mapping.

### (a) Maps

The following maps were prepared for the study:

i) Relief map.
ii) Vegetation map.
iii) Drainage map.
iv) Slope map.
v) Geological map.
vi) Map of the Major Ecological Zones of the district.

### (b) Analysis of Soil: Methods

i) Soil Sampling : Using Composite Soil Sampling Method.

ii) The physico-chemical properties of the soils are determined by employing standard methods. With the help of maps related to relief, slope, vegetation, drainage and climate 10 major ecological zones of the district have been identified out of which six zones have been selected for detailed analysis. At micro-level land facets have been identified on the basis of the following criteria:

i) Valley bottom,

ii) Gentle slopes,

iii) Steep slopes, and

iv) Crests.

Keeping in view, the topographical characteristics of landfacets, 72 landfacets have been selected from six ecological zones. The six ecological zones cover more than 70 per cent of the total geographical area of the district.

There are twelve variables which have been identified as the most important ones and obtained by field collection and measurement of physical and chemical characteristics of the soil and by observation of site characteristics of the samples. All the twelve variables have been classified into three groups.

Group A: Physical Characteristics.

$X_1$: Texture.

$X_2$: Structure

$X_3$: Colour

Group B: Chemical Characteristics.

$X_4$: pH value.

$X_5$: Kg/Ha of Nitrogen (N).

$X_6$: Kg/Ha of $P_2O_5$.

$X_7$: Kg/Ha of $K_2O$

$X_8$: Kg/Ha of organic Carbon

Group C: Site Characteristics.

$X_9$: Altitude.

$X_{10}$: Degree of Slopes.

$X_{11}$: Vegetation Cover.

$X_{12}$: Topography.

The Soil Rating Index attempted in the present study is by way of combining the above twelve variables into a numerical Composite Index using Kendall's Principal Component Analysis technique. This has been done in two stages. First, by grouping the variables at the level of the three sub-groups and finally, combining the subgroups into the final composite index indicating the overall rating status.

IV. From the above study, the following findings can be observed:

The Composite Index (I) i.e., of the three subgroups A, B and C for the 72 soil samples shows a consistent gradation of index values from high positive in case of valley bottom (1.866) to high negative in case of crest (-1.152) samples. It may indicate that there are positive average values in case of chemical and site characteristics of soil in valley bottom facets. In case of physical characteristics, there is an average negative value, because of the combination of all the three principal physical characteristics. It has been noticed that the valley bottom facets are five times more favourable than the gentle slopes, although the latter shows an average positive value. There is a sharp decline of all the three characteristics of soil in the steep slopes and crest samples.

The Clay (C) category of soil texture dominates the samples with an overall share of 47.3 per cent. The second most dominant textural class is the Loam (L). Sandy Loam (sL) dominates this group by 15.3 per cent in the overall share. The soil textural map shows that out of six ecological zones, Zones 1, 3 and 4, which are predominantly highland areas, are dominated by Sandy (S) and Loam or Loam group of soil except the isolated valley facets, where clay group can be observed. On the other hand, ecological zone 2, 5 and 6, which are predominantly valley areas and low lands, are dominated by clay group of soils except the isolated spurs where, the loam or sand group can be observed.

The Brown (B) Colour Soil (10YR5/3) dominates the samples with 15.3 percent of share within the 19 classes of soil colours. On the other hand, the brown group of soil has a significant dominance with 90.5 per cent of the share of samples. This overall dominance of brown group might have resulted due to several factors, such as, the presence of large humus content in valley soils, presence of semi-decomposed and unconsolidated biotic matter in valley and gentle slopes, and forested sites, presence of iron oxides which diluted with humus under moist conditions would provide brownish colour etc.

There is a distinct spatial distribution within brown colour group of soils. In the slope areas i.e., gentle slopes, steep slopes and crests, are dominated by Brown, Dark Brown (Db) and Strong Brown (Sb) colour of soils. On the other hand, light brown (Lb) and Pale Brown (Pb) colour of soils are found in the lowlying areas, particularly, valley bottom lands. This is because the valley soils are dominated by greater percentage of humus in the top layers as well as the greater percentage of clay particles, whereas, the slope soils are dominated by sand and loam textures with presence of quartz, silica, with a fair amount of ferrous oxide ($Fe_2O_5$) which gives it a dark brown and reddish brown colour.

The Soil Rating Status (Ecological Zonewise)

The Ecological Zone 6, i.e. Balat Zone, has the best quality of soil (among the six ecological zones) indicating 50.0 percent of very good soils (IV) class. This may be because of low altitude and mixed deciduous forests which could conserve the nutrients from erosion, clay dominance of texture and higher humus availability. It has also a significant percentage of good soils (III) and medium (II) quality soil classes and there are no samples belonging to the low class i.e., very poor(I) soils. The statuswise the second highest zone is the Mairang Zone i.e., Zone 5, has 50.0 percent of samples under good soils (III) category, with 16.7 percent as very good (IV) soils. This is because of the extensive valley bottom (flat) lands with small hill ranges, which are fully utilised for cultivation.

The Zone 5, i.e., Mawsynram and its annexe zone has come the third best zone in terms of soil quality, indicating 33.3 percent of good soils, 25.0 percent of very good soils and 16.7 percent under the poor quality of soils. It is because of the gentle slopes, the mixed forests mainly bamboo interspersed with a great many river valleys and valley soils. The percentages of poor soil category (I) in Zone 1, 3 and 4, are much higher and therefore, dominance of below average quality of soils. The soil quality is generally poor in ecological Zone 3 i.e., Nongstoin Zone with 75.0 percent of poor quality of soils (I). The occurrence of poor soil is very high because of its topographical characteristics. This Zone is largely a plateau top with high hill ranges and sparsely distributed. pine vegetation.

Soil Rating Status (Landfacets-wise)

The Soil Rating Status (Landfacets wise) shows 77.5 percent of very good quality of soils under valley bottom landfacets.

The gentle slopes have 22.2 percent and 44.4 percent of very good quality and good quality of soils, respectively. In case of steep slopes and crests, the very good quality of soil is less (very good zero in both cases and good soils 22.2 percent each). Therefore, these seem to be a very positive relationship between soil quality and the landfacets. The quality of soil decreases in the increase in slope. It is possible that, due to 'deforestation' and 'Jhum' cultivation, the upland soils have been degradation.

V. It can be generally concluded from the study that while valley lands and gentle slopes have the most suitable soils the steep slopes and the crest facets indicate poor quality of soils. This may be due to the continued deforestation of these ecologies and quick degradation in land quality. There are also inherent deficiencies in soils of steep slopes and crests due to the shallow depth of soil and low retention capacity.

Among the ecological zones, the highland zones (four) are the least fertile, while Mairang and Balat Zones which contain a large number of river valleys are the most fertile.

Although one cannot be absolute sure about the relationship between deforestation, land degradation and soil quality changes due to the one-time-point nature of the study, but there are sufficient indications to surmise that the relationship still holds good. Moreover, the steep slopes and the crest lands are the most vulnerable from ecological point of view and needs greater land management measures.

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**1987**

DEDICATED

TO

MY MOTHER

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Dr. A.C. Mohapatra
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## CERTIFICATE

This is to certify that the thesis submitted by Sri Munindra Konwar for the degree of the Master of Philosophy (M. Phil) at the Department of Geography, North Eastern Hill University, Shillong, Meghalaya, entitled "Soil Rating Status in Different Ecological Zones: A Field Based Study of West Khasi Hills District of Meghalaya", is a bonafide study of the author to the best of my knowledge and belief.

This study may now, be placed before the examiners for due evaluation.

A Mohapatra

The Sixteenth November, 1987.

( A. C. Mohapatra )
Supervisor

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Mr. Joseph F. Khongbuh, who has typed out my dissertation with much patience and care eminently deserves my sincere gratitude.

Munindra Konwar.

SHILLONG

THE 16th NOVEMBER, 1987.

(MUNINDRA KONWAR)

## C O N T E N T S

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# CHAPTER - I

## INTRODUCTION

### 1.1 Statement of the Problem

The physical environment of man consists of landforms, climate, water, soil, natural vegetation and the native animal life. This resource complex is necessary for human existence; it provides him with living space, with food and with a vast variety of raw materials used in the satisfaction of human wants. Land resources play a strategic role in the determination of man's economy, social and cultural progress which could be easily seen and clearly understood through reference to economic development of different countries. It has been noticed that in many parts of the world, the soils have been so damaged by mismanagement and abuse that it will never again be able to sustain a viable food production system. Nearly, 50 per cent of the world population depends directly or indirectly on land and land based resources for their living. This dependency is more significant in terms of the developing countries than the developed countries. Therefore, the assessment, management, preservation and maintenance of land resources is the most important task to the present civilization.

The mismanagement of land has led to soil erosion on a vast scale, i.e. the physical loss of the upper layer or top soil, the most vital part necessary for healthy plant growth.

Once this top soil or layer has been lost, it is for all practical purposes, gone for good. For example, even under natural conditions of cover, it takes from 300 to 1000 years or more to generate an inch of top soil, and it would need 2000 to 7000 years to generate seven inches of top soil.

Historical evidence indicates that in the Eastern Mediterranean region during Roman times millions of hectares of land became desert;[1] in China, vast areas became eroded and abandoned, and as recently as 1934 records indicate that the Yellow River carried silt washed down from cultivated lands equivalent to soil one metre deep, over 145,000 hectares. In Latin America, there are densely populated areas where the soil is very susceptible to erosion and losses have been so high as to place at least three countries there among the low-calorie areas of the world.

In case of India also, it has been noticed that the good soils have been degraded due to climatic factors, its improper management and misuse. Here, in India, deforestation is a major cause of soil erosion. The extent of annual deforestation of rainforest in India is about 80,000 to 1,00,000 sq.km.[2] This

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1. "Soil Conservation for Developing Countries" in Soil Bulletin No.30, FAO, 1977 & 1978.

2. F.A.O., Op.cit.

scale of deforestation, not only makes ecological imbalance in our country but also causes the soil erosion and degradation. It can be mentioned here that in India, one-third[3] of the arable land is threatened with total loss of top soil.

The main casuality of this process of deforestation is occurring in the hill areas of North Eastern Region of India, which is being washed away by its faulty use pattern. It has about 4.94 percent of closed forest[4] cover, but of these forest are secondary vegetation, the 10 years old bamboo shrubs developing after shifting cultivation.[5] It is also estimated that about 5.5 thousand square kilometres of additional forest is cleared every year in the region, 50 percent of which is primary forest due to slash and burn practices.[6] At this rate, all the primary vegetation would vanish from the region within a span of 25-30 years. This will distort not only the ecology in this region but also will degrade the soil fertility.

The pressure of population on the land resources and land based resources are increasing tremendously in the region. Gradually, the tropical rainforest ecology is being converted to degraded grassland ecology, a transformation both in the structure and as well as the functions of the system. This process

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3. M. Kamal, "Soil Erosion Threatens World Agriculture", Mazingira, Indian Edition, Vol. 8, No. 3, 1984.
4. National Remote Sensing Agency, 1983.
5. P.S. Ramakrishnan, "Tribal Man in the Humid Tropics of the North-East India", Man in India, Vol. 65, No.1, March 1985.
6. P.S. Ramakrishnan, Op.cit.

is similar both at the low latitude as well as the high altitude rainforests. The pressure on the land is progressively increasing with a exponential rate of growth of population at 3 percent per annum. The gentler slope and spurs which come usually under first stage shifting cultivation (Jhuming) have been severely degraded with the parent materials exposed and their soil cover eroded due to shortening of the Jhuming cycle to less than 10 years. It is now the steeper slopes and crests of hills which are under severe strain of slash and burn. The gentler slopes are normally more fertile and have a greater soil retention capacity. The steeper slopes and the crests ecologies are the most vulnerable and if not protected, get degraded after one or two of the shortened shifting cycles. This, particularly, is true in case of West Khasi Hills district of Meghalaya. A large area of this district is totally deforested and has given way to extensive degraded grassland vegetation with little hope of reversal.

There are also no accurate information available on these processes:

(a) The extent of erosion of soil.

(b) The pattern and quality of soil at different stages of degradation.

(c) The quality of soil at different slopes, valley bottom and crests.

## 1.2 Objective of the Study

The main objectives of the present study are as the following:

(a) To prepare a detailed soil map of the district on the basis of ecological landunits and at the various degrees of slopes and stages of degradation.

(b) To analyse the physical characteristics like, colour, texture, porosity, depth of horizons, thickness of humus etc. and chemical characteristics like available NPK status, pH value, available carbon content, etc, which will be measured from sample collections covering selected sample areas.

(c) Finally, to prepare a soil rating index in different ecological zones and preparation of the soil map of the district indicating degraded areas for their suitable management.

## 1.3 Hypotheses and Research Questions

### 1.3.1 Hypotheses

The following hypotheses have been proposed to be tested in the study:

(a) That clearing and cultivation of steeper slopes ( $>10^{o}$) and crest lands lead to quicker removal of top soil and fall in fertility status of the soil.

(b) That arrested jhum cycles ( $<$5-10 yrs) and shortened cycles ( $<$5 yrs) allow for large nutrients loss from the soil, and distort the soil characteristics.

(c) That the progressive desertification of the slope-ecology may lead to sharp degradation on valley-bottom-ecology and the cultivation practices.

(d) That the clearing of the forest by burning in shifting cultivation has resulted in increase of soil pH, available potash and calcium and decrease in organic carbon.

Besides these hypotheses, there are a few general research querries which shall be attempted to be studied.

1.3.2 Research Questions

(a) What will be the NPK status in different ecological landunits? Does it vary along with slopes and stages of degradation?

(b) What is the effect of altitudes and topography on the physico-chemical properties of the soils?

(c) Are there any differences among the soil texture, colour, and depth of horizon in relations to steep slopes, gentle slopes and valleys?

(d) How the soil texture is governed by the parent materials?

## 1.4 Study Area

For the present analysis, the study area, chosen, is a district of the State of Meghalaya which is the West Khasi Hills district.

### (a) Location

The West Khasi Hills district is situated in the west of East Khasi Hills district of Meghalaya. The district lies between $25^{\circ}10'$N to $25^{\circ}51'$N Latitude and $90^{\circ}45'$E to $91^{\circ}52'$ E Longitude. The district headquarters is located at Nongstoin, at a distance of 96 Km from Shillong, the capital of the State. The district is bounded by East Khasi Hills district of Meghalaya on the east, Kamrup district of Assam on the North, East Garo Hills and West Garo Hills districts of Meghalaya on the West and Bangladesh to the South.

The map No. 1 shows the location of the West Khasi Hills district of Meghalaya.

In the district, there are four Community Development Blocks. They are Nongstoin, Mawshynrut (Sonapahar), Mawkyrwat and Mairang. They provide the operational jurisdiction of the district.

The total geographical area of the district is 5,247 sq. kms.[7] occupying about 24 percent of the total geographical area

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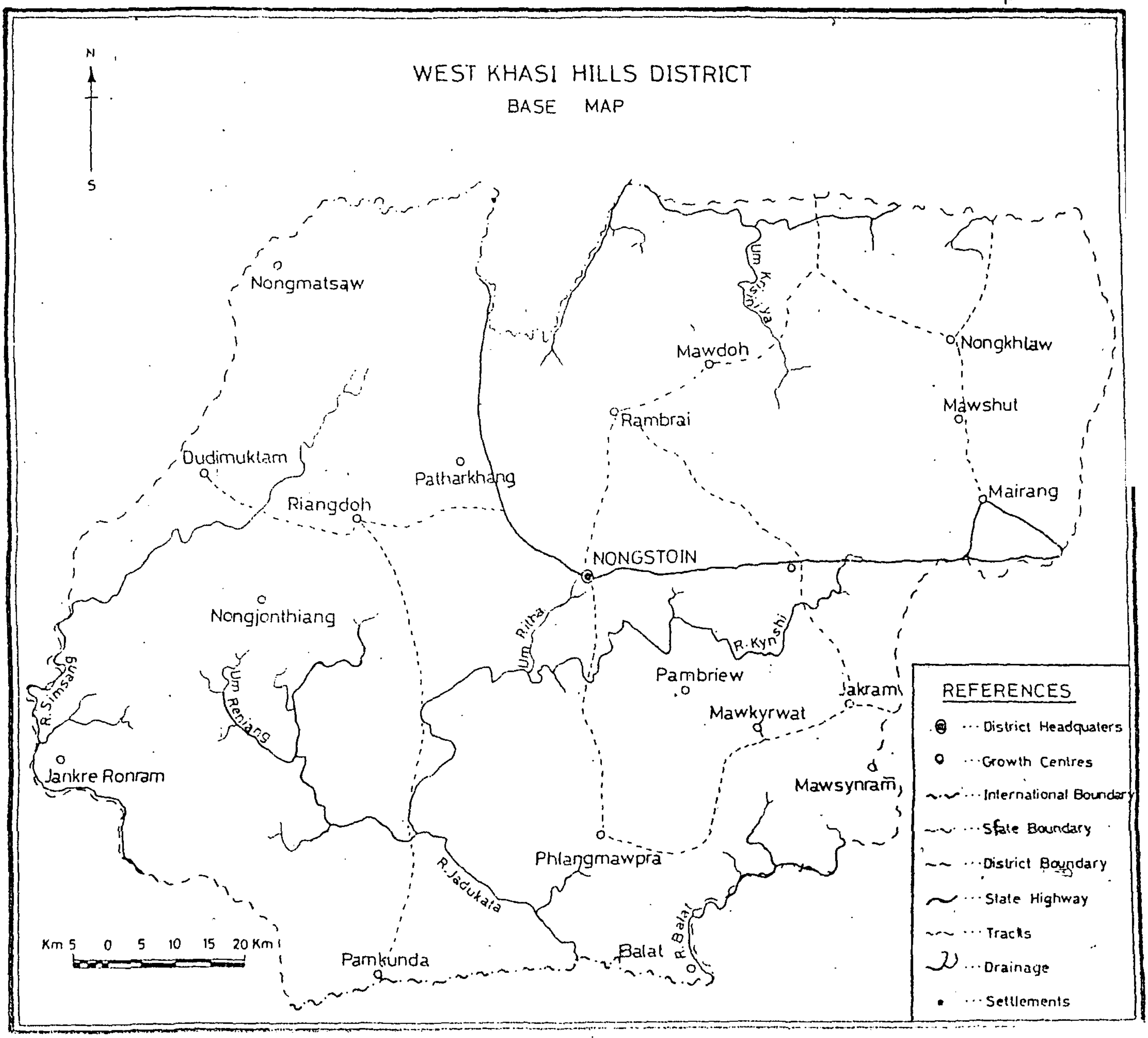
7. Government of Meghalaya, "Socio-Economic Review" West Khasi Hills district 1981, District Statistical Office, West Khasi Hills, Nongstoin.

Map No.1


WEST KHASI HILLS DISTRICT
BASE MAP
N
S
Nongmatsaw
Dudimuktam
Riangdoh
Patharkhang
Nongjonthiang
Jankre Ronram
R. Simsang
Um Reniang
Um Kynshi
Mawdoh
Rambrai
Nongkhlaw
Mawshut
Mairang
NONGSTOIN
Um Riltra
R. Kynshi
Pambriew
Jakram
Mawkyrwat
Mawsynram
Phlangmawpra
R. Jadukata
Pamkunda
Balat
R. Balat
Km 5 0 5 10 15 20 Km
REFERENCES
District Headquaters
Growth Centres
International Boundary
State Boundary
District Boundary
State Highway
Tracks
Drainage
Settlements

of the State of Meghalaya. The district had a total number of 813 villages.[8] The district comprises of some of the most backward areas of the State. In 1975-76, the Government of Meghalaya declared 432 villages of the district as "Most Backward" and another 105 villages as "Specially Backward".[9]

(b) Geology

The soils of the North-Eastern Hill Region have developed under the influence of many types of bed-rock conditions. The major areas of Khasi Hills have been formed of gneissic rocks.[10] The rocks comprise mainly of biotite-gneiss, biotite-granulite, tourmaline schist etc.

The rocks in Meghalaya belongs to five geological formations. These five formations[11] are:

i) The Archaean Gneissic Complex,
ii) The Lower Gondwana Rocks,
iii) The Sylhet Traps,
iv) The Shillong Group of Rocks, and
v) The Cretaceous Tertiary Sediments.

Table No. 1.1 shows the Geological formation and the rock types of Meghalaya.

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8. Ibid., p. 2.
9. Ibid., p. 2.
10. G.S.I., Misc. Publication No. 30 (1974), Part IV, pp.70-75.
11. T. Oldham, "Notes on the Geological Structure of the part of the Khasi Hills: Memo", G.S.I. Vol. 1, No. 2.

Table No. 1.1: Geological Formation and Rock Types in Meghalaya

| Geological Age | Group | Formation | Rock Type |
|---|---|---|---|
| Recent | New Alluvium (Thickness not known) | Unclassified | Sand, Silt, Clays |
| | | Unconformity | |
| Pleistocene | Older Alluvium (Thickness not known) | Unclassified | Sand, Clay, Pebble, Gravel and Boulder deposits. |
| | | Unconformity | |
| Mio-pliocene | Dupi Tila group (1050 m) | Unclassified | Mottled Clays, Feldspathic Sandstone, Conglomerate. |
| | | Unconformity | |
| Oligo-Miocene | Garo Group | Chengapara formation (700m) | Sand, Siltstone, Clay, Marl. |
| | | Baghmara formation (530m) | Feldspathic Sandstone, Pebble, Conglomerate, Clay. |
| | | Simgsang formation (1150m) | Siltstone, Sandstone, alternations Sand. |
| Eocene | Jaintia Group | Kopili formation (500m) | Shale, Sandstone, Marl. |
| | | Shella formation (600m) | Alternation of Sandstone, Limestone. |
| | | Langpar formation (100m) | Calcareous Shale, Sandstone, Limestone |

Table No. 1.1 (Contd.)

| Geological Age | Group | Formation | Rock Type |
|---|---|---|---|
| Upper Cretaceous | Khasi Group | Mahadek formation (150m) | Arkose (Glauconitic) |
| | | Bottom Conglomerate formation | Conglomerate, Arkose |
| | | Jadukata Formation (140m) | Sandstone, Conglomerate alternations. |
| - - - - - - - - - - - - - - | | Unconformity - - - - - - - - | - - - - - - - - - - - - - - |
| Jurassic | Sylhet Group (600m) | - | Basalt, Rhyolite, Acid Tuff. |
| - - - - - - - - - - - - - - | | Unconformity - - - - - - - - | - - - - - - - - - - - - - - |
| Pre-Cambrian | - | Intrusives (acid & basic) | Porphyritic & Coarse Granites Pegmatite, Aplite, Quartz-Vein, Epidiorite, Dolerite, Basalt. |
| | | Shillong Group | Quartzite, Phylite, Conglomerate. |
| - - - - - - - - - - - - - - | | Unconformity - - - - - - - - | - - - - - - - - - - - - - - |
| Archaean | - | Gneissic Complex | Biotite, Gneiss-Biotite-Hornblende, Gneiss, Granitic Gneiss, Migmatite, Mica Schist, Sillimanite-Quartz, Schist, Biotite Granulite, Amphibiotite, Pyroxene Granulite, etc. |

Source: Geological Survey of India, Misc. Publication No. 30 (1974) Part -IV, p. 73.

The rocks of the West Khasi Hills district of Meghalaya is also formed from above mentioned five geological formations. The Map No. 2 shows the distribution of different types of rocks in the district.

(i) Archaean Gneissic Complex

This Archaean Gneissic Complex occupies the major portion of the district. The rocks in this complex are biotite, gneiss, quartzite, schist, sillimanite etc. They are composed of mainly gneisses mignatites and meta-sedimentary beds.

(ii) The Lower Gondwana Rocks

The Lower Gondwana rocks are found in south-west corner of this district, where coal is available. In this Lower Gondwana-coalfield with thick coal seams, underlying the dolomites and phyllites.[12]

(iii) The Sylhet Traps

This type of formation is found in the southern part of the district. The direction of the formation is east to west bounded in a narrow strip. Balat area of the district is composed of this type of formation. Sylhet Trap includes predominantly Basalt, Rhyrolites and acid tuffs. Sylhet Trap and the adjoining Archaean rocks to the north are characterised by several Basalt Dykes.

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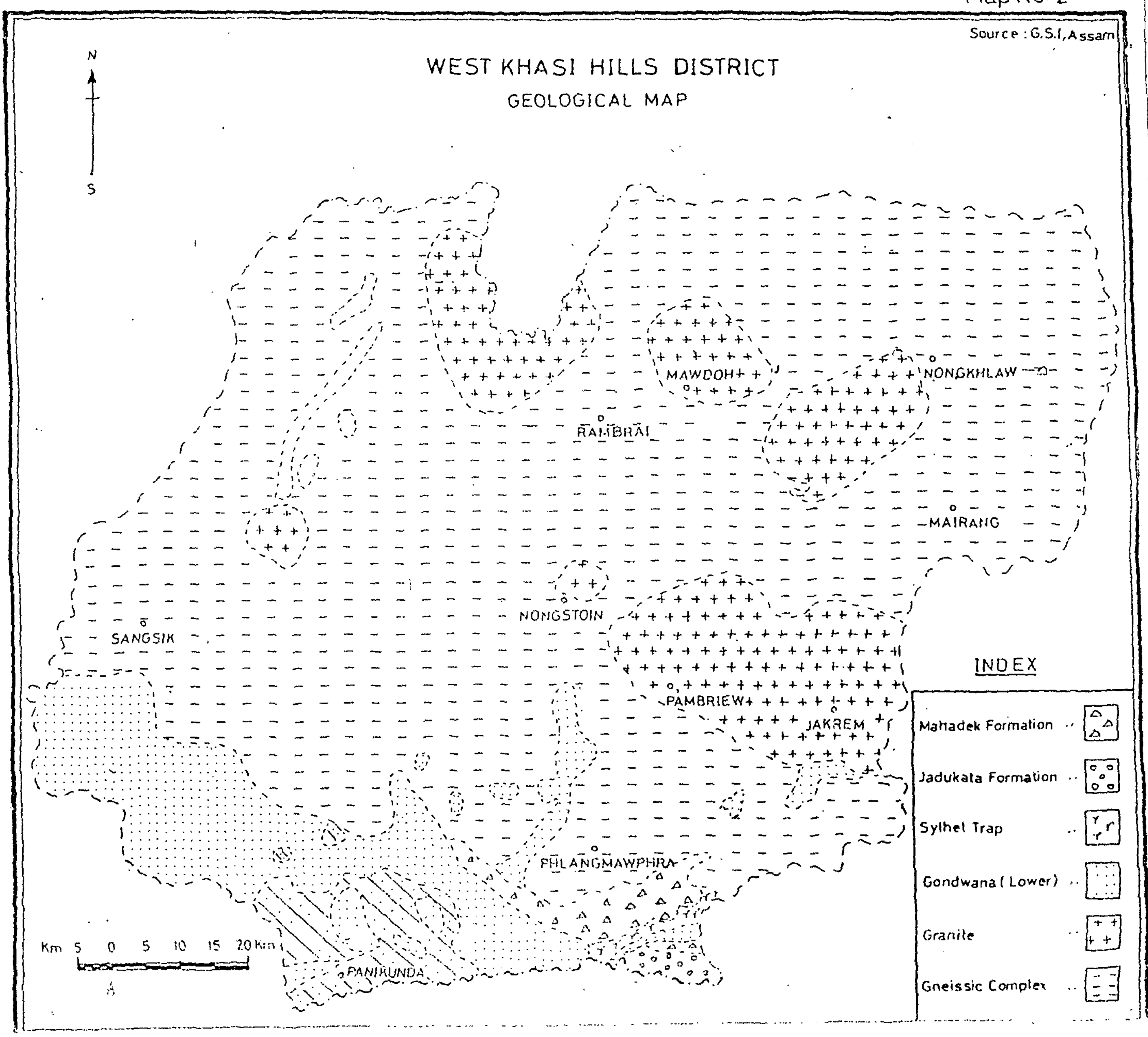
12. D.N. Wadia, Geology of India, 4th Edition; Tata McGraw-Hill Publishing Company Ltd., New Delhi, 1975, pp.172-180.

Map No. 2


Source : G.S.I, Assam
WEST KHASI HILLS DISTRICT
GEOLOGICAL MAP
N
S
MAWDOH
NONGKHLAW
RAMBRAI
MAIRANG
NONGSTOIN
SANGSIK
PAMBRIEW
JAKREM
PHLANGMAWPHRA
PANIKUNDA
Km 5 0 5 10 15 20 Km
INDEX
Mahadek Formation
Jadukata Formation
Sylhet Trap
Gondwana (Lower)
Granite
Gneissic Complex

(iv) The Shillong Group

In the eastern part of the district, Shillong Group of rocks are found. They are composed of Quartzite, Phylites, Schists, Conglomerates etc.

(v) The Cretaceous-Tertiary Sediments

This formation occupies the southern parts of this district. The rocks are mainly sandstone, shale, and limestone.

This formation is divided into three groups:

(a) The Khasi Group,

(b) The Jaintia Group, and

(c) The Garo Group.

(a) The Khasi Group

The Khasi Group, again divided into two formations: (i) The Mahadek, and (ii) The Jadukata formation.

The Jadukata formation consists of alternation of Conglomerate and limestone. It overlies non-conformably the Sylhet Trap and occurs to the north of the Riba Fault. The Mahadek formation consists of coarse arkose rocks

(c) Physiography

Among the seven States in the North Eastern Region of India, Meghalaya is one of the most rugged State in the region. It is full of hills, valleys, plateau and rivers. In the north, the small hillocks are found and which merge with the plains of

Assam. In the south, the slopes are very steep and there are deep gorges and spurs. The middle portion of Meghalaya, i.e. plateau proper, looks like an imposing table-land with steep escarpments and deep valleys bordering the Sylhet plains of Bangladesh.

Physiographically, the district can be divided into three main physical zones, i.e.

(i) the Central Highland,

(ii) the Southern Slopes, and

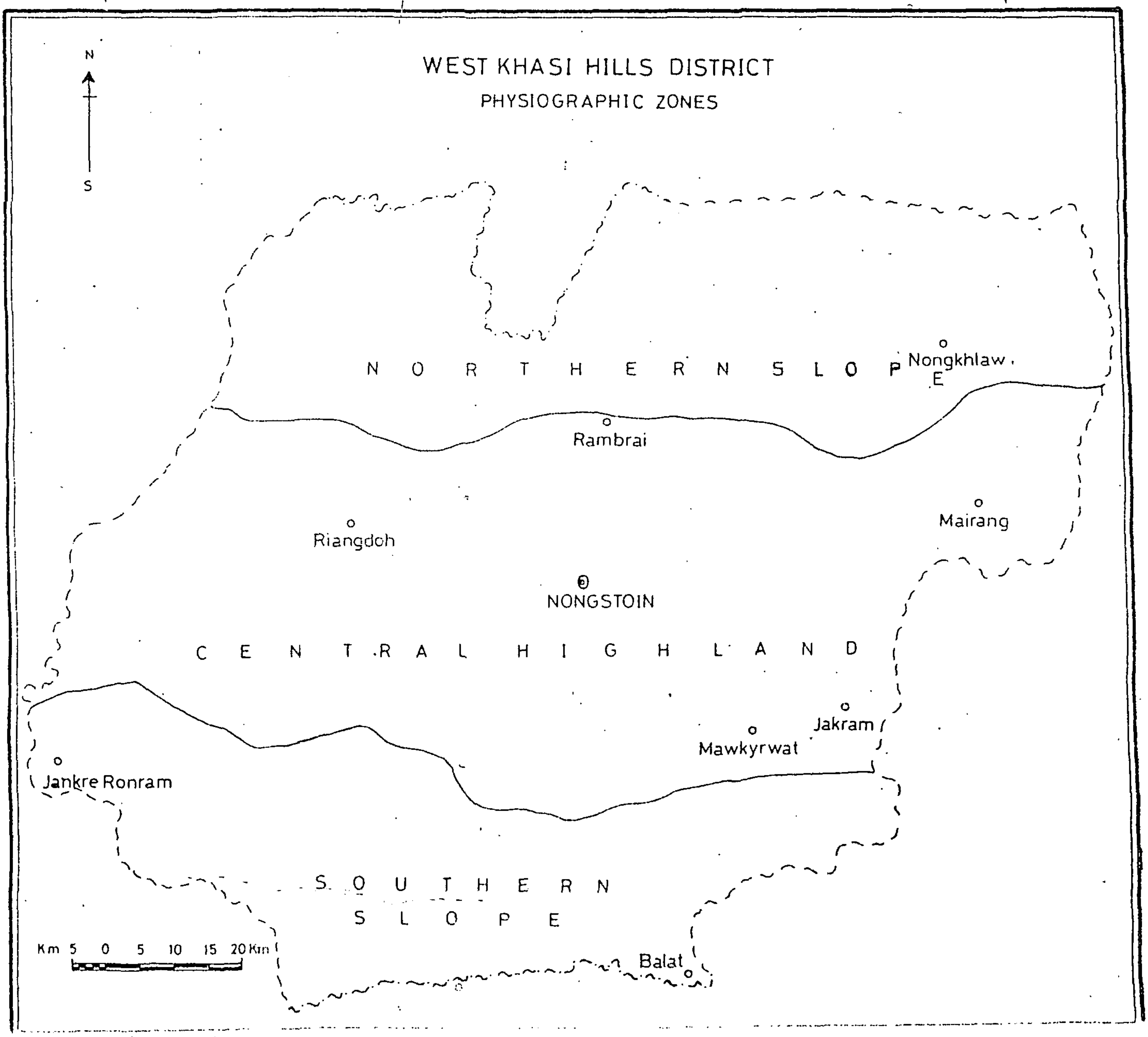
(iii) the Northern Slopes.

Map No. 3 shows the physiographic zones of the West Khasi Hills district.

(i) The Central Highland

The Central Highland of the district forms the western part of the Ri Khasi (Shillong) plateau of Meghalaya. This zone occupies the central portion of the district. Mairang, Markasa, Nongstoin etc. lie within this zone. The second highest peak of Meghalaya, Thadraishan (1893 metres) is located in this zone, lying between Mairang and Nongstoin. This Central Highland Zone climbs down gradually to meet the hills of Garo Hills at the elevations ranging from 1200 metres to 600 metres at various places. A number of rivers originate in this highland zone and drain both to the north and the south.

Map No.3


WEST KHASI HILLS DISTRICT
PHYSIOGRAPHIC ZONES
N
S
NORTHERN SLOPE
Nongkhlaw
Rambrai
Riangdoh
Mairang
NONGSTOIN
CENTRAL HIGHLAND
Jakram
Mawkyrwat
Jankre Ronram
SOUTHERN SLOPE
Balat
Km 5 0 5 10 15 20 Km

(ii) The Southern Slopes

The southern slopes comprise of a belt of lower hills and valleys. Mawkyrwat, Ranikor, Borsora etc. are situated in this zone. The hills in this zone are in north-south alignment. In many places, the slopes are very steep starting and ending abruptly. Cliffs and precipies overlook gorgeous valleys at many places. This zone touches the plains of Bangladesh in the south at elevations of 200-300 metres above the mean sea level. The Rongkhai, the Kynshiang and Um Ngi are the principal rivers flowing southward through the western, central and eastern parts, respectively. There are many smaller rivers and streams such as the Wah Butit, Wah Iaw, Um Wosar, Um Blei, Um Waisar, Um Tham, and Rilang, which join the Kynshiang after criss-crossing the central part of this zone.

(iii) The Northern Slopes

The Northern Slope Zone is a belt of low hills. The elevation gradually decreases northward to meet the plains of Assam at an elevation of 150 metres above mean sea level. The Khri, Um Synthi, Um Siri, Um Kamran, Tyrsung and part of the Umtrew are the rivers in the area.

(d) Drainage

A few rivers are flowing in the district. The Central Highland Plateau is the watershed zone and the rivers are flowing towards north and south of this highland. The major rivers like, river Kynshiang, river Balat and river Simsang are flowing towards the south and in the north, rivers like Um Krisiniya and Umtrew river are flowing to the plains of Brahmaputra valley.

It has been noticed that these rivers carry the nutrients from the hill slopes and get deposited in the valley area, which is suitable for paddy cultivation. Moreover, the river water is the main source of drinking water for the hill people.

(e) Climate

The climate of district is tropical to sub-tropical. In the Northern Slopes and in the Southern Slopes, the experiences in summer is hot and the winter is mild. In the Central Highland, there is prevalence of temperate climate with maximum summer temperature generally not rising above 27$^{o}$C and minimum winter temperature dropping down to as low as 1$^{o}$C.

The following table No. 1.2 shows the Average Annual Maximum and Minimum Temperature at important centres of the West Khasi Hills district.

Table No. 1.2: West Khasi Hills District - Average Annual Maximum and Minimum Temperature (temperature in degree centigrade).

| Year | NONGSTOIN | | RIANGDO | |
|---|---|---|---|---|
| | Max | Min | Max | Min |
| 1979-80 | 24.70 | 16.74 | 22.58 | 15.27 |
| 1980-81 | 24.30 | 18.55 | 22.11 | 13.67 |
| 1981-82 | 24.33 | 18.16 | 23.25 | 15.83 |
| 1982-83 | 23.75 | 16.97 | 24.41 | 15.08 |

Source: District Statistical Abstract West Khasi Hills 1983.

The variation of temperature in four years at the selected centres is very little. In Nongstoin, the maximum temperature was 24.70°C in 1979-80 and in Riangdo, it was 24.41°C in 1982-83. The minimum temperature is found 16.74°C in 1979-80 at Nongstoin and 13.67°C at Riangdo station in 1980-81. The four years maximum and minimum temperature is shown by the diagram No. 1.

Rainfall

Rainfall is generally assured during the summer, but it varies greatly in intensity and duration from region to region within the district. The South-West Monsoon accounts for most of the rainfall. The Southern Slopes which face the incoming rain-bearing winds, receive the maximum of rainfall, recording an annual average of upto 12,000 mm[13] in the eastern border near Mawsynram. In the Central Highland, the annual rainfall averages 2,500 mm to 3,000 mm, whereas in the Northern Zone, which lies in the rain shadow area and the precipitation is less, recording as low as 1,250 mm per annum at certain places in this zone. There is no accurate data of the relative humidity, available, but it is learnt that December, January, February, March and April are the dry months when relative humidity becomes as low as 50 percent. The rest of the period of the year is more humid, recording even 90 percent relative humidity in June, July and August.

13. Rainfall figures are collected from the District Statistical Abstract for West Khasi Hills 1983.

## WEST KHASI HIILS DISTRICT

AVERAGE ANNUAL MAXIMUM & MINIMUM TEMPERATURE

( In Degree Centigrade )

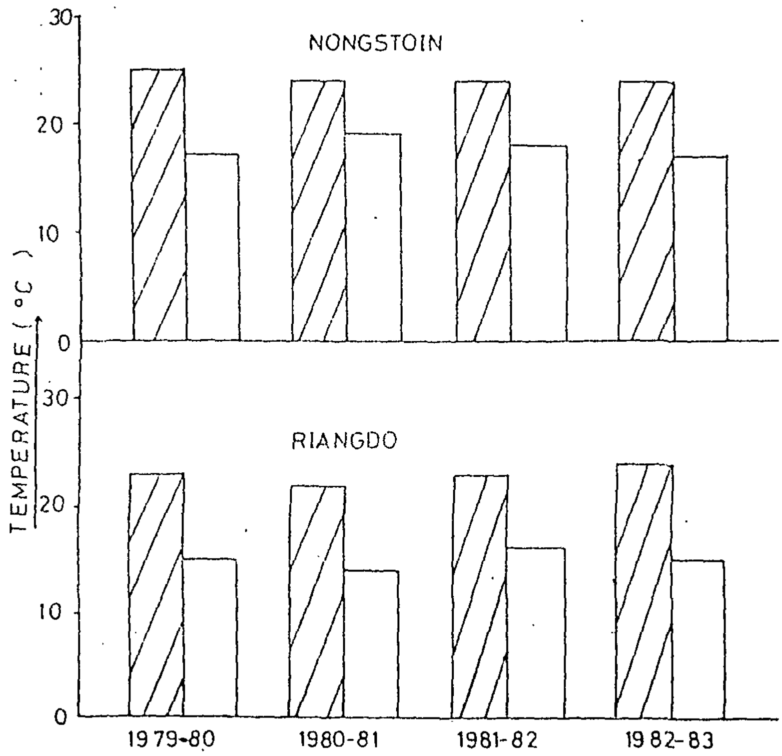


Table No. 1.3 shows the average annual rainfall at important centres of West Khasi Hills.

Table No. 1.3: West Khasi Hills District Average Annual Rainfall (Rainfall in mm).

| Year | Nongstoin | Riangdo |
|---|---|---|
| 1979-80 | 3789.9 | 2915.0 |
| 1980-81 | 3169.7 | 3301.9 |
| 1981-82 | 3643.3 | 3218.0 |
| 1982-83 | 4136.6 | 3223.2 |

Source: District Statistical Abstract West Khasi Hills 1983.

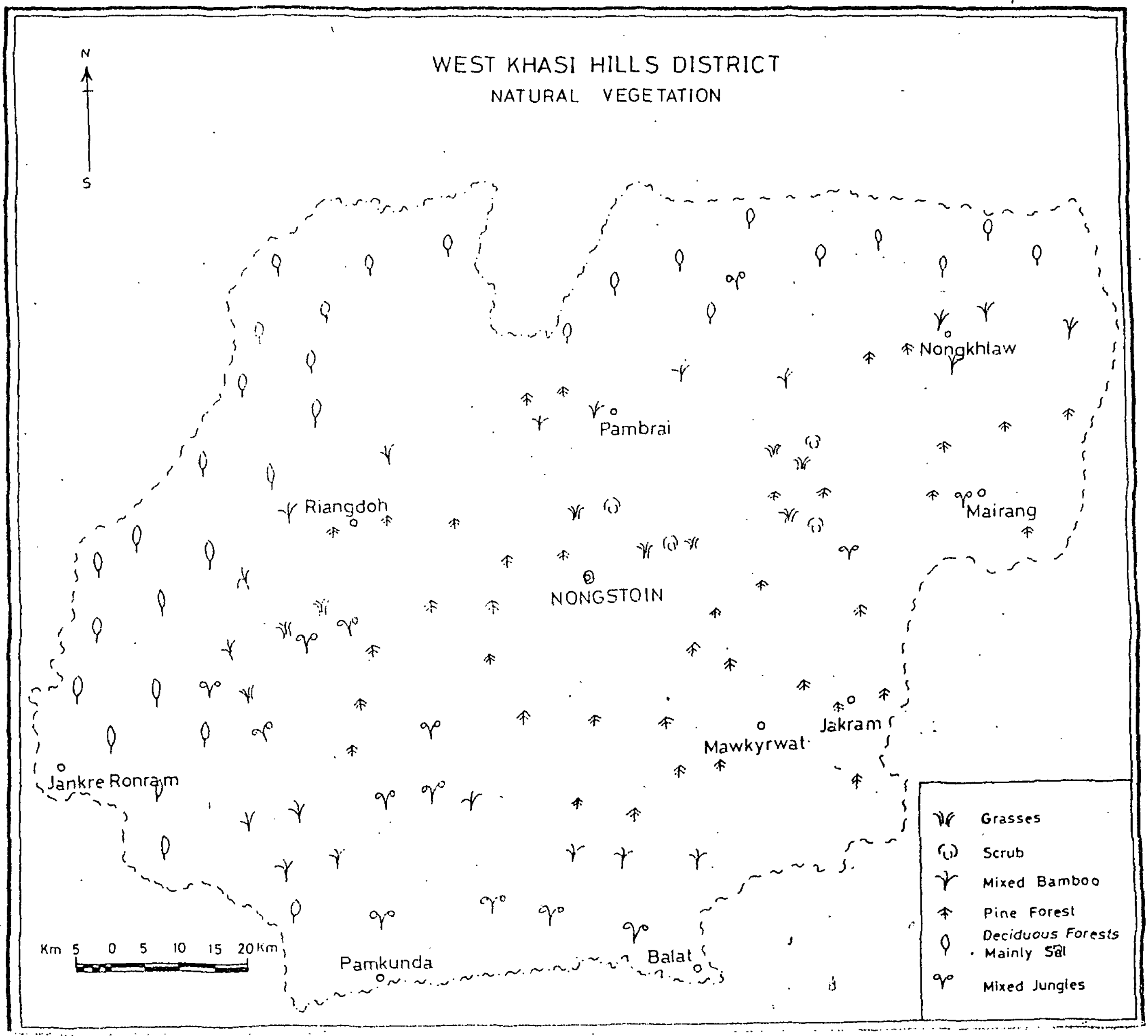
(f) Natural Vegetation

A variety of natural vegetation, ranging from sub-tropical to temperate vegetation can be found in the district, according to the regions and climatic zones. Tropical vegetation is seen generally upto an elevation of 600 metres, upto 900 metres, temperate forests and grasslands are found.

The natural vegetation has enriched the district with forests of valuable timber like, Pine, Teak, Sal etc. specially in Nongstoin, Mawshynrut (Sonapahar) and Mairang Development Blocks. Commercially important cane and bamboo are also found in abundance.

Map No. 4 shows the distribution of natural vegetation of West Khasi Hills district.

Map No.4


WEST KHASI HILLS DISTRICT
NATURAL VEGETATION
N
S
Nongkhlaw
Pambrai
Riangdoh
Mairang
NONGSTOIN
Mawkyrwat
Jakram
Jankre Ronram
Pamkunda
Balat
Km 5 0 5 10 15 20 Km
Grasses
Scrub
Mixed Bamboo
Pine Forest
Deciduous Forests Mainly Sal
Mixed Jungles

Forest

The area under forest as estimated for the four constituent Development Blocks of the district is about 35 percent[14] of the total geographical area of this district. Nearly,90 per cent of the total forested area is under the control of the District Council and the rest under the Government, while the most forest under the control of the Government are managed under regular working plans and schemes, those under the District Council had no such plans.

Table No. 1.4 shows the area under reserved, protected, unclassified and leased forests in the district for the three years (1982, 1983 and 1984).

Table No. 1.4: West Khasi Hills District Area Under Forests.

(in sq.km)

| Year | Reserved forest | Protected forest | Unclassified forest | Private forest of leased | Village forest of other | Total area under forest |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1982 | NR* | NR | 1640 | NR | NR | 1640 |
| 1983 | NR | NR | 1640 | NR | NR | 1640 |
| 1984 | NR | NR | 1640 | NR | NR | 1640 |

*NR = No Record

Source: District Statistical Abstract, West Khasi Hills 1983.

14. Op.cit., p. 21.

Forest Type

The type of the forest for the district could be classified into four types on the basis of altitudinal and climatic variations. These four types for forest are:

(a) Subtropical Pine Forest.

(b) Moist mixed deciduous forest (with sal).

(c) Very moist Sal bearing forest.

(d) Reserved forest.

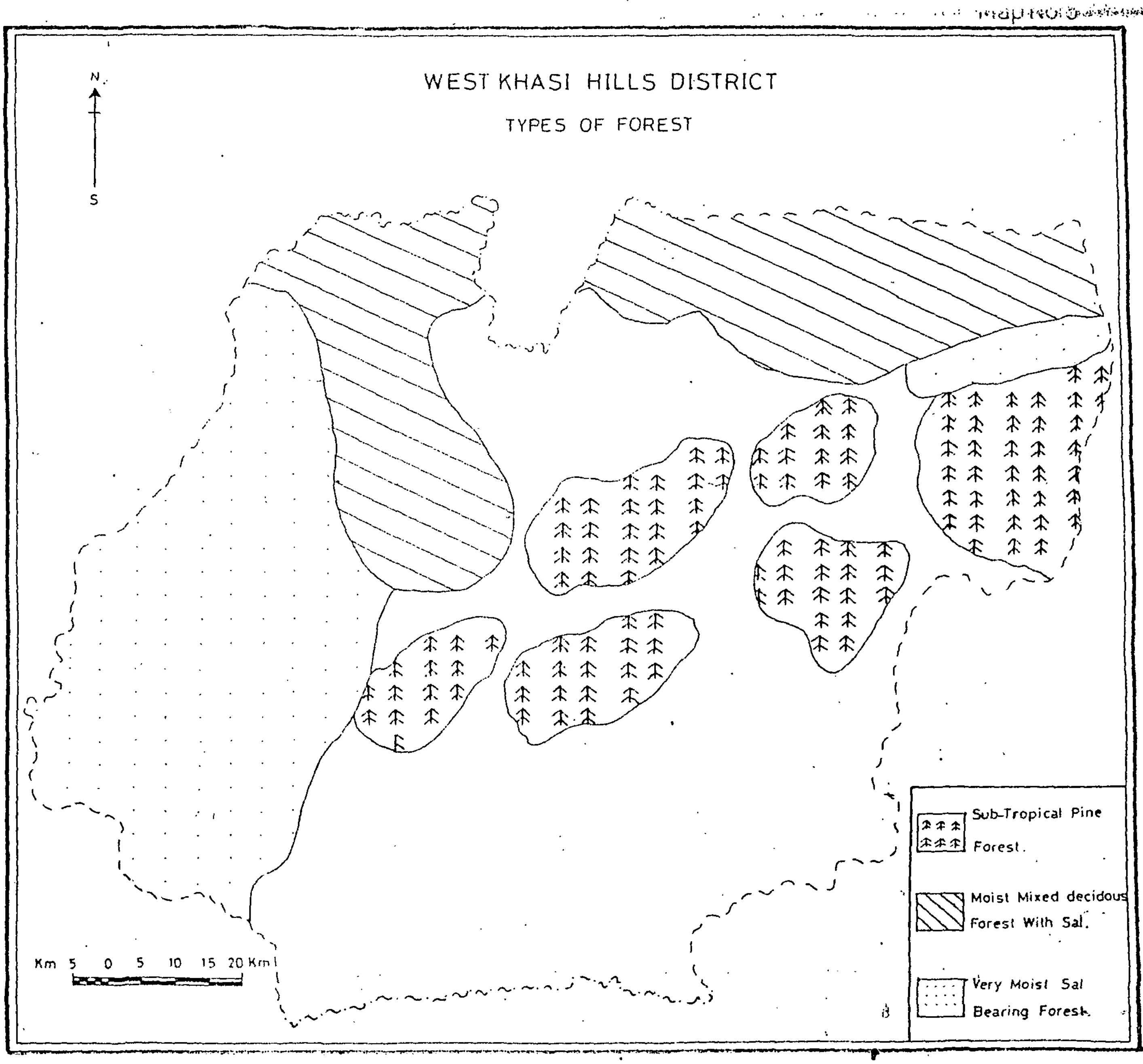
Map No. 5 shows the distribution of forest types in West Khasi Hills district of Meghalaya.

Turn Over of Forest Products

As a result, the extent of degenerate and unproductive forests is very large about 90 percent or so of the total forested area. The average yield from the degraded forests is below 80 Cu metre per hectare. On the other hand, about 90 per cent of Government managed forests are still inaccessible. All these lead to very little earning from the forest and a paradox for an otherwise forested district.

1.5 Survey of Existing Literature

The studies of soil have been recognised at various levels in the world. But the number of studies devoted particularly to soil rating status in different ecological zones is not substantial. Among the few studies, the following studies could be reviewed in brief.


WEST KHASI HILLS DISTRICT
TYPES OF FOREST
N
S
Km 5 0 5 10 15 20 Km
Sub-Tropical Pine Forest.
Moist Mixed decidous Forest With Sal.
Very Moist Sal Bearing Forest.

A study in relation to an ecological approach to land capability classification has made by R.K. Gupta and T.A. Singh.[15] In their studies, they discussed about the biotic and abiotic factors which are responsible for soil formation and soil fertility. They also discussed the influence of topographical features like, altitude, vegetation, temperature and rainfall on the soil fertility and soil formation. W.B. Bollen[16] has made a broad review of the soil as a biological system. He has examined its ecological significance. R. Dayal and L. Giri[17] have made a field study of Varanasi area in relation to the soil moisture, pH and other characteristics. The ecology of soil fungi and other biotic factors of Uttar Pradesh is studied by R.K. Saksena,[18] Nand Krishna[19] and A.R. Sarbhoy.[20]

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15. R.K. Gupta and T.A. Singh; Laboratory Studies of Phosphorus forms and test procedures on soils under aerobic and anaerobic conditions, Geoderma, Vol. 15, No.3, pp. 40-45, 1975.
16. W.B. Bollen; The soil as a biological system and its ecological significance, Proceedings of National Academy Science, Section A, Vol. 37, No. 3, 1976.
17. R. Dayal and L. Giri; Soil Fungi in Leguminous fields of Varanasi, India, Oikos, Vol. 22, No.1, 1971.
18. R.K. Saksena; Ecology of the Soil Fungi of Uttar Pradesh, Proceedings of the National Institute Sciences of India, Part B, Vol. 33, No. 3, 1967.
19. Nand Krishna; Soils of the Himalayan forests and their microfungi, Proceedings of the National Institute Sciences of India, Part B, Vol. 33, No. 4, 1976.
20. A.R. Sarbhoy; Soils of the Sub-Himalayan tract and their microfungi, Proceedings of the National Institute Sciences of India, Part B, Vol. 33, No. 4, 1967.

Gurmel Singh,[21] Rajbans Dayal and S.N. Bhola have investigated the soil and water loss under different slope ranging between half degree and one degree.

Yadav[22] has sought to establish the ways in which the physico-chemical characteristics of soils, including of the profile are influenced by different types of forest cover. K.K.M. Nambiar,[23] Rajbans Dayal and P.R. Mishra have studied how the soil structure improves while under different grasses. B.M. Sarma[24] has analysed with the aid of a large number of soil samples and soil profiles the phosphorus and pH status of the soils on the one hand and their correlation with the plant species of the region on the other.

The Geographer, on the other hand, is primarily concerned with the criteria and scheme of classification of land categories. Such studies are mainly at meso-levels.

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21. G. Singh, R. Dayal and S.N. Bhola; Soil and water loss (run off) studies under different vegetation covers on 0.5 and 1.0 degree slope at Kota, Journal of Soil and Water Conservation in India, Vol. 15, No. 1, 2, 1967.

22. J.S.P. Yadav; Physicochemical Characteristics of some typical soils of Indian Forests, The Indian Forester, Vol. 94, No.1, 1968.

23. K.K.M. Nambiar, Dayal, Rajbans and P.R. Mishra; Study of relative degree of improvement of soil structure under different grasses, The Indian Forester, Vol. 94, No.7, 1968.

24. B.M. Sarma; Nitrogen, phosphorus and Potassium status of soils under certain plant communities of Churu, Rajasthan, The Indian Forester, Vol. 94, No. 8, 1968.

Among the studies of Raychaudhury[25] in relation to different aspects of soils is more significant. In 1967, he studied relation of soil characteristics with soil profiles. Again, in 1967, he studied the ratio of soil fertility with agricultural production on one hand, and the role of organic manure and green manuring in the maintenance of soil fertility on the other. In his book "Land and Soil"[26] discussed the importance of land resource and he has made a classification of Indian soil according to its ecological status. Ramanathan[27] have used profile characteristics to device on scheme and map of land capability classification of the soils of the Anna farm in Kudumiamala (T.N.) at micro-level. Bagchi[28] and Saha have classified the land of Dwarka-Brahmini Command area in Birbhum district of West Bengal on the basis of soil texture.

There is no extensive studies on the soil in relation to the North Eastern Hill Region of India. The Indian Council

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25. S.P. Raychaudhury; Soil Correlation, Journal of Soil and Water Conservation in India, Vol. 14 & 15, No. 1,2, 1967.

26. S.P. Raychaudhury; Land and Soil, India, The Land and People, NET, Publication, Delhi, 1967.

27. S. Ramanathan, C.S. Balasundaram; H.H. Khan and K. Subramanian; Profile Characteristics and Land Capability Classification of Soils of Anne Farm, Kudumiamalai, Madras, Agricultural Journal, Vol. 8, No.1, 1973.

28. K. Baghchi and P.K. Saha; Land Classification on the basis of texture of the soils and slope of the land in Dwarka-Brahmini Command Area, District Birbhum, Geographical Review of India, Vol. 32, No. 4, 1970.

of Agricultural Research (ICAR), Research Complex for N.E. Region, Shillong, has been studying the soil of this region. They collect samples from different farms and analyse the available nutrients in the soil for agricultural purposes only. A.R. Borah has discussed the problems and prospects of better utilisation of land in the hills of North East India. R.P.M. Bordoloi,[29] has studied Jhum field and their role in soil conservation and soil fertility. R.N. Prasad,[30] Rati Ram and Munna Ram, have discussed about the soils of North Eastern Hill Region and their properties. They discussed the altitudinal variation of soil fertility.

There is no specific study on soils of the West Khasi Hills district of Meghalaya.

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29. R.P.M., Bordoloi; Plant pioneers in Jhum Field and their role in soil conservation and soil fertility, in 3(1) Seminar on Shifting Cultivation, 1976, p.4.

30. R.N. Prasad, Rati Ram and M. Ram; Soils of North Eastern Hill Region and their properties, Journal of Meghalaya Science Society, Vol. 4, pp. 39-46, 1980.

# CHAPTER - II

## DATA BASE AND METHODOLOGY

### 2.1 Data Base

Keeping in view the objectives of the study, three types of information and data will be required for the purpose. These are:

(1) Secondary information on general characteristics of the population, agricultural, landuse and settlement pattern etc., for the West Khasi Hills district of Meghalaya.

(2) Map based information on relief, vegetation, drainage, slope and other ecological parameters for the study area, and

(3) Primary data, i.e. collection of field samples of soils on the various macro and micro ecological conditions.

In connection with item (1) i.e. regarding general characteristics of population, agriculture, landuse and settlements, major source of information have been: (i) various census publications particularly District Census Handbook[1] and Village Directory for 1971 and 1981. Apart from this source, other secondary and tertiary sources like, the District Statistical Handbook[2] and Data collected from the Department of

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1. Government of Meghalaya, <u>Statistical Handbook</u>, 1984, Director of Economics.

2. <u>Ibid</u>.

Agriculture, Government of Meghalaya and Department of Forestry, Government of Meghalaya have been used also.

In the circumstances of the weaker data base of the entire North Eastern Region, particularly information on Agriculture and Landuse etc., which are largely gross estimated figures, it remains a major limitation of any substantive work based on secondary information. However, in the present study, the uses of such information are only limited to providing a general background to the study and therefore, it may not hamper in any serious manner, the scope and generalisations of the study.

In connection with item (2), i.e., map related information, there are two major sources:

(a) Topographical Sheets[3] of both 1:63,360 and 1:50,000 Scales of 1910 to 1911 and subsequently revised version of 1966-67 published by Survey of India.
(b) Satellite imageries pertaining to West Khasi Hills District of Meghalaya. The available satellite imageries in the scale of 1 to 1 million or 1:1,000,000 published by National Remote Sensing Agency, Hyderabad.

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3. Topographic Sheets No.
Scale, 1:63,360 - 78(0/1, 0/2, 0/3, 0/4, 0/5, 0/6, 0/7, 0/8, 0/9, 0/10, 0/11, 0/12, 0/13).
Scale, 1:50,000 - 78(K/3, K/5, K/13, K/14, K/15, K/16).
Published by G.S.I. 1910-11 and 1966-67 (Revised).

The topographic sheets provide basis, first, for a base map for the entire district showing broad relief, drainage, settlement pattern and road network. It may be mentioned that no such detailed base map was available. The base maps were prepared both at 1:50,000 and a reduced scale 1 cm to 5 Km. The Satellite images were used to identify landfacies and vegetation cover.

In connection with item (3), i.e., primary collection of soil samples, it may be mentioned that about 200 soil samples and samples of profiles were collected through a number of field trips covering nearly the entire West Khasi Hills district. Both physical and chemical analysis of soils, particularly relating to texture, structure, colour, pH, NPK status and Organic Carbon were obtained by the researcher by analysing these samples at the Soil Laboratory of the concerned institution. Some additional help however, was taken from the Soil Analysis Laboratory of Department of Agriculture, Government of Meghalaya.

## 2.2 Methdology

For the purposes of the present study, the plan of work has been dividing into three parts:

(a) Maps,

(b) Analysis of Soil - (i) Physical and (ii) Chemical characteristics of soil, and

(c) Soil Rating Index and Soil Classification and mapping.

(a) Maps

Maps are the tools of Geographers. It is with the help of maps and diagrams that many complicated landforms may be explained in a simplified manner.

Keeping the objectives of the present study in view, the following maps were prepared:

(1) Relief map,
(2) Vegetation map,
(3) Drainage map,
(4) Slope map,
(5) Geological map, and
(6) Map of the Major Ecological Zones of the district.

It is to be mentioned that a soil is the unique result of the interrelated factors: like-relief, vegetation, geology or parent rock materials, drainage, slope etc. Therefore, it is necessary to make a good estimate of the topographic maps for soil classification.

2.2.1 Relief

The term relief indicates the variation in the nature of the land surface or in other words, the lie of the land. It shows the broad features and relative heights of highlands and lowlands which are portrayed by such term as hills, knolls, spurs and valleys etc.

Methods of Representation

The different methods employed to represent elevation and relief can be grouped under there heads:

(i) Pictorial,
(ii) Mathematical, and
(iii) Combination of the previous two.

Among the three methods, 'Contours' Method of Mathematical method is the standard method of representing relief.

Contours Method

Contouring is the standard method of representing relief. Contours are imaginery lines of the ground joining adjacent places at the same height above sea levels.

Construction of Relief Map

Contours, of an interval of 150 metres have been traced from the topographical sheets of West Khasi Hills district of Meghalaya. Both 1:63,360 and 1:50,000 scales were used. By taking contour interval of 150 metres, the average relief map was prepared. After the preparation of relief map, the map was reduced to a scale of 1cm to 5 Kms.

### 2.2.2 Vegetation Map

Vegetation map shows the overall distribution of vegetation in a particular area of the earth surface. The importance of vegetation map is to correlate the nature of vegetation with the type of climate prevailing there. It has to study, for example, where the pine forests are found much, whether it is on the slopes of the hills, on highlands or in the river valley.

Considering the above criteria, an attempt has made to prepare the vegetation map of West Khasi Hills district.

#### Preparation of Vegetation map

The interpretation of vegetation map has been done with the help of topographic sheets and landsat imageries of West Khasi Hills district. Both 1:63,360 and 1:50,000 scales were used. In case of landsat images 1 to 1 million photographs have been used. Both coloured and black and white landsat imageries were used. With the help of Stereoscope and magnifying lenses, it was possible to identify the vegetation cover of the district.

On the basis of altitude and climatic variations, the forest types of the district could be classified into four forest types. These are:

(i) Sub-tropical high altitude Pine Forest

(ii) Moist mixed deciduous forest (with sal),
(iii) Very humid Sal bearing forest, and
(iv) Reserved forests.

### 2.2.3 Drainage map

Drainage map is important not only for the sake of convenience trace out important rivers and their tributaries but their impact on social life also. Drainage conditions are necessary in both soil descriptions and definitions. Drainage, primarily relates to the soil, water and its effect on the profile development through weathering and erosion and producing their soil cover on steep slopes and deposition of soil material down. The direction, intensity, frequency and distribution of drainage influences the course of soil formation.

Preparation of drainage map

For the preparation of drainage map of West Khasi Hills district, both 1:63,360 and 1:50,000 scales of topographic sheets were used. The major drainage and their tributaries were used. The major drainage and their tributaries were traced and reduced the map to a scale of 1 cm to 5 Kms.

### 2.2.4 Slope Map

The analysis of the gradient of slope in a region makes landform classification easier. But in any area the gradient of slope is seldom uniform. Its irregularities are apparent from the contour maps. Therefore, it is necessary to calculate the average slope of a region.

In defining soil classificational units, soil slope is given special attention. As with other important soil characteristics, the relative significance of differences in slope depends upon the other characteristics of the soil.

There are several methods of average slope determination of which Wentworth's method is a 'general and random' method and is easier to follow. The formula of Wentworth's method is given below:

$$\theta = \tan^{-1} \frac{N \times I}{3,361}$$

Where, 'N' is the average number of crossings of contours per mile,
'I' is the contour interval,
'$\theta$' is the average angle of slope and
3,361 is constant number.

Construction of slope map

Taking one inch equal to one mile, the topographic sheets were divided into a number of small squares. To determine the average angle of slopes for every square had to calculate their angles in degrees. The calculated angles were plotted in their respective squares and a choropleth map has drawn to depict the variations in the angles of slope over the different parts of the district. The slope classification has done in the following manner:

(a) Not available (NA) category: There are some areas where contours are not available. It is not because of the lowlying area but might be other reason which was not mentioned in the topographic sheets.

(b) Below $10^{\circ}$ slope
(c) $10^{\circ}$ - $15^{\circ}$ slope
(d) $15^{\circ}$ - $25^{\circ}$ slope
(e) $25^{\circ}$ - $40^{\circ}$ slope
(f) $40^{\circ}$ and above.

2.2.5 Geological Map

A geological map shows the geographical distribution of different rock formations or strata at the ground surface. Its interpretation leads to an understanding of the lithology and structure of the underlying rocks which, in turn, helps in the study of the evolution of landforms in a particular area.

The development and formation of soil depends upon the parent rock materials. The parent material refers to the unconsolidated mass from which the solum develops. It includes the C-horizon and other materials above the C from which the solum developed. In many soils the solum is underlain with an unconsolidated nonconforming geological stratum. Such geological strata have an influence on the genesis and behaviour of the soil.

Preparation of Geological Map

The Geological Survey[4] of India has prepared the geological and mineral map of Meghalaya. The scale of the map was 125,00,000 or 1 cm to 5 Kms. The district geological map of West Khasi Hills district has been traced and it had to enlarge (for district map) to a scale of 1 cm to 5 Kms.

2.3 Soil Sampling

"The analysis can be no better than the sample".[5]

The sampling of soils is a challenging problem, worthy of detailed consideration. The general problem of soil sampling has been summarized by the Association of Official Agricultural Chemists[6] as follows:

> 'In view of the variability of soils, it seems impossible to devise of the procedure should be determined by the purpose for which the sample is taken.'

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4. G.S.I., <u>Geological and Mineral Map of Meghalaya</u>, Scale; 1:5,00,000 or 1 cm to 5 Kms, 1977.

5. M.L. Jackson, <u>Soil Chemical Analysis</u>, Second Indian Reprint, pp. 10-11, 1973.

6. <u>Ibid</u>.

The above passage brings into focus the twin problems of soil variability (sampling "all out-of-doors") and the divergency of types of analyses to be performed on samples. Soil sampling includes taking the soil material so as to take into account the variability of soil, handling and processing the samples for actual analytical determination.

Method

The method which is applied for sampling for this study is known as Composite Soil Sampling Method.[7] It gives a mean analytical value representative of the soil sampling volume from which the composite sample was drawn, using this method, the top soil from different landfacets with a depth of 6-9 inches have been collected from each horizons.

Sampling tools

The tools, which are used for collection are — a hand pick and soil auger, spade, paper bags, screw auger etc.

2.4 Analysis of Soil

According to the soil characteristics, the analysis part can be divided into two i.e.,

(i) Physical, and

(ii) Chemical Analysis of Soil.

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7. M.L. Jackson, Op.cit., pp. 12-13.

2.4.1 Determination of physical characteristics of soil

Before going into a discussion on the method of determination of physical characteristics of soil, it is important to discuss the significance of the physical characteristics.

The soil is a complex mechanical system consisting of three physical states. These three physical states are solid, liquid and gaseous. The bulk of the solid phase, occupies approximately fifty percent of the total volume of soil. It consists of primarily of the mineral materials and organic matter. The rest of the volume makes up for the pore space being occupied by liquid and gaseous substances. Thus, the proportion of the four major components of soil - inorganic particles, organic particles, water and air - vary greatly in different kinds of soil and from place to place and also with difference in the depth of the soil.

The physical properties of soil depend on the amount, size, shape, arrangement and mineral composition of its particles. The kind and amount of organic matter and the volume and form of its pores are related to its physical properties. The particle sizes of the solid material is extremely important in the process of cation exchange i.e. leading to circulation of nutrients in the soil. Therefore, this colloidal properties is important in texture determination of the soil. In this study, some important physical properties of soil like - Texture, Colour and structure have been analysed.

2.4.2 Mechanical Analysis and soil texture

The mineral component constitutes the largest volume of soil mass and plays a vital role in determining most of the physical properties of soil. This mineral component consists of particles of various sizes. According to the sizes, the soil particles are grouped into gravels, sands, silts and clay which are termed as soil 'separate' or 'fractions'. The proportionate composition of various separates in soil, defines the soil texture which can be determined by mechanical analysis of the sample.

Soil texture

The soil texture refers to the relative percentage of sand, silt, and clay below 2 millimetre in diameter in a solid state. Natural field soils are always mixtures of soil separates. The relative percentage of the various soil separates in the field soil are almost infinite in possible combinations. It is, therefore, necessary to establish limits of various sizes among the soil separates so as to group them into textual classes, such as sandy, silty loamy and clayey etc.

The list shows the more common textural classes in order of increasing fineness.

1. Sands
2. Loamy sands
3. Sandy loams
4. Loam
5. Silt loam
6. Silt
7. Sandy clay loam
8. Clay loam
9. Silty clay loam
10. Sandy clay
11. Silty clay
12. Clay

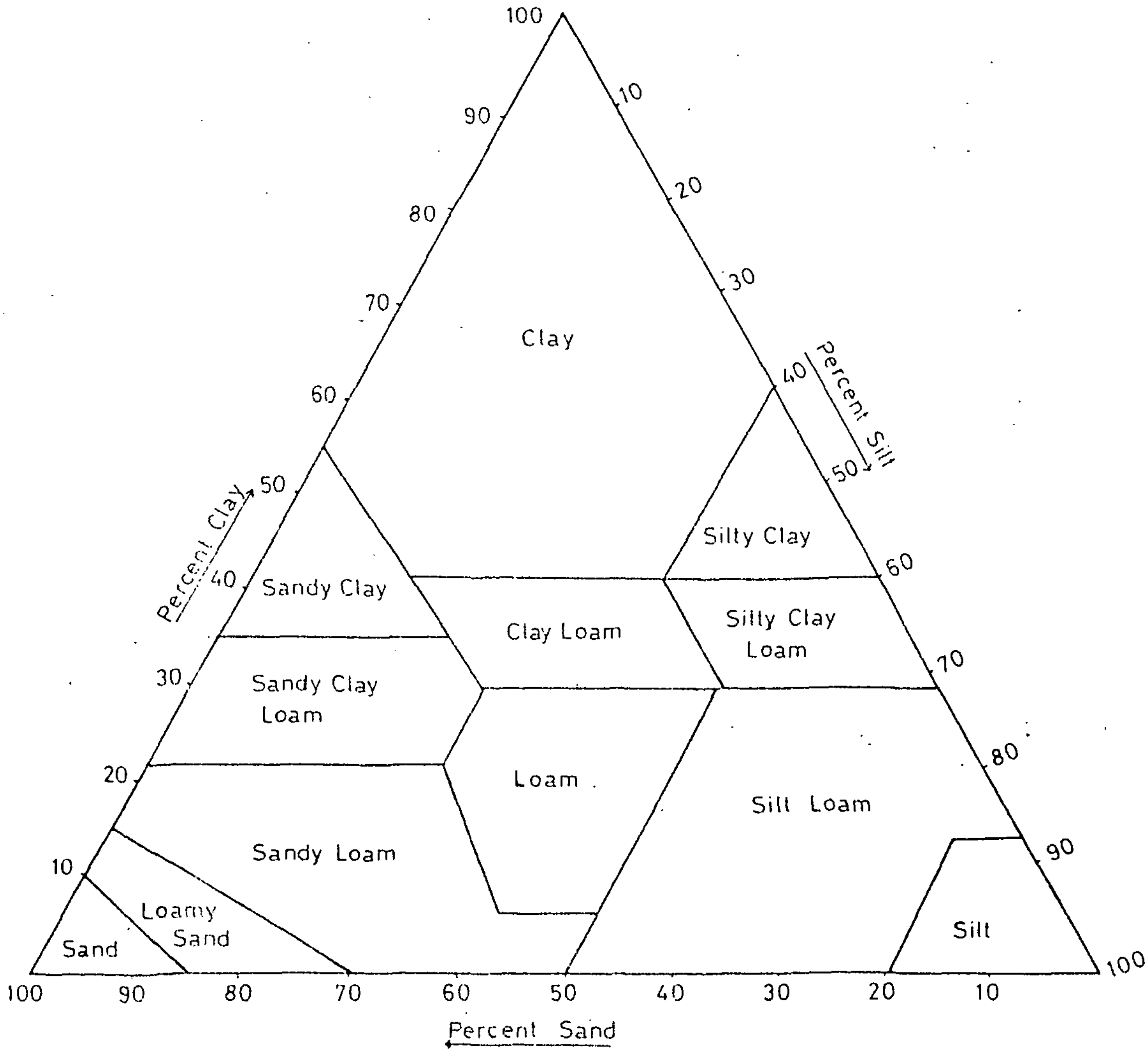
To determine the textural name of a soil, an equilateral triangle can be used. This triangle is known as the 'Textural triangle' (Fig No.2). The three sides of the triangle can be used to represent a three co-ordinate system representing the percentage of all the three size classes of particles in the sample, i.e. sand, silt and clay, by graduating each side from origin, zero to minimum hundred and thereby determining a single point inside the triangle representing values of all the three attributes. The U.S. Department of Agriculture scale has used for measuring the soil texture.

Materials and Methods

There are two methods to determine the percentage of various particle sizes in soil. The International Scale

Fig. No.2

TEXTURAL TRIANGLE



(International Society of Science) and the U.S.D.A. Scale (U.S. Department of Agriculture).

The table No. 2.1 shows the size grades of mineral material.

Table No. 2.1

| Fraction | International | | U.S.D.A. | |
|---|---|---|---|---|
| | mm | um | mm | um |
| Coarse Sand CS | 2.2-0.2 | 2000-200 | 2.0-0.2 | 2000-200 |
| Fine Sand FS | 0.2-0.02 | 200-20 | 0.2-0.05 | 200-50 |
| Silt Z | 0.02-0.002 | 20-2 | 0.05-0.002 | 50-2 |
| Clay C | $< 0.002$ | $< 2$ | $< 0.002$ | $< 2$ |

Source: Smith, R.T. and Atkinson, K. Techniques in Pedology, a handbook for environmental and resource studies, London, 1975.

There are two methods for determining the mechanical analysis of soil. One is called Pipette Method and the other Hydrometer Method. But, for accurate work, the Pipette method is employed. This method is based on the Stock's Law.[8] For this study, the Pipette method has been used.

8. Stock's Law: "Stock's (1851) suggested the relationship between the radius of a spherical particle and its rate of fall in a liquid. He stated that resistance offered by the liquid to the fall of the particle varied with the radius of the sphere and not with the surface." The formula is given below -

$$V = \frac{2gr^2(dp-d)}{9n}$$

Where, V = Velocity in Cm/Second.

Procedure (Sand, Silt and Clay separation)

20gm of air-dry fine earth ( 2mm diameter) is transferred to a 1000ml beaker. 60ml of 6% (20 volumes) $H_2O_2$ is added and mixed well and allowed to react for 5 minutes. After 15 minutes, the beaker is immersed into the Hot Water bath for 5 minutes. Stirring was continued to avoid frothing over. To remove, a further 35 ml of $H_2O_2$ is added and after a minute, the beaker is replaced on top of the Hot Water bath for 10 minutes and then immersed again for 5 minutes. The solution is diluted to about 150 ml and brought to boil on a burner.

Acid treatment

1. After cooling the beaker, 25 ml of 2NHCl is added.
2. The sample is diluted to approximately 250 ml and allowed to react for an hour, rubbing at 15 minutes intervals.
3. After an hour, the solution is filtered through a Buchner funnel using hardened filter paper (11 Cm Whatman No. 44).
4. After the washing was complete, the filter paper was spreaded out and transferred the material to the 1000 ml cylinder.

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g = acceleration due to gravity.
dp = density of the particle.
d = density of the liquid.
n = absolute viscosity of the liquid.

Dispersion (Silt and Clay separation)

The volume was made up after rendering it alkaline to phenolphthalein, with 10 ml of N/1 NaOH solution. After shaking (on a shaker), the suspension was allowed to stand for overnight.

Separation of Silt, Clay and Sand

Using the table for time of sedimentation for the clay and silt fractions, calculation was made for silt and clay. But for sand again the decantation method is applied.

2.4.3 Soil Colour

Soil colour is the most obvious and easily determined of soil characteristics. It is an easily observable characteristic and is an important criterion in description and classification of soils. It could be named in many soil groups after prominent soil colours such as Black soils, Red-Yellow Latosols, etc.

The content of organic matter in soil is namely responsible for soil colour. Generally, in temperate climate dark coloured soils are relatively higher in organic matter than light coloured soils. The surface horizon of soil is commonly darkest due to the presence of organic matter. Red colour is associated with unhydrated ferric oxides, whereas yellow colour indicates some degree of hydration.

Determination of Soil Colour

The soil colours are most conveniently measured by comparison with standard Colour Charts. The "Munsell"[9] soil Color Chart was used for this purpose. The colour of soil is the result of the light reflected from the soil and it depends upon the combination of three simple variables of Colours namely - "Hue", "Value", and "Chroma". "Hue" is the dominant spectral colour. "Value" is the brilliance or total quality of light. "Chroma" is the relative purity or saturation of the dominant Spectral Colour.

To determine the soil colour, the Munsell Soil Color Charts has been used and various types of colours have been identified for the samples.

2.4.4. Soil Structure

The primary soil particles - Sand, Silt and Clay - usually occur in the form of aggregates. The arrangement of these individual particles and their aggregates into certain defined patterns is called structure. Structure is best studied in the field under natural conditions and it is described under three categories:

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9. "Munsell Soil Color Chatts", Munsell Color Company Inc. Baltimore 2, Maryland, 1975.

(i) Type - Shape or form and arrangement pattern peds.

(ii) Class - Size of peds.

(iii) Grade - Degree of distinctness of peds.

(i) Types of Structure

There are four principal geometric forms of soil structure:

(a) Plate-like

(b) Prism-like

(c) Block-like.

(d) Sphere-like spheroidal.

(ii) Classes of Structure

Each primary structural type of soil is differentiated into five size-classes depending upon the size of the individual peds. The term commonly used for the size classes are:

(i) Very fine or very thin.

(ii) Fine or thin.

(iii) Medium

(iv) Coarse or thick.

(v) Very coarse or very thick.

(iii) Grades of Structure

Grade indicates the degree of distinctness of the individual peds. It is determined by noting the stability of the aggregates and the ease with which they separate from other peds. Grade of structure is influenced by the moisture content of the soil. Under moist conditions the soil structure is usually not very distinct. Four terms commonly used to describe the grade of soil structure are:

(a) Structureless
(b) Weak
(c) Moderate
(d) Strong

Importance of Soil Structure

Structure is very important in plant growth relationships, because it influences the amount and nature of porosity and regulates the moisture air regime in the Soil. Platy structure normally hinders free drainage. Some structures are mechanically stable and strong but when they absorb moisture and are wet, they become soft and lose their shape and size.

Structure is one of the soil properties which is easily liable to changes under different management practices such as ploughing, draining, liming, fertilising and manuring. Addition of organic matter and its proper decomposition are important for building up and maintenance of soil structure.

Table No. 2.2 shows how to determine soil structure.

Table No. 2.2

| Samples | Grade | Class | Type | Structural Name |
|---|---|---|---|---|
| A | Strong | Fine | Granular | Strong fine granular |
| B | Moderate | Very coarse | Granular | Moderate very coarse granular |

Using this above table, soil structure for the district has been determined.

2.5. Chemical Characteristics of Soil

The chemical analysis have become an integral part of soil classification. It helps to study the available nutrients in the soils, the leaching process and soil genesis. The growth of a plan is directly dependent upon soil nutrients and its formations. Therefore, one should study the chemical composition of soil for better understanding of soil classification and genesis.

Soils are chemically a heterogeneous medium. It is more important to measure a particular fraction of an element in the soil than to know its total concentration. Therefore, the most essential elements like, Nitrogen, Phosphorus, Potassium and Organic Carbon are selected for this study. Soil reaction or pH is also taken to be an overall indication of chemical status of a soil.

## 2.5.1 Nitrogen in the Soil

"Nitrogen — essential link in protein".

Among the various plant nutrients, nitrogen probably has been subjected to the greatest amount of study and still receives much attention. The amount in the soil is small, while the quantity withdrawn annually by crops is comparatively large. Sometimes the soil nitrogen is too readily soluble and is lost in drainage, at other times, it suffers volatilization; at still other times it is definitely unavailable to higher plants.

### Forms of Soil Nitrogen

There are three major forms of Nitrogen in mineral soils:

(a) Organic nitrogen associated with the soil humus,

(b) Ammonium nitrogen fixed by certain clay minerals, and

(c) Soluble inorganic ammonium and nitrate compounds.

Most of the nitrogen in soils is associated with the organic matter. Relatively small amounts ordinarily occur in ammonium and nitrates, the available forms.

There are two types of analytical procedures, which are widely used — the Kjeldahl Conversion of Nitrogen to $(NH_4)_2SO_4$ and the Dumas Conversion to nitrogen gas. The Kjeldahl method is employed in macro, micro and ultramicro procedures. For the estimation of total nitrogen in soil the Kjeldahl digestion distillation method[10] has been followed.

Determination of available Nitrogen in soil

For each sample, 10.0 g of sieved ( $< 0.2$mm) soil was taken in a 300 ml Kjeldahl digestion flask. 20 g of $Na_2SO_4$ plus catalyst digestion mixture were then added. 35ml of conc. $H_2SO_4$ was added and the digestion was done on the Kjeldahl digestion rack till the solution was cleared. 200 ml distilled water was added to the cooled solution and mixed carefully. The solution was then ready for the determination of ammonia content by distillation. The ammonia was distilled in boric acid which was then blank titrated with N/14 HCL.

Calculation

$\therefore$ % of Nitrogen = T x dilution factor x N $\frac{1.4}{S}$

Where, T = Sample titration, ml standard acid,

N = Normality of Standard acid,

S = Sample weight, and

1.4 is a constant factor.

2.5.2 Available Phosphorus in Soils

Phosphorus rarely comprises more than 0.1% of the soil and only a small amount of plant available inorganic orthophos-

10. M.L. Jackson; Op.cit., pp. 183-193.

phate ion is present at any time. The bulk of phosphorus is usually unavailable. It is fixed either as Ca - phosphate at high pH or Allumium and Iron phosphates at low pH. Measurement of total phosphorus is, therefore, of limited value in determining phosphorus availability except that low concentration usually indicates deficiency.

Determination of available phosphorus in soil using Bray's Method No.1 (For Acid Soil)

Reagents

(1) Bray's extractant No.1.

(2) Molybdate solution.

(3) Stannous Chloride Stock Solution ($SnCl_2 2H_2O$).

(4) Working solution for $SnCl_2 2H_2O$.

Procedure

4 g of sieved (< 0.2 mm) soil was taken in 250 ml conical flask to which 14 ml of Bray's extraction solution was added and stired for 15 minutes with the help of magnetic stirrer. The solution was filtered through Whatman No. 44 filter paper. 2ml of the filtrate was taken in a testtube diluted with 5 ml distilled water and 1 ml of ammonium molybdate and 1 ml of stannous chloride solution were added. The test tube was shaken for 10 minutes. After 20 minutes optical density was determined at 660 mm using Bray's extract from the control (without soil) as the blank.

Calculation

$$\% \text{ Phosphorus} = \frac{C(mg) \times \text{Solution Volume (ml)}}{10 \times \text{Aliquot (ml)} \times \text{Sample weight (g)}}$$

Where, C = mg Phosphorus obtained from the Standard Curve

To convert P to $P_2O_5$ the above figure was multiplied by 2.29.

Table No. 2.3 shows the Guide to phosphate status in soil.

Table No. 2.3

| Phosphate Status | mg $P_2O_5$/100 gm soil |
|---|---|
| Very low | 0 - 1.4 |
| Low | 1.5- 3.0 |
| Medium | 3.1- 6.0 |
| Medium High | 6.1-10.0 |
| High | 10.1-20.0 |
| Very High | > 20.1 |

Source: Figures from Gilchrist - Shirlaw (1967)

2.5.3 Available Potassium in Soil

Fixation of Potassium

There is some mechanism in the soil that fixes available Potassium in a form which is not available to plants. The factors influencing the amount of potassium fixation are:

1. The kind of clay minerals present. Kaolinite does not appear to fix potassium, while large quantities are fixed by montmorillonite.
2. The relative amount of exchangeable K. The greater the percentage of exchangeable K in relation to the total exchange capacity, the greater the K fixation.
3. Wetting and drying of the Soil. Soils that are wetted and dried fix large amounts of exchangeable potassium. One explanation for this mechanism is that K-ions move inside the clay-crystal lattice, when it is wet and expanded, and upon drying, the ions are trapped inside.
4. The presence of organic matter.

Determination of exchangeable 'K' in soil

The exchangeable 'K' has determined by Flame photometer method using ammonium acetate extraction solution as outlined by Jackson (1973).

Reagents

(a) Normal Neutral Ammonium acetate solution.

(b) Standard Potassium Solution.

(c) Working Solutions.

Procedure

5g of air-dry soil ( $< 0.2$mm) is transferred to a 500 ml conical flask and 25 ml of ammonium acetate extraction solution (pH 7) is added stirred for 1 hour with the help of mechanical shaker. The solution is filtered through Whatman No. 44 filter paper. 2ml of the filtrate is diluted with 10 ml of distilled water and read in Flame Photometer.

Calculation

$$\% K = \frac{C(mg/L) \times Solution\ Volume\ (ml)}{10 \times Sample\ weight\ (g)}$$

Where, C = mg/L of 'K' obtained from Standard Curve.

To convert 'K' to $K_2O$ the above figure was multiplied by 1.20.

Table No. 2.4 shows the figures from Gilchrist-Shirlaw (1967) for Potash status.

Table No. 2.4

| Potash Status | mg $K_2O$/100gm soil |
|---|---|
| Very low | 0 - 6 |
| Low | 6 - 10 |
| Medium | 10 - 18 |
| Medium High | 18 - 28 |
| High | 28 - 35 |
| Very High | >35 |

2.5.4 Available Organic Carbon in Soil

"Organic matter ... a distinction of soil from rock."[11]

Carbon occurs in soils in four forms of mineral and organic matter:

1. Carbonate mineral forms, chiefly $CaCO_3$ and $MgCO_3$,
2. Highly condensed, nearly elemental organic Carbon (Charcoal, graphite, coal),
3. Altered and rather resistant organic residues of plants, animals and micro-organisms, sometimes termed "humus" or "humate", and
4. Little altered organic residues of plants and animals, and living and dead micro-organisms, subject to rather rapid decomposition in soils.

The total carbon of soils obviously includes all 4 forms of carbon. The organic carbon includes the three forms except the first one. Here, the total organic carbon in soil has been determined by the Walkly and Black's (1934) rapid titration method.

Determination of Organic Carbon by Walkly and Black's (1934) Method

Reagents

(i) Potassium Dichromate (N/1) Solution: 49.04 g of $K_2Ca_2O_7$ are dissolved in water and diluted to 1 litre.

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11. M.L. Jackson. Op.cit., pp. 205.

(ii) Ferrous Ammonium Sulphate (N/2) Solution: 392 g of A.R. Grade $Fe(NH_4)_2 (SO_4)_2 6H_2O$ in 800 ml water with 15 ml conc. $H_2SO_4$ and diluting to 2 litre of water.

(iii) Diphenylamine indicator: 0.5 g diphenylamine is dissolved in 20 ml of water and 100 ml conc. $H_2SO_4$.

(iv) Phosphoric Acid ($H_3PO_4$, 85%).

(v) Conc. $H_2SO_4$ not less than 96%.

Procedure

Air-dry soil is ground to pass a 100-mesh sieve. About 1g is transferred to a 500 ml conical flask. 10 ml N/1 $K_2Ca_2O_7$ is added, followed by 20 ml 96% $H_2SO_4$. The flask is swirled gently for about a minute ensuring that no soil escapes contact with the reagents. The flask is then allowed to stand for 20-30 minutes on a heat proof surface. The solution is diluted with 200 ml distilled water and 10 ml 85% Orthophosphoric acid ($H_3PO_4$). To this mixture is added 0.2 g solid NaF and 1 ml diphenylamine indicator. This is then titrated against the standard ferrous solution (in burette). Initially, a dull green Chromous Colour is observed; this will turn blue, while the end point (quite sharp) is a bluish green. A blank titration is run using the same procedure but without adding soil. This standardises the ferrous solution against the chromic acid.

2.5.5 Soil pH

The importance of soil pH for the classification of soil has already been described in the earlier chapter. Here, an attempt has been made to group the soil samples for determining the soil pH. The following table No. 2.5 shows the corresponding terms to use for range in pH.

Table No. 2.5

| Acidic Group | pH | Alkaline group | pH |
|---|---|---|---|
| Extremely acid | Below 4.5 | Neutral[1] | 6.6 - 7.3 |
| Very strongly acid | 4.5 - 5.0 | Mildly alkaline | 7.4 - 7.8 |
| Strongly acid | 5.1 - 5.5 | Moderately alkaline | 7.9 - 8.4 |
| Medium acid | 5.6 - 6.0 | Strongly alkaline | 8.5 - 9.0 |
| Slightly acid | 6.1 - 6.5 | Very strongly alkaline | 9.1 & above |

1. Strict neutrality is pH 7.0.

Determination of Soil pH by pH Meter Method

10g of air dried soil has taken in a 250 ml beaker and added 25ml of distilled water. After shaking of 30 minutes reading is taken from pH meter. Before this, the pH meter is adjusted by using buffer of pH 4 and pH 9.2 (Tablets to be dissolved for respective buffers). In the soil suspension, both the electrodes have been deepened and soil pH reading has been taken using 0 to 7 or 7 to 14 pH scale of the pH meter. Care has to be taken to keep the pH meter in zero position while changing the soil samples.

Calculation

The average of three readings have been taken for pH value of soil.

2.6 Soil Rating Index

There are two standard methods to prepare Soil Rating Index. The Storie Multiplication System (1954) and the Clarke Index (1951).

2.6.1 The Evaluation of Land according to the Storie Index

The index for rating soil which has been developed by Storie (1954) has been widely used in North America and elsewhere. The Storie Index is a numerical rating of the degree to which a particular soil has physical, chemical and biological properties suitable for the growth of crops. It is basically an index which reflects the soils potential utilization and productive capacity.

Three principal factors are considered in computing the Storie Index of a soil unit. These are:

(a) The characteristics of the profile as reflected in texture, structure and inherent fertility (i.e. depth and colour).

(b) Topography, and

(c) Other modifying factors like, climate, salinity/alkalinity, degree of stoniness and susceptibility to erosion. Each of these three factors (a, b and c) is rated on the basis of 100 points for the most favourable or ideal conditions.

2.6.2 Soil Rating according to the Clarke Index

Clarke Index is suitable for evaluating soil quality in the field. This points system gives a numerical rating to a soil profile on the basis of the physical characteristics of texture, depth and drainage status.

Clarke's Index is defined as:

Profile Value = texture value (V) x drainage factor (G)
Where, texture value (V) = Depth (D) x texture rating (T)

The texture rating (T) is derived from the field textural designation.

The attraction of the Clarke Index lies in the fact that only three fundamental physical properties are used. Each of these can be determined relatively easily in the field. It is an index which lends itself particularly well to correlation and regression analysis in relation to figures for crop yields.

2.6.3 In this study, rating index has been prepared by using Storie Multiplication Index of soil rating. Since, the study deals with twelve variables which could be rated only by this method. Moreover, the Storie Multiplication System is not a rigid system which is applied directly and unchanged to any area. Depending on the soil and climatic conditions of the region under study, it was necessary to rearrange some factors and to add others in order that a more accurate expression of prevailing environmental conditions is reflected in the rating.

There are twelve variables have been taken into consideration representing three major groups. These three major groups and their conversion scale from qualitative attributes to quantitative figures have been shown in the following ways:

2.6.3.1 Group A: Physical Characteristics

(1) Texture: This factor has a maximum rating of 100 points.

| Textural Name (Soil Class) | | 100 Points |
|---|---|---|
| (i) | Sand | 10 - 20 |
| (ii) | Loamy Sand | 15 - 25 |
| (iii) | Sandy Loam | 30 - 35 |
| (iv) | Loam | 40 - 60 |
| (v) | Silt Loam | 50 - 70 |
| (vi) | Silt | 45 - 65 |

| Textural Name (Soil Class) | | 100 Points |
|---|---|---|
| (vii) | Sandy Clay Loam | 60 - 80 |
| (viii) | Clay Loam | 65 - 85 |
| (ix) | Silty Clay Loam | 50 - 70 |
| (x) | Sandy Clay | 30 - 40 |
| (xi) | Silty Clay | 50 - 60 |
| (xii) | Clay | 35 - 55 |

(2) Structure: It has a maximum rating of 10 points scale.

| Grade | | 10 Points |
|---|---|---|
| (i) | Structureless | 4 |
| (ii) | Weak | 6 |
| (iii) | Moderate | 9 |
| (iv) | Strong | 7 |

(3) Colour: The maximum rating point is 2.5

| Colours | | 2.5 Points |
|---|---|---|
| (i) | Black to Grey | 1.5 to 2.5 |
| (ii) | Light, White & Grey | 1.25 to 1.75 |
| (iii) | Red, Brown Yellow | 1.0 to 1.5 |
| (iv) | Brown Colour | 1.5 to 2.0 |

2.6.3.2 Group B: Chemical Characteristics of Soil

(1) pH Value: Though the pH itself is a quantitative value but for our convenience the values were converted into a 10 points scale on the basis of its capacity of cation exchange.

| | | pH | 10 points |
|---|---|---|---|
| (i) | Extremely acid | Below 4.5 | 1 |
| (ii) | Very strongly acid | 4.5 - 5.0 | 2 |
| (iii) | Strongly acid | 5.1 - 5.5 | 3 |
| (iv) | Medium acid | 5.6 - 6.0 | 5 |
| (v) | Slightly acid | 6.1 - 6.5 | 7 |
| (vi) | Neutral | 6.5 - 7.5 | 9 |
| (vii) | Slightly alkaline | 7.6 - 8.0 | 7 |
| (viii) | Medium alkaline | 8.1 - 8.5 | 5 |
| (ix) | Strongly alkaline | 8.6 - 9.0 | 3 |

2.6.3.3 Group C: Site Characteristics

(1) Type of Vegetation: The type of vegetation has a maximum rating of 100 points.

| Type of Vegetation | | 100 Points |
|---|---|---|
| (i) | Barren | 10 |
| (ii) | Wild grass | 10 - 20 |
| (iii) | Grasses & Shrubs | 15 - 25 |
| (iv) | Mixed Forest & Shrubs | 30 - 40 |
| (v) | Temperate vegetation mainly pine | 20 - 30 |
| (vi) | Mixed decideous forests | 50 - 70 |
| (vii) | Cultivated fields | 50 - 70 |
| (viii) | Marshy uncultivated fields | 25 - 35 |

(2) Topography: The maximum rating point is 100 points scale.

| | Topography | 100 Points |
|---|---|---|
| (i) | Flate to depression | 10 - 80 |
| (ii) | Gently undulating | 90 -100 |
| (iii) | Moderately undulating | 80 - 90 |
| (iv) | Very gently rolling | 70 - 80 |
| (v) | Gently rolling | 60 - 70 |
| (vi) | Strongly undulating | 40 - 60 |
| (vii) | Moderately rolling | 40 - 60 |
| (viii) | Strongly rolling | 30 - 40 |
| (ix) | Hilly | 20 - 30 |
| (x) | Steep slopes | 10 |

Taking the data from twelve variables (from three groups A, B and C) one faces the problem of devising a method of combining all the variables into a single index so as to make comparison of the indices indicating the different types of soils.

To solve the above problem, the Principal Component Analysis by M. Kendall has been used. The details of Kendall's method has been described in Appendix I.

# CHAPTER - III

## IDENTIFICATION OF ECOLOGICAL ZONES AND LANDFACETS

### 3.1 Introduction

The term "Ecology" is used in this chapter in a specific manner, without distorting its actual meaning. Literally, 'ecology'[1] is the study of the earth's 'households' including the plants, animals, micro-organisms, and people that live together as independent components. Ecology is concerned not only with organisms but with energy flows and material cycles on the lands, in the oceans and in the air. In this study, "Ecology Zone" means the 'spatial' distribution and significance of various ecological factors, like — topography, slope, vegetation, drainage climate etc., which are responsible directly or indirectly for soil formation and its physical and chemical properties.

### 3.2 Interaction of Ecological Factors

The effects of the soil environment mostly depends on the interaction of ecological factors. Under natural conditions, at the same time, the characteristics of soil is affected with variations in ecological factors. All the factors are inter-

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1. E.P. Odum: "Ecology" Second Edition, 1975.

related. For instance, increase in deforestation would result soil erosion and soil degradation, a specific type of vegetation would result in a specific type of humus formation, which in turn is guided by specific climate etc.

### 3.3 Identification of Major Ecological Zones

The West Khasi Hills district is a large area and it is not easy to make a field survey in each and every corner of the district. Therefore, the district is divided into ten major ecological zones (as has been shown in Map No. 9). The following criteria have been used for demarcation of these ecological zones:

(a) Relief,
(b) Slope,
(c) Vegetation,
(d) Drainage, and
(e) Climate.

It is true that all the criteria are not equally significant in the demarcation of the ecological zones but to some extent, they are responsible for creation of homogeneous conditions within the ecological zones and differentiates with adjacent ecological zones/regions.

## 3.4 Justifications of criteria used for demarcation of Ecological Zones

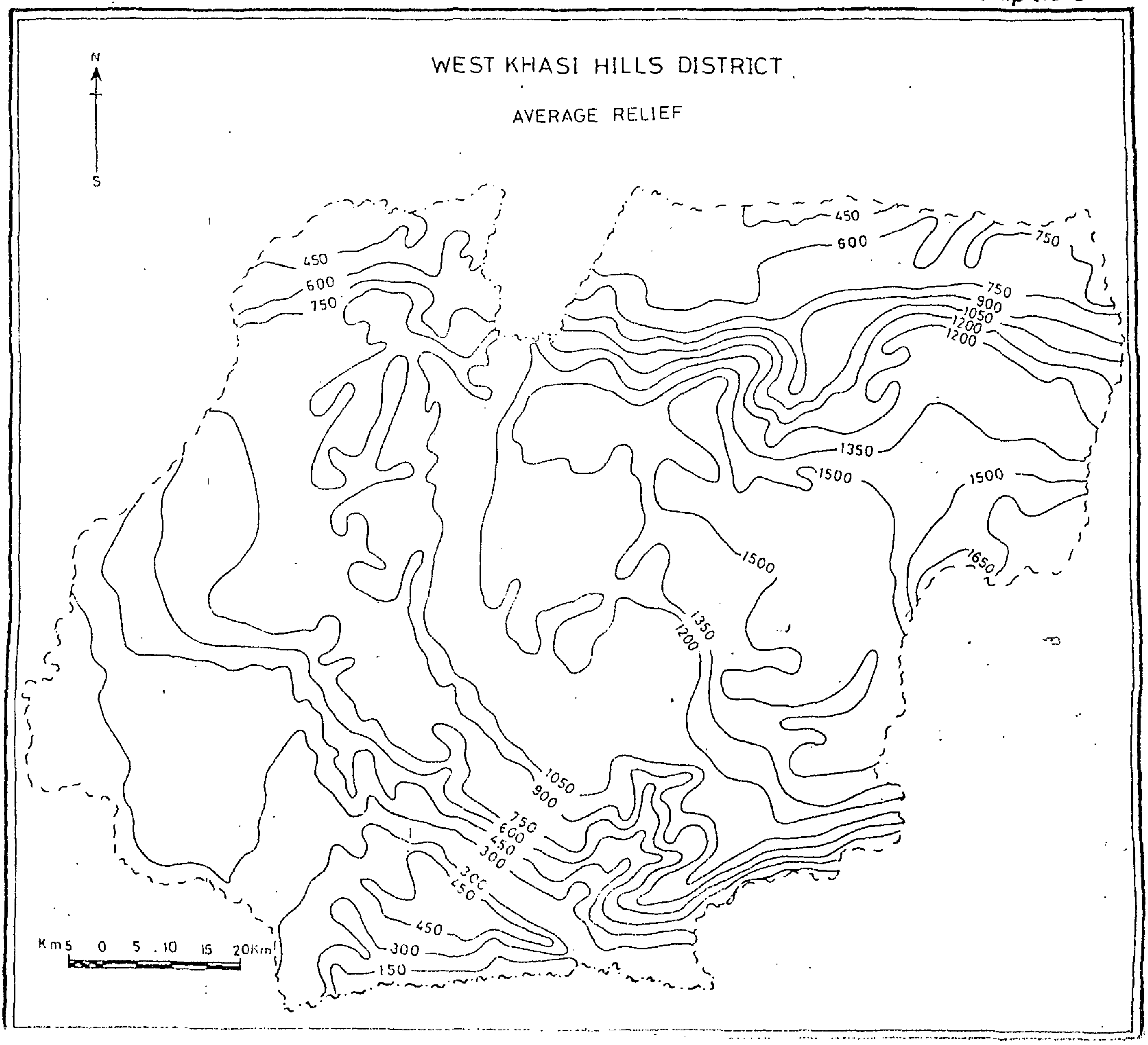
The justification of various criteria used for demarcation of ecological zones in the district, could be stated as in the following manner:

### 3.4.1. Relief

The topography of the West Khasi Hills district is very rugged. It is full of high hill ranges, plateaus and valleys. The altitude and the direction of mountain chains and valleys clearly show three physiographic divisions in the district. These divisions are - the Central Highland, the Southern Slopes and the Northern Slopes. Map No. 6 shows the average relief map of the district.

The variation of altitude varies from 600 metres to 1800 metres and above. The second highest peak of Meghalaya, 'Thadraishan' (1893 m) is located in between Mairang and Nongstoin. The hill range of Central Highland plateau climbs down gradually to meet the hills of Garo Hills at elevations ranging from 1200 metres to 600 metres at various places. In the Central Highland, there are many hill ranges and plateaus having different topographical characters. It could be cited in the examples of Sohiong and Nongshillong valleys etc. Both the valleys having same types of hillocks and valleys with different

Map No. 6


WEST KHASI HILLS DISTRICT
AVERAGE RELIEF
N
S
450
600
750
900
1050
1200
1350
1500
1650
300
150
Kms 5 0 5 10 15 20Km

elevations. The directions of the mountain chains and plateaux are not homogeneous. Most of the hill ranges and plateaux are lying in north-east to south-west direction, in case of southern part of the district. In the Northern Slopes, the direction of hill ranges and plateaux are in the east-west direction. This, also, is true in case of Central Highland plateau.

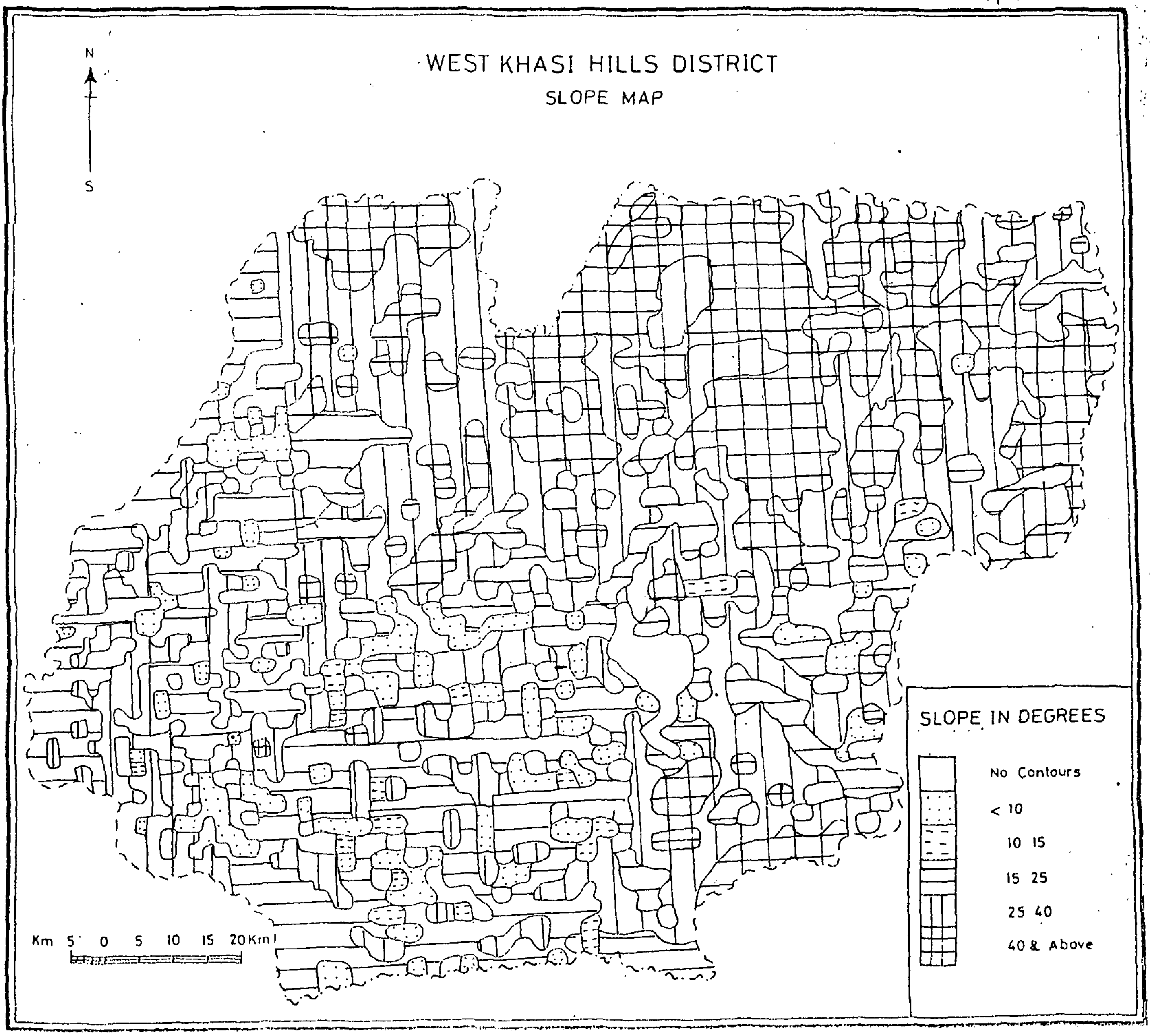
3.4.2 Slope

The slopes of the high mountains and plateaux play a vital role for demarcation of ecological zones in the district. Due to the rugged terrain, the variation of slopes in the hill ranges and plateaux are significant. In the northern slopes of the district, slopes vary from $25^{\circ}$ to $40^{\circ}$. About 70 percent of the area of this northern slope having average slope of $40^{\circ}$ and more. In the southern slopes, there are steep slopes ranging from $30^{\circ}$ to $40^{\circ}$. The steepness is very high due to the Dawki fault line, which disected the district from the Bangladesh plains.

It is estimated that more than 50 percent area of the district has $25^{\circ}$ to $40^{\circ}$ slopes. This could be easily estimated from the slope map of West Khasi Hills district of Meghalaya.

Map No. 7 shows the average slope of West Khasi Hills district of Meghalaya.

Map No. 7


WEST KHASI HILLS DISTRICT
SLOPE MAP
N
S
SLOPE IN DEGREES
No Contours
< 10
10 15
15 25
25 40
40 & Above
Km 5 0 5 10 15 20 Km

In the valleys and flat areas, silt deposition is common in this district due to the degradation of steep slopes and crests.

### 3.4.3 Vegetation

The regional variation of natural vegetation is significant in the district. The available natural vegetation, varies from sub-tropical to temperate vegetation in the district, according to the altitudinal regions and climatic zones. Tropical vegetation is found generally upto an elevation of 600 metres, upto 1200 metres, Sub-tropical forests and above 1200 metres temperate forests and grasslands are found. In case of some regions, the variation of vegetation is not related to its altitude. Generally, evergreen forests are growing in low altitude and it is also found in vast areas of the southern and northern slopes of the district, where elevation is less than 600 metres. But, it is also notable that the evergreen forests are also found in the regions where elevation is more than 1800 metres or so. The pine vegetation are common in this district where elevation is more than 1200 metres high.

The tropical vegetation, like - Sal, Teak, etc. are available in Sonapahar and Balat areas. The average altitude in this two areas is below 600 metres high.

### 3.4.4 Drainage

There are very few rivers in the district. The Central Highland plateau is controlling the directions of rivers and acts as the water-shed and the rivers flow towards north and south of this highland. The Map No. 8 has shown the distribution of rivers in the district.

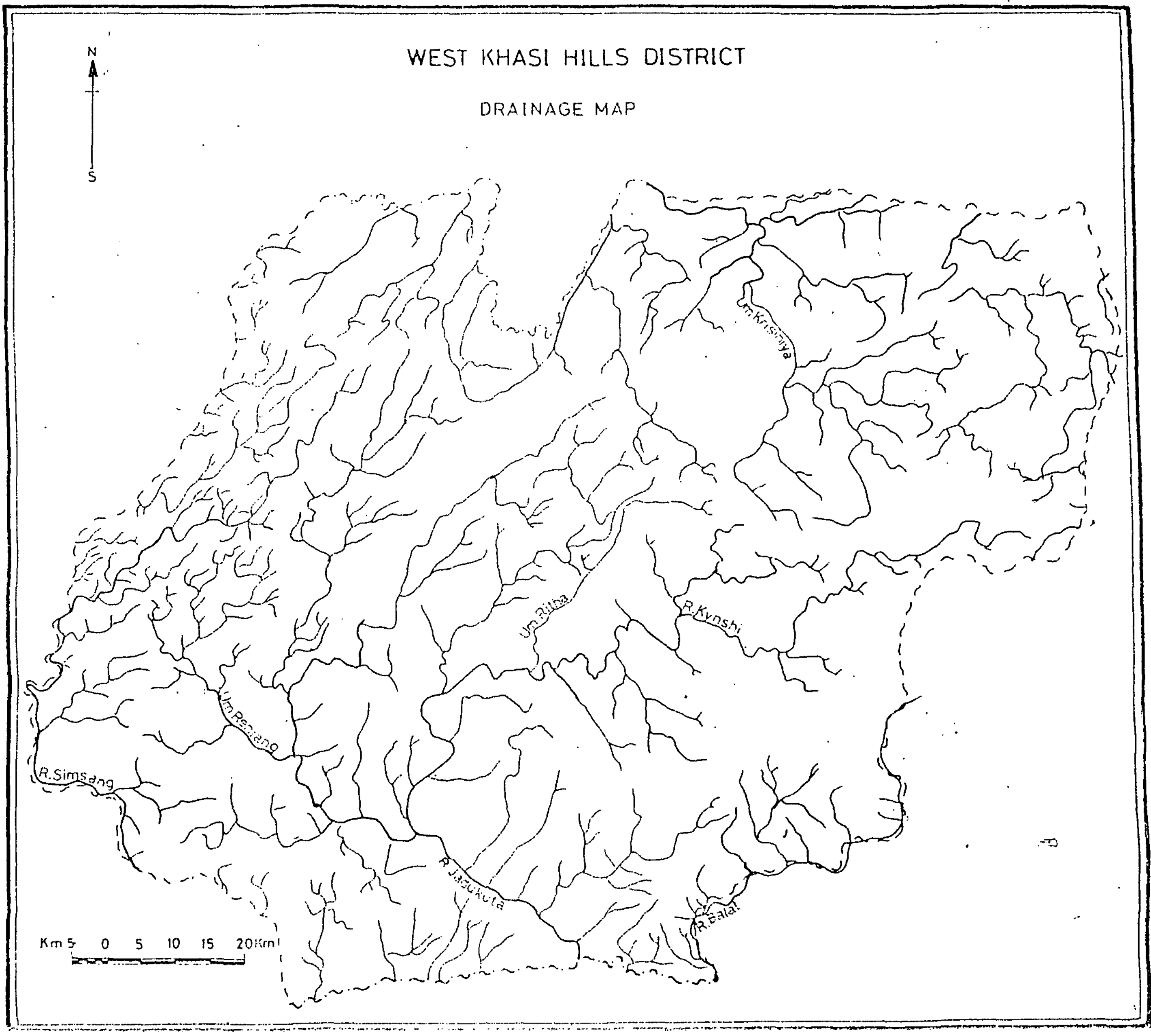
In the southern part, there are two big rivers, namely, river Balat and river Jadukata. River Balat flows in between West Khasi Hills district and East Khasi Hills district of Meghalaya. River Jadukata is almost draining throughout the southern parts of the district. In the western part of the district, river Simsang is flowing towards Bangladesh plains. The rate of soil erosion is very high. These rivers have to overcome hill ranges and plateaus, making gorges and waterfalls and carry a large amount of debris to the plains.

Um Krisiniya, is flowing towards the plains of Assam in the northern slopes of the district. It has got few tributaries coming from the Central Highland. In the Central Highland, River Kynshi is flowing to the East Khasi Hills district. Due to the inadequate water supply facility, the hill people have to settle down along the riverside or near the spring site. Most of the settlements are found near the water only.

### 3.4.5 Climate

The climate of the district is tropical to sub-tropical climate. There is no variation of climate in the district. The experience of temperature especially in summer season is getting

Map No. 8


WEST KHASI HILLS DISTRICT
DRAINAGE MAP
N
S
Um Krishiya
Um Ritha
R. Kynshi
Um Rentang
R. Simsang
R. Jadukata
R. Balat
Km 5 0 5 10 15 20 Km

higher and higher because of deforestation in the district. Due to the shortening of "Jhum" period (which has come down from 20 years to 5 years), and the increase of population pressure, the district gets degradation of primary forests which is largely responsible for changes of climatic factors.

Keeping the importance of all the criteria and their characteristics, an attempt has been made to identify the major ecological zones for the West Khasi Hills district of Meghalaya. The identification have been done by superimposing all the ecological factors, like - relief, slope, vegetation, drainage and climate. There are ten ecological zones, identified for the whole district, shown in map No. 9.

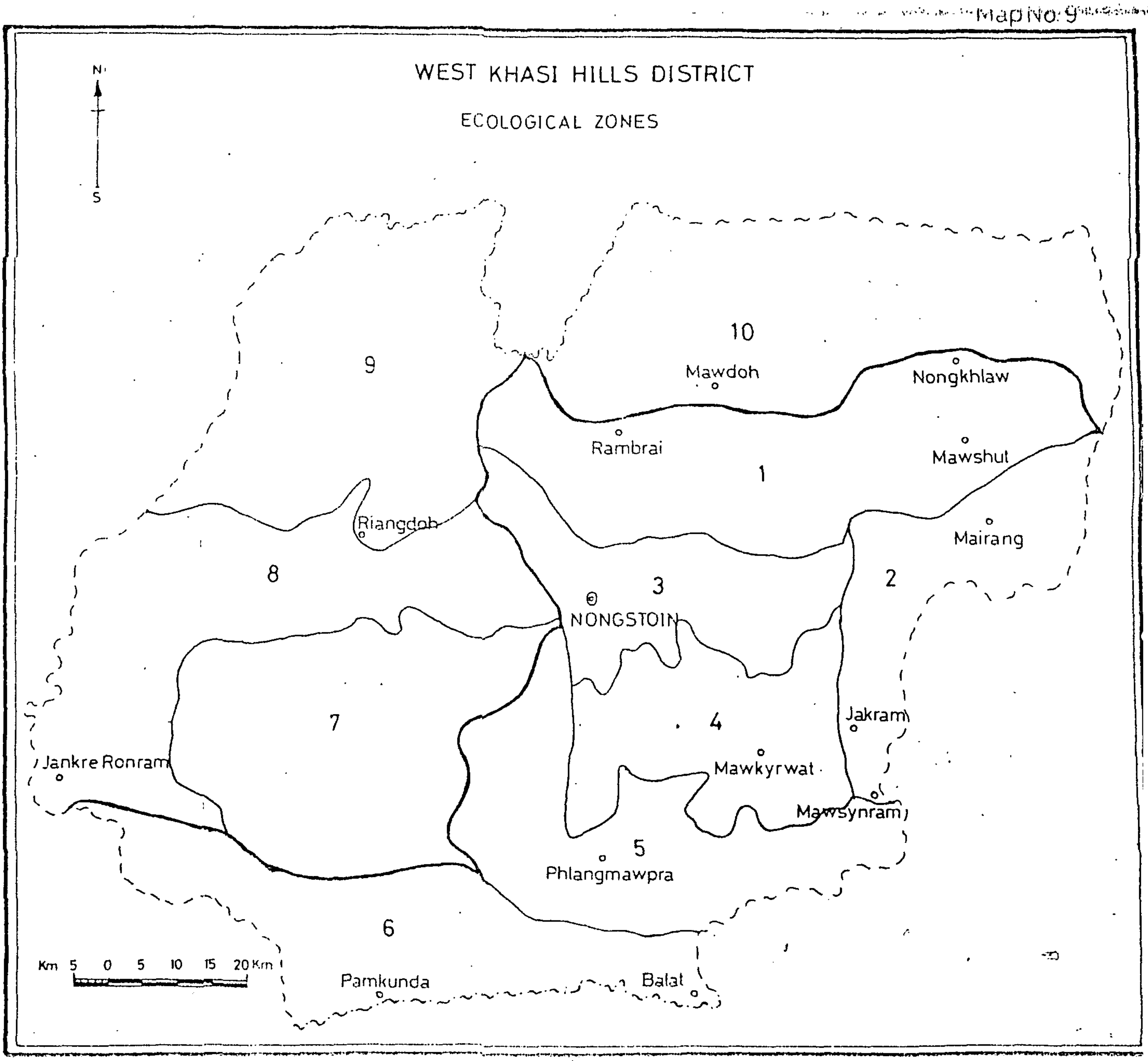
### 3.5 Characteristics of Ecological Zones

#### 3.5.1 Ecological Zone No. 1

This is a flat plateau top area with a few small defined plateaus and valleys. This zone includes market centres, like - Rambrai and Mawshut.

The composition of rocks in this zone is mainly Gneissic complex of rocks. A few granitic rock formation is found in the easternmost part of this zone. The average altitude ranges from 1600 metres to 1900 metres high. Vegetation is mainly Sub-tropical Pine forests and some patches of evergreen forests are also

Map No. 9


WEST KHASI HILLS DISTRICT
ECOLOGICAL ZONES
N
S
10
9
Mawdoh
Nongkhlaw
Rambrai
Mawshut
1
Riangdoh
Mairang
8
3
2
NONGSTOIN
7
4
Jakram
Jankre Ronram
Mawkyrwat
Mawsynram
5
Phlangmawpra
6
Km 5 0 5 10 15 20 Km
Pamkunda
Balat

available in certain pockets of this zone. The average slope is very high, about 40° and above in the hill ranges. The rainfall is less because it falls under rainshadow zone. High hills and plateau tops obstruct rainfall from rain bearing clouds from the south.

3.5.2 Ecological Zone No. 2

This zone is extremely disected with a number of small hillocks and plateaus. The valleys i.e. flat areas are fully utilised for agriculture. This zone includes the greater parts of Mairang Sub-division, Sohiong valley and Jakrem areas.

The composition of rocks is the gneissic complex at Mairang and Sohiong valley but in case of Jakrem area, the composition of rocks is granitic formation. The average altitude is varying from 1200 m to 1700 m and the average slopes vary from 15° to 20°. Sub-tropical Pine vegetation is available in this zone.

3.5.3 Ecological Zone No. 3

This zone is a part of central highland of the plateau. River Kynshi is flowing in the southern part of this zone. The District Headquarters belong to this zone at Nongstoin. Some parts of Markasa Sub-division is also included in this zone.

The rock composition is the Gneissic Complex. In the northern part, granitic rock formation is found. The average altitude is 1400 m to 1600 metres. The vegetation is Sub-tropical Pine Forests. The average slopes vary from 25° to 40°. The annual average rainfall at Nongstoin recorded as 4200[2] mm in 1983.

3.5.4 Ecological Zone No. 4

This zone includes the growth centres of Mawkyrwat and Pambriew.

The composition of rocks in this zone is mainly granite. The average altitude ranges from 1000 m to 1300 metres. The vegetation is mainly Pine and dense bamboo forests. The hill ranges and plateau tops are exposed with bedrocks. In northern part of this zone, some tributaries of River Kynshi and River Balat are flowing downward through this zone. In summer, rainfall is high due to the southeast monsoon.

3.5.5 Ecological Zone No. 5

Some parts of Mawsynram and Weiloi market centre have been included in this zone. This zone is adjacent to Mawsynram, the place where world's highest rainfall[3] (12,163 mm) is recorded in 1983.

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2. Rainfall Data collected from <u>Statistical Hand Book 1984</u>, Director of Economics Statistics & Evaluation, Meghalaya, Shillong, pp. 36-37.

3. *Ibid*.

The bedrock formation is the Gneissic Complex. This zone is disected by Dawki fault from southern part of the district. The average altitude varies from 500 metres to 900 metres. Vegetation is mainly bamboo forests. The average slope is very high ranging from $42^{o}$ and above in the high hill ranges.

3.5.6 Ecological Zone No. 6

This zone is disected from the main land by Dawki fault stretching from east to west. The southern most parts, like - Balat, Pamkunda belong to this zone.

The Khasi Groups of rocks are found in this zone. This group of rocks have three formations — Mahadek, Jadukata and Sylhet trap.

The vegetation is mixed deciduous forests with Sal and Teak forests. The average altitude is less than 500 metres. River Balat drains through this zone.

3.5.7 Ecological Zone No. 7

This zone is almost a valley with extensive flat land. The river Jadukata flows towards the south through this zone.

Geologically, rock formation is the Gneissic complex. The average altitude ranges from 400 metres to 700 metres. Vegetation is mainly Bamboo forests. Some patches of mixed forests is also available in this zone. The average slopes vary from $15^{o}$ to $25^{o}$. Summer rainfall is medium to high.

3.5.8 Ecological Zone No. 8

The southern part of Riangdo, Nongumdang, Nongjonthaing and Jankre include in this zone.

The formation of rock is the Gneissic Complex with varying depth of its composition. The average altitude varies from 400 metres to 600 metres. Vegetation is mainly dense mixed jungle with Sal forests.

3.5.9 Ecological Zone No. 9

The world's largest deposits of Sillimanite is found in this zone. This zone includes Riangdo proper and it acts as a watershed zone lowering to the plains of Kamrup district of Assam.

This entire zone is covered by Gneissic complex. In Riangdo proper, the formation of rock is sillimanite and granitic. This zone is forested by moist deciduous forests with Sal and Teak forests. The average altitude varies from 800 metres to 1400 metres high.

3.5.10 Ecological Zone No. 10

This zone is sloping down towards the plains of Assam. It includes Nongkhlaw and Mawdoh areas.

The rock formation in this zone is mainly of Gneissic Complex. The granitic formations is also available in this zone.

The average altitude varies from 500 metres to 1200 metres with few hills and plateaus. The average slopes vary from $40^{\circ}$ and above. Sub-tropical Pine forest, moist mixed deciduous forest with Sal trees are common vegetation in this zone. Rainfall is medium to high during summer season.

3.6 Identification of Landfacets

In the present study, 'landfacet' means the relative position of the topographic features over the earth surface. The relative position of the topographic features over the earth surface vary from one region to another region. It could vary even within the same region. Therefore, 'landfacet' identification has been done within the ecological zones only. (As has been shown in Map No. 10).

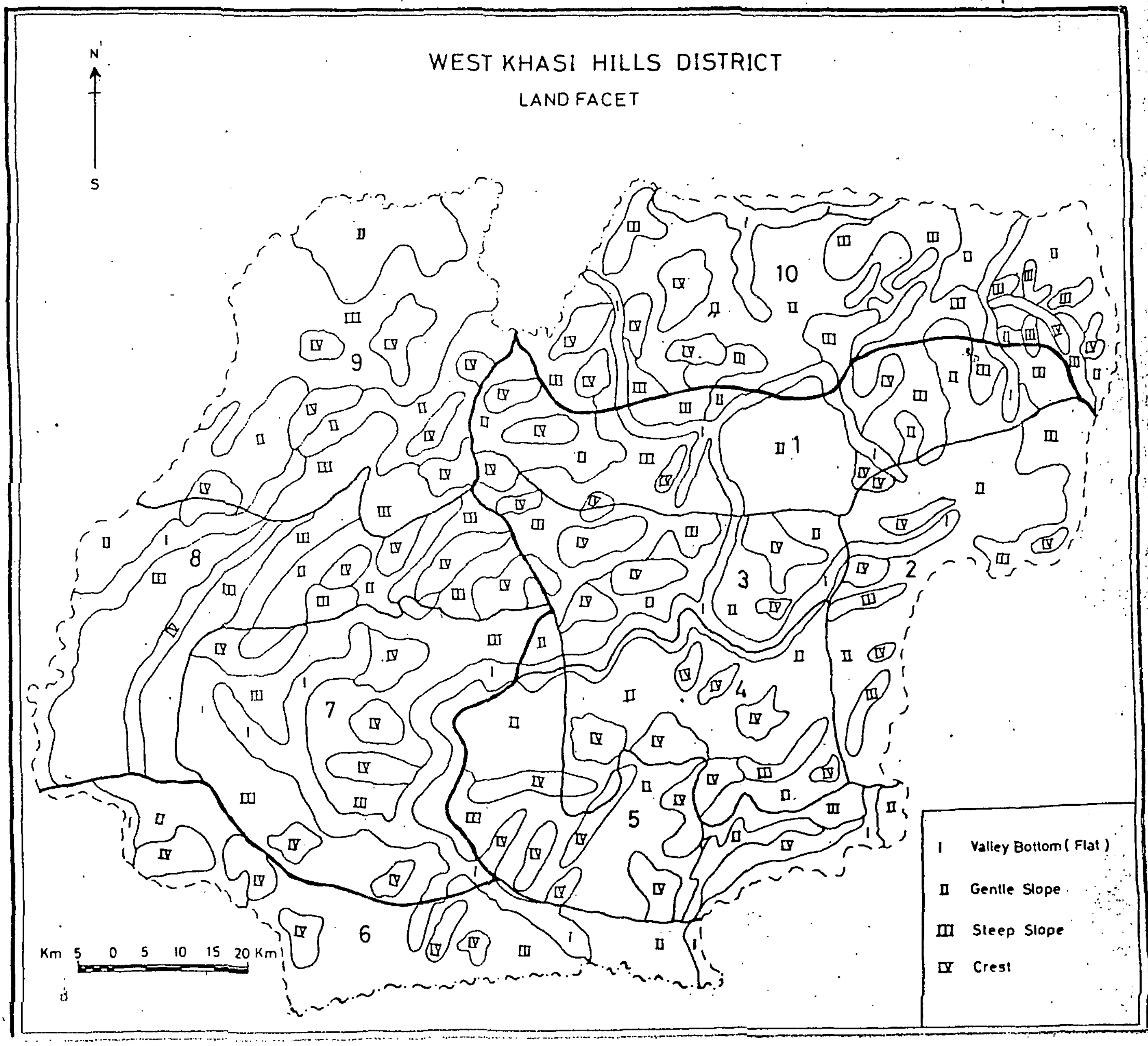
Four categories of landfacets have been identified for the study. They are:

(i) Valley bottoms (flat land),
(ii) Gentle slopes,
(iii) Steep slopes, and
(iv) Crests.

Table No. 3.1 shows the ecological zones and their landfacets.

It has been noticed that the topographical characteristics of valley bottoms (flat land) differ from one place to

Map No. 10


WEST KHASI HILLS DISTRICT
LAND FACET
N
S
I Valley Bottom (Flat)
II Gentle Slope
III Steep Slope
IV Crest
Km 5 0 5 10 15 20 Km

another. These differences occur within the same ecological zone also. Some valley bottoms (flat land) are located at higher elevations and some are at low altitude. The vegetation cover obviously differs from each other because of its difference in altitudes.

Usually "Jhum" cultivation is practised in the gentle slopes and steep slopes. Due to the pressure of population, the cycle of Jhum cultivation has got reduced from 20 years to 5 years. Moreover, the rate of soil erosion is faster in the slopy areas compared to the valley areas. It also depends upon the vegetation cover of the soil. After slash and burning, the top soil is exposed and gets degraded quickly. It is true in case of hill regions, that potentiality of soil could be preserved by afforestation and using it judiciously.

Table No. 3.1: Shows the Ecological zones and Landfacets of West Khasi Hills District of Meghalaya.

| Ecological Zone Nos. | Landfacets | | | | Total |
|---|---|---|---|---|---|
| | Valley Bottom (flat land) | Gentle Slopes | Steep Slopes | Crests | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| 1. | 4 | 3 | 3 | 3 | 13 |
| 2. | 17 | 7 | 8 | 3 | 35 |
| 3. | 8 | 4 | 5 | 3 | 20 |
| 4. | 3 | 3 | 3 | 3 | 12 |
| 5. | 3 | 3 | 3 | 3 | 12 |

Table No. 3.1 (Contd.)

| Ecological Zone Nos. | Landfacets: Valley Bottom (flat land) | Gentle Slopes | Steep Slopes | Crests | Total |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
| 6. | 3 | 3 | 3 | 3 | 12 |
| 7. | 2 | 1 | 1 | 1 | 5 |
| 8. | 1 | 2 | 1 | 1 | 5 |
| 9. | 3 | 3 | 3 | 3 | 12 |
| 10. | 4 | 5 | 3 | 3 | 15 |
| | | | | Total | 141 |

Keeping in view, the topographical characteristics of landfacets, 72 numbers of landfacets have been selected from six ecological zones (out of 10 ecological zones) for the detailed study. These six ecological zones cover more than 70 percent of the total geographical area of the district.

Table No. 3.2 shows the distribution of six ecological zones and their landfacets.

Table No. 3.2

| Ecological Zone Nos. | Landfacets: Valley bottom (flat) | Gentle slopes | Steep slopes | Crests | Total |
|---|---|---|---|---|---|
| 1. | 3 | 3 | 3 | 3 | 12 |
| 2. | 3 | 3 | 3 | 3 | 12 |
| 3. | 3 | 3 | 3 | 3 | 12 |
| 4. | 3 | 3 | 3 | 3 | 12 |
| 5. | 3 | 3 | 3 | 3 | 12 |
| 6. | 3 | 3 | 3 | 3 | 12 |
| | | | | Total | 72 |

## 3.7 Concluding Statement

3.7 The above discussion could be summed up into two parts. The first part deals with the identification of ecological zones and the second part deals with the landfacets.

In this chapter, the term 'Ecological Zone' means the spatial distribution and significance of various ecological factors like - topography, slope, vegetation, drainage, climate etc. These factors are responsible directly or indirectly for soil formation and its physical and chemical properties. The effects of the soil environment mostly depends on the interaction of these ecological factors. Therefore, the West Khasi Hills district of Meghalaya has been divided into ten major ecological zones on the basis of above ecological factors.

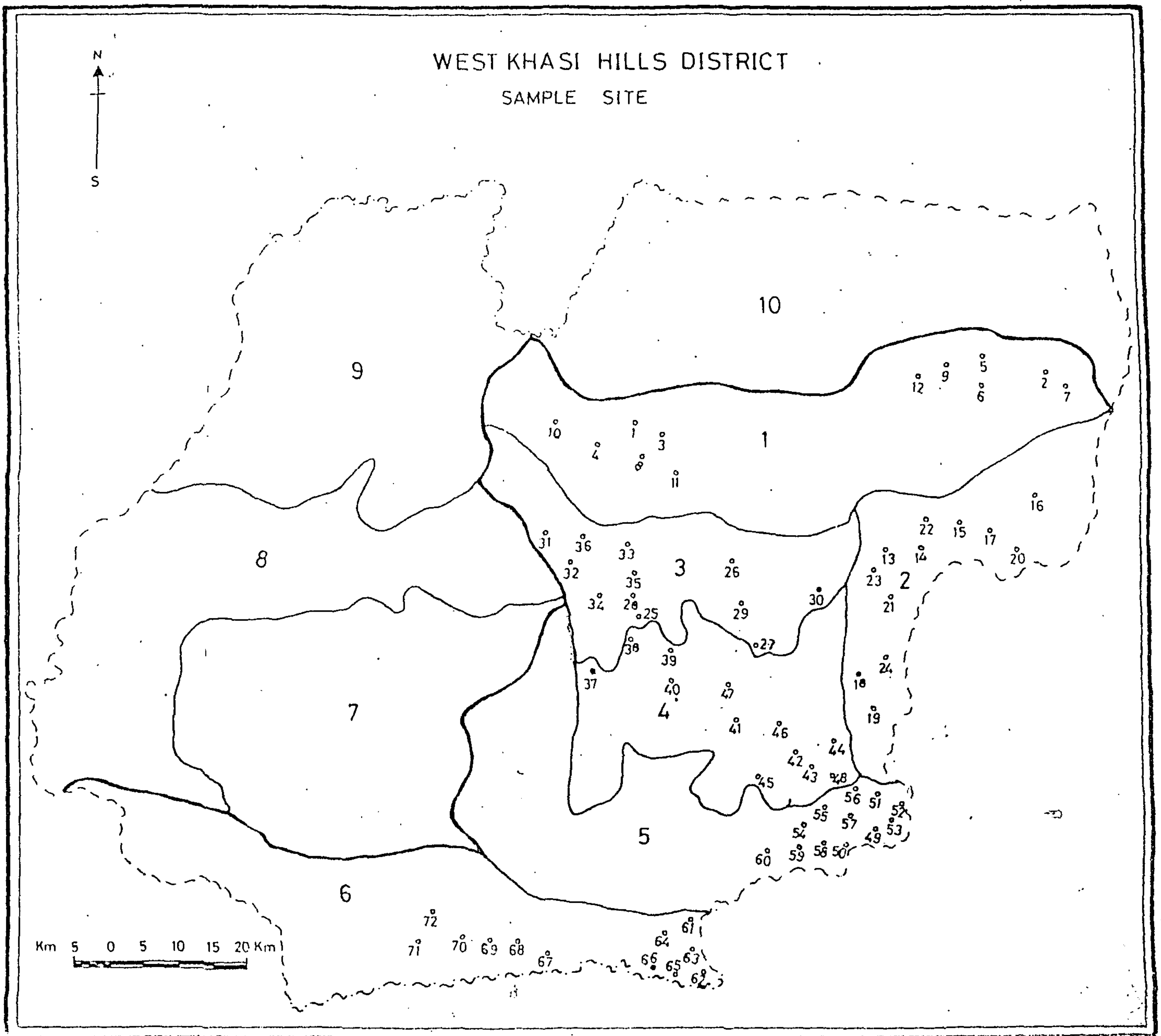
A discussion has been made for the justification of ecological factors used for the demarcation of ecological zones. At the same time the chracteristics of each and every ecological zone has been discussed in brief also.

In the second part, attention has been paid for 'landfacets' identification. 'Landfacet' means the relative position of the topographic features over the earth surface. The relative position of the topographic features vary from one region to another region. It could vary even within the same region. Therefore, this identification of landfacet has been done within the ecological zones only. There are four categories of landfacets have been identified. They are — Valley bottom (flat land), Gentle slopes, Steep slopes and Crests.

Six ecological zones have been selected out of ten ecological zones for soil sampling and about 72 soil samples have been collected for analysis of physical and chemical properties of soil.

The identification of ecological zones and landfacets would lead to a micro-level study. This level of study could focus the problems of soil erosion and degradation in the West Khasi Hills District.

Map No.11


WEST KHASI HILLS DISTRICT
SAMPLE SITE
N
S
Km 5 0 5 10 15 20 Km
1
2
3
4
5
6
7
8
9
10

# CHAPTER - IV

## SOIL STATUS AND SOIL RATING INDICES

### 4.1 Introduction

In understanding ecological processes and their impact on soil quality changes, it is necessary not only to evaluate the soil under different ecological conditions but also to classify and map it, in order to help in policy formulation and land management and consequently, for better planning and land utilisation.

Keeping in view, the above objective, the 72 field samples of soil from six ecological zones of West Khasi Hills District have been classified into soil rating indices. There are twelve variables which have been identified as the most important ones and obtained by field collection and by measurement of physical and chemical characteristics of the soil and observation of site characteristics of the samples. All the twelve variables have been classified into three groups. They are:

A. Physical Characteristics;

B. Chemical Characteristics, and

C. Site Characteristics.

A detailed list of the variables is as the following:

Group A: Physical Characteristics:

$X_1$ : Texture

$X_2$ : Structure

$X_3$ : Colour

Group B: Chemical Characteristics:

$X_4$ : pH

$X_5$ : Kg/Ha of Nitrogen

$X_6$ : Kg/Ha of Phosphorus

$X_7$ : Kg/Ha of Potassium

$X_8$ : Kg/Ha of Organic Carbon

Group C: Site Characteristics:

$X_9$ : Altitude

$X_{10}$: Degree of Slopes

$X_{11}$: Vegetation, and

$X_{12}$: Topography.

As has been mentioned in Chapter - II, the Soil Rating Index attempted in the present study is by way of combining the above twelve variables into a numerical Composite Index using Kendall's Principal Component Analysis Technique (Appendix - I). This has been done in two stages. Firstly, by grouping the variables at the level of the three sub-groups and finally combining the subgroups into the final composite index indicating the soil rating status.

In the process of preparing the Composite Index, the Kendall's technique uses the correlation matrices of different groups of variables which give us valuable information and insight into the relationship of the variables, since the technique tries to optimize the sum of squared correlations of the explanatory variables.

4.1.2 An analysis of the inter-correlations of the variables of physical characteristics (Group A) shows that the correlation between $X_1$ (Texture) and $X_2$ (Structure) is positive and significant at 90 per cent level of confidence. But, the correlation co-efficients between $X_1$ and $X_3$ (Colour) and $X_2$ and $X_3$ are both negative and significant at 95 per cent and 90 per cent level of confidence, respectively. This may be due to that soil texture does not vary with soil colour. Texture and colour have independent characteristics. The negative correlation between structure and colour might be because of independent characteristics of structure and colour. Soil colour varies mainly due to the organic matter content in the soils. Therefore, there is negative correlation. The positive correlation between texture and structure is due to that the primary soil particles - sand, silt and clay - usually occur grouped together in the form of aggregates. These aggregates form a certain patterns is called structure. Therefore, the positive correlation is obvious.

Table No. 4.1: Correlation Matrix of Physical Characteristics

| | $X_1$ | $X_2$ | $X_3$ |
|---|---|---|---|
| $X_1$ | 1.000 | | |
| $X_2$ | 0.129 | 1.000 | |
| $X_3$ | -0.179 | -0.134 | 1.000 |

4.1.3 An analysis of the correlation matrix of group of variables under chemical characteristics, indicate that the correlation co-efficients between the pH ($X_4$) and nitrogen ($X_5$), phosphorus ($X_6$), and organic carbon ($X_8$) are negative and significant at 90 percent level of confidence both $X_6$ and $X_8$. It is insignificant in case of $X_4$ and $X_5$. The correlation co-efficients in between phosphorus ($X_7$) and $X_4$, though positive, it is not significant. But the correlation coefficients between $X_5$ and $X_6$ and $X_8$ are positive. It is significant at 99.99 percent level of confidence between $X_5$ and $X_8$ and insignificant between $X_5$ and $X_6$. Again, the correlation coefficients between $X_6$ and $X_7$ and $X_8$ are positive. It is significant at 95 percent level of confidence between $X_6$ and $X_8$. It is insignificant between $X_6$ and $X_7$. There is insignificant positive correlation between $X_7$ and $X_8$.

Table No. 4.2: Correlation Matrix of Chemical Characteristics.

| | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ |
|---|---|---|---|---|---|
| $X_4$ | 1.000 | | | | |
| $X_5$ | -0.070 | 1.000 | | | |
| $X_6$ | -0.172 | 0.029 | 1.000 | | |
| $X_7$ | 0.002 | -0.174 | 0.098 | 1.000 | |
| $X_8$ | -0.143 | 0.798 | 0.175 | 0.059 | 1.000 |

From the above discussion it can be seen that there is negative correlation between soil pH and soil primary nutrients —nitrogen, phosphorus (though it is positively correlated but insignificant), potassium and organic carbon. The availability of the primary nutrients of soil do not depend on the soil pH but there is the range of maximum availability of the primary nutrients in the soil is at a pH range of 6.5 to 7.5,[1] since this range nearly belongs to the neutral point of pH. Moreover, the average pH value of the 72 soil samples is 4.9 which is very acidic. Therefore, the negative correlation between soil pH and soil primary nutrients is obvious. There is a strong positive correlation between nitrogen and organic carbon. Most of the soil nitrogen occurs in organic combinations, only a small fraction, about 1-3 percent, occurs in inorganic forms. The carbon-nitrogen ratio in the soils of North Eastern Hills Region is approximately 20:1. Therefore, it is natural that the two variables i.e. nitrogen and organic carbon should be (highly) positively correlated.

Since, the general availability of phosphorus and potassium in the samples are not adequate, they do not indicate any significant relationship either within themselves or within the nitrogen, phosphorus, organic carbon complex.

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1. R.V. Tamhane, D.P. Motiramani, Y.P. Bali and R.L. Donahue. <u>Soils: Their Chemistry and Fertility in Tropical Asia</u>, pp. 182-183, Prentice-Hall of India Pvt. Ltd., New Delhi, 1970.

4.1.4. An analysis of the correlation of the variables of Group C, i.e., group of variables under Site Characteristics show that there is positive relationship (significant at 90 per cent level) between altitude ($X_9$) and slope ($X_{10}$). This may be due to higher slope occurring in relatively higher altitude areas of the district. There is a high negative relationship between altitude and vegetation ($X_{11}$). In the score system used, pine vegetation gets a lower score, because of the fact that under pine vegetation, the soil is generally acidic and pine litter is not easily decomposed to form humus. Therefore, altitude and vegetation are negatively related. The relationship between altitude and topography ($X_{12}$) is also negatively significant at 90 percent level because higher altitude areas have greater ruggedness which gets a low score on the basis of topographic scoring system (after Clarke's). The relationship between slope and vegetation is negative and significant at 99.99 percent level. This may be due to the fact that higher slopes zones are either degraded or occupied by pine vegetation which get low score.

Table No. 4.3: Correlation Matrix of Site Characteristics

| | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ |
|---|---|---|---|---|
| $X_9$ | 1.000 | | | |
| $X_{10}$ | 0.239 | 1.000 | | |
| $X_{11}$ | -0.436 | -0.398 | 1.000 | |
| $X_{12}$ | -0.273 | -0.663 | 0.529 | 1.000 |

The correlation between slope and topography is highly, significantly negative (99.99 percent level). For reasons that higher slopes indicate areas of high ruggedness which get low score by topographic principle. Finally, the correlation between vegetation and topography are positively significant (99.99 percent level) which indicates higher score areas under topography occupying the valley areas and low altitudes (which are also areas of deciduous vegetation which get a higher vegetation score).

4.2 Analysis of Eigen values

In Kendall's technique of compositing variables into an index involves the use of eigen values or characteristics roots which are derived out of the correlation matrix. In the present study, the first eigen value which has also the highest value among the vector of eigen values is taken to derive the weight vector or eigen vector which then is used as a multiplicative weight system on the variables. But, the given eigen value also indicates a very significant characteristics of the relationship between the composite index and the individual variables. The relationship is given by the value of the eigen value divided by the number of variables provides the ratio (or percentage) of variables in the group of variables explained by the variation in the composite index. Therefore, this becomes a very significant indicator of how adequate or otherwise has been the use of a particular eigen value in the preparation of the composite index.

In case of the group of physical variables (Group A), the highest eigen value (first principal component) has a value of 1.30, which explains 43.3 percent of variations in

Table No. 4.4: Eigen values and variation explained

| Group | First Principal Component | Nos. of Variables | % Variation Explained |
|---|---|---|---|
| A | 1.30 | 3 | 43.3 |
| B | 1.87 | 5 | 38.0 |
| C | 2.30 | 4 | 57.5 |

the group of variables. In variables of Group B, the highest eigen value has a value of 1.87, which accounts for 38.0 per cent of variations and in the group C (Site Characteristics) the eigen value has a very high value of 2.30, which accounts of 57.5 percent variations. In case of all the three groups of variables, the first Principal Component accounts for more than 1/3 of the variations which is considered adequate in such analyses. However, since the eigen values are derived out of the correlation matrix, a high consistency in the correlation matrix is usually reflected in high value of first principal component. This is shown in case of Group C variables.

4.3 Analysis of the Soil Rating Indices

As has been explained in Chapter - II, the 72 soil samples along with the related twelve variables falling into three distinct characteristics groups have been first composited into three indices - Index A, Index B, and Index C indicating composite score of physical characteristics, chemical characteristics and site characteristics of the samples, respectively. In the second stage, all the three composite indices have been further composited into a single Index I, representing the complete numerical soil rating status index for the samples.

At first, all the samples and therefore, the 72 observations have been classified into four groups on the basis of the characteristics of the landfacets i.e. into samples in valley bottoms, gentle slopes, steep slopes and crest lands. An analysis of table 4.5 indicating the classification of the composite index of physical characteristics shows that the

Table No. 4.5: Composite Index of Physical Characteristics: Index A.

| Sl. No. | Valley Bottom (flat land) | Gentle Slopes | Steep Slopes | Crest |
|---|---|---|---|---|
| 1. | -2.189 | -0.243 | 0.003 | 1.546 |
| 2. | -1.696 | 0.722 | 0.961 | 1.258 |
| 3. | -1.682 | 1.300 | 0.792 | 2.646 |

Table No. 4.5(Contd.)

| Sl. No. | Valley Bottom (flat land) | Gentle Slopes | Steep Slopes | Crest |
|---|---|---|---|---|
| 4. | -1.928 | -1.647 | 0.792 | 0.792 |
| 5. | -0.181 | -0.257 | -0.646 | -0.441 |
| 6. | -0.427 | -0.455 | 0.764 | 0.313 |
| 7. | -0.723 | 2.203 | 0.792 | 1.258 |
| 8. | -0.727 | 0.969 | 2.887 | -0.674 |
| 9. | 0.687 | -0.688 | 1.258 | 2.873 |
| 10. | 0.532 | 1.653 | -0.413 | 2.887 |
| 11. | -0.688 | 0.969 | -0.970 | 1.426 |
| 12. | -0.674 | -2.422 | 1.258 | -1.188 |
| 13. | -1.738 | -1.154 | -0.660 | -0.660 |
| 14. | -1.724 | -1.477 | 1.258 | 1.258 |
| 15. | -1.154 | 0.229 | 1.258 | 1.258 |
| 16. | -1.928 | 0.229 | -1.413 | 0.687 |
| 17. | -1.928 | -0.907 | -0.195 | 1.258 |
| 18. | -0.195 | -1.956 | -0.441 | 1.0011 |
| Average value | -1.004 | -0.226 | 0.460 | 0.973 |

samples (18) under valley bottom landfacets are of consistently negative values with an average of -1.004. The highest positive values are indicated in the crest samples with an average 0.973. The gentle slopes indicate an average score value of -0.226 and steep slopes, 0.460. Therefore, there seems a consistence gradation of index value from high negative in case of valley bottom to high positive in case of crest samples. It may be noted that because of 'normalisation' of variables, the average for index scores is zero. It may indicate that overall, physical characteristics of soil of valley bottom facets are not favourable. This may be due to the fact that although the soil may be texturally favourable, they are not favourable colour-wise and structure-wise. On the other hand, the crest soils are favourable because of the combination of all the three principal physical chracteristics.

An analysis of table 4.6 indicating the classification of the composite index of chemical characteristics shows the samples (18) under valley bottom landfacets are of highly positive values with an average of 0.416, which is the highest positive value. The gentle slopes indicate an average score

Table - 4.6: Composite Index of Chemical Characteristics: Index B.

| Sl No. | Valley Bottom (flat land) | Gentle Slopes | Steep Slopes | Crest |
|---|---|---|---|---|
| 1. | 1.547 | -3.130 | -0.883 | -0.676 |
| 2. | 1.178 | -2.875 | -1.644 | -1.186 |
| 3. | -0.854 | -2.895 | -0.806 | 1.971 |
| 4. | -0.941 | -0.447 | -2.208 | -0.440 |
| 5. | -3.843 | 0.095 | -2.617 | -0.098 |
| 6. | 1.291 | 0.032 | 0.764 | 0.769 |
| 7. | 1.200 | 0.531 | 3.466 | 3.932 |

Table 4.6 (Contd.)

| Sl. No. | Valley Bottom (flat land) | Gentle Slopes | Steep Slopes | Crest |
|---|---|---|---|---|
| 8. | 1.467 | 1.657 | 0.983 | -2.508 |
| 9. | 2.265 | 2.545 | -0.285 | 3.135 |
| 10. | -1.050 | -0.899 | 2.485 | -0.554 |
| 11. | -0.252 | 0.856 | 0.564 | -0.903 |
| 12. | -0.785 | 2.545 | -0.025 | -0.867 |
| 13. | 0.978 | 2.584 | 0.978 | 1.916 |
| 14. | 2.136 | 1.824 | 2.136 | 0.075 |
| 15. | -0.452 | 3.048 | -0.452 | -3.384 |
| 16. | -1.433 | -0.473 | -0.403 | -1.954 |
| 17. | 3.918 | -1.186 | -0.648 | -1.978 |
| 18. | 1.117 | 2.227 | -2.723 | -0.473 |
| Average value | 0.416 | 0.336 | -0.073 | -0.179 |

value of 0.336. In the steep slopes and crest samples are of consistently negative values with the averages of -0.073 and -0.179, respectively. It has been noticed that there is a gradation of index values from high positive in case of valley bottom to low negative in case of crest samples. Therefore, it may indicate that the chemical characteristics of soil in the 'valley bottom' facets are most favourable. This may be due to the flat land, where deposition is more from uplands and marginal impact of soil erosion or degradation. On the other hand, in the steep slopes and the crest samples, the composition of chemical characteristics of soil are poor with negative index scores. This may be due to the fact that these areas are most 'vulnerable' areas of the district, due to its steepness of the slopes which causes soil erosion and degradation.

An analysis of table 4.7 indicating the classification of the composite index of Site Characteristics shows that the samples (18) under valley bottom landfacets are of consistently

Table 4.7: Composite Index of Site Characteristics: Index C.

| Sl. No. | Valley Bottom (flat land) | Gentle Slopes | Steep Slopes | Crest |
|---|---|---|---|---|
| 1. | 3.621 | -0.704 | -2.175 | -1.253 |
| 2. | 3.091 | -0.557 | -1.954 | -1.116 |
| 3. | 3.528 | -0.010 | -1.792 | -1.546 |
| 4. | 2.918 | -1.406 | -2.419 | -2.255 |
| 5. | 2.097 | -0.257 | -1.080 | -2.494 |
| 6. | 3.284 | 1.555 | -2.320 | -1.345 |
| 7. | 0.238 | 2.016 | -2.118 | -1.763 |
| 8. | 3.284 | 0.165 | -2.379 | -4.583 |
| 9. | -0.378 | -0.553 | -2.239 | -1.487 |
| 10. | 3.528 | -0.698 | -2.331 | -2.334 |
| 11. | 2.899 | 0.438 | -1.763 | -1.944 |
| 12. | 3.045 | 0.103 | -1.763 | -3.171 |
| 13. | 3.103 | -0.813 | -2.605 | -2.605 |
| 14. | 0.899 | -0.549 | -2.605 | -2.605 |
| 15. | 2.575 | -1.069 | -2.249 | -2.249 |
| 16. | 5.003 | 3.554 | 0.860 | 0.721 |
| 17. | 5.048 | 3.554 | 0.002 | 0.821 |
| 18. | 3.554 | 2.987 | 0.002 | -0.011 |
| Average value | 2.852 | 0.431 | -1.695 | -1.734 |

positive values with a highest average value of 2.852. The negative values -1.695 and -1.734 are indicated in cases of the steep slopes and crest samples, respectively. In the gentle slopes, indicate an average score value of 0.431. Therefore, there seems a consistent gradation of index value from high positive in case of valley bottom to high negative in case of steep slopes and crest samples. It may indicate that site characteristics of soils of valley bottom facets are most favourable. This may be due to the fact that the availability of (soil) major nutrients for plant growth are favourable. It is also favourable in case of topography in the valley bottom since the land surface is almost flat or plain. But in case of gentle slopes, topography which is somewhat undulating gets less score. The ruggedness is more prominent in cases of steep slopes and crest lands, where practically no favourable site characteristics for plant growth can be observed.

An analysis of table 4.8 indicating the classification of the Composited Index I, shows that the samples (18) under valley bottom landfacets are of consistently positive value with a highest average score of 1.866. In the steep slopes and crest samples, are of consistently negative values with the averages of -1.058 and -1.152, respectively. The gentle slopes indicate an average score value of 0.339. Therefore, there seems to be a consistent gradation of composite Index value

Table 4.8: Composited Index of A, B, and C: Index I.

| Sl. No. | Valley Bottom (flat land) | Gentle Slopes | Steep Slopes | Crest |
|---|---|---|---|---|
| 1. | 2.984 | 0.286 | -1.535 | -1.507 |
| 2. | 2.478 | 0.300 | -1.566 | -0.868 |
| 3. | 1.900 | -0.282 | -1.026 | -2.135 |
| 4. | 2.484 | 1.138 | -1.134 | -1.136 |
| 5. | 1.297 | -0.136 | 0.913 | 0.240 |
| 6. | 1.529 | 1.248 | -1.404 | -0.806 |
| 7. | -0.595 | 1.287 | -1.789 | -2.264 |
| 8. | 2.137 | -1.820 | -2.855 | -1.699 |
| 9. | -1.327 | -1.368 | -2.311 | -2.312 |
| 10. | 1.332 | 0.660 | -0.225 | -3.185 |
| 11. | 2.196 | -0.241 | -0.382 | -1.588 |
| 12. | 2.166 | -0.982 | -1.598 | -0.896 |
| 13. | 2.003 | 0.584 | -0.495 | -0.368 |
| 14. | 1.658 | 0.610 | -2.086 | -1.170 |
| 15. | 2.854 | -0.230 | -1.383 | 0.030 |
| 16. | 2.917 | 1.399 | 0.541 | -0.469 |
| 17. | 3.036 | 2.146 | -0.668 | -0.467 |
| 18. | 2.530 | 1.503 | -0.058 | -0.141 |
| Average value | 1.866 | 0.339 | -1.058 | -1.152 |

from high positive in case of valley bottom to high negative in case of crest samples. It may indicate that there are positive average value in cases of chemical and site characteristics of soil in the valley bottom facets. In case of physical characteristics, there is an average negative value because of all the three principal physical characteristics of soil. It has been noticed that the valley bottom land is five times favourable than the gentle slopes, although it has got an average positive value. The parameters of all the three characteristics of soil have been found unfavourable towards highlands and crest ecologies.

4.3.1. Out of a total of ten ecological zones identified in the district of West Khasi Hills, six ecological zones namely, No. 1: Rambrai Zone, No. 2: Mairang Zone, No. 3: Nongstoin Zone, No. 4: Mawkyrwat Zone, No. 5: Mawsynram and its annexe, and No. 6: Balat-Pamkunda Zone have been taken for detailed analysis in the present study.

In this six ecological zones, all the 72 soil samples were taken purposively, twelve from each zone and keeping in view that they are well distributed spatially as well as over the four main categories of landfacets.

Analysis of the composite indices over the six ecological zones would provide comparison of the soil status and soil suitability between different ecological zones. The index of physical characteristics has shown in table 4.9, shows that the average value of the composite scores of physical parameters are positive in ecological zone 1, 3 and 4, the average value being 0.164, 0.850 and 0.342, respectively. One may point out, as seen in earlier part of this chapter that physical parameters are relatively favourable towards highlands and crest ecologies. It can be seen that the ecological zones 1, 3 and 4 are largely plateau top areas and highlands. The highest average positive value occurring in the Nongstoin Zone which has many hill ranges. The average negative values occur in zone 2, 5 and 6 which are essentially low slope areas, valley areas and low altitude areas.

Table -4.9: Composite Index of Physical Characteristics: Index A.

| Sl. No. | Ecological Zone 1 | Ecological Zone 2 | Ecological Zone 3 | Ecological Zone 4 | Ecological Zone 5 | Ecological Zone 6 |
|---|---|---|---|---|---|---|
| 1. | -2.189 | -1.928 | -0.723 | 0.532 | -1.738 | -1.928 |
| 2. | -1.696 | -0.181 | -0.427 | -0.688 | -1.724 | -1.928 |
| 3. | -1.682 | -0.427 | 0.687 | -0.674 | -1.154 | -0.195 |
| 4. | -0.243 | -1.647 | -0.907 | -0.688 | -2.422 | 0.229 |
| 5. | 0.722 | -0.257 | 2.203 | 1.653 | -1.154 | -0.907 |
| 6. | 1.300 | -0.455 | 0.969 | 0.969 | -1.477 | -1.956 |
| 7. | 0.003 | 0.792 | 0.792 | -0.413 | -0.660 | -0.413 |
| 8. | 0.961 | -0.646 | 2.887 | -0.970 | 1.258 | -0.195 |
| 9. | 0.791 | 0.764 | 1.258 | 1.258 | 1.258 | -0.441 |
| 10. | 1.546 | 0.792 | 1.258 | 2.887 | -0.942 | 0.687 |
| 11. | 1.258 | -0.441 | -0.674 | 1.426 | 0.080 | 1.258 |
| 12. | 2.646 | 0.313 | 2.873 | -1.188 | -0.942 | 1.011 |
| | 0.164 | -0.277 | 0.850 | 0.342 | -0.801 | -0.398 |

An analysis of the index of chemical parameters table 4.10 indicates that ecological zone 3 i.e. Nongstoin Zone has the highest average score of 1.532. This indicates that this Zone is most favourable both by physical parameters and chemical parameters. The other ecological zone with positive average score is Zone 5. The rest of the four zones have average negative score values. This would indicate that by chemical parameters only two ecological zones have, on an average favourable soil qualities.

Table - 4.10: Composite Index of Chemical Characteristics: Index B.

| Sl. No. | Ecological Zone 1 | Ecological Zone 2 | Ecological Zone 3 | Ecological Zone 4 | Ecological Zone 5 | Ecological Zone 6 |
|---|---|---|---|---|---|---|
| 1. | -0.676 | -0.440 | 3.932 | -0.554 | 1.916 | -1.954 |
| 2. | -1.186 | -0.098 | -2.508 | -0.903 | 0.075 | -1.978 |
| 3. | -3.130 | -0.769 | 3.135 | -0.867 | -3.384 | -4.009 |
| 4. | -3.130 | -0.447 | 0.531 | -0.899 | 2.584 | -0.473 |
| 5. | -2.875 | 0.095 | 1.657 | -0.856 | 1.824 | -1.186 |
| 6. | -2.895 | 0.032 | 2.545 | 2.545 | 3.048 | 2.227 |
| 7. | 1.547 | -0.941 | 1.200 | -1.050 | 0.978 | -1.433 |
| 8. | 1.178 | -3.843 | 1.467 | -0.252 | 2.136 | 3.918 |
| 9. | -0.854 | 1.291 | 2.265 | -0.785 | -0.452 | 1.117 |
| 10. | -0.883 | -2.208 | 3.466 | 2.485 | -0.393 | -0.403 |
| 11. | -1.644 | -2.617 | 0.983 | 0.564 | 0.405 | -0.648 |
| 12. | -0.806 | 0.764 | -0.285 | -0.025 | -1.087 | -2.723 |
| | -1.019 | -0.637 | 1.532 | -0.058 | 0.478 | -0.629 |

An analysis of the composite index of site parameters (Characteristics) has been shown in table 4.11, which indicates that ecological zone 6 i.e., Balat-Pumkunda Zone has the highest average score of 2.243. This indicates that this zone is most favourable by site parameters. The rest of the five zones have average negative score values. This would indicate that by site parameters only one ecological zone has an average favourable soil qualities.

Table - 4.11: Composite Index of Site Characteristics: Index C.

| Sl. No. | Ecological Zone 1 | Ecological Zone 2 | Ecological Zone 3 | Ecological Zone 4 | Ecological Zone 5 | Ecological Zone 6 |
|---|---|---|---|---|---|---|
| 1. | 3.621 | 2.918 | 0.238 | 3.528 | 3.103 | 5.003 |
| 2. | 3.091 | 2.097 | 3.284 | 2.899 | 0.899 | 5.048 |
| 3. | 3.528 | 3.284 | 0.378 | 3.085 | 2.575 | 4.374 |
| 4. | -0.704 | -1.406 | 2.016 | -0.698 | -0.813 | 3.554 |
| 5. | -0.557 | -0.257 | 0.165 | 0.438 | -0.549 | 3.554 |
| 6. | -0.010 | 1.555 | -0.553 | 0.103 | -1.069 | 2.987 |
| 7. | -2.175 | -2.419 | -2.118 | -2.331 | -2.605 | 0.860 |
| 8. | -1.954 | -1.080 | -2.379 | -1.763 | -2.605 | 0.002 |
| 9. | -1.792 | -2.320 | -2.239 | -1.763 | -2.249 | 0.002 |
| 10. | -1.253 | -2.255 | -1.763 | -2.334 | -1.441 | 0.721 |
| 11. | -1.116 | -2.494 | -4.583 | -1.944 | -2.588 | 0.821 |
| 12. | -1.546 | -1.345 | -1.487 | -3.171 | -1.195 | -0.011 |
| | -0.072 | -0.310 | -0.753 | -0.333 | -0.711 | 2.243 |

An analysis of the composited index I has shown in table 4.12. The average scores of composited index I are positive in ecological zones 1, 2, 5 and 6, the average value being

0.012, 0.208, 0.059 and 1.231, respectively. The rest of the two ecological zones i.e. Zones 3 and 4 have average negative scores of -1.186 and -0.317, respectively. The highest average positive value occurs in the Balat-Pumkunda Zone which has low altitude areas, gently undulating topography and thick jungle of evergreen forests. The second highest positive value occurs in the Mairang Zone, which has extensively large valley areas in between many hill ranges. Although, the average composite index values are positive in case of Zones 1 and 2, they are not significant. This may be due to the location of the zones. Zone 1 falls under the rainshadow of the South-West Monsoon and Zone 5 falls in the steep slopes of the southern part of the district. This would indicate that by the parameters of the composite three indices only two ecological zones i.e. Zone 2 and 6 have an average favourable soil qualities.

Table - 4.12: Ecological Zone-wise Classification of Composite Index I.

| Sl. No. | Ecological Zone No.1 | Ecological Zone No.2 | Ecological Zone No.3 | Ecological Zone No.4 | Ecological Zone No.5 | Ecological Zone No.6 |
|---|---|---|---|---|---|---|
| 1. | 2.834 | 2.356 | -0.446 | 1.133 | 1.730 | 3.507 |
| 2. | 2.465 | 0.915 | 2.100 | 1.717 | 1.353 | 3.530 |
| 3. | 1.841 | 1.292 | -1.327 | 1.755 | 2.488 | 2.737 |
| 4. | 0.656 | 0.576 | 1.166 | 0.375 | 0.516 | 1.304 |
| 5. | 0.067 | 0.036 | -1.672 | -0.620 | 0.039 | 2.163 |
| 6. | -0.072 | 0.846 | -1.416 | -1.172 | -0.262 | 1.742 |
| 7. | -0.194 | -1.147 | -1.562 | -0.362 | -0.815 | 0.923 |

Table - 4.12(Contd.)

| Sl. No. | Ecological Zone No.1 | Ecological Zone No.2 | Ecological Zone No.3 | Ecological Zone No.4 | Ecological Zone No.5 | Ecological Zone No.6 |
|---|---|---|---|---|---|---|
| 8. | -1.597 | 0.933 | -2.985 | -0.012 | -2.254 | -0.848 |
| 9. | -0.935 | -1.643 | -2.150 | -1.220 | -1.484 | -0.009 |
| 10. | -1.180 | -0.773 | -2.268 | -3.219 | 0.126 | 0.049 |
| 11. | -0.767 | -0.019 | -1.546 | -1.722 | -1.113 | -0.290 |
| 12. | -1.969 | -0.878 | -2.212 | -0.462 | 0.389 | 0.059 |
| | 0.012 | 0.208 | -1.186 | -0.317 | 0.059 | 1.231 |

4.3.2 As has been mentioned in Chapter - II, the Soil Texture and Soil Colours of the samples have been presented in textural and colour classes.

4.3.2.1 Soil Textural Classes

An analysis of Table 4.13 indicating Soil Textural classes shows that out of the 72 samples, 16 samples constituting 22.2 percent are of Clay (C) Category. The Clay Category

Table - 4.13: Soil Textural Classes.

| Sl. No. | Textural Names (Soil Class) | Textural Symbol | Nos. of Samples | Percentage (%) |
|---|---|---|---|---|
| 1. | Sand | S | 0 | 0.0 |
| 2. | Loamy Sand | LS | 3 | 4.2 |
| 3. | Sandy Loam | sL | 11 | 15.3 |
| 4. | Loam | L | 6 | 8.3 |
| 5. | Silt Loam | SL | 3 | 4.2 |
| 6. | Silt | Si | 0 | 0.0 |

Table - 4.13 (Contd.)

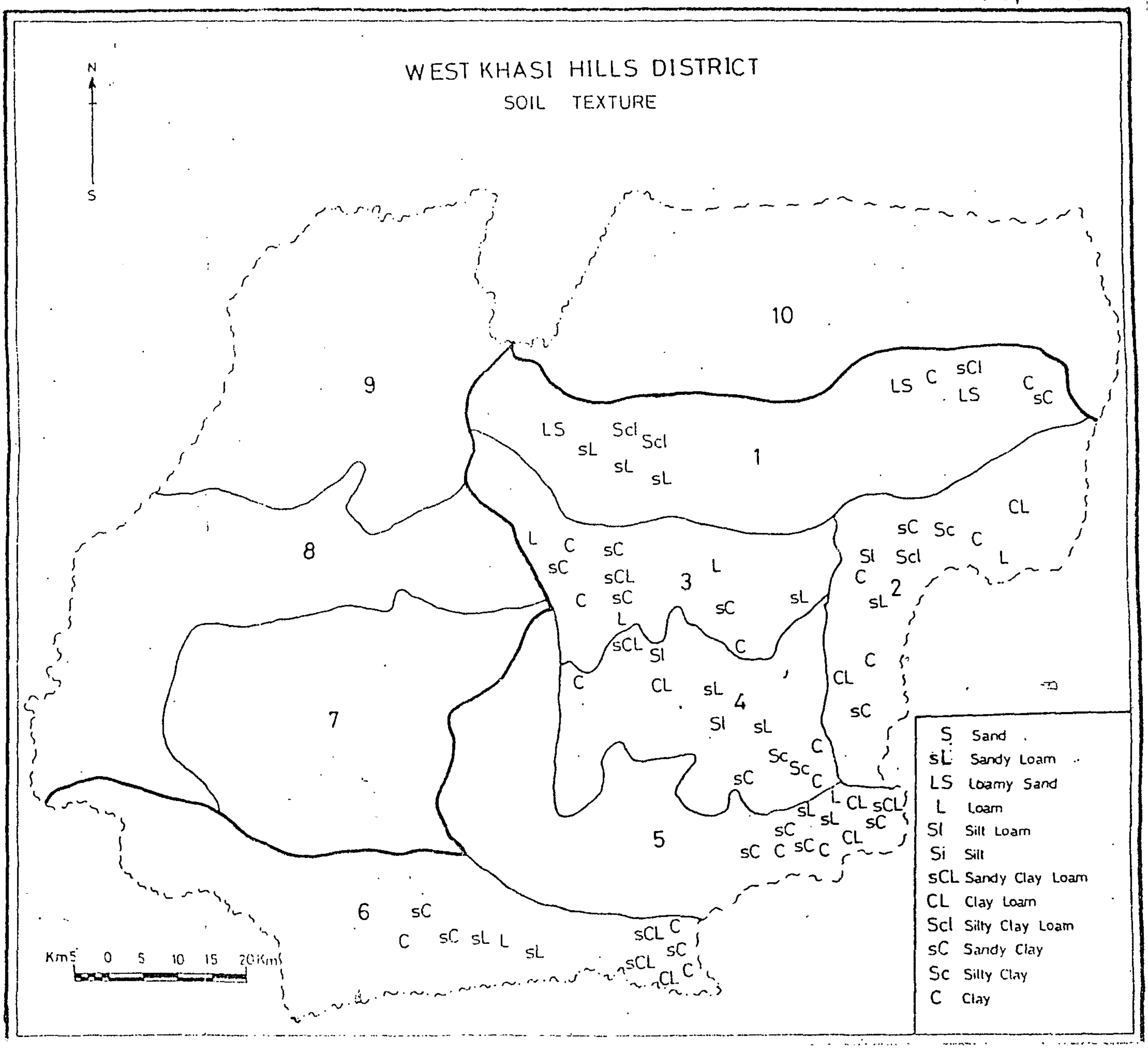
| Sl. No. | Textural Names (Soil Class) | Textural Symbol | Nos. of Samples | Percentage (%) |
|---|---|---|---|---|
| 7. | Sandy Clay Loam | SCL | 6 | 8.3 |
| 8. | Clay Loam | CL | 6 | 8.3 |
| 9. | Silty Clay Loam | Scl | 3 | 4.2 |
| 10. | Sandy Clay | sC | 13 | 18.1 |
| 11. | Silty Clay | Sc | 5 | 7.0 |
| 12. | Clay | C | 16 | 22.2 |
| | Total | | 72 | 100.0 |

dominates with an overall share of 47.3 percent. The second most dominant textural class is the Loam (L). Sandy Loam (sL) dominates this group by 15.3 percent in the overall share. However, the loam group as a whole has 49.6 percent share of the samples.

It may be noted that the valley soils are of depositional character and the finer particles get deposited year after year. It is natural that the valley soils would be dominated by greater percentage of clay group of soil. The gentle slopes and crest facets would be of mild erosional character, but are dominated by loam group of textures.

Map No. 12 shows that out of the six ecological zones, Zone 1, 3 and 4, which are predominantly highland areas, are dominated by Sandy (S) and Loamy or Loam group of soil except the isolated valley facets, where clay group can be observed.

Map No. 12


WEST KHASI HILLS DISTRICT
SOIL TEXTURE
N
S
S Sand
sL Sandy Loam
LS Loamy Sand
L Loam
Sl Silt Loam
Si Silt
sCL Sandy Clay Loam
CL Clay Loam
Scl Silty Clay Loam
sC Sandy Clay
Sc Silty Clay
C Clay
Km 5 0 5 10 15 20 Km

On the other hand, ecological Zone 2, 5 and 6, which are predominantly valley areas and lowlands, are dominated by clay group of soils except the isolated spurs where, the loam or sand group can be observed.

4.3.2.2 Soil Colour Classes

An analysis of table - 4.14 indicates that, Brown (B) Soil (10 YR5/3) dominates the samples with 15.3 percent of share within the 19 classes of soil colours. On the other hand,

Table - 4.14: Soil Colour Classes

| Sl. No. | Name of the Soil Colour | Colour Symbol | Nos. of Samples | Percentage (%) |
|---|---|---|---|---|
| 1. | Yellow Brown (10YR5/4) | Yb | 4 | 5.6 |
| 2. | Ligh Yellow Brown (2.5Y6/4) | Lyb | 6 | 8.3 |
| 3. | Olive Brown (2.5Y4/4) | Ob | 1 | 1.4 |
| 4. | Pale Brown (10YR6/3) | Pb | 6 | 8.3 |
| 5. | Brown (10YR5/3) | B | 11 | 15.3 |
| 6. | Yellowish Brown (10YR5/4) | Yeb | 3 | 4.2 |
| 7. | Brownish Yellow (10YR6/6) | By | 4 | 5.6 |
| 8. | Light Brownish Gray (2.5Y6/2) | Lbg | 4 | 5.6 |
| 9. | Pinkish Gray (7.5YR6/2) | Pg | 1 | 1.4 |
| 10. | Pale Yellow (2.5Y7/4) | Py | 2 | 2.8 |
| 11. | Strong Brown (7.5YR4/6) | Sb | 6 | 8.3 |
| 12. | Yellow (10YR7/6) | Y | 1 | 1.4 |
| 13. | Reddish Yellow (7.5YR6/6) | Ry | 1 | 1.4 |
| 14. | Dark Yellow Brown (10YR4/4) | Dyb | 5 | 7.0 |
| 15. | Very Pale Brown (10YR7/4) | Vpb | 5 | 7.0 |
| 16. | Dark Brown (10YR4/3) | Db | 6 | 8.3 |
| 17. | Grayish Brown (2.5Y5/2) | Gb | 3 | 4.2 |
| 18. | Dark Grayish Brown (2.5Y4/2) | Dgb | 1 | 1.4 |
| 19. | Very Dark Grayish Brown (10YR3/2) | Vdgb | 1 | 1.4 |
| | Total | | 72 | 100.0 |

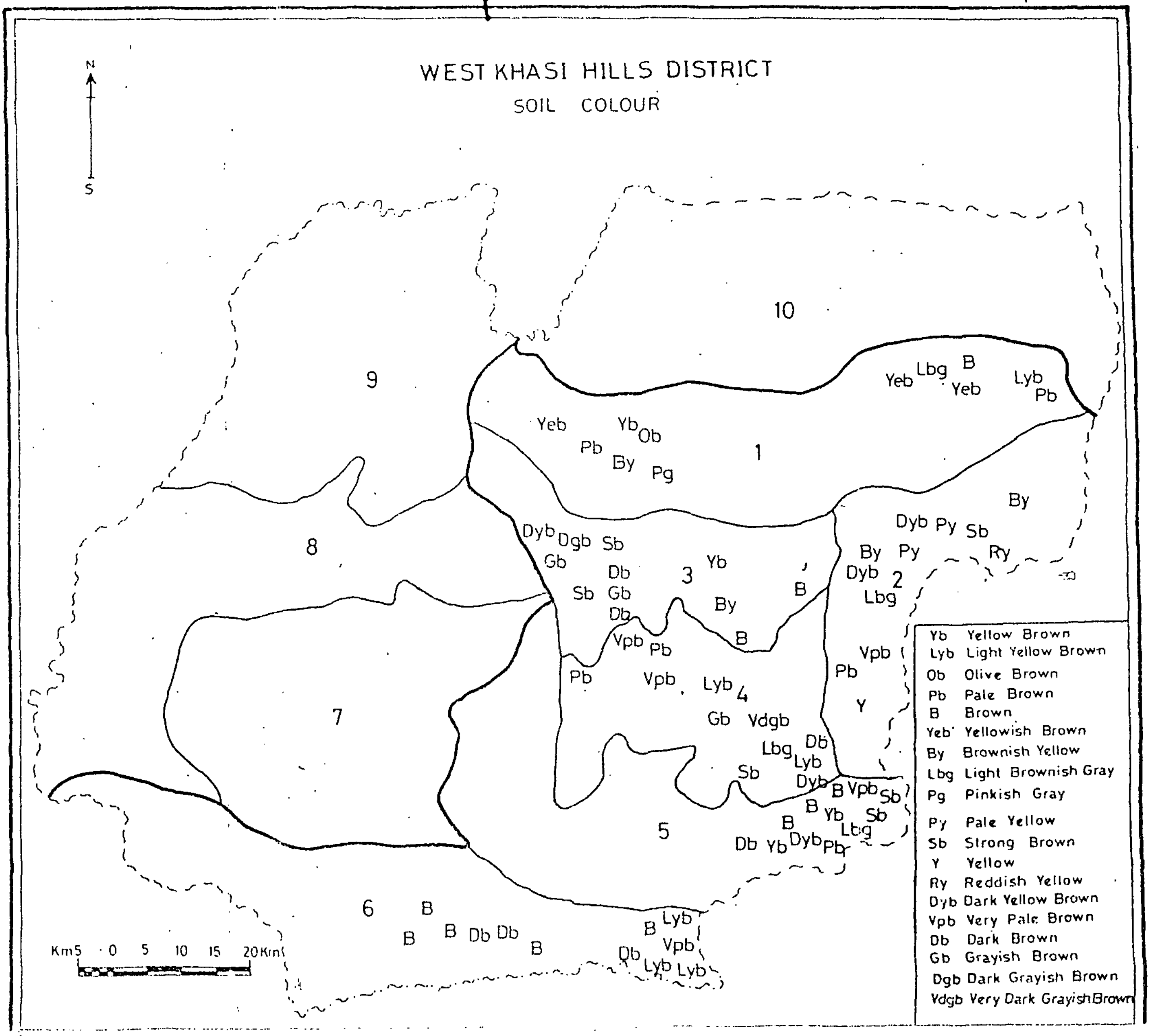
the brown group of soil has a significant dominance with 90.5 percent of the share of samples. This overall dominance of brown group might have resulted due to several factors, such as the presence of large humus content in valley soils, presence of semi-decomposed and unconsolidated biotic matter in valley and gentle slopes, and forested sites, presence of iron-oxides which diluted with humus under moist conditions would provide brownish colour etc.

Map No. 13 shows the spatial distribution of soil colour and it has been noticed that there is distinct spatial distribution within brown colour group of soils. In the slope areas i.e. gentle slopes, steep slopes and crests, are dominated by Brown, Dark Brown (Db) and Strong brown (Sb) colour of soils. On the other hand, light brown (Lb) and Pale brown (Pb) colour of soils are found in the lowlying areas, particularly valley bottom lands. This is because the valley soils are dominated by greater percentage of humus in the top layers as well as the greater percentage of clay particles, whereas the slope soils are dominated by sand and loam textures with presence of quartz, silica, with a fair amount of ferrous oxide ($Fe_2O_5$) which gives it a dark brown and reddish brown colour.

4.3.3. Soil Rating Status

The Composite Index I, i.e. of the three sub-groups A, B and C for the 72 soil samples have been arranged in ascending order and the samples have been quartiled into Category I;

Map No.13


WEST KHASI HILLS DISTRICT
SOIL COLOUR
N
S
10
9
1
8
3
2
7
4
5
6
Yeb Lbg B Yeb Lyb Pb
Yeb Yb Ob Pb By Pg
Dyb Py Sb By Ry
By Py Dyb Lbg
Dyb Dgb Sb Gb Db Sb Gb Db Yb By B B
Vpb Pb Pb Vpb Lyb Gb Vdgb Lbg Db Lyb Sb Dyb
Vpb Pb Y
B Vpb Sb B Yb Sb B Lbg Db Yb Dyb Pb
B B B Db Db B
B Lyb Vpb Db Lyb Lyb
Km5 0 5 10 15 20Km
Yb Yellow Brown
Lyb Light Yellow Brown
Ob Olive Brown
Pb Pale Brown
B Brown
Yeb Yellowish Brown
By Brownish Yellow
Lbg Light Brownish Gray
Pg Pinkish Gray
Py Pale Yellow
Sb Strong Brown
Y Yellow
Ry Reddish Yellow
Dyb Dark Yellow Brown
Vpb Very Pale Brown
Db Dark Brown
Gb Grayish Brown
Dgb Dark Grayish Brown
Vdgb Very Dark Grayish Brown

Poor Soils; Category - II: Medium Soils; Category - III: Good Soils and Category - IV: Very Good Soils.

At first all the samples, therefore, all the 72 observations have been categorised into ecological zone-wise. An analysis of table 4.15 shows that the Soil Rating Status (Ecological Zone-wise) that the ecological Zone 6, i.e., Balat Zone has the best quality of soil (among the six ecological zones) indicating 50.0 percent of very good soils (IV) class within its 12 samples. This may be because of low altitude and mixed deciduous forests which could conserve the nutrients from

Table 4.15: Soil Rating Status (Ecological Zone Wise)

| Ecological Zones | Category - I Poor Soils | | Category-II Medium Soils | | Category-III Good Soils | | Category-IV Very Good Soils | |
|---|---|---|---|---|---|---|---|---|
| | Nos. of Samples | Percent | Nos. of samples | Percent | Nos. of Samples | Percent | Nos. of Samples | Percent |
| 1. | 3 | 25.0 | 4 | 33.3 | 2 | 16.7 | 3 | 25.0 |
| 2. | 1 | 8.3 | 3 | 25.0 | 6 | 50.0 | 2 | 16.7 |
| 3. | 9 | 75.0 | 1 | 8.3 | 0 | 0.0 | 2 | 16.7 |
| 4. | 3 | 25.0 | 4 | 33.3 | 3 | 25.0 | 2 | 16.7 |
| 5. | 2 | 16.7 | 3 | 25.0 | 4 | 33.3 | 3 | 25.0 |
| 6. | 0 | 0.0 | 3 | 25.0 | 3 | 25.0 | 6 | 50.0 |

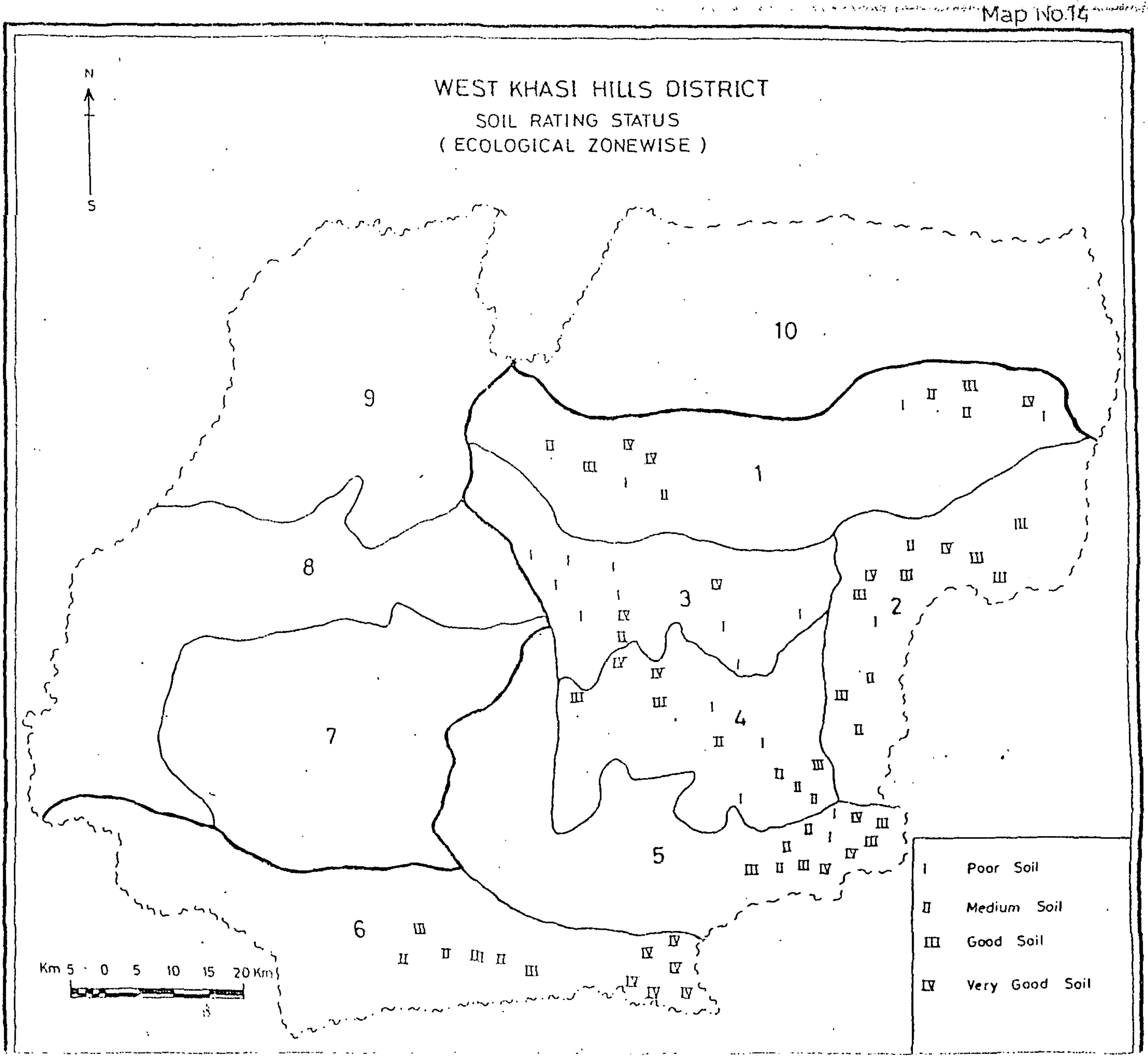
erosion, clay dominance of texture and higher humus availability. It has also a significant percentage of good soil (III) and medium (II) quality soil classes and there are no samples belonging to the lowest class i.e. very poor (I) soils. Soil status-wise the second best ecological zone is the Mairang zone, i.e. Zone 2. It has got 50.0 percent of samples under good soil category (III), with 16.7 percent as very good (IV) soils. This is because of the extensive valley bottom (flat) lands with small hill ranges, which are fully utilized for cultivation. The occurrence of medium (II) quality of soil is 25.0 percent and 8.3 percent is poor (I) category of soil. The third best zone in terms of soil quality is Zone 5, i.e. Mawsynram and its annexe Zone, indicating 33.3 percent of good soils (III), 25.0 percent of very good soils (IV) and 16.7 per cent under the poor (I) quality of soils. In case of medium (II) quality soil, it has got also 25.0 percent of the samples. It is because of the gentle slopes, the mixed forests mainly bamboo interspersed with a great many river valleys and valley soils. The Zone 1, i.e. Rambrai Zone, has come next to Mawsynram and its annexe zone, in terms of soil quality status. This zone has 25.0 percent of very good soils (IV), 33.3 percent of medium (II) quality of soils and 16.7 percent of good (III) quality of soils, respectively. The percentage of medium quality of soils is high, because Rambrai is dominated by highlands, sparse pine vegetation, soil degradation and low rainfall. The Zone 4, i.e. Mawkyrwat Zone has 33.3 percent of medium soils (II), 25.0 percent of poor soils (I) and therefore, dominance of below average quality of soils. The soil quality is generally poor in ecological Zone 3, i.e., Nongstoin Zone with 75.0 per cent of poor quality of soils (I) and 16.7 percent of very good quality of soils. The occurrence of poor quality of soil is very high because of its topographical characteristics. This Zone is largely a plateau top with high hill ranges and sparsely distributed pine vegetation. The soil quality under pine vegetation is generally, not favourable for the plant growth or cultivation. Moreover, most of the hill slopes have been utilised for 'Jhum' cultivation resulting in soil erosion and degradation. Map No.14 shows the distribution of Soil Categories in the ecological zones.

An analysis of table 4.16 indicating Soil Rating Status (landfacets wise) shows 77.5 percent of very good quality of soils under valley bottom landfacets. The gentle slopes

Table 4.16: Soil Rating Status (Landfacets-wise).

| Land-facets | Category-I Poor Soils | | Category-II Medium Soils | | Category-III Good Soils | | Category - IV Very good Soils | |
|---|---|---|---|---|---|---|---|---|
| | Nos. of Samples | Per cent | Nos. of Samples | Per cent | Nos of Samples | Per cent | Nos. of Samples | Per cent |
| Valley Bottom (flat land) | 1 | 5.6 | 1 | 5.6 | 2 | 11.1 | 14 | 77.8 |
| Gentle Slopes | 2 | 11.1 | 4 | 22.2 | 8 | 44.4 | 4 | 22.2 |
| Steep Slopes | 9 | 50.0 | 5 | 27.8 | 4 | 22.2 | 0 | 0.0 |
| Crests | 6 | 33.3 | 8 | 44.4 | 4 | 22.2 | 0 | 0.0 |

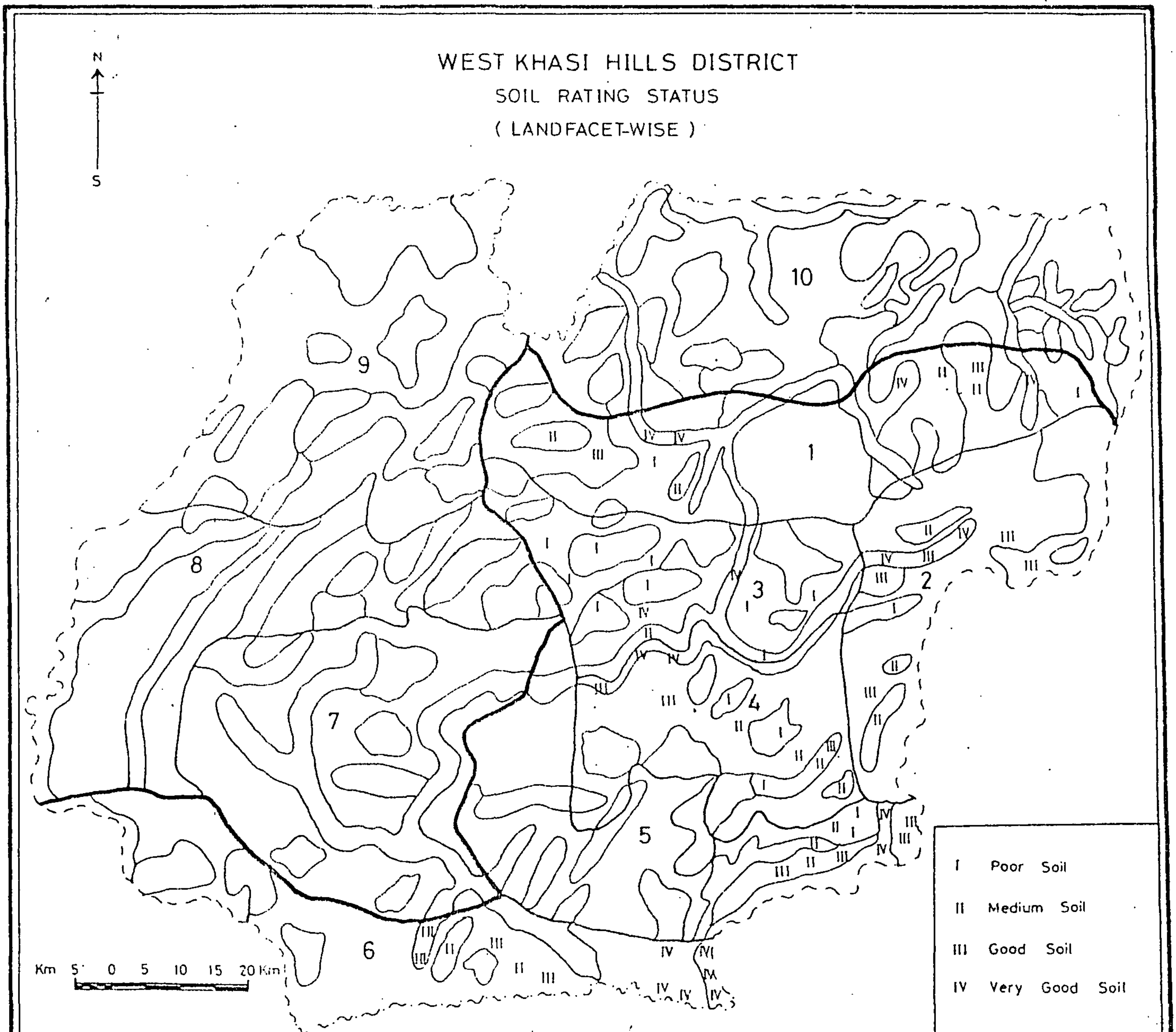
Map No.14


WEST KHASI HILLS DISTRICT
SOIL RATING STATUS
( ECOLOGICAL ZONEWISE )
N
S
1
2
3
4
5
6
7
8
9
10
Km 5 0 5 10 15 20 Km
I Poor Soil
II Medium Soil
III Good Soil
IV Very Good Soil

have 22.2 percent of very good quality of soils and 44.4 per cent good soils. In cases of steep slopes and crests, the very good quality of soil is less (very good zero in both cases and good soils 22.2 percent each). Therefore, there seems to be a very positive relationship between soil quality and the landfacets. The quality of soil decreases in the increase in slope. It is possible that, due to 'deforestation' and 'Jhum' cultivation, the upland soils have been degraded.

Map No. 15 shows that the very good soils are mostly dominated in Valley bottom (flat) lands and the poor soils are found in the steep slopes and creats, accounting more than 50.0 percent and 33.3 percent, respectively. In Valley bottom and gentle slopes, the occurrence of medium and good soils are also noticeable. This is because of greater soil retention capacity of soils in these facets.

Map No.15


WEST KHASI HILLS DISTRICT
SOIL RATING STATUS
( LANDFACET-WISE )
N
S
1
2
3
4
5
6
7
8
9
10
Km 5 0 5 10 15 20 Km
I Poor Soil
II Medium Soil
III Good Soil
IV Very Good Soil

# CHAPTER - V

## SUMMARY AND CONCLUSION

5.1 Contrary to popular notions, land is the 'ultimate resource'. The growing demands on non-renewable resources by the present 'Industrial Civilization' and constant depletion in these resources has now raised a question mark on the viability of this consumerist society. Sometime or other, the human society has to fall back on the more tangible resources of life as well as a greater sustainable standard of living. In this context, pre-eminence of land as the most durable resource of sustenance of human beings comes to the fore. After all, the interplay of all other renewable resources like water, vegetation, solar energy and the various nutrients of the ecosystem takes place largely on the landmass, since its contact with the human society from the point of view of habitation and food is much greater than the aquatic ecosystem, since, man after all is a terrestrial being.

Therefore, understanding, management and preservation of this vital resource i.e., land is of the greatest importance to man now. More so, is the case of the developing countries, because of the overwhelming dependence of their population on the land and soil resources. The North East Region of India is especially dependent on land resources, since nearly 90 per cent or more of the population still depend on agriculture or land related activities. The problem becomes even more acute in the case of the large tracts of areas inhabited by tribal population, principally the hill areas of the region. The general level of backwardness in these areas is even more striking. Unfortunately, the land resource which is the chief means of living of the population is the least managed along scientific principles; rather it is subjected to fast ecological degradations due to age old practices, and taboos, some of which are certainly harmful and destructive. The case in point may be the 'shifting cultivation', although opinions may be divided on the beneficience or otherwise of these techniques of agriculture. With the growth in population and the falling 'carrying capacity' of land, these traditional techniques which might have served usefully the society, have outgrown their utility, because the socio-economic context has changed or are changing very fast.

However, little scientific data and analysis have been carried out in these areas in terms of the nature of land uses and the character of soil quality and degradations of land under the accentuating ecological stresses and strains to which these areas have been subjected in recent times. It may be further noted that being 'non-cadestral' and 'non-land-record' areas any accurate information on land uses and soil productivities are totally unavailable. The secondary information dished out by the State Statistical Bureaus are at best 'informational guess works'.

It is with this background that the present study for soil quality of the West Khasi Hills District of Meghalaya, one of the most vulnerable (ecologically) areas of the region was undertaken. The main objectives could be outlined as the following:

a) Regionalization of West Khasi Hills District into ecological zones.

b) Classification of the larger ecological zones into landfacets, and

c) Finally, collect soil samples from ecological zones and landfacets (by stratification) and classify soil samples to finally prepare soil ratings and map them.

On the basis of relief, topography, slope, drainage and vegetation the district was divided into ten ecological zones out of which six zones were taken up for detailed study. The ecological zones were divided into a number of landfacets on the basis of four categories: (a) the valley land, (b) the gentle slopes, (c) the steep slopes, and (d) the crest lands.

In all, 72 surface samples (depth of 9") were collected, 18 each from the four landfacet groups and 12 each from the six ecological zones. The characteristics of these soil samples were grouped into 3 main groups viz. (a) physical characteristics (texture, colour and structure), (b) chemical characteristics (pH, N, P, K and Organic Carbon), and (c) Site characteristics (topography, slope, altitude and vegetation cover). These twelve variables representing the principal three groups of soil characteristics have been composited into soil rating indices in two stages, first compositing at the group level and then, the group indices to the final Index (I). The technique for preparing the composite indices has been Kendall's Principal Component Method.

5.2 With the increase in population and without any significant availability of other avenues of employment, there is a consistent pressure on land, particularly, its extensive dimension in the district. With persistence of traditional agricultural practices among which the shifting agricultural technique is predominant there is a constant quest by the native population for additional areas for agriculture. Most of the valley areas and gentle slopes have been already put under agricultural practices and now it is the steep slopes and crest lands where deforestation, at one hand, and agricultural colonisation on the other, is taking place at brisk pace.

From ecological point of view, steep slopes are not only the most difficult to manage but also the most vulnerable because of its high risk for quick soil erosion and therefore, degradation of land. The position of crest lands is similar if not to the same extent. It is with this situation in mind, the present study was contemplated to assess the situation of soil status under different micro-ecologies (Landfacets) and macro-ecologies (zones) of the West Khasi Hills district.

To a great extent, the findings of the study do substantiate the above points of view.

1. It has been ascertained that out of the three groups of soil characteristics namely, the physical, the chemical, and the site characteristics, the later two are highly favourable to the valley bottom and gentle slopes landfacets of district. The physical characteristics, are not as favourable to the valleys and gentle slopes, although the textures of finer, the colours deeper (Deep Brown) and the structures strong. From the availability of chemical nutrients, valley soils are the best with high NPK status and availability of larger formations of humus and therefore, the presence of organic carbon. However, the pH status of the entire district is highly acidic and therefore, it hampers the process of nutrients transfer (cations exchange) from soil to plants.

There is also a 'gradation' of soil properties from valley bottom facets to gentle slopes to crests and finally to the steep slopes so far as chemical & site characteristics are concerned. So far as the physical characteristics are concerned the gradation is of the reverse order.

2. The overall position of soil status as indicated by the final Soil Rating Index (I) indicates that valley soils are the best with an average index value of 1.866 compared to 0.339 of the gentle slopes, nearly five times. On the other hand, the soil status is unfavourable in the crest lands with the average score value of -1.521 and the steep slopes with average score value of -1.158. These score values are to be interpreted with the average being zero and standard deviation being unity i.e., the final index being a 'normalised vector'. Therefore, there is substantial difference between the soil status of valley and gentle slope lands and those of the crests and steep slope land of the district.

3. When interpreted ecological zone-wise (there are six contiguous ecological zones which have been undertaken for study out of the total of ten zones in the district), it is noticed that the soil rating status of four ecological zones namely, Rambrai Zone, Nongstoin Zone, Mawkyrwat Zone and Mawsynram Zone are relatively poor. It may be pointed out that these ares contain less of valley areas and more steep slopes and high hill ranges. The Mairang Zone and Balat Zone contain on an average a better soil status as indicated by the presence of 66.7 percent and 75.0 percent of good or very good soils,

respectively. On the other hand, the Nongstoin Zone has 75.0 percent of poor soils. Mairang and Balat Zones have a larger percentage of valley areas. The Mairang Zone is also agriculturally the most developed in the district with a large area devoted to cash crops, particularly, potato, which is grown in two seasons. This Zone is also highly populated. The Balat Zone is in low altitude with a number of rivers draining into Bangladesh through this zone. However, the Zone as a whole, although very suitable for agriculture has lost its former importance due to the partition and restrictions on border trade.

5.3 Overall, it can be said on the basis of the analysis of soils from a large part of the West Khasi Hills district that the valley soils and soils on the gentle slopes are the most suitable for agricultural purposes, although they are acidic and the farmers might be required to buffer the acidity by use of alkalic matters like lime treatment etc. The soils are also deficient in phosphorus ($P_2O_5$) although nitrogen (N) and potassium ($K_2O$) are relatively adequate. Conversely, the steep slopes and the crests are poor in soil quality and deficient in physical and chemical compositions. It may seem pedestrian that something which the farmers have empirically assessed over years has been proved scientifically here. But, it has to be seen that the quality of valley and gentle slopes which have been rigorously cultivated, have not been scientifically studied and this study provides details about the soil qualities. On the other hand, the steep slopes and the crests which have been, recently put under cultivation due to shortage of land are extremely vulnerable from ecological point of view ( in this case soil) and needs to be kept under natural vegetation cover. However, this study does not conclusively say about the relationship of deforestation with that of soil degradation in the steep slopes and crest lands, due to the limitation of the scope of the study. However, it is of common knowledge that a large part of West Khasi Hills District is subjected to large scale clear cutting of its natural vegetation in the past decade or so. The Nongstoin Zone, which is one of the most ravaged areas, so far as deforestation is concerned, indicates the poorest soil status among all the six ecological zones studied in this dissertation.

5.4 The major limitations of the study are:

i) That the soil samples correspond to one time period due to the temporal scope of the study and therefore, no time scale comparison is possible to indicate the process of soil degradation or otherwise.

ii) This study also suffers from the limitation of not covering all the areas of the six zones largely because of logistics in carrying out sampling at a larger number of sites.

However, the study differs from the available scanty governmental statistics on soil largely by the fact that while the latter concentrates on sampling from agricultural fields alone the present study has a comprehensive coverage over the entire area including different ecological zones and various landfacets. This type of study is also important, since, it generates field based scientific data in a region where there is severe paucity of data on land and agriculture. Further, these areas being constantly subjected to ecological stresses and strains in recent times, is of importance that though scientific studies are made not only to assess the nature and trend of ecological degradation but also to indicate methods of preservation, management and conservation of natural resources of the region, particularly, land on which the dependence of the local tribal population is overwhelming.

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PLATE NO. 1: Deciduous Forests Near Mawsynram.

PLATE NO. 2

Slash and Burn for
Jhum Cultivation near Jakrem

PLATE NO. 3

Slash and Burn for
Jhum Cultivation near Mawkyrwat

PLATE NO. 4: Balat River Valley.

PLATE NO. 5

Extensive Wild Grassland
Near Weiloi

PLATE NO. 6

Cultivated Valley
Near Jakrem

## APPENDIX - I

### A. PRINCIPAL COMPONENT ANALYSIS

(After M. Kendall)

1.1 Suppose that we have observations of P variables X on each n individuals. Now, an attempt has been made to simplify the situation, whether it is possible to find some new variables $\xi_1$, $\xi_2$ ............ $\xi_p$ which are linear functions of the X's but are themselves uncorrelated. In fact we look for $p^2$ constants $l_{ij}$ (i, j = 1, ....., p) such that

$$\xi_i = \sum_{j=1}^{p} l_{ij} X_j \quad \text{...........} \quad (1.1)$$

If the X's are measured from their means, the sum of any $X_j$ over the n individuals is zero and hence, from (1.1), the same is true of any $\xi_i$. We now impose the condition that the $\xi$'s be uncorrelated, i.e. that

$$E(\xi_i, \xi_j) = E \sum_{k=1}^{p} l_{ik} X_k \sum_{m=1}^{p} l_{jm} X_m = 0,$$

$$i \neq j \quad \text{.....}(1.2)$$

This equivalent to,

$$\sum_{k,m=1}^{p} l_{ik} l_{jm} E(X_k X_m) = \sum_{k,m=1}^{p} l_{ik} l_{jm} C_{km} = 0, \ \ldots \ (1.3)$$

Where $C_{km}$ is the covariance of $X_k$ and $X_m$. We note from (1.2) that this imposes $\frac{1}{2}p(p-1)$ conditions on the l's. There are $P^2$ of them, so we can impose a further $p^2-\frac{1}{2}p(p-1)$ conditions and still find a solution. We have to impose the condition that the transformation is self-orthogonal, i.e. that

$$\sum_{i=1}^{p} l_{ij}l_{ik} = 0, \quad j \neq k$$
$$= 1, \quad j = k \qquad \ldots\ldots\ldots \quad (1.4)$$

This thus absorbs the $\frac{1}{2}p(p+1)$ degrees of freedom in the transformation, so that under these conditions there will, in general, be only a finite set of solutions.

Geometrically, the orthogonality conditions (1.4) mean that in the First Space we are looking for a rotation of the co-ordinate axes about the origin. The relations are most conveniently expressed in matrix form. Representing the X's by the column (P X 1) Vector X and similarly for the $\xi$'s, we have, corresponding to (1.1)

$$\xi = lx \qquad \ldots\ldots \quad (1.5)$$

The orthogonality conditions (1.4) are equivalent to

$$ll' = I \qquad \ldots\ldots \quad (1.6)$$

Where I is the identity matrix (i.e. a P X P matrix with units in the diagonals and zeros elsewhere). If we premultiply (1.6) by l' and postmultiply by the inverse of l', we have equivalently

$$l'l = I \qquad \ldots\ldots \quad (1.7)$$

It will follow from (1.5) that

$$X = l' \xi \qquad \ldots\ldots (1.8)$$

For the covariances of the $\xi$'s we have, corresponding to (1.3)

$$E(\xi \xi') = E \{ lx (lx)' \} = E (lxx'l') = lcl' = \Lambda \ldots (1.9)$$

Where $\Lambda$ is a matrix with zero off-diagonal elements and with diagonal elements $\Lambda_1, \Lambda_2, \ldots\ldots \Lambda_p$ representing the variances of the $\xi$'s. Premultiplying (1.9) by $l'$, we find that,

$$Cl' = l' \Lambda \qquad \ldots\ldots (1.10)$$

In full this is,

$$\begin{bmatrix} c_{11} & c_{12} & \ldots & c_{1p} \\ c_{21} & c_{22} & \ldots & c_{2p} \\ \ldots & \ldots & \ldots & \ldots \\ c_{p1} & c_{p2} & \ldots & c_{pp} \end{bmatrix} \begin{bmatrix} l_{11} & l_{21} & \ldots & l_{p1} \\ l_{12} & l_{22} & \ldots & l_{p2} \\ \ldots & \ldots & \ldots & \ldots \\ l_{1p} & l_{2p} & \ldots & l_{pp} \end{bmatrix}$$

$$= \begin{bmatrix} l_{11} & l_{21} & \ldots & l_{p1} \\ l_{12} & l_{22} & \ldots & l_{p2} \\ \ldots & \ldots & \ldots & \ldots \\ l_{1p} & l_{2p} & \ldots & l_{pp} \end{bmatrix} \begin{bmatrix} \Lambda_1 & & & \\ & \Lambda_2 & & \\ & & \ldots & \\ & & & \Lambda_p \end{bmatrix} \qquad (2.11)$$

Expanded in full this would give us $p^2$ equations. Consider the subset of P derived from the first column in the matrix product:

$$\begin{array}{lllll} C_{11}l_{11} + C_{12}l_{12} + & \cdots & + C_{1p}l_{1p} & = l_{11}\lambda_1 & \\ C_{21}l_{11} + C_{22}l_{12} + & \cdots & + C_{2p}l_{1p} & = l_{12}\lambda_1 & \\ \cdots \quad \cdots & \cdots & \cdots & \cdots & \\ C_{p1}l_{11} + C_{p2}l_{12} + & \cdots & + C_{pp}l_{1p} & = l_{1p}\lambda_1 & \ldots(1.12) \end{array}$$

Or,

$$\begin{array}{ll} (C_{11} - \lambda_1)l_{11} + C_{12}l_{12} + \cdots C_{1p}l_{1p} = 0 & \\ C_{21} + (C_{22} - \lambda_1)l_{12} + \cdots\cdot + C_{2p}l_{1p} = 0 & \\ \cdots \quad \cdots \quad \cdots \quad \cdots & \\ C_{p1}l_{11} + C_{p2}l_{12} + \cdots + (C_{pp} - \lambda_1)l_{1p} = 0 & \ldots(1.13) \end{array}$$

Eliminating the l's, we have,

$$\begin{vmatrix} C_{11} - \lambda_1 & C_{12} & \cdots & C_{1p} \\ C_{21} & C_{22} - \lambda_1 & \cdots & C_{2p} \\ \cdots & \cdots & \cdots & \cdots \\ C_{p1} & C_{p2} & \cdots & C_{pp} - \lambda_1 \end{vmatrix} = 0 \quad \ldots \ (1.14)$$

Or, in matrix notation,

$$\left| C - \lambda_1 I \right| = 0 \quad \ldots \quad (1.15)$$

It will be found that the other equations in $\lambda_2, \ldots,$ $\lambda_p$ are of exactly the same kind. Thus the required $\xi$'s (the variances of the $\xi$'s) are the p roots of

$$\left| C - \lambda I \right| = 0 \qquad \ldots\ldots \quad (1.16)$$

The $\lambda$'s are, in fact the so-called eigen values of the matrix C. The corresponding l's are the components of the eigen vector.

The new functions $\xi$ are known as principal components. They are uncorrelated linear functions of the original variables. In particular, if the original variables were normally distributed, the new variables $\xi$ are not only uncorrelated but independent. It is remarkable that they have another useful properties. Suppose that we had approached the subject from a different viewpoint and looked for the linear functions of the X's which have stationary values of their variance. If one of these is $\zeta$, expressed as

$$\zeta = \sum_{j=1}^{p} l_j x_j \qquad \ldots\ldots \quad (1.17)$$

Its variance is given by

$$\mathrm{Var}\ \zeta = \sum_{j=1}^{p} \sum_{k=1}^{p} l_j l_k \,\mathrm{Cov}(x_j x_k) \ \ldots\ldots \ (1.18)$$

We require to find the stationary value of this, subject to the condition

$$\sum_{j=1}^{p} l_j^2 = 1 \qquad \ldots\ldots (1.19)$$

This is equivalent to an unconditional stationary value of

$$\Sigma l_j l_k C_{jk} - \lambda \Sigma l_j^2 \qquad \ldots\ldots\ldots (1.20)$$

where $\lambda$ is an undetermined multiplier. Differentiation by $l_j$ leads to

$$\sum_{k=1}^{p} l_k C_{jk} - \lambda l_j = 0 \qquad \ldots\ldots (1.21)$$

This leads to equation (1.16) with $\lambda$ as one of the eigen values. In other words, the linear combinations with stationary values are the principal components. If we christen the components according to the magnitude of their eigen values (variances), we may say that the first component $\xi_1$, has the largest possible variance of any linear functions; the second, $\xi_2$, has the largest variance subject to being uncorrelated with the first; the third has the largest variance of linear functions which are uncorrelated with the first and second; and so on, down to the smallest eigen value, which corresponds to the linear combination with the smallest variance.

# BIO-DATA

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|---|---|---|
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