

**PHYTOGEOMORPHOLOGY OF THE KHRI BASIN,  
MEGHALAYA**

***ABSTRACT***

**LAITPHARLANG CAJEE  
DEPARTMENT OF GEOGRAPHY**

**SUBMITTED IN PARTIAL FULFILMENT  
OF THE REQUIREMENT OF THE  
DEGREE OF DOCTOR OF PHILOSOPHY IN GEOGRAPHY  
OF THE  
NORTH EASTERN HILL UNIVERSITY  
SHILLONG**

**2002**

## **ABSTRACT**

The term phyto-geomorphology can be defined as the study of relationships between the earth's relief features and the distribution of plant species. The subject matter laid emphasis on the importance of combining plants and landforms in studies related to the land surface of the earth and in recognition of their interdependence. Thus, in combination, the two form a powerful tool for the survey, management and planning of our environment. However there are more specific discipline-oriented studies that can benefit directly or indirectly from a phyto-geomorphic approach. It is observed that a balance between landforms and vegetation varies greatly. Thus an integral concept of geomorphology with vegetation to land-use planning though is relatively new, can highlight a number of aspects of renewing this world to a better place to live in.

### **Statement of the Problem:**

Phytogeomorphology offers a broad base synthesis of the important relationship between plants and landforms in studies related to the surface of the earth. Whereas the present landforms equally predate history, plant communities reflect interaction of current environmental factors. Excluding those creatures that live wholly on the produce of the seas, all life depends directly or indirectly on a very thin mantle of the earth's surface. This is closely associated with geology, landscape and soil, which in turn reflect the operation of climate on the vegetation and the physical materials of the earth's surface. Civilisation can be defined as man's gradual conquest of his environment, but how far this process, in sober facts gave is a matter for careful thought. In some way, containing man's mastery over nature is complete enough where he exploited the resources of the mineral world to a remarkable degree but has been less successful in establishing a relationship with the plant world which is the time basis of human economy. Naturally enough vegetation is as susceptible to man's destructive propensities as any other part of

nature and in many respects it can be as easily exploited by him, but unlike the rest he cannot entirely bind it to his own will.

### **Objectives of study:**

Geomorphic processes and vegetation influence the development of the natural landscape. Therefore landform characteristics of the concerned area are an important aspect to be understood. So also is the distribution and characteristics of flora in relation to soil characteristics would require adequate consideration. However in other circumstances climatic variations may predominate. Thus the study focuses particularly on the study of landforms, soils and distribution of the dominant tree species. Keeping in mind with the discussions mentioned earlier, the objectives are formulated as stated below:

- i) to study the geomorphic attributes and landform characteristics of the area.
- ii) to describe the morphological characteristics of the major plant species
- iii) to correlate landform characteristics and morphological characteristics of the dominant plant species in the study area.

### **Research Questions:**

On attempting this study, a number of questions are set in the mind of the researcher.

- (1) What are the geomorphic attributes of the study area ?
- (2) What are the geomorphic attributes and how are they influencing the distribution of major plant species of the study area ?

**Data Base:**

Data used in the present study is broadly of two different types i.e. primary and secondary data. Since not much reliable secondary data is available for the study area, primary data is accounted to be the main source important for the study. Primary data was collected through a number of field visits the researcher undertook. Such data was collected from 10 (ten) different sample study villages situated within the basin. This entire process was performed through demarcation of 4 (four) micro-areas determined by altitudinal variation.

Secondary data was collected from different sources to supplement the various requirements needed in the present study. This was done in order to generate a general understanding on the various physical complexities present in the study area.

**Methodology:**

In the present study 2 (two) major methods are being used that is, (1) Field Methods (2) Laboratory Methods.

**Field Methods:**

Field observations played a very important role in the present study where a general geographical personality have been accounted particularly to the various landscape formations, the dominant plant species of the area and certain physical properties of the soils like colour, texture, shape and type.

**Laboratory Methods:**

The topographical sheets served as a vital source of information about the basin. The morphometric techniques used reveal number of facts important for understanding the landform characteristics of the basin. Survey of India, Topographical sheets No. 78 O/5, 6, 9 and 10 with R.F. 1 : 50,000 have been used to analyse relief, average slope, drainage, drainage density and drainage frequency etc. Soil and vegetal studies were carried out in 10 (ten) villages that are sample areas of the research work. Studies of the morphological characteristics of the dominant plant species were carried out in the field.

**Statistical Analysis:**

Statistical methods like correlation and regression analysis have been used to establish a relationship between the geomorphic attributes, soil characteristics and the morphological characteristics of the dominant plant species of the study area.

The research work was divided into 3 (three) phases namely, pre-field, field and post-field phases. Each of these phases have their distinctiveness throughout the entire study.

**Plan of Work:**

The whole research work is organised into 7 (seven) chapters in which the detail plan of work of each of these chapters is given in the following paragraphs.

In the first chapter a general introduction of the topic is outlined which provides an insight into the research framework. This chapter includes the literature

survey, statement of the problem, aims and objectives, along with some research queries, database, methodology, general geographical personality of the study area and a plan of work of each chapter.

The geological setup of the study area is dealt in the second chapter. It also includes the description of geology of the state of Meghalaya in general and the basin under study in particular.

The third chapter deals with the geomorphic attributes of the study area where a detailed description of the landform characteristics of the basin is discussed. Relief, slope and drainage aspects have been discussed in great detail in this chapter.

Chapter four deals with the soil characteristics of the study area. A detailed discussion has been worked out with regard to certain physical characteristics that include the shape, size, colour of the soil grains and a general textural classification of the soils have been analysed in the laboratory with regard to percentage composition of sand, silt and clay. The chemical characteristics of the soils have also been discussed in detail which involves the analysis of the composition of Organic Carbon which is the Nitrogen equivalent, Phosphorus and Potassium content. The pH value has also been found.

The fifth chapter describes the morphological characteristics of the dominant plant species studied in the 10 (ten) chosen sample villages. It includes the measurement of the average height of the matured plant, leaf size and pattern, nature of the bark, and such other related aspects.

Chapter six deals with the relationship between the geomorphological attributes, (relief, average slope and drainage density), soil characteristics (both

physical and chemical) and the morphological characteristics of the dominant plant species. An insight on the role of the parent rock material that is the geological structure and other related aspects were also developed.

The last chapter gives the summary and findings with suggestions synthesised out of the research study.

### **Findings:**

The study area Khri Basin, extends to an area of about 1067.75kms<sup>2</sup> occupies a very important position in understanding the interrelationship between geomorphic features, plant distribution and soil characteristics. Soil is the most important component on which man relies directly or indirectly other than water and is influenced by the parent rock material, landscape and vegetal cover in association with the climatic parameters which reign in a particular location.

The following findings are mainly highlighted through the landform-plant-soil relationships with the interplay of both climate and geology.

#### **1. Climate:**

The area experiences a tropical monsoon type of climate where maximum rainfall is received during the months of June to October accounting to about 85% of the total annual rainfall. In the study area that two major types of weather conditions prevail. The High Uplands enjoy temperate humid climatic conditions with harsh cold winters accompanied with winter winds, whereas as we move to low lying areas the weather conditions change and gets warmer. The uniformity of the climatic phenomena is that the basin under study generally experiences a monsoonal type of climate throughout the year.

## **2. Geology:**

Three major rocks have been identified in the study area, that is, gneiss, granite and schist. All these three major rock structures are overlying the Gneissic Complex. Gneiss is found to be the most common signifying that the rocks are very hard and resistant. Granites are predominantly found in the Mid-Central Uplands and in the other zones where the main drainage basin passes through. Schist has been accounted in a small portion in the High Upland areal unit.

## **3. Physical Setting:**

The study area has diverse and varied topography that is highly marked, dissected and irregular terrain. The area is also notable for its rolling uplands intersected by streams and rivers and dotted by rounded hills, scarps, gorges, deep valleys etc. The area is formed by contours ranging from 200 -1800 metres. The 4 (four) zones mentioned earlier could be termed "Uplands" and are broadly classified into 4 (four) divisions where each micro areal unit is under study.

- (i) High Uplands (above 1500 metres)
- (ii) Mid-Central Uplands (1000 - 1500 metres)
- (iii) Low Uplands (500 - 1000 metres)
- (iv) Lowlands (below 500 metres)

The main physical features of the study area are the presence of rounded hill tops, escarpments, cliffs, waterfalls, ridges, valleys and low-lying areas with gentle and undulating slopes and a smooth skyline showing the true nature of a plateau with a rolling topography.

#### **4. Dissection Index:**

Level of dissection within the Khri Basin varies from 0.1 to 0.8 that signifies that the basin is highly contrasting. It is noted that the level of dissection in general is seen to increase with lowering of altitude where maximum dissection is noted at the lowlands particularly in the areas where the main course of the river is flowing. Dissection is high at those areas where the higher stream orders are present and diminishes in the areas where the 1<sup>st</sup> and 2<sup>nd</sup> stream orders are present. In the basin most of the areas are not highly dissected and results show that there is a trend of progressive dissection through the intensity of rainfall especially during the monsoon season. This is the period when the streams are at spate eroding the soils and carrying along with them a massive load and transporting the debris in the form of sediments down stream. Dissection with indices above 0.3 is continuous suggesting some kind of transition from one plane to another.

#### **5. Slope:**

The study area has lowest slope at 4.5° and the highest being at 29° approximately. Steepest slopes i.e. above 24° are present where the main drainage line passes or cuts through forming deep valleys, gorges, and ravines with highly rugged terrain. It may be noted here that the main Khri Basin bifurcates into two major sub-basins at Mawdem village forming the interfluve. The main drainage line known as Khri-Synia that passes through Tyllang Nongriat – Kynrud – Mawdoh stretch and the other major sub-basin known as Khri-Bah that passes through Warmawsaw – Mawskei – Patharkmah – Nongliput – Nongthliew stretch. It is in these areas where deep cutting of water takes place.

## **6. Drainage Density:**

Maximum drainage density is recorded where the slopes are at the steepest and where the main drainage line passes through. In accordance to Morisawa's Classification this part of the Khri Basin has a medium texture and the lithological conditions of the underlying rocks signify that they are permeable.

## **7. Land Classification:**

Undulating lands coupled with gentle to moderately sloping hills interspersed by wide valleys and the dominance of rolling uplands signifies the true nature of a plateau represented in the basin. The hill ranges are found dipping from almost SSW direction to NNW direction. The south-western portion, central western portion and the central eastern portion are marked by steep hills interspersed by narrow valleys, deep gorges, ravines etc.

## **8. Soil:**

The dominant types of soil in the study area are that of red loamy Soils and laterite soils which are a result of the weathering of the exposed parent rock material such as granites, gneiss's, quartzite's, schist, conglomerates and dolerites which are rich in clay forming minerals, iron and aluminium. They vary from clayey to sandy loamy to loamy soils that are yellowish to brown to dark brown in colour. The soils of the low lying areas and valleys particularly those having loamy soils are the newly formed alluvial soils known as "Khabdar" where new layers are deposited year after year during the monsoon season. As the basin experiences humid climatic conditions, the formation and development of soils are similar to other humid areas where cation exchange is high resulting to the acidity of soils. The type and structure of rocks also play an important role in the evolution of soils. Granites and gneiss's

dominate the basin and they are transformed mainly into kaolinite but the ferruginous concretions give such soils a reddish colour.

## **9. Vegetation:**

Natural vegetation varies from mixed tropical evergreen forests to that of temperate forests mainly based on altitude and rainfall distribution. The main tree species found in the study area are that of pines (*Pinus khasyana* and *Pinus insularis*), *shorea*, *schima*, *litsea* and *tectona* species. From the various areal units where vegetation is studied it is observed that as we move higher in altitude the shape of the leaves gradually becomes acute signifying that the leaves in trees in the lower elevations are broader thus having more canopy coverage rather than that at higher elevations.

## **10. Statistical Findings:**

(a) The height of the tree species varies with change in altitude primarily because of a number of physical factors of which the most outstanding being climate, soil depth and the influence of the parent rock material.

(b) The size, length and width of the leaves or folicles of the three species are reduced with increase in altitude. This is again mainly because of climatic variations especially with regard to relative humidity having an effect on the rate of transpiration. However, it is interesting to find that this is not true with regard to the *schima* species where at the lower altitudes the leaves are narrower and shorter than those found at the higher altitudes.

## **Conclusion:**

(1) Phytogeomorphic studies can provide the base for geological exploration and survey not only for the normal mapping of stratigraphic units but also for that of mineral and water resources.

(2) Mineral resources tend to be related to landscape through a number of predictions. They occasionally are visible on the surface but are more usually interpreted from the understanding of the location of plant groups under particular soil conditions reflecting geological formation.

(3) Geomorphic attributes can assist in landuse and land evaluation studies where the effects of geomorphology through the parent rock material, the topography and drainage system with the interplay of climatic factors would reveal a lot of information on the potential landuse.

(4) Topography along with the influence of soils and the natural and induced vegetation becomes a prime determinant of landuse planning.

(5) Slope has a strong influence on the mechanization of activities. At the point where the slope is too steep land is devoted to forestry though the soil may be well suited for farming.

(6) As natural vegetation is an excellent expression of the total effect of environmental factors, the population of the plant community, its species composition (including the dominant species) and vegetal succession contributes a lot to maintain the ecological balance and bio-diversity.

(7) Landforms and vegetation in association with soil can effectively be used to the classification of landscape for various engineering purposes.

(8) Studies in phytogeomorphology can be used for the management of forest either for the classification of existing forest or for land under afforestation particularly in relation to site quality.

(9) Soil erosion in high to medium relief and also in low relief areas is vigorous in humid areas particularly through rainfall and fluvial activity. Soil degradation assessment can highly be ascertained through a phytogeomorphic approach.

(10) Since soils are natural bodies that are closely related to geology, climate, geomorphology and vegetation, phytogeomorphic interpretation can be used as a fundamental tool for explaining soil formation in different environments.

Thus Phytogeomorphology provides a sound base to an integrated approach of dividing landscapes into meaningful units, which have a uniformity of geology, geomorphology, vegetation, climate and soil.

**PHYTOGEOMORPHOLOGY OF THE KHRI BASIN,  
MEGHALAYA**

**LAITPHARLANG CAJEE  
DEPARTMENT OF GEOGRAPHY**

**SUBMITTED IN PARTIAL FULFILMENT  
OF THE REQUIREMENT OF THE  
DEGREE OF DOCTOR OF PHILOSOPHY IN GEOGRAPHY  
OF THE  
NORTH EASTERN HILL UNIVERSITY  
SHILLONG**

**2002**

## CONTENTS

### Page Nos.

*Acknowledgement*

*List of Tables*

*List of Figures*

*List of Graphs*

Chapter I :	INTRODUCTION	1 - 20
Chapter II :	GEOLOGY	21 - 43
Chapter III :	MORPHOMETRIC ANALYSIS AND GEOMORPHIC LANDFORMS	44 - 61
Chapter IV :	SOIL CHARACTERISTICS	62 - 83
Chapter V :	MORPHOLOGICAL CHARACTERISTICS OF THE DOMINANT TREE SPECIES	84 - 106
Chapter VI :	LANDFORMS – SOIL – PLANT RELATIONSHIP	107 - 140
Chapter VII :	CONCLUSIONS AND SUGGESTIONS	141 - 154

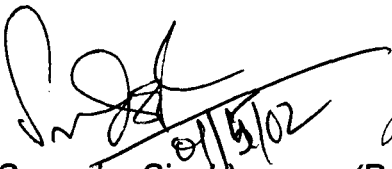
Bibliography

Photographs of Khri Basin

**NORTH EASTERN HILL UNIVERSITY, SHILLONG  
MAY, 2002**

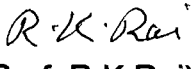
I Laitpharlang Cajee, hereby declare that the subject matter of the thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University / Institute.

This is being submitted to the North Eastern Hill University for the Degree of Doctor of Philosophy in GEOGRAPHY.

  
(Prof. Surendra Singh)

**HEAD**  
**Department of Geography**  
**North Eastern Hill University**

HEAD  
Department of Geography  
North- Eastern Hill University  
Shillong- 793014.

  
(Prof. R.K.Rai)

**SUPERVISOR**

Department of Geography  
**NORTH-EASTERN HILL UNIVERSITY**  
**SHILLONG-14**

  
Laitpharlang Cajee

## ACKNOWLEDGEMENT

I would like to take this opportunity to extend my sincere gratitude to Prof. R.K. Rai without whose guidance and untiring zeal this research work would not have come to the present form. Through this, I express my deep sense of gratitude to him.

I also acknowledge sincere thanks for the encouragement given to me by Prof. Surendra Singh, Prof. B.S. Mipun, Prof. D.K. Nayak, Dr. H.J. Syiemlieh and also to all the faculty members of the Department of Geography, during the deliberation for the preparation of this work. Thanks are due to Dr. R. Khongsdier, Reader, Department of Anthropology for the help he rendered in processing statistical data.

I express my warmest appreciation to Mr D. Synnah, Ms A. Dohling and Mr P. Thapa for their valuable assistance rendered in the preparation of the various figures and computer typing.

I gratefully acknowledge the help received from the Geological Survey of India, North Eastern Region, Shillong for their help they provided in extracting important sources of information in geological studies of the study area.

I also extend my gratitude to the Research Laboratory, Department of Agriculture, Government of Meghalaya for their help in analysing the chemical characteristics of the soil and its textural composition.

Finally, I express my appreciation to the technical staff of the Department for their help and cooperation in completing this research work.

Dated Shillong,  
May, 2002.

  
( Laitpharlang Cajee )

## **LIST OF FIGURES**

Figure No. 1	LOCATION OF THE STUDY AREA
Figure No. 2	BASIN BOUNDARY
Figure No. 3	REGIONAL GEOLOGICAL MAP
Figure No. 4	GEOLOGY
Figure No. 5	CONTOUR
Figure No. 6	ABSOLUTE RELIEF
Figure No. 7	DISSECTION INDEX
Figure No. 8	AVERAGE SLOPE
Figure No. 9	DRAINAGE NETWORK
Figure No. 10	DRAINAGE DENSITY
Figure No. 11	DRAINAGE FREQUENCY
Figure No. 12	LANDFORM CLASSIFICATION
Figure No. 13	VEGETATION
Figure No. 14	PHYTO-GEOMORPHOLOGICAL RELATIONSHIPS

## **LIST OF TABLES**

- Table No. 1 Climatic Parameters of Khri Basin at different Altitudinal Heights.
- Table No. 2 General Stratigraphic Sequence of the Formation of Meghalaya Plate
- Table No. 3 General Stratigraphic Sequence of Khri Basin
- Table No. 4 Absolute Relief
- Table No. 5 Dissection Index
- Table No. 6 Average Slope
- Table No. 7 Relationship of Drainage to Lithological Condition
- Table No. 8 Drainage Density
- Table No. 9 Drainage Frequency
- Table No. 10 Landform Classes
- Table No. 11 Classification of Tropical Soils
- Table No. 12 Classes and Types of Soil structure
- Table No. 13 Physical Characteristics of the Soils of Khri Basin
- Table No. 14 Chemical and Physical Characteristics of the Soils of Khri Basin
- Table No. 15 Soil Rating Chart
- Table No. 16 Landforms - Soil - Plant Relationship of the most Dominant Tree Species
- Table No. 17 Multiple Regression - Dependant Variable: Height of Pine species
- Table No. 18 Correlation - Dependant Variable: Height of Pine species

- Table No. 19 Multiple Regression - Dependant Variable:  
Pine follicles**
- Table No. 20 Correlation - Dependant Variable:  
Pine follicles**
- Table No. 21 Multiple Regression - Dependant Variable:  
Height of Schima species**
- Table No. 22 Correlation - Dependant Variable:  
Height Schima species**
- Table No. 23 Multiple Regression - Dependant Variable:  
Schima leaf Size**
- Table No. 24 Correlation - Dependant Variable:  
Schima leaf size**
- Table No. 25 Multiple Regression - Dependant Variable:  
Height Litsea species**
- Table No. 26 Correlation - Dependant Variable:  
Height of Litsea species**
- Table No. 27 Multiple Regression - Dependant Variable:  
Litsea Leaf**
- Table No. 28 Correlation - Dependant Variable: Litsea Leaf**

## LIST OF GRAPHS

- |              |                                                                |
|--------------|----------------------------------------------------------------|
| Graph No. 1  | ANNUAL RAINFALL AND TEMPERATURE OF UPPER SHILLONG ( > 1500 m ) |
| Graph No. 2  | ANNUAL RAINFALL AND TEMPERATURE OF SHILLONG ( 1000 – 1500 m )  |
| Graph No. 3  | ANNUAL RAINFALL AND TEMPERATURE OF BARAPANI ( 500 – 1000 m )   |
| Graph No. 4  | ANNUAL RAINFALL AND TEMPERATURE OF BYRNIHAT ( < 500 m )        |
| Graph No. 5  | HEIGHT OF PINE – ALTITUDE                                      |
| Graph No. 6  | LENGTH OF PINE FOLLICLE – ALTITUDE                             |
| Graph No. 7  | HEIGHT OF SCHIMA SPECIES – ALTITUDE                            |
| Graph No. 8  | SIZE OF SCHIMA LEAF – ALTITUDE                                 |
| Graph No. 9  | HEIGHT OF LITSEA SPECIES – ALTITUDE                            |
| Graph No. 10 | SIZE OF LITSEA LEAF – ALTITUDE                                 |

## **LIST OF PLATES**

- |              |                                                             |
|--------------|-------------------------------------------------------------|
| Plate No. 1  | VIEW OF THE KHRI RIVER AT THE INTERFLUVE                    |
| Plate No. 2  | KHRI RIVER AT WARMAWSAW                                     |
| Plate No. 3  | ROADSIDE CUTTING AT KYNRUD                                  |
| Plate No. 4  | ROADSIDE CUTTING AT KHAWAI                                  |
| Plate No. 5  | EXPOSED QUARTZITE ROCK AT KYNRUD                            |
| Plate No. 6  | ROADSIDE CUTTING AT KYNRUD EXPOSING QUARTZITE               |
| Plate No. 7  | GRANITE MASS AT KYNRUD                                      |
| Plate No. 8  | WEATHERED GRANITE ROCK AT KYNRUD                            |
| Plate No. 9  | VIEW OF THE KHRI RIVER AT PATHARKHMAH                       |
| Plate No. 10 | VIEW OF THE KHRI RIVER DURING THE DRY SEASON AT PATHARKHMAH |
| Plate No. 11 | TRIBUTARY OF THE KHRI RIVER AT KHAWAI                       |
| Plate No. 12 | TRIBUTARY OF THE KHRI RIVER AT KHAWAI                       |
| Plate No. 13 | TRIBUTARY OF THE KHRI RIVER AT MAWIONG                      |
| Plate No. 14 | GROUND FLORA AT WARMAWSAW                                   |
| Plate No. 15 | SUB – TROPICAL FOREST COVER AT PATHARKHMAH                  |
| Plate No. 16 | DEGRADED PINE FOREST AT KHAWAI                              |
| Plate No. 17 | MIXED DECIDUOUS FOREST AT KYNRUD                            |
| Plate No. 18 | MIXED DECIDUOUS FOREST AT KYNRUD                            |

## CHAPTER-I

### INTRODUCTION

The term phyto-geomorphology can be defined as the study of relationships between the earth's relief features and the distribution of plant species. The subject matter laid emphasis on the importance of combining plants and landforms in studies related to the land surface of the earth and in recognition of their interdependence. Thus, in combination, the two form a powerful tool for the survey, management and planning of our environment. However there are more specific discipline-oriented studies that can benefit directly or indirectly from a phyto-geomorphic approach. It is observed that a balance between landforms and vegetation varies greatly. Thus an integral concept of geomorphology with vegetation to land-use planning though is relatively new, can highlight a number of aspects of renewing this world to a better place to live in<sup>1</sup>.

The history of related terminology is of interest in helping to place phyto-geomorphology in perspective and shows the frequency with which it had been necessary to coin new words and combination of words to express the earth – surface relationships and concepts. One of the earliest significant word is *physiography*, first introduced by Linnaeus, which, although less used today and succeeded partly by the term *biogeocoenose*, has retained the wider meaning of the study of all the earth's exterior features, including atmosphere and oceans as well as living things. *Geomorphology* is narrower and means the study of the origin and systematic development of all types of landforms, including their relief. *Relief* has a still narrower meaning and can be defined as the elevations and the surface undulations of the landscape.

The term *plant geography* was used by Schimper (1903) and Warming (1909), and *phytogeography* was termed by Croizat (1952) as a general term for the study of geography of plants. In Europe this term is now known as *floristic*

*geobotany*. Troll also suggested the term *Landschaftsoklgie (landscape ecology)* as early as 1939. He advised that the science it represented be used in conjunction with the interpretation of the aerial photographs as a means of exploring little known landscapes, and that this would be one of the most important directions for geographical research in the future (1971).

From the broader phyto-geographical standpoint, plant ecology was also termed as *ecological plant geography*. Warming (1909) subdivided plant geography into floristic plant geography and ecological plant geography. The former is concerned with the division of the earth's surface into major districts characterised by particular plant or taxonomic groups, whereas the latter seeks to ascertain the distribution of plant communities in relation to their habitats.

### **Literature Survey:**

Phytogeomorphology is an interfaced discipline between plant ecology, geography and geology. As a result, the study of phyto-geomorphology has attracted geographers, plant ecologists and also geologists each with diverse objectives. Originally the term geobotany was commonly used all over Europe or else referred to as traditional plant taxonomy. Around 1800 A.D Alexander von Humboldt expanded its use to cover the discipline of plant geography (Meyen 1846, Schimper 1898, Good 1939). In Europe the term has come to be applied to field botany (Grisebach, 1872; Rubel, 1930; Mueller – Dumbios and Ellenberg, 1974).

Several related works have been carried out in this field of study showing strong relationship to vegetation, landforms, soils, climate and the study of communities especially in relation to the higher levels of organisation through the efforts of Warming (1909), Bowman (1914), Clements (1916), Raunkaier (1934), Du Reit (1936), Beard (1944), Holdridge (1947), Smith (1949), Dansereau,(1951),

Croizat (1952), Bray and Curtis (1957), Wood and Williams (1960), Kuchler (1967), Strahler (1969), Tivy (1971), Webster (1977), Howard and Mitchell (1980), O' Hare (1988), etc. In the past few decades the term has also been used for the science concerned with the recognition of geological phenomena, particularly mineral resources, from their plant cover Sukachev and Dylis (1966), Brooks (1983).

Geomorphological studies of the late 19<sup>th</sup> Century and the early 20<sup>th</sup> Century had strong influence of geology. Around the middle of the 20<sup>th</sup> Century geomorphologists like Smith (1935), Kesseli (1946), Russel (1949), Bryan (1950), Kesseli (1950), Mather (1950), Hammond (1954), Kassel (1954), Hammond (1957), Ahnert (1962), Hammond (1962), Robinson (1963), Hammond (1965) etc strongly advocated an empirical or descriptive approach to Geomorphology. Zakrzewska (1967) opined that simple descriptive geomorphology is incomplete without the genetic information, for which integration of geology with geomorphology was a pre requisite. Significant contributions in these lines is also been made by Yakushova (1983)

On the other hand qualitative geomorphology was gradually incorporating quantification mainly through the efforts of Horton (1932), Smith (1935), Horton (1945), Strahler (1950a, 1950b, 1952a, 1952b), Thornbury (1954), Schumm (1956), Strahler (1957, 1958), Morisawa (1958), Chorley (1959), Scheidegger (1961), Chow (1964), Hammond (1964), Leopold et al (1964), Strahler (1964), Chorley (1966), Durry (1967), Doornkamp and King (1971), Young (1972), Gibson (1976), Hart (1986), etc. Indian geographers in the field of geomorphology have made significant contributions such as Singh (1969), Pal (1972, 1973), Singh (1974), Dikshit (1976), Soni (1984), Rai (1987), Singh (1991), Mitra and Rao (1993), etc.

In the field of pedology significant contributions have been made through the efforts of Birkeland (1974), Kalpage (1974), S.V.Zoon (1986), Hare (1988), Gerrard (1992).

With regard to the geology of the study area, Oldham (1858) was the first to document the geology of Khasi Hills region. Subsequently, Medicot (1869), La Touche (1883), Smith (1896), Palmer (1923), Evans (1932), Das Gupta (1934), Ghosh (1952), Banerjee (1964), Mathur and Evans (1964), Gogoi (1975), Mazumdar (1976), Murthy et al (1976), Mazumdar (1986) gave the geological account of the area. In the field of geomorphology not much work has been done in the study area. A comprehensive work has been done with regard to vegetation of the state of Meghalaya (Rao, 1971 and Joseph, 1981).

### **The Study Area**

The study area is found in Survey of India, Toposheet No.78 0/5, 6, 9, 10 with a scale of 2 cms = 1 km. (ie. RF 1 : 50,000) surveyed in the year 1966-67. The study area covers an area of about 1067.75 km<sup>2</sup> and the whole area is within the Khri Drainage Basin. The area approximately lies between 25° 32' N - 25° 57' N latitudes and 91° 20' E - 91° 45' E longitudes. The area studied is part of the Ri-Bhoi District, West Khasi Hills District and a very small portion of the study area falls within the East Khasi Hills as shown in Fig. No.1. The study area can be classed into 4 zones depending upon the altitude of the place where micro areal studies have been conducted. Kamrup District in the North, Bangladesh in the South, Jaintia Hills in the East and East Garo Hills in the West surround the study area.

# LOCATION OF THE STUDY AREA

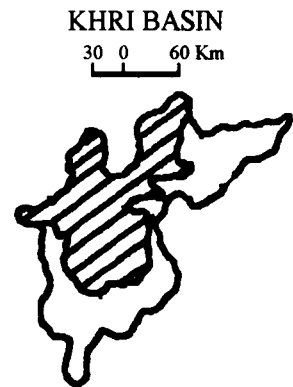
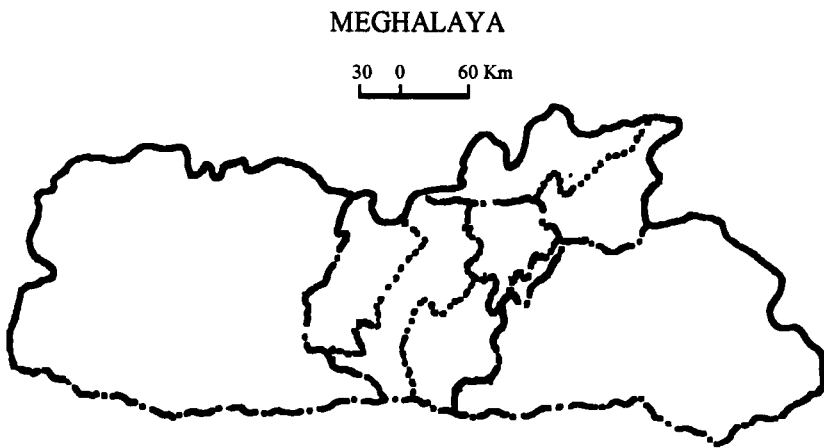
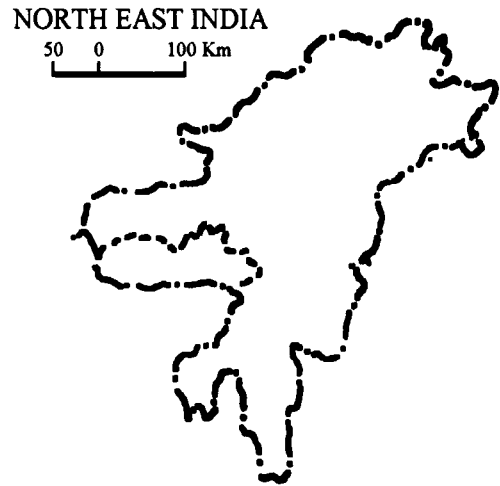
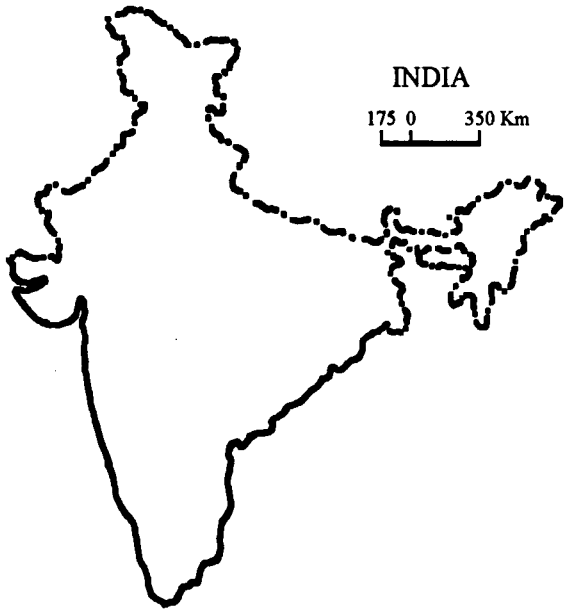


Fig No. 1

## **Statement of the Problem**

Phytogeomorphology offers a broad base synthesis of the important relationship between plants and landforms in studies related to the surface of the earth. Whereas the present landforms equally predate history, plant communities reflect interaction of current environmental factors.

Excluding those creatures that live wholly on the produce of the seas, all life depends directly or indirectly on a very thin mantle of the earth's surface. This is closely associated with geology, landscape and soil, which in turn reflect the operation of climate on the vegetation and the physical materials of the earth's surface<sup>2</sup>.

The whole mass of plant species is in a certain proportion to the different latitudes of the earth's surface. The proportion increases as we approach to the equator and decreases as we move away from it<sup>3</sup>.

In addition worldwide distribution of vegetation clearly mirror variations of climate-induced topography and topographically induced climate and also that plant communities influence local climate to a great extent. As a result vegetation modifies landforms though its effect on soil by penetrating through rock cracks and converting the parent rock material to the mantle of unconsolidated surface material called regolith. Thus their total effect is increasing soil depth and diminishing its movement<sup>4</sup>.

Civilisation can be defined as man's gradual conquest of his environment, but how far this process, in sober facts gave is a matter for careful thought. In some way, containing man's mastery over nature is complete enough where he exploited the resources of the mineral world to a remarkable degree but has been less

successful in establishing a relationship with the plant world which is the time basis of human economy. Naturally enough vegetation is as susceptible to man's destructive propensities as any other part of nature and in many respects it can be as easily exploited by him, but unlike the rest he cannot entirely bind it to his own will<sup>5</sup>.

However, it can be seen that plant-landforms relationship where studies on soil characteristics and parent rock material can throw a lot of light not only on many present-day questions and in lessening the limitations under which man labours, his inability to see into the future ?

Thus in the light of the above discussions the present study - **"Phyto-Geomorphology of Khri Basin", Meghalaya**, has been chosen.

### **Objectives of study**

Geomorphic processes and vegetation influence the development of the natural landscape. Therefore landform characteristics of the concerned area are an important aspect to be understood. So also is the distribution and characteristics of flora in relation to soil characteristics would require adequate consideration. However in other circumstances climatic variations may predominate. Thus the study focuses particularly on the study of landforms, soils and distribution of the dominant tree species. Keeping in mind with the discussions mentioned earlier, the objectives are formulated as stated below:

- i) to study the geomorphic attributes and landform characteristics of the area.
- ii) to describe the morphological characteristics of the major plant species
- iii) to correlate landform characteristics and morphological characteristics of the

dominant plant species in the study area.

## **Research Questions**

On attempting this study, a number of questions are set in the mind of the researcher.

(1) What are the geomorphic attributes of the study area ?

(2) What are the geomorphic attributes and how are they influencing the distribution of major plant species of the study area ?

## **Data Base**

Data used in the present study is broadly of two different types i.e. primary and secondary data. Since not much reliable secondary data is available for the study area, primary data is accounted to be the main source important for the study. Primary data was collected through a number of field visits the researcher undertook. Such data was collected from 10 (ten) different sample study villages situated within the basin. This entire process was performed through demarcation of 4 (four) micro-areas determined by altitudinal variation.

The Survey of India topographical sheets were largely used as they contain valuable information and are the base for the preparation of various thematic maps of the study area. For morphometric analysis, data was extracted from Survey of India, topographical sheets No. 78 O/5, 6, 9 and 10.

The soil samples collected from the field have been analysed at the Research Laboratory, Department of Agriculture, Meghalaya. The results of the physical (textural composition) and chemical characteristics of the soils have been ascertained.

# KHRI BASIN BASIN BOUNDARY (Sample sites)

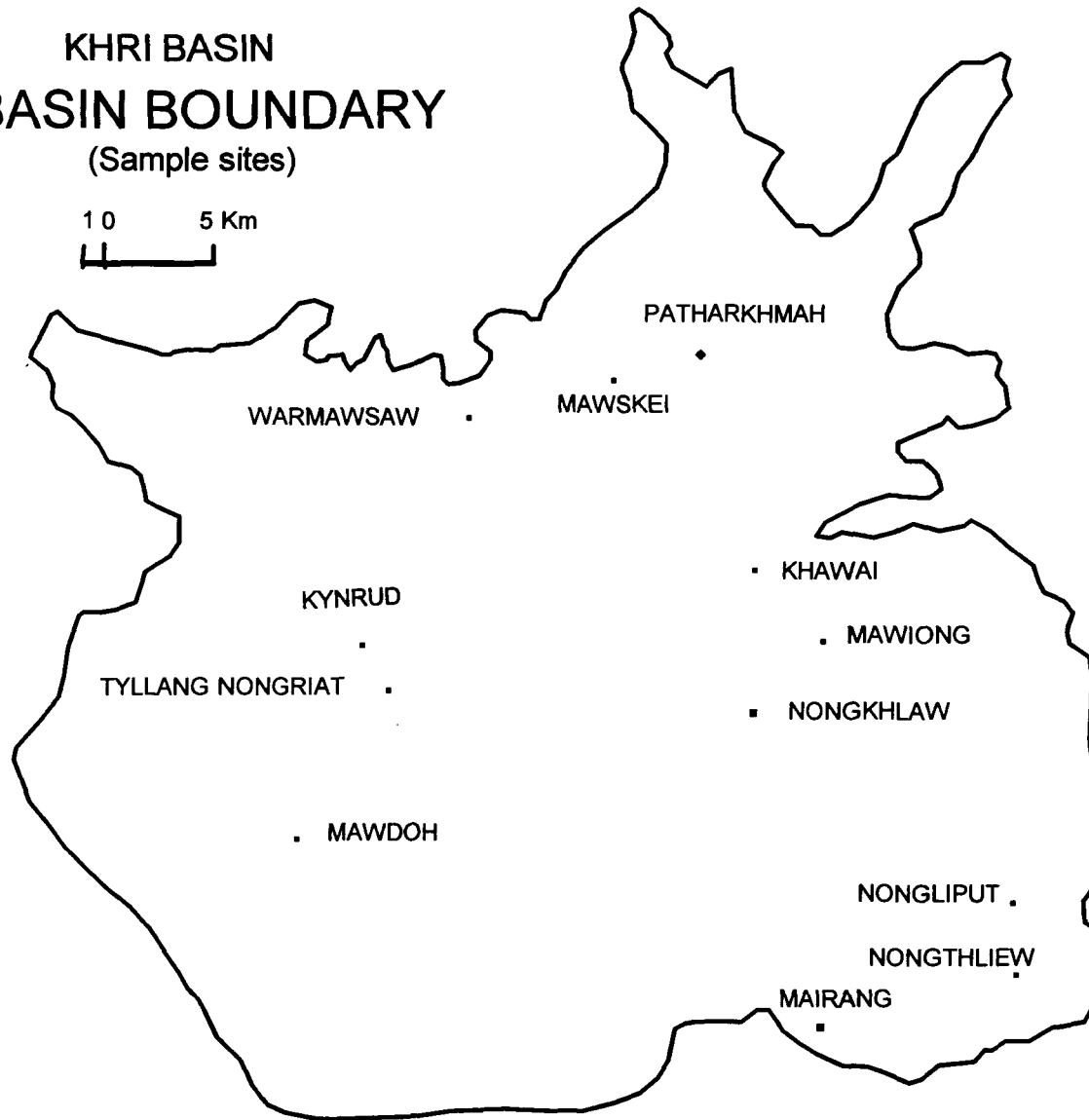


Fig No. 2

Secondary data was collected from different sources to supplement the various requirements needed in the present study. This was done in order to generate a general understanding on the various physical complexities present in the study area.

## **Methodology**

In the present study 2 (two) major methods are being used that is, (1) Field Methods (2) Laboratory Methods.

### **Field Methods:**

Field observations played a very important role in the present study where a general geographical personality have been accounted particularly to the various landscape formations, the dominant plant species of the area and certain physical properties of the soils like colour, texture, shape and type.

In addition a field survey of the morphological characteristics of the major plant species was taken into account and also the selection of the 4 different types of micro-areas particularly on the basis of altitude, temperature variation and vegetation was chosen.

### **Laboratory Methods:**

The topographical sheets served as a vital source of information about the basin. The morphometric techniques used reveal number of facts important for understanding the landform characteristics of the basin. Survey of India, Topographical sheets No. 78 O/5, 6, 9 and 10 with R.F. 1 : 50,000 have been used to analyse relief, average slope, drainage, drainage density and drainage frequency

etc. Soil and vegetal studies were carried out in 10 (ten) villages which are sample areas of the research work. Soil samples were collected and analysed at the Research Laboratory, Department of Agriculture, Meghalaya. Studies of the morphological characteristics of the dominant plant species were carried out in the field.

### **Statistical Analysis**

Statistical methods like correlation and regression analysis have been used to establish a relationship between the geomorphic attributes, soil characteristics and the morphological characteristics of the dominant plant species of the study area. Most of the work depended on the information that have been collected and extracted where such information was converted into maps, tables, charts, etc.

The research work was divided into 3 (three) phases namely, pre-field, field and post-field phases. Each of these phases have their distinctiveness throughout the entire study.

### **Pre-Field Phase**

During this phase all preparations for the research work have been taken up. This involved a thorough reading and literature survey of the various relevant documents. At this stage draft map preparation from toposheets was also involved. Morphometric analysis such as relief, average slope, drainage density and frequency was done.

## **Field Work Phase**

Fieldwork involved the collection of various kinds of primary data from the sample sites and also their evaluation. This included the study of the morphological characteristics of the dominant plant species and the collection of the soil samples. Here certain physical characteristics of the soils were also ascertained such as colour, size and the general texture. Important and relevant photographs of the study area were also taken.

## **Post Field Work Phase**

This phase forms the terminal end of the research work. It is in this phase that maximum work is involved. The work starts with the compilation of the various data collected from the field and also secondary data derived from various records and documents. Data collected is then analysed and represented either in tables, charts or maps. The end part of this phase is the most important and involves enormous time and labour. This is the period when the writing starts and a number of changes, modifications and adjustments take its own shape.

## **Physical Setting**

The study area has diverse and varied topography that is highly dissected with irregular terrain. The area is also notable for its rolling uplands intersected by streams and rivers and dotted by rounded hills, scarps, gorges, deep valleys etc. The study area have elevation ranging from 200 -1800 metres above mean sea level. The 4 (four) zones mentioned earlier could be termed "Uplands" and are broadly classified into 4 (four) divisions where each micro areal unit falls under each of these categories.

- (i) High Uplands (above 1500 metres)
- (ii) Mid-Central Uplands (1000 - 1500 metres)
- (iii) Low Uplands (500 - 1000 metres)
- (iv) Lowlands (below 500 metres)

The High Uplands are hilly and rugged associated with steep slopes. Small streams are seen to start arising from this areal unit. The streams cut through the rugged topography carving through the exposed rock surfaces. This areal unit is also marked with peaks reaching to 1800 metres in height i.e. Nongthliew Peak and is also dotted by rounded hills.

The Mid-Central Uplands have altitude ranging between 1000 – 1500 metres. Here the streams are wider and fast flowing cutting through the dissected topography. The drainage pattern within this areal unit is mainly dendritic in nature and a rolling type of topography showing the true nature of being a plateau. Scarps, cliffs and waterfalls are notable features and hills with rounded tops are prominent in this areal unit.

The Low Uplands have altitude ranging between 500 – 1000 metres. The slopes are gentle and the streams are almost parallel. Hills with rounded tops, scarps, valleys and ridges are commonly found.

The Lowlands have altitude ranging below 500 metres. Here the slopes are very gentle and undulating. In this area we encounter the meandering of streams that are slow flowing signifying the maturity of the river courses.

Thus in general we can say that the main physical features of the study area are the presence of hills with rounded tops, escarpments, cliffs, waterfalls, ridges,

valleys and low-lying areas with gentle and undulating slopes and a smooth skyline showing the true nature of a plateau with a rolling topography.

### **Geological formations**

T.Oldnam (1859)<sup>6</sup> was the first to make a geological study of the region. H.B. Medlicott (1869)<sup>7</sup>, Godwin Austin (1869)<sup>8</sup>, La Touche (1883, 1889)<sup>9</sup> and F.R. Mallet (1875)<sup>10</sup> carried out detail work with regard to a systematic Geological mapping of the region. Later workers namely R.W. Palmer (1923)<sup>11</sup>, C.B. Fox (1936-38)<sup>12</sup>, V.R. Khedkar and P.N. Mukherji (1938-39)<sup>13</sup> and A.M.N. Ghosh (1936-39)<sup>14</sup> led establishment of stratigraphic sequence of different rock suits of the region.

A.C.Bhattacharya, G.Barman, B.K.Duara, C.Chakravarti, B.D.Adhikari, K.K.Sen and S.K.Srivastava have mapped the self-sediments of the southern parts of the plateau during the field trips from 1961-62 to 1972-73<sup>15</sup>. Their work led to the delineation of different litho-stratigraphic units of the Tertiary Self-Sediments.

Physiographically, the Meghalaya Plateau represents a remnant of an ancient plateau of Pre-Cambrian Indian Peninsular Shield, block uplifted to its present height of about 600-1800 metres above mean sea level. The kernel of the plateau is the exposed Archaean gneisses and schist covered in the central and the eastern parts by Pre-Cambrian quartzites and phyllites intruded later by younger granites and basic / ultra basic suites. Three major rocks had been identified in the study area, that is, gneiss, granite and schist. All these three major rock structures belong to the Shillong Group of Rocks that are overlying the Gneissic Complex. Gneiss was found to be the most common signifying that the rocks are very hard, resistant and are matured.

## **Climate**

The area experiences a tropical monsoon type of climate where maximum rainfall is received during the months of June to October accounting to about 85 % of the total annual rainfall. However a lot of temperature variations are accounted where the high altitudinal areas differ greatly from the low altitudinal areas. These differences do also occur in short distances depending on the differences in height and due to the nature of terrain and other local conditions. However it is accounted in the study that two major types of weather conditions prevail. The High Uplands enjoy temperate humid climatic conditions with harsh cold winters accompanied with strong winds, whereas as we move towards lowlying areas the weather conditions change and gets warmer. The Lowlands experience warm tropical to sub-tropical climatic conditions. The uniformity of the climatic phenomena is that the basin under study generally experiences a monsoonal type of climatic conditions throughout the year particularly during the months, May to the end of September.

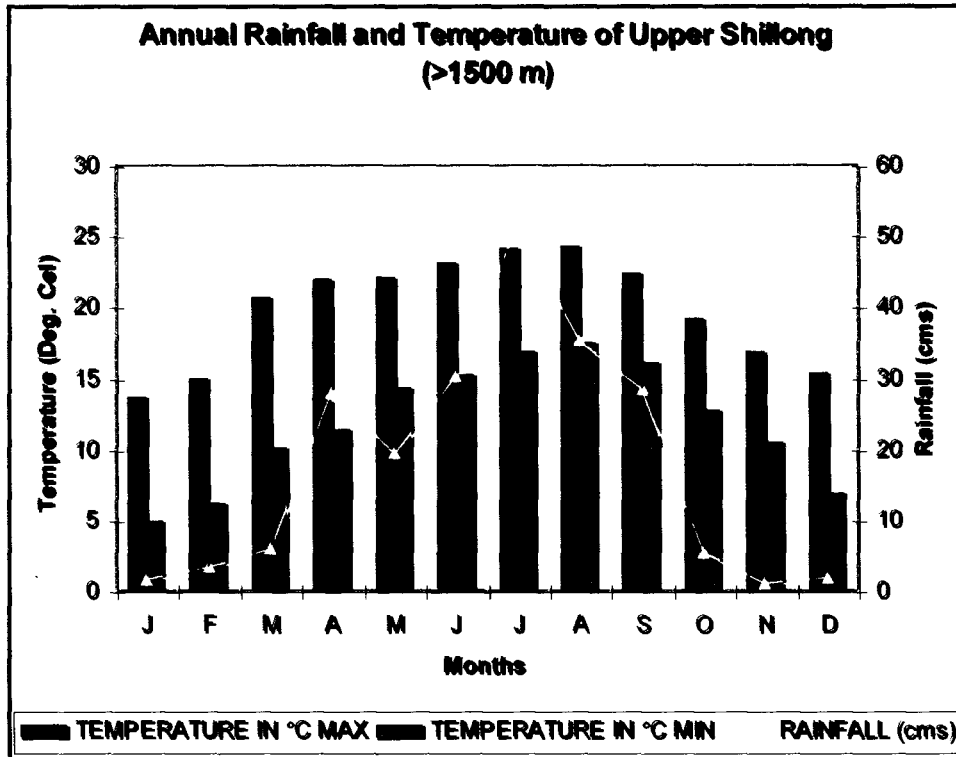
The basin has its own extremities in its relief with contours ranging between 200 – 1800 metres above the mean sea level, thus bringing about local changes in the weather conditions. The High Uplands experience cool summers and harsh cold winters whereas the Lowlands experience warm to hot summers and cool pleasant winter conditions. Table No 1 would give a clear understanding to the climatic conditions of the basin.

Humidity is comparatively high throughout the year. Highest humidity is felt during the summer months. The relative humidity during such month's reaches to 90 – 95 percent whereas during the winter months when the relative humidity is at it's lowest it reaches to 20 - 25 percent. Generally there are 4 (four) seasons in a year with short winters and long summers in the Lowlands of the basin and slightly longer winters in the High Uplands.

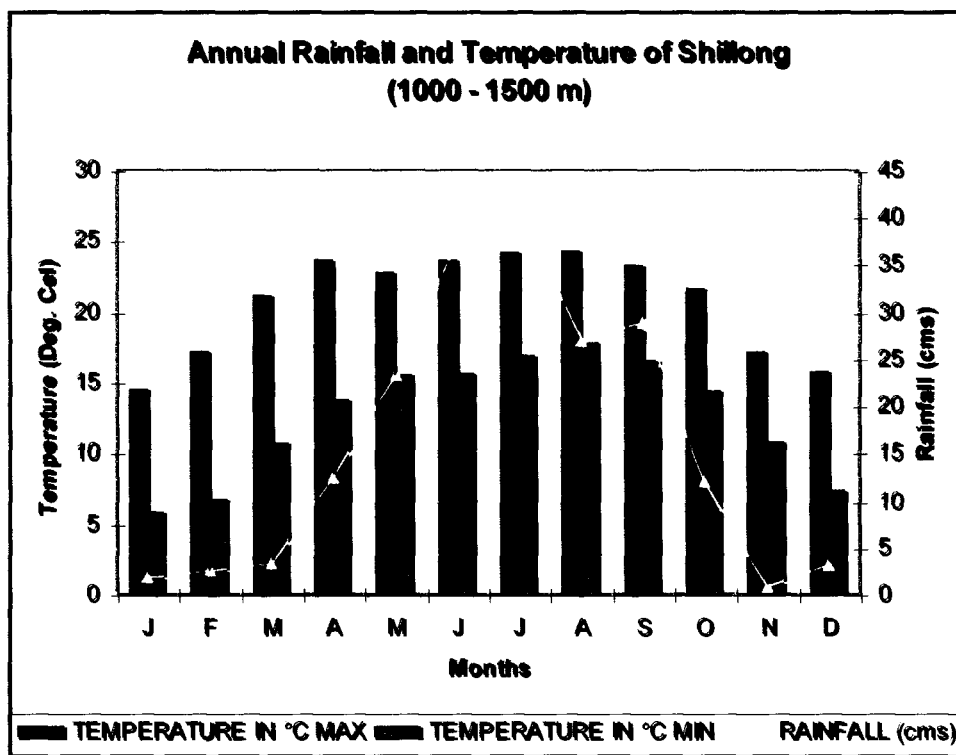
**TABLE No. 1 CLIMATIC PARAMETERS OF KHRI BASIN AT DIFFERENT ALTITUDINAL HEIGHTS**

MONTHS	CLIMATIC PARAMETERS AT UPPER SHILLONG ( 1500 > m MSL )				CLIMATIC PARAMETERS AT SHILLONG ( 1000 - 1500 m MSL )				CLIMATIC PARAMETERS AT BARAPANI ( 500 - 1000 m MSL )				CLIMATIC PARAMETERS AT BYRNIHAT ( < 500 m MSL )			
	TEMPERATURE IN °C		R.H %	RAIN (mm)	TEMPERATURE IN °C		R.H %	RAIN (mm)	TEMPERATURE IN °C		R.H %	RAIN (mm)	TEMPERATURE IN °C		R.H %	RAIN (mm)
	MAX	MIN			MAX	MIN			MAX	MIN			MAX	MIN		
JAN	13.7	4.8	76	16.1	14.5	5.8	72	17.9	18.5	6.1	65	24.3	14.8	12.2	79	2.1
FEB	14.9	6.1	72	33.4	17.1	6.7	64	24.5	18.9	8.1	60	20.2	17.3	14.8	81	21.7
MARCH	20.7	10.1	66	59.1	21.1	10.7	55	31.8	24.9	13.4	66	77.9	21.3	16.3	77	3.2
APRIL	21.9	11.3	84	278.1	23.7	13.7	65	123.3	24.4	14.2	80	249.8	24.6	17.4	70	3.4
MAY	22.1	14.3	75	193.7	22.7	15.5	79	231.8	26.9	17.2	73	237.9	26.1	18.2	83	191.5
JUNE	23.1	15.2	83	301.1	23.7	15.6	85	371.7	27.1	19.2	85	249.4	27.3	23.1	89	316.2
JULY	24.1	16.8	87	516.1	24.2	16.9	88	414.1	27.3	20.6	84	412.6	27.7	25.2	90	425.3
AUG	24.2	17.5	86	352.5	24.3	17.8	85	269.5	27.8	20.5	89	340.6	28.2	24.1	89	278.1
SEPT	22.3	16.1	87	282.8	23.2	16.5	83	288.5	26.1	18.7	88	465.1	26.6	24.6	86	184.1
OCT	19.1	12.8	77	53.3	21.6	14.4	80	120.2	24.6	14.1	79	124.3	23.1	20.4	80	31.2
NOV	16.9	10.5	76	9.4	17.1	10.8	73	7.9	22.6	11.9	81	35.1	19.6	16.3	78	12.7
DEC	15.3	6.9	79	18.1	15.7	7.4	72	30.2	18.9	8.9	55	48.9	15.6	13.9	78	8.1

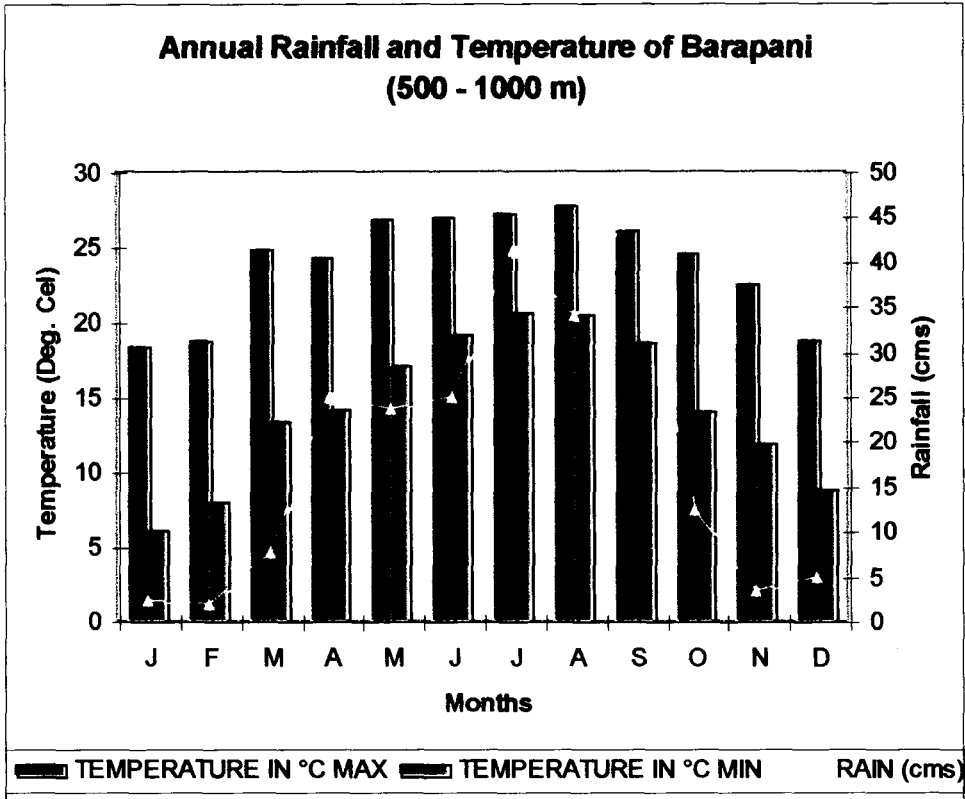
**GRAPH NO. 1**



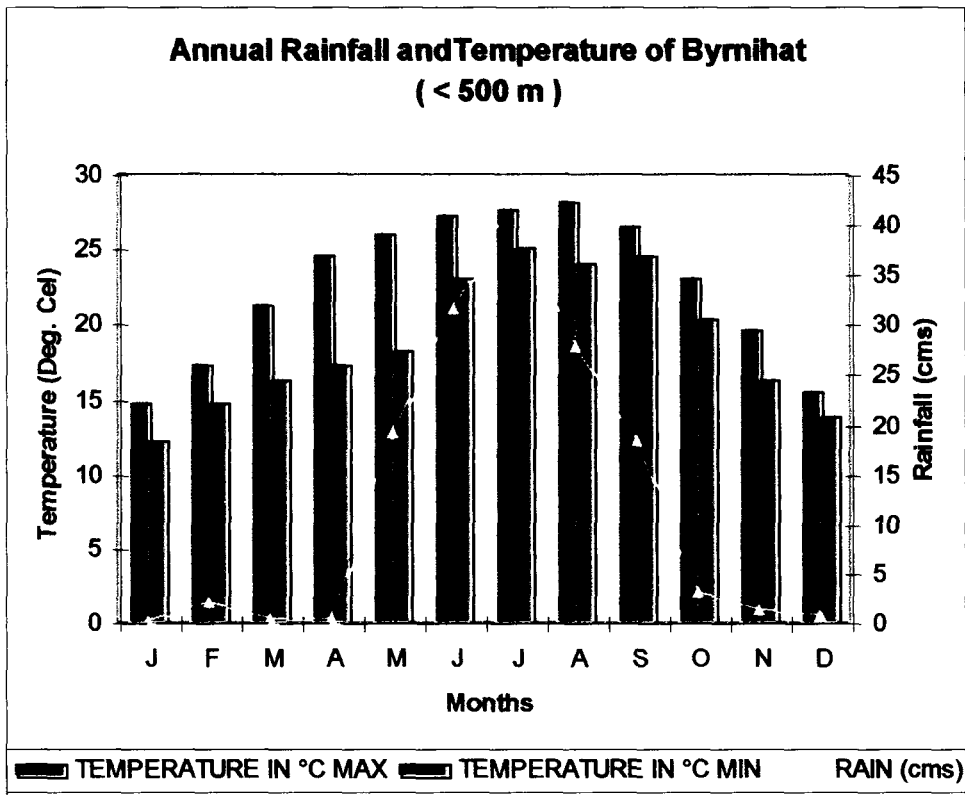
**GRAPH NO. 2**



**GRAPH NO. 3**



**GRAPH NO. 4**



**(i) Winter:** Winter starts in the third week of November in the High Upland areas and extends till the end of March whereas in the Lowlands winters are felt during Mid-December till the beginning of March. This season is usually a dry with abrupt showers accompanied with thunder and lightning at certain periods. The High Uplands experience frost cover throughout the winter season. During winters temperature goes as low as  $-5^{\circ}\text{C}$  in the High Uplands and barely crosses  $13^{\circ}\text{C}$  during the midday. On the other hand in the Lowlands the temperature does not go below  $8^{\circ}\text{C}$  and midday temperatures reaches to about  $20^{\circ}\text{C}$  on an average.

**(ii) Pre-Monsoons:** The pre-monsoon starts from around the middle of March till the end of May depending on altitudinal variations. Here temperatures start soaring high in the Lowlands with temperatures reaching to about  $30^{\circ}\text{C}$ . During this period the conditions are generally very dry and dusty as they are accompanied with strong winds. In the High Uplands the conditions prevailing are more or less the same but here the midday temperatures reaches to about  $18^{\circ}\text{C}$  and the nights are cold as the strong winds are icy cold. The basin experiences pre-monsoon showers during the month of April - May.

**(iii) Monsoons:** Monsoon starts during the first week of June and extends till the end of September. During this season the conditions are hot and humid with very sticky conditions prevalent in the Lowlands. Temperatures rise to about  $32 - 34^{\circ}\text{C}$ . Similar conditions are felt in the High Uplands but with more tolerable conditions where midday temperature reaches to about  $25^{\circ}\text{C}$ .

**(iv) Post Monsoons:** After the long monsoon rains follows a brief period of cool conditions before winter sets in. Mornings and evenings are generally cool occasionally accompanied by light showers. This season is brief and recedes by the end of November as the cold winter arrives.

## Soil

The soils vary all over the Meghalaya plateau both in physical and chemical characteristics. The soils are mostly lateritic in origin and vary from sandy loam, red loam to clay loam. The soils in the plains are comparatively more fertile than that in the uplands. In general three main types of soils are accounted i.e. Laterite, Ferruginous red soil, mountain and hill soils.

**Laterite soils:** This type of soil is derived directly from the residuary basic and intermediate igneous rocks produced through weathering in the warm and humid climates. These soils are deficient in potash, phosphorus and calcium.

**Ferruginous red soils:** These soils are poor in potash, calcium, phosphorus, nitrogen and iron oxide. Throughout the range the red soils differ greatly in depth and soil fertility.

**Mountain and hill soils:** This is the most predominant type of soil in Meghalaya. Here the percentage of organic carbon varies from 1 to 3, and the pH of the soil ranges from 4.5 – 5.5. These are mostly red loamy and lateritic in origin.

The dominant types of soils in the study area are that of Red Loamy Soils and Laterite Soils that are a result of the weathering of the exposed parent rock material such as granites, gnessis's, quartzite's, schist, conglomerates and dolerites which are rich in clay forming minerals, iron and aluminium. They vary from clayey to sandy loamy to loamy soils that are yellowish to brown to dark brown in colour. The soils of the low lying areas and valleys particularly those having loamy soils are the newly formed alluvial soils known as "Khaddar" where new layers are deposited year after year during the monsoon season. As the basin experiences humid climatic conditions, the formation and development of soils are similar to other

humid areas where cation exchange is high resulting to the acidity of soils. The type and structure of rocks also play an important role in the evolution of soils. Granite and gneiss dominate the basin and they are transformed mainly into kaolinite but the ferruginous concretions give such soils a reddish colour.<sup>16</sup>

## **Vegetation**

Natural vegetation varies from mixed tropical evergreen forests to that of temperate forests mainly based on altitude and rainfall distribution. The main tree species found in the study area are that of pines (*Pinus khasyana* and *Pinus insularis*), *shorea*, *schima*, *litsea* and *tectona* species. From the various areal units where vegetation is studied it was observed that as we move higher in altitude the shape of the leaves gradually becomes acute signifying that the leaves in trees in the lower elevations are broader thus having more canopy coverage rather than that at higher elevations. The tropical forests can further be classified into numerous subtypes such as evergreen, semi-evergreen, moist and dry deciduous forests, etc. These forests usually occur in high rainfall areas as well as near catchment areas. They harbour very rich species diversity forming a closed evergreen canopy. The temperate forests on the other hand occupy the higher elevations mostly along the southern slope of the study area. Such forests are having high rainfall with severe winters during the months of November to March. Ground frost is also common during the months of December – January.

## **Plan of Work**

The whole research work is organised into 7 (seven) chapters in which the detail plan of work of each of these chapters is given in the following paragraphs.

In the first chapter a general introduction of the topic is outlined which provides an insight into the research framework. This chapter includes the literature survey, statement of the problem, aims and objectives, along with some research queries, database, methodology, general geographical personality of the study area and a plan of work of each chapter.

The geological setup of the study area is dealt in the second chapter. It also includes the description of geology of the state of Meghalaya in general and the basin under study in particular.

The third chapter deals with the geomorphic attributes of the study area where a detailed description of the landform characteristics of the basin is discussed. Relief, slope and drainage aspects have been discussed in great detail in this chapter.

Chapter four deals with the soil characteristics of the study area. A detailed discussion has been worked out with regard to certain physical characteristics that include the shape, size, colour of the soil grains and a general textural classification of the soils have been analysed in the laboratory with regard to percentage composition of sand, silt and clay. The chemical characteristics of the soils have also been discussed in detail which involves the analysis of the composition of Organic Carbon which is the Nitrogen equivalent, Phosphorus and Potassium content. The pH value has also been found.

The fifth chapter describes the morphological characteristics of the dominant plant species studied in the 10 (ten) chosen sample villages. It includes the measurement of the average height of the matured plant, leaf size and pattern, nature of the bark, and such other related aspects.

Chapter six deals with the relationship between the geomorphological attributes, (relief, average slope and drainage density), soil characteristics (both physical and chemical) and the morphological characteristics of the dominant plant species. An insight on the role of the parent rock material that is the geological structure and other related aspects were also developed.

The last chapter gives the summary and findings with suggestions synthesised out of the research study.

## REFERENCES

- 1 & 2 : Howard J.A. and Mitchell C.W.** *Phytogeomorphology*. A Wiley-Interscience Publications; John Wiley & Sons 1985 pg.1 & 3.
- 3 : Meyen F.J.F.** (1846) *Geography of Plants*, London; Avishkar Publishers Reprinted 1986 pg.3.
- 4 : Howard J.A. and Mitchell C.W.** *Phytogeomorphology*. A Wiley- Interscience Publications; John Wiley & Sons 1985 pg.3.
- 5 : Good R.** (1974) *The Geography of Flowering Plants*, Longman Group Ltd. pg.1.
- 6 : Stratagraphical position of the Cherra sandstone, Assam.** The Records of the Geographical survey of India, Vol.IXXV presonal paper No.4(1940) pg.7.
- 7 : Spate O.H.K.** (1967) *India & Pakistan*.(3rd ed.) Methuen & Co. Ltd. pg. 15
- 8 : Oldham, T.** (1959) *On geological structure of a part of "Khasi Hills"* Mem;G.S.I. Vol.1, pg.99-210.
- 9 : Medlicott,H.B.** (1869); *Geological Sketch of the Shillong Plateau* Mem; G.S.I. Vol.7;Pt.1; pg.151-207.
- 10 : Godwin Austin, H.H.** (1869); *Notes to accompany a Geological Map of a portion of the Khasi Hills*, Journal,A.S.B. Vol.38. pt.2,1869.
- 11 : La Touche T.H.D.** (1883): *Cretaceous Coal resources in the Khasi Hills*, Rec. G.S.I. Vol.16, pg.164 - 165. (1839): *On Cherrapunji coalfields*, Rec. G.S.I. Vol.8, pt. 3, pg. 167 - 171.
- 12 : Mallet, F.R.** (1875): *Notes on Coal Recently found near Mawphlang, Khasi Hills*, Rec. G.S.I. Vol.8, pt.3.
- 13 : Palmer R.V.** (1923): *Geology as part of the Khasi and Jaintia Hills*, Rec. G.S.I, Vol.55, pt.2, pg.143-187.
- 14 : Fox C.S.** (1936 - 38): *General Report*, G.S.I., Rec.G.S.I., Vol.69, pt.1, pg.82-84, Vol. 71, pt.1, pg. 81 - 86, Vol.72, pt.1, pg.85 - 90, Vol.73, pt.1, pg.75-80. Vol.74, pt.1, pg.55-63.
- 15 : Khedkar, V.R. and Mukherji, P.N.** (1938-39): *Unpublished Progress Report of G.S.I. Assam.*

**16 : Ram M and Singh B.D (1993): "Soil Fertility Management in Farming Systems", Lecture Notes: Off-Camping Training on Farming Systems, Aizawl, Department of Agriculture Mizoram and ICAR Research Complex for NEH Region, Barapani, 1993. Pp. 47-48.**

## **CHAPTER-II**

### **GEOLOGY**

#### **INTRODUCTION:**

The Archaean basement of Meghalaya is a remnant of the northeasterly extension of the Indian Peninsula that had experienced frequent earth movements. This has led to complete folding and fracturing of the ancient rocks till Pre-Cambrian times. As a result the central part now covering the Eastern Khasi and Central Jaintia Hills developed into a trough over which the sediments of the Shillong Group of rocks are laid down. The sediments, later uplifted and folded, experienced low-grade metamorphism as a result of granitic (Myliem granites) and basic / ultra basic (Khasi greenstone) intrusion<sup>1</sup>.

#### **GEOLOGICAL INVESTIGATIONS:**

T. Oldham (1859)<sup>2</sup>, H.B. Medlicott (1869)<sup>3</sup>, Godwin Austin (1869)<sup>4</sup>, La Touche (1883, 1889)<sup>5</sup> and F.R. Mallet (1887)<sup>6</sup> made the first geological study of the region. They carried out detail work with regard to a Systematic Geological Mapping. Later workers namely R.W. Palmer (1923)<sup>7</sup>, C.S. Fox (1936 - 38)<sup>8</sup>, V.R. Khadkar and P.N. Mukherji (1938 - 39)<sup>9</sup> and A.M.N. Ghosh (1936 - 39)<sup>10</sup> led establishment of stratigraphic sequence of different rock suits of the region.

The Tertiary sediments of the southern parts of the plateau have been mapped by A.C. Goswami, M.K. Das, S.C. Talukdar, A.C. Bhattacharya, G. Barman, B.K. Duara, C. Chakravarti, B.D. Adhikari, K.K. Sen and S.K. Srivastava during the field seasons from 1961-62 to 1972-73<sup>11</sup>. Their work led

to the delineation of different litho-stratigraphic units of the Tertiary sediments.

### **STRATIGRAPHY:**

Physiographically, the Meghalaya Plateau represents a remnant of an ancient plateau of Pre-Cambrian Indian Peninsular Shield, block uplifted to its present height of about 600-1800 metres above mean sea level. The kernel of the plateau is the exposed Archaean gneisses and schist covered in the central and the eastern parts by Pre-Cambrian quartzites and phyllites intruded later by younger granites and basic / ultra basic suites.

During the post Pre-Cambrian till the Jurassic times peneplanation was observed which resulted to the formation of a flat level surface. Towards the end of the Jurassic period the southern end of Khasi Hills experienced eruption of plateau basalt, the Sylhet Trap through E-W fissures of which the Southern block subsided and the Northern block upheaved. However, the rate of subsidence gradually slowed down towards the Palaeocene – Eocene times. On the other hand upliftment of the Khasi Block resulted to the deposition of the oldest sandstone and limestone beds over the plateau and the younger ones along the Southern fringe of the plateau. The eastern Jaintia and Garo blocks experienced progressive downsinking in the later part of the Eocene period initiating the deposition of the coal bearing sandstone and limestone. However, major upliftment of the plateau as a whole started at the end of the Miocene period that resulted to the formation of land-locked shallow water lacustrine basins along the southern fringe of the Khasi and Garo Hills<sup>12</sup>.

The ancient (Pre-Cambrian) peneplained surface of the plateau is still preserved, with marks of different cycles of denudation, in the central and northern part. It is hidden in the Mesozoic traps along the central southern fringes and Cretaceous, Tertiary and Post-Tertiary sediments over the southern, south-eastern and south-western parts. Several rivers and a network of their tributaries and lateral streams dissect the plateau standing as a watershed between the Suma Valley of Bangladesh on the south and the Brahmaputra Valley in the north. The state of Meghalaya comprises of Khasi-Jaintia Hills and that of Garo Hills and is occupied by the following stratas of rock structures and complexes as shown in Fig No. 3.

- (i) Archaean gneissic complex, with acid and basic intrusives.
- (ii) Shillong Group of rocks.
- (iii) Lower Gondwana rocks.
- (iv) Sylhet Traps.
- (v) Cretaceous - Tertiary rocks.
- (vi) Quarternary and Recent Deposits

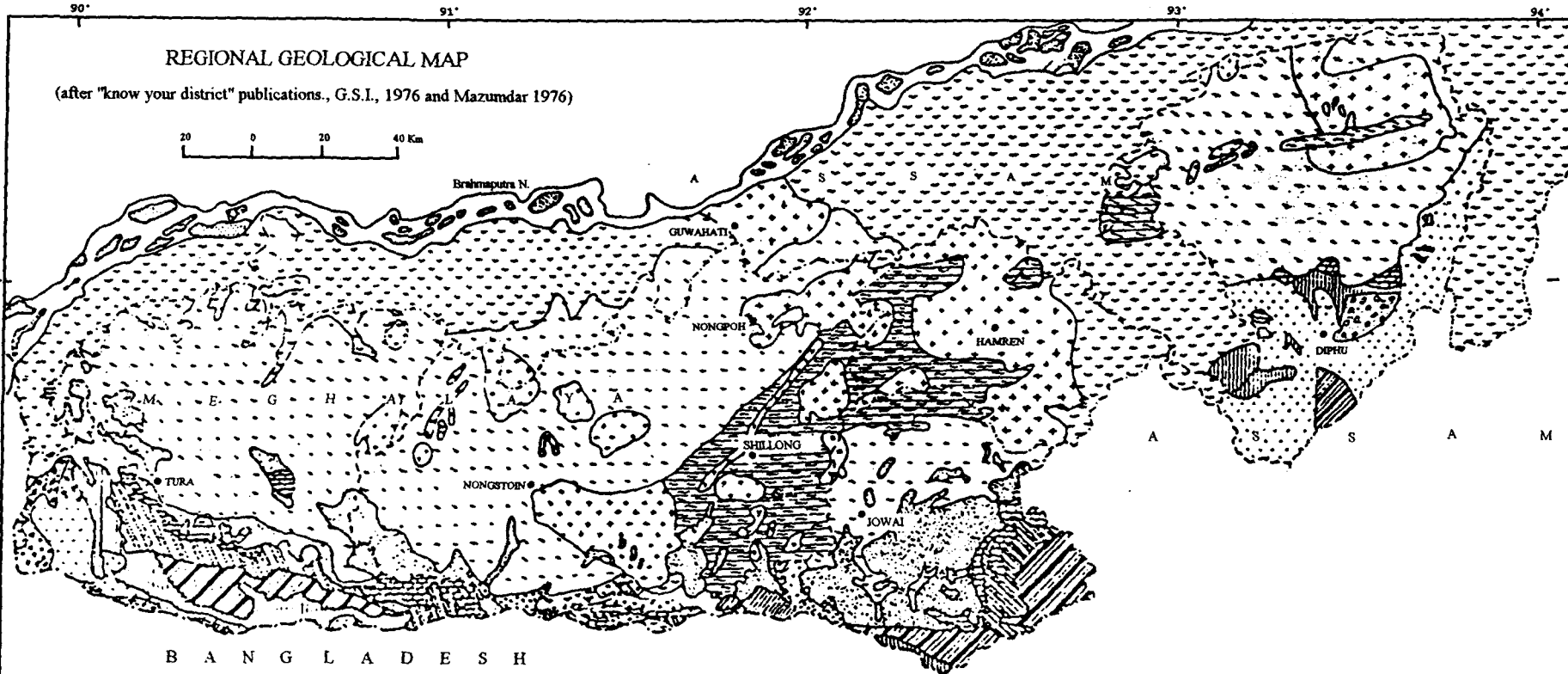
**(i) Archaean :**

The Archaean gneissic complex is exposed in the central and northern parts of the Meghalaya Plateau. The rocks are believed to be the northeastern extension of the Indian Peninsular Block, separated from it by the Garo-Rajmahal trough fault.

The rocks are composed predominantly of para and ortho-gneisses, migmatites and meta sedimentary bands. They comprise mainly biotite-gneiss, biotite-granulite, amphibolite, calc-granulite, banded-magnetite quartzite, etc. Some of the schistose rocks such as the biotite-schist, quartz-

# REGIONAL GEOLOGICAL MAP

(after "know your district" publications., G.S.I., 1976 and Mazumdar 1976)



## LEGEND

### JAINTHIA GROUP

- Alluvium (Undifferentiated) ... [Pattern]
- Dupitilla / Dihing Formation ... [Pattern]

### GARO GROUP

- Chengapara Formation (Tipam) ... [Pattern]
- Baghmara Formation (Surma) ... [Pattern]
- Simsang Formation (Barail) ... [Pattern]

- Kopili Formation ... [Pattern]
- Shella Formation ... [Pattern]
- Langpar Formation ... [Pattern]

### KHASI GROUP

- Mahadek Formation ... [Pattern]
- Jadukata Formation ... [Pattern]

- Alkaline - Ultramafic - Complex ... [Pattern]
- Sylhet Trap ... [Pattern]
- Lower Gondwana Group ... [Pattern]
- Granitoids ... [Pattern]
- Khasi Greenstone ... [Pattern]

- Shillong Group ... [Pattern]
- Gneissic Complex ... [Pattern]
- Quartz - Sillimanite Schist ... [Pattern]
- Quartz - Mica Schist ... [Pattern]
- Boundary International ... [Pattern]
- State District ... [Pattern]
- Riverine islands / sandbars ... [Pattern]

Fig No. 3

sillimanite schist, etc. occur as detached remnants over the older gneissic complex around Sonapahar. There is a possible presence of unconformity between these two groups of rocks.

The mafic rocks within the Archaean include - (a) Ortho-amphibolite, and (b) Meta-dolerite. They show mostly concordant and partly discordant relationship with the associated gneisses (Table No. 2)

**(ii) Shillong Group:**

The Shillong Group of rocks are exposed in the central and eastern parts of the Meghalaya Plateau, where current bedding is noticed in these rocks. These rocks generally lie unconformably over the gneissic rocks with a thick bed of conglomerate in the western part. These rocks generally strike in a NE-SW direction. The mildly folded sediments have suffered low-grade metamorphism and are dissected by numerous faults along which the different blocks move up and down during the Tertiary period.

Ultramafic and acidic sills and dykes intrude these rocks where the acidic intrusives comprise large bosses of granites with pegmatite and quartz veins<sup>13</sup>. The granite intrusive along the axial region of the Shillong Group of rocks around Mylliem is termed as Mylliem granite. Several other granite bosses include the South Khasi batholith, Kyllang pluton etc that are intrusive into the gneissic complex in different parts of the plateau.

**(iii) Lower Gondwana:**

Lower Gondwana rocks identified at Singnimari in the Garo Hills, consist of pebbles beds, sandstone and carbonaceous shale with streaks and

**Table No.2 : General Stratigraphic Sequence of the Formation of Meghalaya Plate<sup>14</sup>**

Geological Age	Group Name	Formation Name	Rock Types
Recent	Newer Alluvium (thickness not known)	(Unclassified)	Sand, silt and clay
UNCONFIRMITY			
Pleistocene	Older Alluvium (thickness not known)	(Unclassified)	Sand, clay, pebble, gravel, and boulder deposits.
UNCONFIRMITY			
Mio-Pliocene	Dupitula Group(1050m)	(Unclassified)	Mottled clays, feldspathic sandstone and conglomerate.
UNCONFIRMITY			
Oligo-Miocene	Garo Group	Chengopara Formation(700m),	Sand, siltstone, clay, marl.
		Baghmara Formation (530m)	Feldspathic sandstone, pebble, conglomerate, clay, silty clay.
		Simsang Formation (1150m)	Shale, sandstone, marl.
Eocene	Jaintia Group	Kopili Formation (500m)	Siltstone - sandstone alternations, sand.
		Shella Formation (600m)	Alternation of sandstone - limestone.
		Langpar Formation (100m)	Calcareous shale, sandstone, limestone.
Upper Cretaceous	Khasi Group	Mahadek Formation (150m)	Arkose(glauconitic)
		Bottom Conglomerate formation(25m)	Conglomerate, arkose.
		Jadukata Formation (140m)	Sandstone – conglomerate alternations.
UNCONFIRMITY			

Jurassic	Sylhet Trap (600m)		Basalt, alkali basalt, rhyolite acid tuff.
-----UNCONFIRMITY-----			
Pre-Cambrian		Intrusives (Acid and Basic)  Shillong Group	Ponphyritic and coarse granites, aplite, quartz vein, epidiorite, dolerite, basalt.  Quartzite, phyllite, conglomerate.
-----UNCONFIRMITY-----			
Archaean		Gneissic Complex	Biotite-gneiss, Biotite - hornblende gneiss, granitic gneiss, migmatite, mica - schist, sillimanite - quartz schist, biotite - granulite - amphibolite, pynoxene - granulite, etc.

lenses of coal and impression of *Vertebraria indica*. The sandstone dips westwards and is intruded by dykes of dolerite.

**(iv) The Sylhet Trap:**

The Sylhet Trap is composed of plateau (flood) Basalt, exposed in a narrow E-W strip 80kms long and 4 kms wide along the southern border of the Shillong Plateau. The maximum exposed thickness is 550-600 metres. They apparently overlie the eroded Pre-Cambrian basement and are overlain non-conformably by the Upper Cretaceous – Eocene sediments. The sediments and the lava form a monocline. This becomes a flexure downwards and the sediments at the crest of the flexure have subsequently been eroded at places exposing the traps as inliers. The flexure at the Therraighat – Shella sector with its East – West axis changes along its trace westward to a high angle reverse fault through normal and vertical faults (Dawki fault) and marks the exposed limit of the Sylhet Traps to the south. To the North the traps at Therraighat are in contact with the gneisses, granites or Shillong Group of rocks along an East – West fault, termed the Raibah fault.

The Sylhet Traps comprise predominantly of basalts and minor alkali basalts, rhyolites and acid tuffs. The basalts occur as flows and are 5 – 7 metres in thickness. The alkali basalts occurs as flows in the Umiew gorge and in the Dwara gorge. Similarly rhyolites associated with the acid tuffs are also found in the Umiew and Dwara gorge.

**(v) Cretaceous- Tertiary Sediments:**

The Cretaceous-Tertiary sediments occupying the southern part of the Meghalaya Plateau are thick and extensive and are considered to be physically continuous with the Cretaceous-Tertiary sediments of the Bengal

Basin. The sediments are mainly of sandstone and shale (mudstone) with exception that of fossiliferous limestone that occurs as (i) discrete outliers and (ii) a continuous narrow belt fringing the southern margin of the State bordering the Bangladesh plains. Here the sediments are divided into two groups, i.e. (a) the Khasi Group and (b) the Jaintia Group.

The Khasi Group is a distinct arenaceous facies consisting of the oldest Jadukata formation, followed by the predominantly conglomeratic Mahadek formation.

The Jaintia Group is a calcareous facies (shelf facies) and is divided into 3(three) formations, namely, the Langpar, the Shella and the Kopili formations<sup>15</sup>.

The Jadukata Formation consists of alternations of conglomerates and sandstone. These rocks overlie nonconformably in the Sylhet Trap and their distribution is limited to the north of Raibah fault that formed the shoreline during their deposition<sup>16</sup>.

The Langpar Formation of the Jaintia Group overlies the Mahadek formation. The rocks consist of calcareous shale, sandy limestone and fine calcareous sandstone. The deposition of these sediments marks the beginning of a table shelf condition that was firmly established later with the deposition of the Shella Formation (600m thick) represented by alternating limestone and sandstone sequence.

The Shella Formation consists of three sandstone and limestone members beginning with sandstone over the Langpar formation. The Upper Sylhet limestone member has been traced northeastwards through Jaintia

Hills into the North Cachar and Mikir Hills and westwards into the Garo Hills. Undifferentiated sandstone termed Sylhet sandstone is traceable above the basement rocks, possibly representing the facies variant of the two lower limestone members.

The Kopili Formation overlies the Shella Formation and is about 500m in thickness. The rocks are alternations of thin sandstone and shale with rare and fossiliferous beds of limestone.

The Simsang Formation is the oldest formation of the Upper Tertiary sediments in the Garo Hills that conformably overlies the Kopili Formation. The Simsang Formation consists of a cycle of massive festoon cross-bedded sand, alternating with siltstone-sandstone units.

The Baghmara Formation conformably overlies the Simsang Formation in the eastern part of the plateau. It consists of irregular beds of coarse feldspathic sand with minor mudstone steaks, pebbles conglomerates, massive clay and silty clay beds and thin alternating beds of mudstone and finesand.

The Chengapara Formation, overlying conformably the Baghmara Formation, consists of poor cemented, fine-grained, micaceous sand, blue to brown siltstone and clays with a few thin marly beds at its base.

**(vi) Quaternary and Recent Deposits:**

Isolated patches of Older Alluvium overlie the Tertiary rocks along the Southern and Western borders of Garo Hills in isolated areas and along the southern fringes of Garo Hills. These deposits consist of beds of assorted

pebbles with coarse, loose sand and brownish clay. These rocks usually form exceptionally flat-topped low hillocks and mounds with red soil cover.

In the Garo hills, along the western border, Older Alluvium is found to occur at various levels, invariably along the abandoned river courses representing a kind of river terraces. Between Mahendraganj and Kalaichar, the deposit occurs only as thin remnants covering the Tertiary rocks over the lower flanks of the hills facing the Bangladesh plains to the west. The older Alluvium covers a considerable area between Mangkachar and Bairagipara over the eroded Barengapara beds of the Rangapani – Barkina – Garo – Doba hillocks. Isolated patches of this formation are also found covering the Boldamgiri and also over the low-lying hills along the Galwang – Sirigwil valley between Rajabala and Bhajarmara.

Along the southern border of Khasi Hills, the Older Alluvium mainly consists of assorted boulder deposits. Recent Alluvium is found in the river valleys of the northern foothill of Garo and Khasi Hills, along the western border of Garo Hills, and southern foothill of Garo and Khasi Hills. The Alluvium consists of fine silty sand and light to dark grayish clay with rare pockets and layers of coarse sand. The fine sand at places contains abundant minute flakes of mica and when extremely fine, resembles the weathered loose siltstone, as seen around Manicachar in the Garo Hills.

#### **GEOLOGY OF THE STUDY AREA:**

S.C Mehrotra and P.R Golani (1984-85) in their study on the lithology of the area around Warmawsaw (Topographical sheet No. 78 <sup>0</sup>/<sub>9</sub>) identified that the area studied comprises mainly of Pre-Cambrian gneisses and granites. The massive quartzite is sheared. Current-bedding and a thin

impersistent conglomerate horizon are also observed at the bank of the Khri river. Large-scale synformal fold is also noticed around the area. The area studied include Kamrup district of Assam and the adjacent areas of Khasi Hills district of Meghalaya identifying that it forms a part of the Archaean Gneissic Complex and the Pre-Cambrian Shillong Group which possibly run towards the North under a vast stretch of alluvium of the Brahmaputra.

A.B.Dutta, G.V.K. Rao and S. Kannon carried out a systematic geological mapping of 660 km<sup>2</sup>, (Topographical sheet No. 78<sup>0/5</sup>). The terrain is a part of the Archaean Gneissic Complex of Meghalaya Plateau where the youngest rock is coarse, pink, porphyritic granite and the older suite is para and ortho-metamorphic rock with considerable extension. The crystalline to massive magnetite bands vary in thickness from about 1mm to over 10cms. One band of actinolite schist is found associated with iron rich amphibole bearing rocks. A series of tight isoclinal folds with nearly vertical axial plane trends NNE-SSW on which is superimposed a second generation of open cross-folds with NE-SW axial trend. One fault could be identified which brings the porphyritic granite in juxtaposition with banded magnetite quartzite. The banded magnetite-quartzite rock in Anadonga and adjoining hills may possess economic mineral deposits.

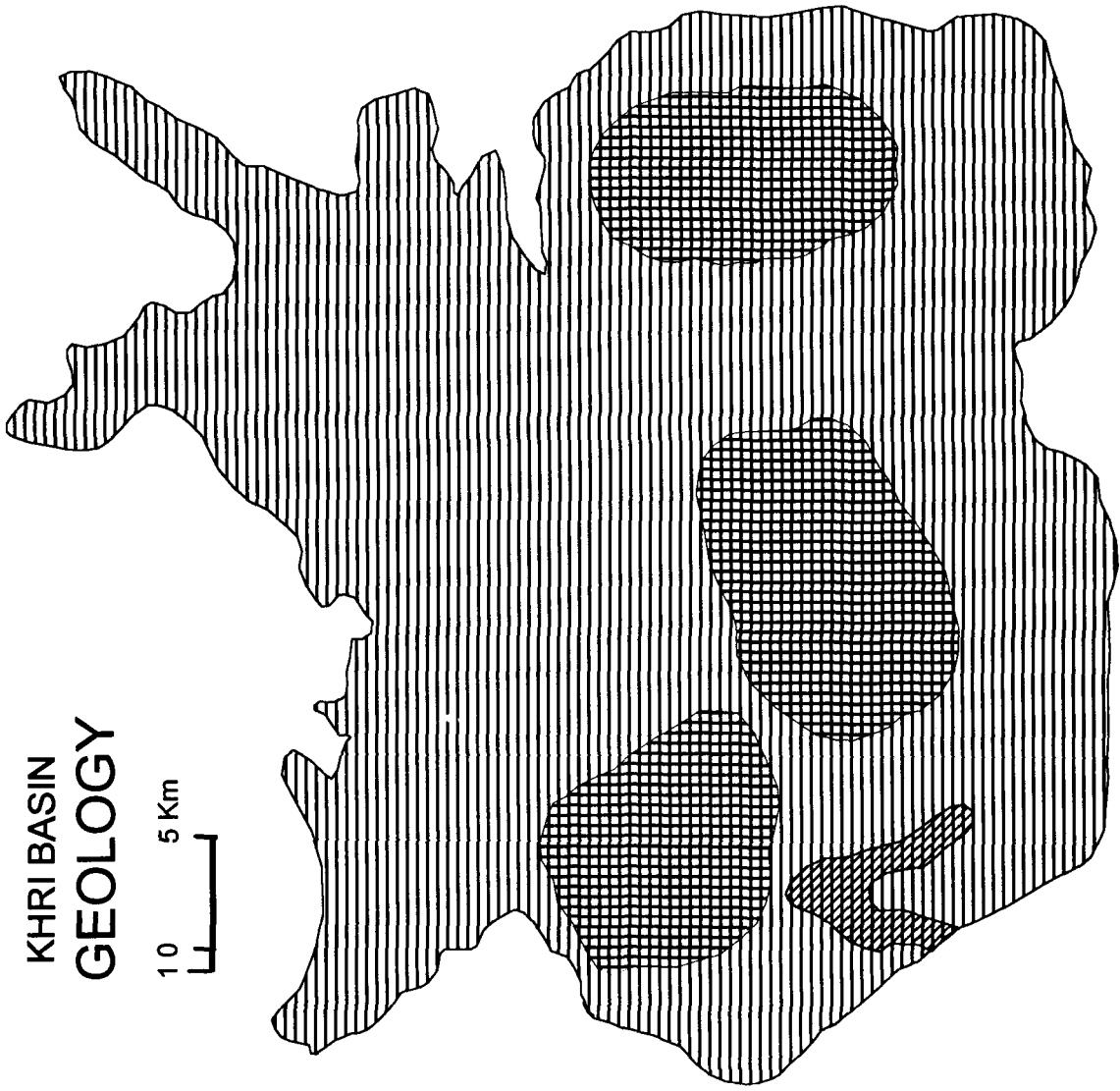
A.K. Roy Chowdhury and U. Bhattacharjee systematically mapped an area of 405 km<sup>2</sup> (Topographical sheet No. 78<sup>0/10</sup>). Major rock types exposed in the area are Archaean gneisses. Two patches of augu gneiss and three patches of mesocratic rocks of anthositic composition were also located.

M.K. Das (1965-66) studied and mapped the central part of the Shillong Plateau (Topographical sheet No. 78<sup>0/10</sup>) where the Archaean metamorphosis covering a large part of North-Western area includes

quartzite, quartz-mica, schist, pink granite schist to coarse biotite-gneiss and granite gneiss. These are intruded concordantly by the granite of Kyllang pluton, which occupies an area of about 80 km<sup>2</sup>, exposed within the Archaean Mass North-west of Mairang and north of Nongstoin. The Archaean gneisses includes quartz biotite gneisses and migmatites with bands of amphibolites, hornblende, gneiss, banded magnetite quartzite, mica schist that are traversed by granitic intrusions and younger basic dykes and quartz pegmatites veins. Away from the pluton the foliation is roughly NE-SW. Two types of granites are seen, the later porphyritic granite intruding into the earlier one in the northern part. A thick sedimentary conglomerate band of the Shillong series trends NE-SW with moderate to high south-easterly dips from Topang to beyond Sohpetbneng. There is a patch of coarse-grained, current bedded Cretaceous sandstone at the north of Mairang.

The geological map of the Khri basin as shown in Fig No.4 was extracted from Geological Survey India publication "Know Your District". Three major rocks had been identified in the study area, that is, gneiss, granite and schist. All these three major rock structures belong to the Shillong Group of Rocks that are overlying the Gneissic Complex. Gneiss was found to be the most common signifying that the rocks are very hard, resistant and are matured. These rocks were found to be present mostly in the High Uplands, Low Uplands and the Lowlands bringing about gentle to moderate slopes signifying the true nature of a plateau. Granites are predominantly found in the Mid-Central Uplands and in the other zones, are mostly confined to the parts where the main drainage basin passes through. Schistose rocks are found in a small pocket in the South-Western part of the study area. Studies undertaken by geologists reveal that the gneissic structure formed the basement of the rock stratum while the non-porphyritic granites, which

**KHRI BASIN  
GEOLOGY**



**INDEX**



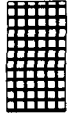
-  SCHIST
-  GNEISS
-  GRANITE

Fig No. 4

are intrusive in nature and a late entrant, occupy the north-eastern quadrant of the basin. Some patches of porphyritic granites have also been noticed.

**(i) Archaean:**

The Archaean metamorphics are represented by a variety of rock types that includes schistose and gneiss present near Mairang and Nongkhlaw. The contact between veins of granite and the metamorphics is quite sharp. The granite is well foliated where the foliation is parallel to the contact.

West of Nongkhlaw a very large number of rock types are identified. Here the rocks are coarse and sometimes become granitic gneiss. A considerable part of the area is predominantly that of Archaean gneissic complex. The following succession of the lithological units established for this part are (1) Alluvium (2) Basic Dykes (3) Pegmatite and Quartz veins (4) Granatoids and Migmatites (5) Granitic gneiss (6) Quartz-Sillimanite schist (7) Temolite-anthophyllite-amphibolite rock and (8) Hornblende-plagioclase gneiss (Grey banded gneiss).

The geological studies conducted in 1985 by the Geological Survey of India clearly indicate the following stratigraphic sequence in the basin<sup>17</sup>:

**Table No.3: General Stratigraphic sequence of Khri Basin**

AGE	GROUP NAME	ROCK TYPES
Pre-Cambrian	Intrusive	Very coarse grained porphyritic granites; khasi greenstone and granophyre dykes
		-----Intrusive Contact-----
	Shillong Series	Conglomerate, sandstone, shale, slate / phyllites
		-----Unconformity-----
Archean	Intrusive	Non-porphyritic granite, Gneisses and schists with meta-quartzites amphibolite, etc.

It is noticed from the above table that the dominating rock type belongs to the Archean age. The gneisses of the area have medium to fine grains. They occur in combination with quartz, biotite or feldspar and sometimes with a band of schists<sup>18</sup>

**(ii) Granite:**

The granitic mass that occurs here largely is of a non-porphyritic variety, though there are patches of the porphyritic type. Its colour is generally grey and at times due to the presence of the pink feldspar there is a pinkish tinge<sup>19</sup>. The non-porphyritic granites are coarse grained in nature. On

the other hand the porphyritic ones have a number of enclaves of gneisses and schists. The porphyritic mass had been considered to be emplaced<sup>20</sup> during the post Shillong period, though the two were never in contact. Granites are intrusive into the gneissic complex<sup>21</sup>.

The schistose rocks occurring in this area are marked with thick argillite sequences accompanied by bands of granites which are resistant and form a prominent ridge. However, the gradual increase in the degree of metamorphism hinders the correct demarcation of the zone of contact between the gneissic structure and the schistose rocks<sup>22</sup>.

Gneisses and schists are the products of sedimentation. Presence of resistant gneiss in alternation with a comparatively soft and weathered prone schist have caused a ridge and valley topography in the mid-central portions of the basin<sup>23</sup>. The gneissic mass is highly deformed. Its subjection to the different forces has reduced it to a highly metamorphosed mass thereby leading to the loss of its primary characteristics. It has been found that other intrusives too have been meta- morphosed,<sup>24</sup> usually inferred as an important mineral zone common in granites<sup>25</sup>.

#### **GEOLOGICAL SETTING:**

The various litho units belonging to the Archaean gneissic complex are folded on regional schistosity into an ENE plunging Umpirtha synform and corresponding Patharkhamah antiform with a number of cross-folds on smaller scale developed on the limbs.

The major litho-assemblages encountered in and around Umpirtha area which corresponds to the Patharkmah – Mawskei – Warmawsaw stretch can broadly be classified into the following groups: -

1. Quartzo-feldspathic gneiss and granitoid, locally varying into gneissic granite with bands of amphibolite, enclaves of granulites and pegmatite veins
2. Quartz-biotite gneiss, often migmatitic in nature with interlayered bands and lenses of various amphiboles - rich basic granulites, carbonates and amphibolites.
3. Micaceous quartz-sillimanite schist.

In the Umpirtha synformal closure area, the youngest unit of micaceous quartz-sillimanite schist occupies the core, flanked on either side by quartz-feldspathic gneiss in most parts. The micaceous quartz-sillimanite schist is in direct contact with the quartzo-feldspathic gneiss. In other places, the micaceous quartz-sillimanite schist is underlain by quartz-biotite gneiss that in turn rests over the group of quartzo-feldspathic gneiss – fine grained granitoid etc.

#### **(i) Quartzo-feldspathic Gneiss with Granitoids and Granulites**

Megascopically the quartzo-feldspathic gneiss is a buff coloured, fine to medium grained rock with occasional concentration of biotite flakes defining the gneissic banding. Microscopically it shows a xenoblastic texture having aggregates of quartz, K-feldspar, plagioclase, biotite and little hornblende as main constituents with apatite and sphene as accessories.

Patchy exposures of fine to medium grained gneissic rock of granitic composition occur within this formation. Thin bands of granitoids have also been encountered cutting across the amphibole rich basic granulites that host the base metal mineralisation of the area in the borehole cores. These are in general medium to coarse-grained rocks with granoblastic texture, often with polygonised grain boundaries comprising quartz, plagioclase (oligoclase) and biotite. Broadly this could be classified as quartz-diorite. Small enclaves of enderbitic granulite are noted from within this group at a number of localities viz., 1km due NW of Bariganj in the roadside section about 0.5 km due west of Sokhitbam etc. (near Patharkmah). Enderbitic granulites composed of quartz-plagioclase-sillimanite-hypersthene and opaques with a granoblastic texture have been identified from few core samples occurring in close association with the amphibolites.

Occurrence of anorthositic rocks has been noticed in a quarry on the Umkangsiar-Warmawsaw road section about 3 km from Umkangsiar. These enclaves from within the quartzo-feldspathic gneiss horizon are composed of plagioclase (mostly andesine), melanite and pargasite with some epidote and opaques. Typical granoblastic texture with polygonisation of feldspar grains is characteristic.

#### **(ii) Quartz-Biotite Gneiss**

The typical quartz-biotite gneiss contains xenoblastic segregates of quartz, K-feldspar, plagioclase, sub-idioblastic biotite and phlogopite with magnetite, apatite and sphene as accessories. Few granite rich samples of quartz-biotite gneiss reveal the presence of quartz-plagioclase-cordierite-spinel-phlogopite and magnetite. Large porphyroblasts of garnet are replete with inclusions of magnetite. Often spinel and cordierite exhibit excellent

sympletitic intergrowth. Another variety of quartz-biotite gneiss is found to be fibrolite rich with equant polygonised grains of quartz along with plagioclase-biotite, little muscovite and opaques. At places the gneiss are studded with large porphyroblasts of anthophyllite and cordierite.

Typical migmatites with enclaves of amphibolites and basic rocks (palaeosomes) within the quartz-biotite gneiss (leucosomes) have been noticed from a number of places viz. South of Bariganj and NE of Patharkmah.

### **(iii) Amphibole rich basic Granulites and other Associated Rocks**

Within the quartz-biotite gneiss unit a group of amphibole rich basic granulites and other related basic rocks with carbonates occur as impersistent lenticular bodies and band as a separate group host the polymetallic base metal mineralisation of the area. In an area with poor outcrops, only scattered boulders are seen on the surface, making it difficult to map the bodies and define their dimensions.

The basic granulites and related basic rocks are mostly very coarse to medium grained, dark green – greenish to grey in colour and massive in nature. These are devoid of any banding, schistosity or any other planar fabric. On the basis of detailed petrographic studies, mostly of the core samples, these basic assemblages could broadly be classified under the following categories.

(a) Medium to very coarse anthophyllite rich assemblage – often with hypersthene (clino-enstatite) and diopsidic augite, olivine and spinel. Chondrodite has been identified in few sections along with cordierite. Veinlets

of serpentine are sometime seen in hypersthene. Some muscovite, which are retrograde products, are noticed in rare instances. Orthoamphiboles are characterised by development of kink bands and are chloritised at places. Another characteristic assemblages closely associated with this type is that of anthophyllite, phlogopite and talc. The distribution of various minerals within this unit is in homogeneous – at places forming almost a monomineralic assemblage of very coarse anthophyllite reaching upto (5 x 2) cm blades occurring as randomly oriented aggregates.

(b) Fine to medium grained cummingtonite rich assemblage often with large (upto 5 cm long) needles of anthophyllite, rare diopside and carbonates.

(c) Actinolite-termolite rich assemblage with biotite in varied proportion, diopsidic augite at many places, rare anthophyllite and cummingtonite.

#### **(iv) Carbonates**

Closely associated with the basic granulites bands (upto about 3 metres) of carbonates have been encountered in a number of boreholes over a strike length of about 500 m. These carbonates composed of calcite, olivine, spinel and tremolite are coarse crystalline rocks with granoblastic texture. The individual calcite grain shows polygonised grain boundaries. At places thin olivine and spinel rich layers alternate with carbonates are encountered. Olivine is serpentinised along fractures. Small aggregates of radiating termolite are seen at places. Chondrodite is a common constituent with little muscovite and chlorite.

#### **(v) Micaceous-Quartz-Sillimanite Schist**

This unit overlies the quartz-biotite gneiss occurring at the synformal cores or in many cases as detached in the mapped area. In general the micaceous quartz-sillimanite schists are ochery red in colour and medium grained schistose rocks often with alternating sheafs of quartz-fibrolite aggregate and the quartz-mica rich layers defining the schistosity. The quartz-fibrolite aggregates often form flat knots which tend to be parallel to schistosity and define a group of mineral lineation. Microscopically this unit consists of quartz, fibrolite, little muscovite, plagioclase and at times cordierite. The fibrolitic felt often shows polygonal arching. Magnetite is a common constituent.

#### **(vi) Amphibolite**

Small bands of amphibolite lenses are found associated with all the major litho units of the area. These are a group of foliated dark grey coloured rocks showing intense crenulation and folding in mesoscopic scale. Veins of coarse hornblende with elongation perpendicular to vein boundary have been noted within the amphibolite. Some of the bore hole core samples contain appreciable quantity of magnetite, flattened parallel to schistosity.

Microscopically the amphibolites rarely preserve the relic sub-ophitic texture in the less schistose types. These are composed of dark green hornblende, plagioclase, minor quartz, biotite, epidote, sphene and magnetite.

In addition, thin bands (upto 1metre) of alkaline rocks viz. lamprophyres have been encountered in few of the boreholes associated with the quartz-biotite gneiss.

#### **DISTRIBUTION OF ROCKS TYPES:**

(i) *Hornblende*: Plagioclase gneisses are exposed in the west of Warmawsaw upto Mawdem, south of Mawblang and north-east of Rajabara. Small patches of this unit are intimately and inextricably mixed up with granitic gneisses in the East and South East of Warmawsaw.

(ii) *Quartz-Sillimanite Schist*: It occurs as lenticular bodies in hornblende plagioclase gneiss. The band is discontinuous with limited lateral extent. The band has been mapped about ½ km South of Warmawsaw village.

(iii) *Tonalitic Granulite*: It occurs as small bodies within quartz rich granitoid gneiss about 1½ km. Northeast of Warmawsaw quartz facies provide fresh surfaces. On weathered surface it appears as fine grained equigranular granite.

(iv) *Granitoid Gneisses*: Around Warmawsaw, Jakhong and Kulsai, it is quartz rich granitoid gneiss containing variable amount of biotite. At several spots the biotite layers are either widely apart or are altogether missing and the rocks appear as equigranular fine grained quartz rich granite with or without biotite. The rock is invariably rich in quartz and at places its content reaches upto 80%. Pink coloured granite - gneisses rich in microcline also occur in Upper Mawskei.

(v) *Amphibolites*: Amphibolites occur generally as concordant bands within quartz rich in granitoid gneisses. Amphibolites present in the rocks are either hornblende or tremolite - actinolite. The latter usually occurs as massive rock and has been recorded at four places, i.e. 1 km NE of Warmawsaw, 3 km east of Nongdung and the Northern band of Khri River and 1 km South of Mawskei. Hornblende bearing amphibolite occurs 1 km South of Langbi (673m spot height) and 1 km NE of Warmawsaw.

## **STRUCTURE:**

The gneissic foliation in the area shows a general trend ENE-WSW with dips moderate to steep in either direction. The gneissic foliation banding swerves round the hill around Warmawsaw. Small folds traceable with the help of their biotite layers also conform to its synformal structure. It increases towards ENE in the area 1km southeast of Umkangsiar around 1km south of upper Mawskei.

On regional scale the major structures around the area could be identified as Umpirtha synform and Patharkmah antiform with E-W axial traces. These major fold structures are defined by the major litho-units of quartzo-feldspathic gneiss, quartz-biotite gneiss and quartz-sillimanite schist.

Intense deformation subsequent to the formation of regional schistosity has resulted in development of two fold systems on surfaces with divergent axial trace. The dominant between the two is the one having ENE-WSW axial trace with varying amount of plunge and axial culminations and depressions. This fold system is characterised by development of crenulation foliation parallel to the axial planes of the puffers and mesoscopic folds. Most of the minor folds in the area that confirm to this category are generally northerly

overturned asymmetric and plunge  $45^{\circ}$  to  $50^{\circ}$  towards ENE. Associated with this fold system is also a group of mineral lineations which are defined by the dimensional orientation of flaky and prismatic minerals and flattened quartz-sillimanite aggregates developed in micaceous quartz-sillimanite schist and some times in fibrolitic quartz-biotite gneiss. These lineations plunging at moderate angle ( $25^{\circ}$  -  $40^{\circ}$ ) in the easterly direction show broad parallelism with other pucker and minor fold axes and in general may be correlated genetically with the second deformation episode.

In addition to the above mentioned fold form, detailed mapping in the area indicates presence of another fold system also developed in regional schistosity with almost N-S trending axial trace and plunging moderately towards south-east or at times having a reclined geometry. However in the absence of development of any axial planar structure related to these folds, it seems likely that these also belong to the same deformation episode.

## REFERENCES

- 1 : **Geological Survey of India, Misc. Publication No. 30** *Geology and Mineral Resources of the States of India- Part IV*: Glasgow Printing Company 1974.
- 2 : **Oldham, T.** (1959) *On geological structure of a part of "Khasi Hills"* Mem;G.S.I. Vol.I, pg.99-210.
- 3 : **Medlicott,H.B.** (1869); *Geological Sketch of the Shillong Plateau* Mem; G.S.I. Vol.7;Pt.I; pg.151-207.
- 4 : **Godwin Austin, H.H.** (1869); *Notes to accompany a Geological Map of a portion of the Khasi Hills*, Journal,A.S.B. Vol.38. pt.2,1869.
- 5 : **La Touche T.H.D.** (1883): *Cretaceous Coal resources in the Khasi Hills*, Rec. G.S.I. Vol.16, pg.164 - 165. (1839): *On Cherrapunji coalfields*, Rec. G.S.I. Vol.8, pt. 3, pg. 167 - 171.
- 6 : **Mallet, F.R.** (1875): *Notes on Coal Recently found near Mawphlang, Khasi Hills*, Rec. G.S.I. Vol.8, pt.3.
- 7 : **Palmer R.V.** (1923): *Geology as part of the Khasi and Jaintia Hills*, Rec. G.S.I, Vol.55, pt.2, pg.143-187.
- 8 : **Fox C.S.** (1936 - 38): *General Report*, G.S.I., Rec.G.S.I., Vol.69, pt.1, pg.82- 84, Vol. 71, pt.1, pg. 81 - 86, Vol.72, pt.1, pg.85 - 90, Vol.73, pt.1, pg.75-80. Vol.74, pt.1, pg.55-63.
- 9 : **Khedkar, V.R. (1938-39) and Mukherji, P.N. (1938-39):** *Unpublished Progress Report of G.S.I. Assam.*
- 10 : **Ghosh, A.M.N.** (1936-39): *General Report G.S.I*, Rec. G.S.I., Vol.71, pt.1, Vol.72, pt.1, Vol.73, pt.1, Vol.74, pt.1.
- 11 : *Unpublished Progress Reports on the Assam Circle*, G.S.I. for the field seasons from 1961-62 to 1972-73.
- 12 : **Geological Survey of India, Misc. Publication No. 30** *Geology and Mineral Resources of the States of India- Part IV*: Glasgow Printing Company 1974.

- 13 : Murphy, M.V.N, (1970):** Tectonic and Mafic Igneous Activity in North-East India in Relation to the Upper Mantle, of Second Symposium on Proc. II Symp Upper Mantle Project, Dec 1970, Hyderabad.
- 14 : Murphy, M.V.N; Chakravarty, G; and Talukdar, S.C. (1971):** Stratigraphic Revision of the Cretaceous – Tertiary Sediments of North Eastern India.Unpublished Paper Read in Seminar on Geology of North Eastern India, Held at Shillong in 1967.
- 15 : Das, M.K; Goswami, A.C; Talukdar, S.C; Mazumdar, S.K; and Murphy, M.V.N. (1967):** The Jadukata Formation the Eldest Formation within Cretaceous Shelf Sediments of the Assam Plateau.
- 16 : Geology of Khasi Hills Based on “Know Your District”,** Published by Geological Survey of India, 1976.
- 17 : Varma, P.P. & Rajendran, N. (1985) :** A Report on the Photo Geological mapping in the area around Nongkhlaw and South of Nongpoh, East and West Khasi Hills District, Meghalaya, GSI Unpubl. Reports, Shillong, p. 12.
- 18 : Ibid., p. 5.**
- 19 : Ibid., p. 5 – 9.**
- 20 : Ibid., p. 10.**
- 21 : Lasker, B. (1949) :** Preliminary Report on the Dam Site on Umtru River in Khasi Hills, GSI Unpubl. Reports, Shillong, p. 12.
- 22. Varma, P.P. & Rajendran, N., op. cit., p. 7.**
- 23. Ibid., p. 12.**
- 24. Bandopadhyay, D.N. (1978) :** Report on Systematic Geological Mapping & Preliminary Investigation in parts of Khasi Hills District ( Meghalaya, Nowgong & Kamrup Districts, Assam ), GSI, Unpublished Reports, Shillong, p. 6 – 7.
- 25. Moore, B. & Moore, C.B. (1982) :** Principles of Geochemistry, Wiley Eastern Ltd. 4 th Ed, N.Delhi, p. 138 – 139.

## **CHAPTER - III**

### **MORPHOMETRIC ANALYSIS AND GEOMORPHIC LANDFORMS**

#### **Introduction:**

The measurement and mathematical analysis of the configuration of the earth's surface and of the shapes and dimensions of its landforms provide the base for the interpretation of maps and geomorphological analysis. This is known as "Morphometry".

The basis of investigation is related to area, altitude, volume, slope, profile and texture of the land. Some of the methods were devised in the last century and a large number are the results of quantification of the present day. It aims for the sake of an articulate description of landscape configuration. However, there had been a significant development in the field of quantification and its application in Physical Geography. As a result geomorphologists have taken keen interest on the use of morphometric techniques to increase quantification of geomorphic attributes.

Miller (1953) commented that much is known from inspecting a map, but when it is all over, more information can be extracted by the use of "quantitative analysis and rearrangement of data".<sup>1</sup>

Monkhouse and Wilkinson (1969) commented "most of these morphometric techniques are concerned with slope and altitude, to the patterns of distribution provided by the dimensions of length and breath"<sup>2</sup>

However, morphometric analysis includes various techniques but only some of the most common and important ones have been used in this study. Thus only relief, slope analysis, stream ordering, drainage density and drainage frequency has been analysed and the prime source of information is derived from the Survey of India Topographical Sheets No. 78 O/5, 6, 9 and 10 having RF 1:50,000.

**Methodology:**

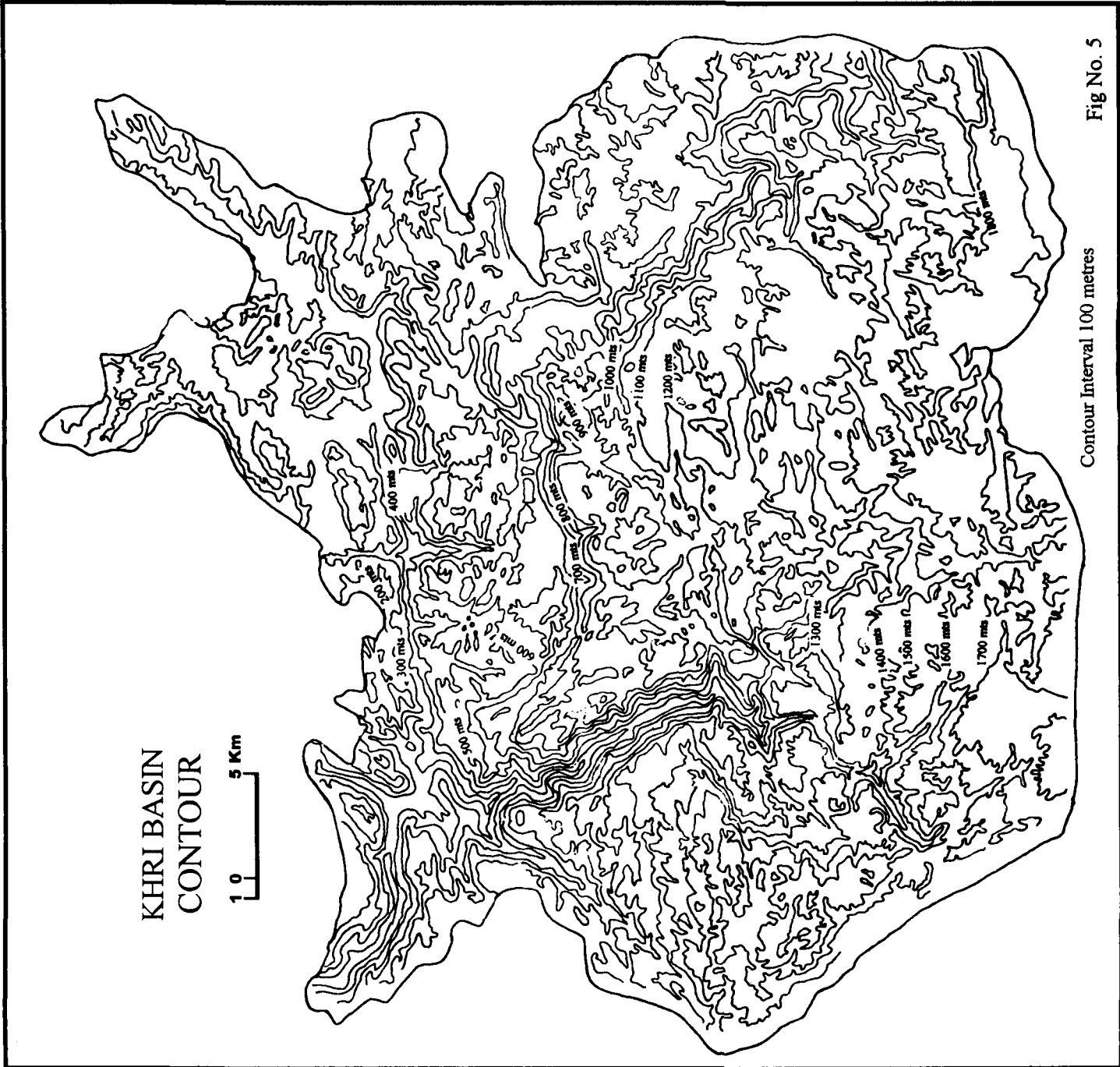
Field observation plays a very important role in the present study and the topographical sheets were inevitable for the extraction of vital information regarding relief, slope, and drainage that is analysed in this study.

To prepare a relief map, a contour map is used with 20 metres interval (Fig No.5) where four categories are depicted in accordance to their absolute height given in the original topographical sheet.

To prepare a dissection index the ratio between the difference of the maximum elevation and the minimum elevation to that of the maximum elevation of each grid (2 x 2) cms, substituted by the formula.

$$\text{Dissection Index (DI)} = \frac{(\text{Maximum Elevation} - \text{Minimum Elevation})}{\text{Max Elevation}}$$

The coefficient of dissection that is derived from the application of the above formula ranges from 0 - 1. The minimum indices that tend towards 0



**KHRI BASIN  
CONTOUR**

1.0 5 Km

Contour Interval 100 metres Fig No. 5

indicate that the area is less dissected while those that tend towards 1 indicate high degree of dissection. The area with the coefficient reaching 1 implies that the area is at base level.<sup>3</sup>

To calculate the average slope Wentworth's method has been used. According to this method the number of contour crossings are being counted and averaged for every kilometre. ( Scale of the topographical sheet is 2cms = 1km; therefore grids for the study area are prepared having (2x2) cms. which represents 1 km<sup>2</sup> ). The result derived from each grid is substituted by the formula

$$\text{Tan } \emptyset = \frac{N \times I}{636.6}$$

Where N is the average number of contour crossings per km<sup>2</sup>

I is the contour interval, and

636.6 is the standard value.

The constant number has been fully explained by Wentworth and its original form for the FPS measurement was 3361. This is derived from the multiplication of 5280 and 0.6366. The value 0.6366 is said to be the mean of all possible values of sin  $\emptyset$ , where  $\emptyset$  is the angle between the grid-lines and the contours. 1000 being the number of metres per kilometre replace 5280 represents the number of feet per mile and this enables the user of Metric sheet to apply the formula without many changes.

To calculate the drainage density, Horton's method has been used. Here the length of the stream channels from the Drainage Network (Fig No.9 ) is being measured for every square kilometre (km<sup>2</sup>) through the preparation of (2 x 2) cms grids. The result obtained is substituted by the formula given below so as to indicate the density per km<sup>2</sup>.

$$\text{Drainage Density} = \frac{\text{Total length of streams}}{\text{Total area}}$$

For determining the drainage frequency the same procedure is used but now the number of streams is counted occurring in each grid and is divided by unit area that is 1km<sup>2</sup>. It is represented by the formula <sup>4</sup>

$$\text{Stream Frequency} = \frac{\text{No. Of streams per km}^2}{\text{Unit area}}$$

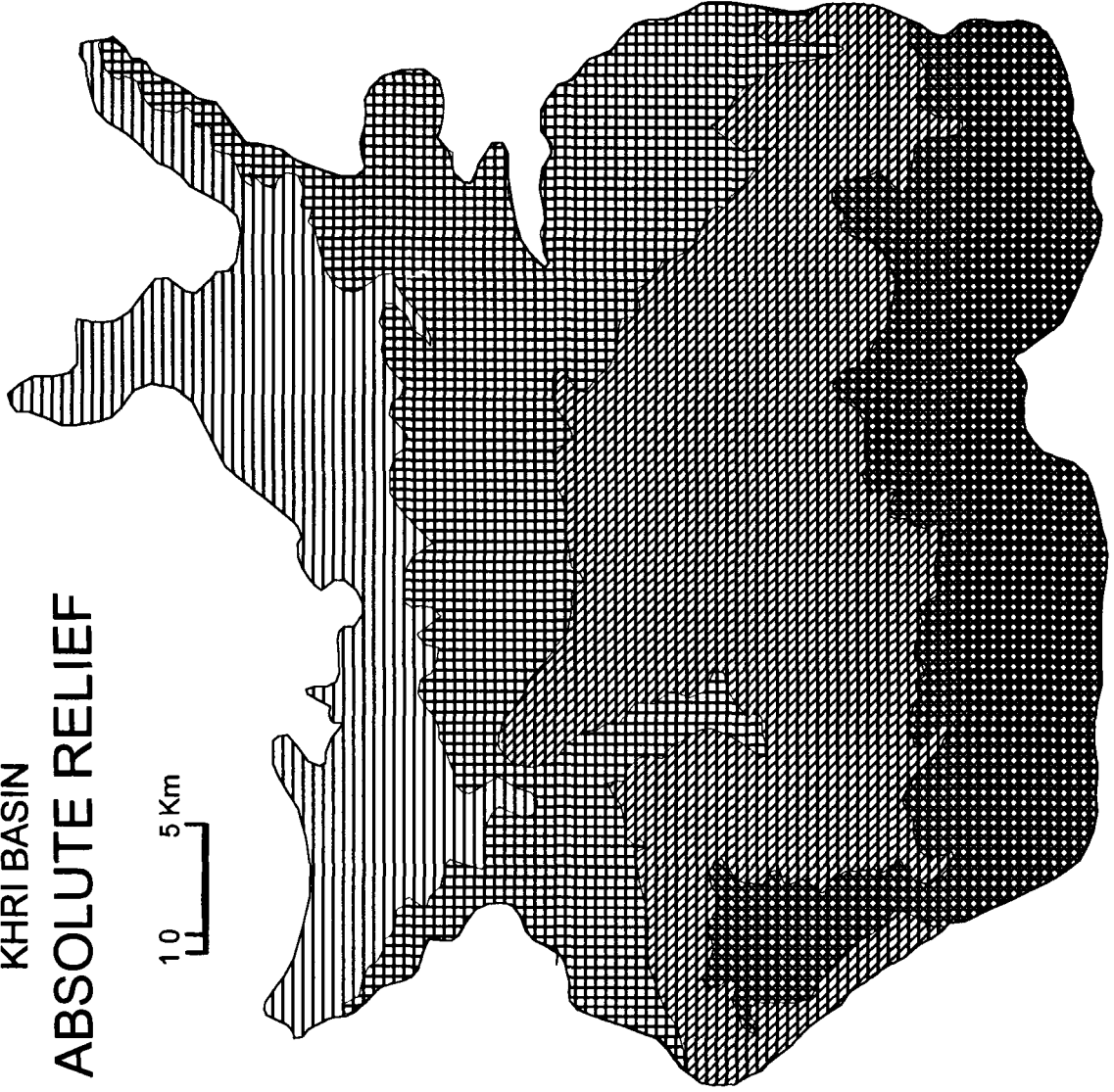
**Absolute Relief:**

The absolute relief map (Fig No.6) shows that the study area can be classified into 4 main zones i.e.

- (i) The high uplands (above 1500 metres) that cover the micro areal unit studied i.e. the Nongthliew – Nongliput stretch located at the south – eastern part of this zone. The high upland zone, which is found in the southern part of the Khri Basin, covers an area of about 250.75 km<sup>2</sup>. This zone is highly marked by gentle

**KHRI BASIN  
ABSOLUTE RELIEF**

10 5 Km



HEIGHT IN METRES

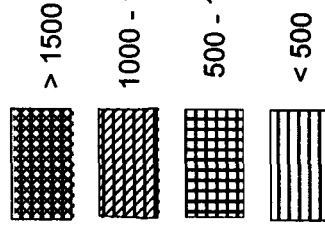


Fig No. 6

to moderately sloping hills, which rises to about 1800 metres showing the true nature of a plateau with rolling uplands.

(ii) The central uplands (1000 – 1500 metres) which covers the micro areal unit studied i.e. the Kynrud – Mawdoh – Tyllang Nongriat stretch is found located in the western central part of this zone. This zone is located all along the central southern part of the Khri Basin covering an area of about 343.25 km<sup>2</sup>. This zone is marked by steep hills. In the eastern most part the area is dissected by ravines, waterfalls and deep gorges and in the western most part moderately sloping hills are present. Other than these two parts this zone is somewhat smooth and undulating showing the true nature of a plateau with rolling uplands.

**TABLE NO.4 ABSOLUTE RELIEF**

<b>HEIGHT IN METRES</b>	<b>AREA (Km<sup>2</sup>)</b>	<b>PERCENTAGE (%)</b>	<b>CATERGORY</b>
> 1500	185.1	23.5	High Uplands
1000 – 1500	288.7	32.1	Mid-Central Uplands
500 – 1000	343.3	27.0	Low Uplands
< 500	250.7	17.3	Lowlands

(iii) The low uplands ( 500 – 1000 metres ) which covers the micro areal Mawiong – Khawai stretch is found located in the north - central part of this zone. This zone is located all along the central northern part of the basin covering an area of about 228.75 km<sup>2</sup>. In the north – western part, south – eastern part and southern most part of this zone we find steep hills dissected by deep narrow valleys, ravines, deep gorges, ridges, etc. Other than these 3 (three) parts the zone is marked by gentle sloping undulating hills.

(iv) The lowlands ( below 500 metres ) that cover the micro areal unit, the Patharkmah – Mawskei – Warmawsaw stretch is found located in the central part of this zone. This zone is located all along the northern part of the Khri Basin covering an area of about 185 km<sup>2</sup>. The western part of this zone is marked by steep hills surrounded by gentle sloping hills. Wide valleys are very common in the eastern and central parts of this zone. Other than these, very gentle undulating sloping land marks this zone.

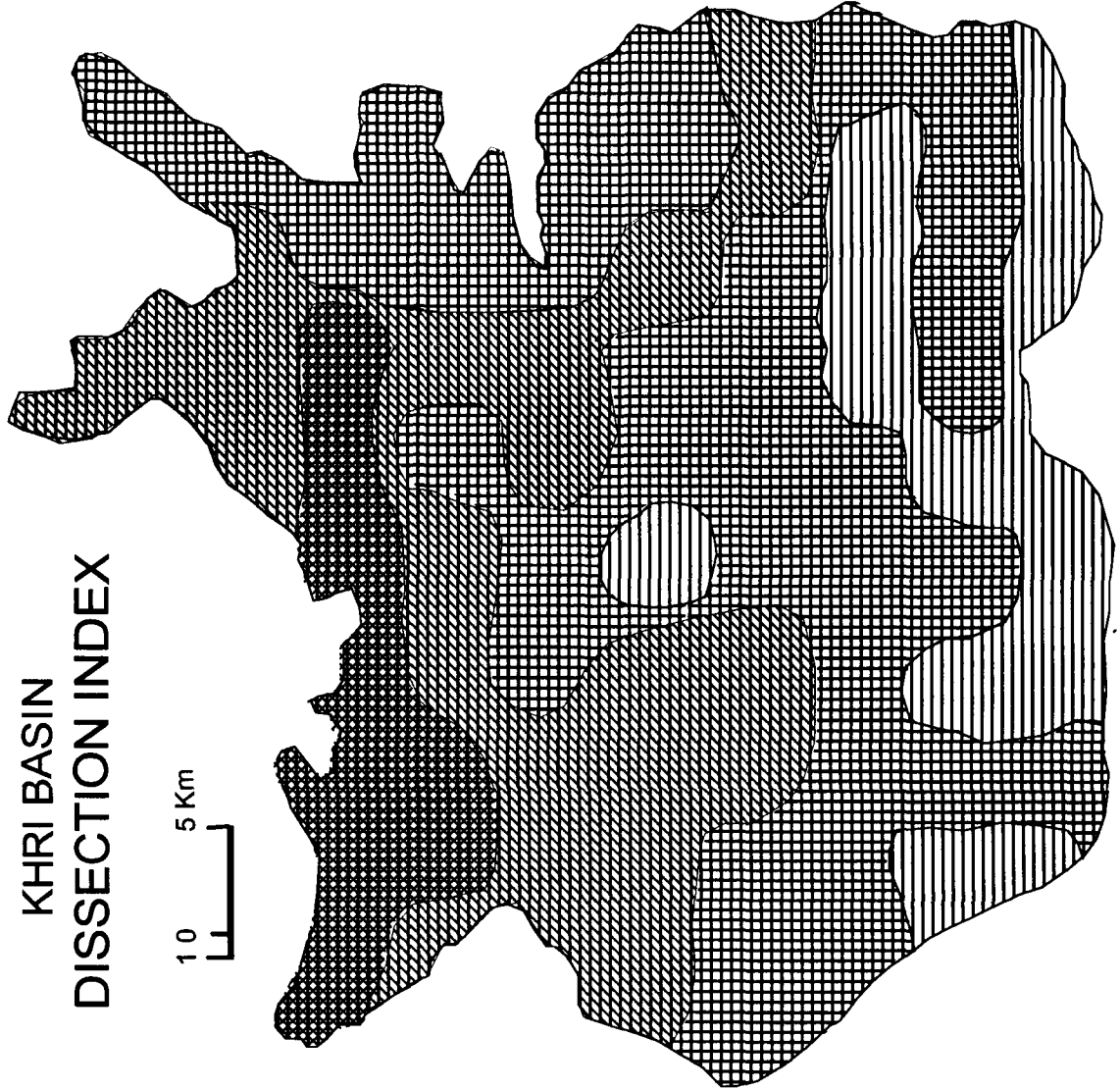
### **Dissection Index:**

From the calculations it is found out that the level of dissection within the Khri Basin varies from 0.1 to 0.8 which signifies that the basin is highly contrasting, where the level of dissection at some areas within the basin is at a low level comprising of about 55 %. On the other hand dissection at a high degree is found mostly at the low-elevated areas (below 500 metres) comprising approximately about 10 % of the basin area. This is largely because of the altitudinal variation, which ranges from about 100 metres to 1800 metres. However, it is noted that the level of dissection in general is seen to increase with lowering of altitude where minimum dissection is noted at the high uplands (Fig. No.7). On the other hand maximum dissection is noted at the lowlands particularly in the areas where the main river is flowing.

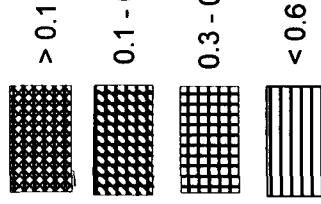
Secondly it is noted that drainage network is also responsible for determining the level of dissection in the Khri Basin. Also the level of dissection is directly proportional to the degree of density and frequency of streams. The analysis reveals that dissection is high at those areas where the higher stream orders are present and diminishes in the areas where the 1<sup>st</sup> and 2<sup>nd</sup> stream

**KHRI BASIN  
DISSECTION INDEX**

10 5 Km



**LEVELS OF DISSECTION**



**Fig No. 7**

orders are present. Thus it supports the fact that since the high-elevated areas which are in the southern part of the basin where only 1<sup>st</sup> and 2<sup>nd</sup> order streams are mostly present that the level of dissection is low. In comparison to low elevated areas found mostly in the northern part where 3<sup>rd</sup>, 4<sup>th</sup>, 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup> ..... order streams are present, level of dissection is much more higher. Fig. No. 6 would reveal a clear picture in this regard. From Table No.5 given below we observe that maximum dissection (above 0.6) is present in the lowlands (i.e. below 500 metres) contributing to about 9.9 % of the basin area corresponding to about 105 km<sup>2</sup> of the basin area. On the other hand it may be noted that about 56.75 % of the zone below 500 metres is highly dissected. This signifies the intensity of work of the Khri River at the lowland areas, thus showing high density and frequency of the said drainage system.

**TABLE NO.5 DISSECTION INDEX**

<b>INDEX</b>	<b>AREA (Km<sup>2</sup>)</b>	<b>PERCENTAGE (%)</b>	<b>LEVELS</b>
> 0.6	105.00	9.9	Highly Dissected
0.3 – 0.6	288.25	26.9	Moderately Dissected
0.1 – 0.3	513.00	48.1	Lowly Dissected
< 0.1	161.50	15.1	Negligible

Dissection of range between 0.3 – 0.6 occurs mainly in the low – uplands of the drainage basin and partly in the mid-central uplands and lowlands. This range contributes to about 26.9 % of the basin area spreading over 288.25 km<sup>2</sup> (approximately).

Dissection of range between 0.1 – 0.3 occur mainly in the mid-central uplands and partly in the low uplands, lowlands and also partly in the high upland region. This range contributes to about 48 % of the basin area spreading over 513 km<sup>2</sup> (approximately).

Lowest dissection that is below 0.1 occurs in the high uplands (i.e. above 1500 metres) and a small part in the mid-central upland contributing to about 15 % of the basin area. On the other hand it may be noted that about 58.25 % of the zone above 1500 metres is negligibly dissected. This signifies the low intensity of work of the Khri Basin at the high upland zone as this is the periphery of the drainage basin or otherwise the origin of smaller rivulets and streams. The only form of dissection is mainly the erosion of the soil top at high slopes being negligible in the overall activity of the 1<sup>st</sup> and 2<sup>nd</sup> order streams.

From the study we can conclude that in the study basin most of the areas are not highly dissected. However, we can infer from the results that there is a trend of progressive dissection through the intensity of rainfall especially during the monsoon season. This is the period when the streams are at spate eroding the soils of the streams carrying along with them a massive load and transporting the debris in the form of sediments down stream. Secondly we can also conclude that the belt of dissection with indices above 0.3 shows a continuous belt suggesting some kind of transition from one plane to another.

## **Slope Analysis:**

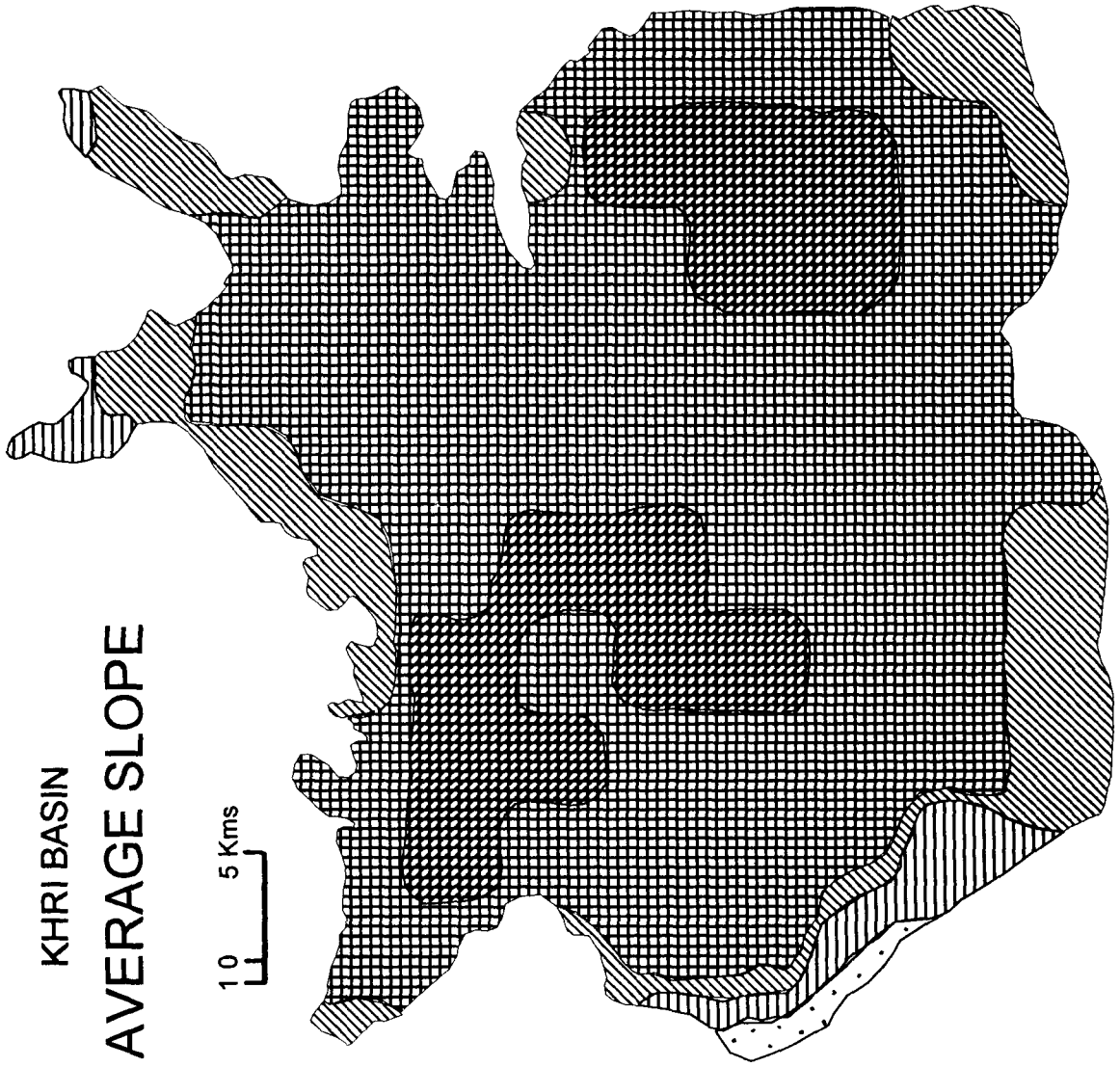
The general average slope of the Khri Basin can be classified into 4 ( four ) different classes i.e. Class I – above 24°; Class II – 18° - 24°; Class III – 12° - 18°; Class IV - 6°–12°, Class V – Below 6°.

However in the analysis of the basin slope it was found that the lowest slope was at 4.5° and the highest being at 22° approximately (Fig. No.8). The map depicts the steepest slopes at the areas where the steep hills are present along with the narrow valleys marked with ravines, deep gorges, waterfalls, etc as dissected earlier while analysing the relief. On an overall picture the average slope is between 12°-18° which occupies more than 60 % of the basin area signifying that the basin is marked mostly by moderate slopes showing the domination of the rolling hills and uplands. Table No.6 below would give a clear understanding as to the distribution of the varied slope indices of the basin.

From Table No.6 we can infer that the highest slopes i.e. above 24° occur where the main drainage line passes or cuts through forming deep valleys, gorges and ravines with highly rugged terrain. It may be noted here that the main Khri Basin bifurcates into two major sub-basins at Mawdem village forming the interfluve. The main drainage line known as Khri-Synnia that passes through Tyllang Nongriat – Kynrud – Mawdoh stretch and the other major sub-basin known as Khri-Bah that passes through Warmawsaw – Mawskei – Patharkmah – Nongliput – Nongthliew stretch. It is in these areas where deep cutting of water takes place. However, the steep slopes occupy an area of about 180 km<sup>2</sup> of the Khri Basin that is about 16.8 % of the basin area.

KHRI BASIN  
AVERAGE SLOPE

1.0  
5 Kms



SLOPE IN DEGREES

- > 24
- 18 - 24
- 12 - 18
- 6 - 12
- < 6

Fig No. 8

**TABLE NO. 6 AVERAGE SLOPE**

<b>SLOPE IN DEGREES</b>	<b>AREA (Km<sup>2</sup>)</b>	<b>PERCENTAGE (%)</b>	<b>CATERGORY</b>
> 24	180.00	16.8	Steep
18 - 24	713.50	66.8	Moderately Steep
12 - 18	127.00	11.9	Moderate
6 – 12	38.25	3.9	Moderately Low
< 6	9.00	1.0	Gentle

Moderately steep slopes ranging between 18°-24° occupy the major area of the drainage basin amounting to about 66.8 % of the basin area spreading to about 713.5 km<sup>2</sup>. The moderate slopes ranging between 12°-18° spread over an area of about 127 km<sup>2</sup> amounting to about 11.9 % of the basin area. Thus the moderately steep to moderate slopes spread to an area of about 840 km<sup>2</sup> which amounts to about 79 % of the basin area. This signifies that the basin in general is within the plateau region with the dominance of rolling uplands having moderately steep to moderate slopes.

The moderately low slopes ranging between 6°-12° and the gentle slopes which is below 6° are found to be present at the periphery of the Khri Basin. The moderately low slopes spread over 38.25 km<sup>2</sup> amounting to about 3.9 % of the basin area while the gentle slopes spread over 9 km<sup>2</sup> amounting to about 1 % of the basin area.

### **Fluvial Morphology:**

The Khri Basin is being located in one of the humid areas. Thus a careful and detailed study of the drainage system is important for understanding of the



Fig No. 9

landform processes. The basin as such is under the influence of the monsoon that receives more than 85 % of its rainfall during the months May to October. The average rainfall pattern as such in the basin differs from place to place depending on its elevation as shown earlier on Table No.1 on the Climatic Parameters of the Khri Basin. However, an overall average rainfall ranges between 160 – 200 cms annually. It is important to note that at the peak of the monsoon i.e. end of June to middle of September the rapid streams are highly violent and turbulent. At such times the runoff in the streams is very high leading to stream overflow or channel overflow. It is at such occasions that the erosion is at its highest coupled with widening the streams channels and also the down cutting of the main river. In the present study two techniques of fluvial morphometry have been carried out i.e. drainage density and frequency.

#### **Drainage Density:**

The analysis of the drainage density can be interpreted from the 4 (four) different categories as shown in Fig. No.10 which signifies the length of streams in km per km<sup>2</sup> i.e. (i) above 8km / km<sup>2</sup> (ii) 6-8 km / km<sup>2</sup> (iii) 4-6 km / km<sup>2</sup> (iv) below 4 km / km<sup>2</sup>.

From Table No.8 we can infer that the drainage density which is over 8km / km<sup>2</sup> spread over an area of 243 km<sup>2</sup> which is about 22.8 % of the basin area. Maximum density is recorded where the slopes are at the steepest and where the main drainage line passes through and also in the central portion of the basin.

Density ranging between 6 - 8 km / km<sup>2</sup> spread over an area of 533.50 km<sup>2</sup> that amounts to about 49 % of the total basin area. This shows that the basin is well drained and has a developed network with moderate density.

Density ranging between 4 - 6 km / km<sup>2</sup> and < 4 km / km<sup>2</sup> are found at the periphery of the basin spreading over an area of 185 km<sup>2</sup> and 116.25 km<sup>2</sup> respectively amounting to 17.3 % and 10.9 % of the Khri Basin area.

Morisawa (1985) in his work on drainage explains that there is an intricate relationship between drainage and the parent rock material of a particular area. Table No.7 after Morisawa helps us to understand such relationships.

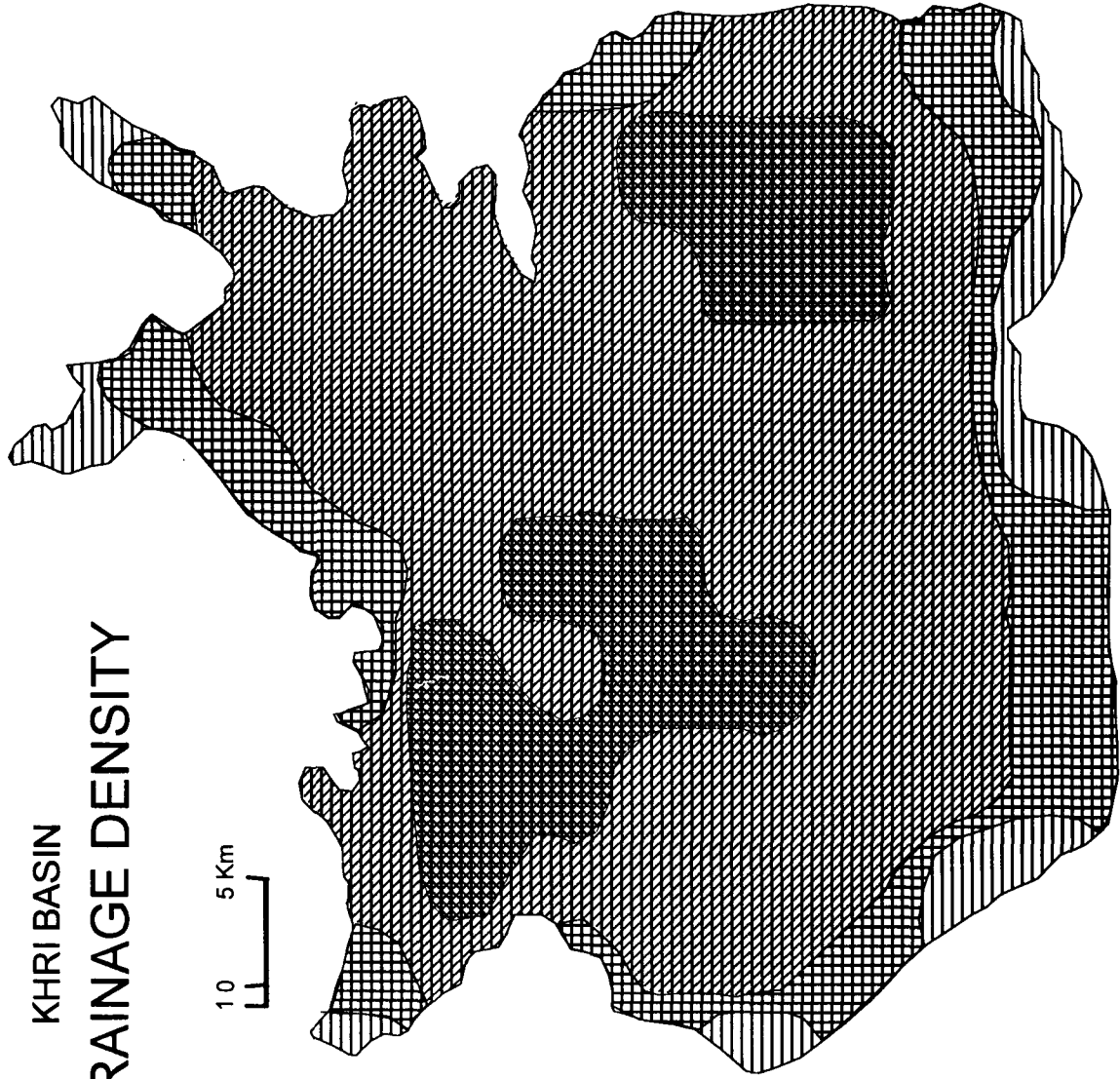
**Table No.7 Relationship of Drainage to Lithological Condition<sup>5</sup>**

<b>Approx Density Km/ km<sup>2</sup></b>	<b>Texture</b>	<b>Corresponding Lithological Condition</b>
< 8	Coarse	Permeable, resistant rocks humid well vegetated
8 – 20	Medium	Permeable, high rainfall, vegetated
20 – 200	Fine	Impermeable surface, low intense rainfall, little vegetation
> 200	Ultra-Fine	Impermeable surface, low intense rainfall, weak rocks, no vegetation

Fig. No.10 shows the highest drainage density which is above 8km / km<sup>2</sup> in the South-eastern part, in the Central part, in the North-western and in the North-eastern part covering a total area of about 243 km<sup>2</sup> of the Khri basin. Density of 4 - 8 km / km<sup>2</sup> is found spreading in the entire basin covering a total

# KHRI BASIN DRAINAGE DENSITY

10 5 Km



LENGTH OF STREAMS  
IN Km/Sq.Km

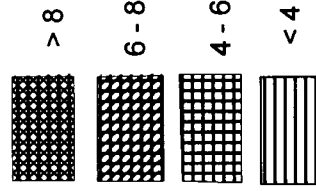


Fig No. 10

area of about 523.50 km<sup>2</sup> whereas the densities 4 - 6 km / km<sup>2</sup> and below 4 km / km<sup>2</sup> are found in the periphery of the Khri Basin with coverage of 185 km<sup>2</sup> and 116.25 km<sup>2</sup> respectively.

**TABLE NO. 8 DRAINAGE DENSITY**

<b>LENGTH OF STREAMS ( Km / Km<sup>2</sup> )</b>	<b>AREA (Km<sup>2</sup>)</b>	<b>PERCENTAGE ( % )</b>	<b>CATERGORY</b>
8 >	243.5	22.8	High
6 – 8	523.5	49.0	Moderate
4 – 6	185.5	17.3	Moderately low
< 4	116.3	10.9	Low

From this analysis we may infer with reference to Table No.7 after Morisawa, that about 243 km<sup>2</sup> of the Khri Basin has a medium texture. Here the lithological conditions of the underlying rocks signify that they are permeable. Since the area is having high rainfall and is well vegetated it enables high level of water holding capacity of the soil in association with the roots. Secondly we may infer that about 50 % of the Khri Basin is under a coarse texture where the underlying rocks are permeable and resistant experiencing heavy rainfall with high humidity signifying again that the area is well vegetated.

**Drainage Frequency:**

The drainage frequency Fig No.11 exhibits similar results where the highest frequency of above 12 streams / km<sup>2</sup> is found in the north central part and south eastern part of the study area covering a total area of about 189.5 km<sup>2</sup>. Drainage frequency between 8 - 12 streams / km<sup>2</sup> spreads throughout the basin covering an area of about 621.25 km<sup>2</sup>. However, the other

two categories i.e. 4 - 8 streams / km<sup>2</sup> and below 4 streams / km<sup>2</sup> are found located towards the periphery of the basin covering an area of about 185.5 km<sup>2</sup> and 71.5 km<sup>2</sup> respectively.

From Table No.9 it is seen that the highest frequency of over 12 streams / km<sup>2</sup> occupies an area of 189.5 km<sup>2</sup> amounting to about 17.7 % of the basin area. Frequency ranging between 8 - 12 streams / km<sup>2</sup> spread all over the basin amounting to an area of about 621.25 km<sup>2</sup> which is about 58.2 % of the basin area.

**TABLE NO. 9 DRAINAGE FREQUENCY**

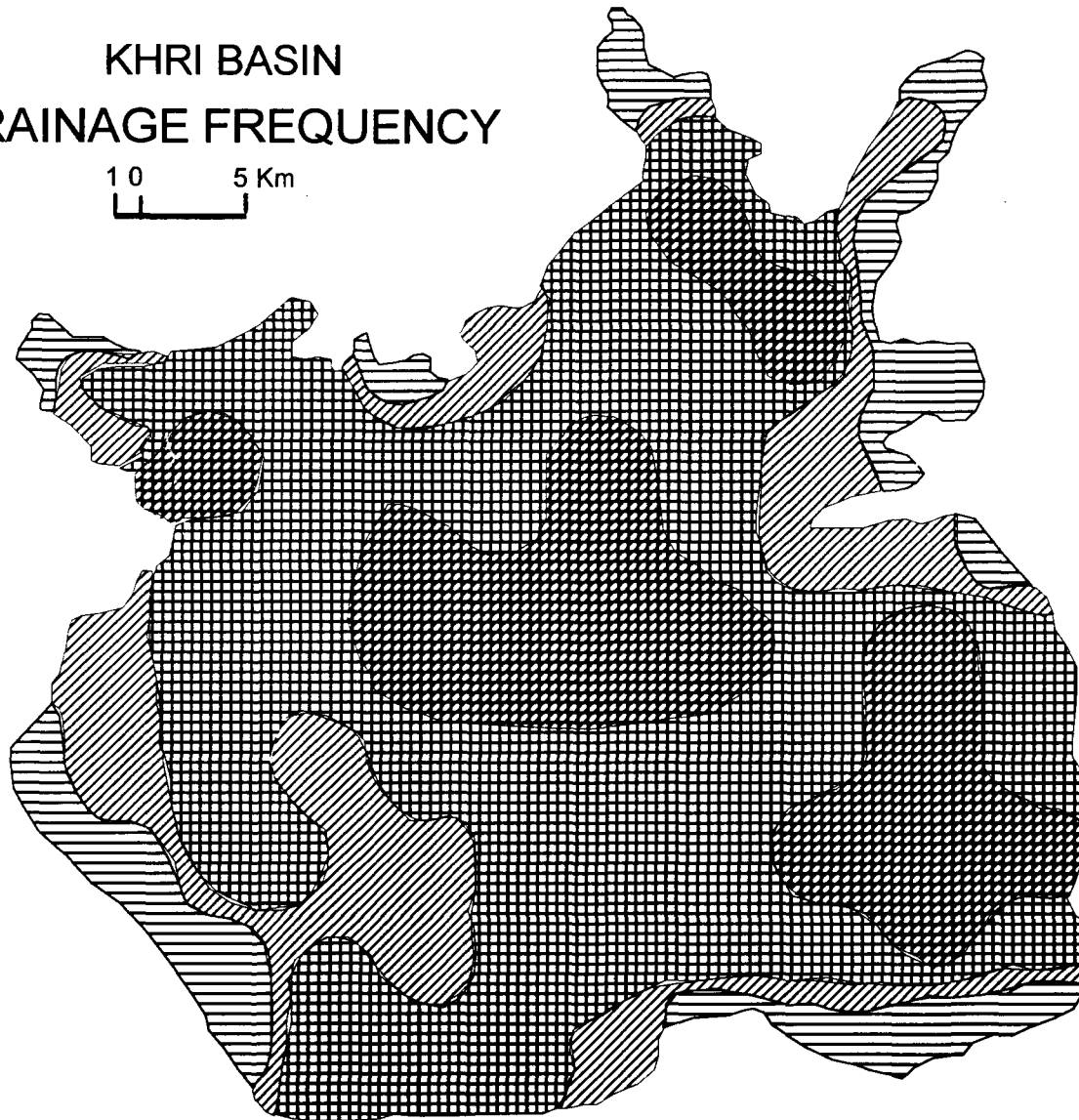
<b>NO. OF STREAMS / Km<sup>2</sup></b>	<b>AREA (Km<sup>2</sup>)</b>	<b>PERCENTAGE (%)</b>	<b>CATERGORY</b>
12 >	189.5	17.7	High
8 - 12	621.3	58.2	Moderate
4 – 8	185.5	17.4	Moderately Low
< 4	71.5	6.7	Low

Frequencies ranging between 4 - 8 streams / km<sup>2</sup> and below 4 streams / km<sup>2</sup> are found only at the periphery of the basin, occupying areas of 185.5 km<sup>2</sup> and 71.5 km<sup>2</sup> respectively that amounts to 17.4 % and 6.7 % of the Khri Basin area.

Thus the drainage frequency analysis signifies that the Khri Basin is well drained where above 800 km<sup>2</sup> i.e. about 75 % of the study area have frequencies above 8 streams / km<sup>2</sup>.

# KHRI BASIN DRAINAGE FREQUENCY

10 5 Km



NO. OF STREAMS / Sq.Km

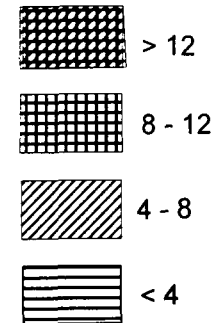


Fig No. 11

## **Landform Classification:**

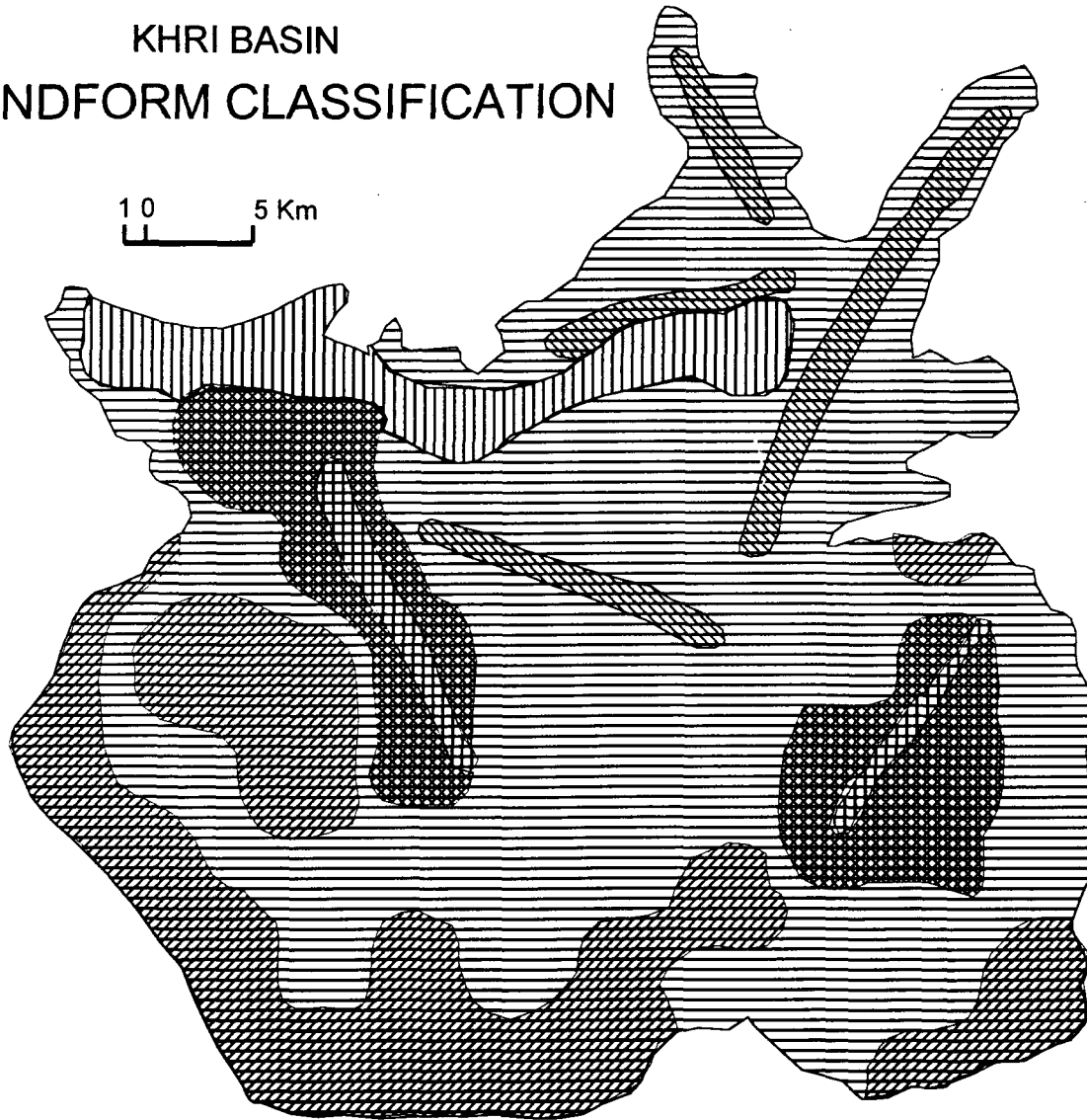
The classification of landforms in the present research has been derived through the superimposition of various maps such as absolute relief, dissection index, average slope, drainage network along with cross-referencing from the topographical sheets. In the analysis various landform characteristics have been identified such as the steep hills, the gently sloping hills, the moderately sloping hills, the wide valleys, the narrow valleys and the undulating lands. Fig. No.12 gives a pictorial representation of these various categories of landform characteristics.

The analysis shows that the undulating lands coupled with the gently to moderately sloping hills interspersed by wide valleys the dominance of rolling uplands signify the true nature of a plateau represented in the basin. The hill ranges are found dipping from almost SSW direction to NNW direction. The south-western portion, central western portion and the central eastern portion are marked by steep hills interspersed (dissected) by narrow valleys, deep gorges, ravines etc.

Table No.10 gives a clear view as to the presence of various landform categories. The steep hills are spread where there is highest river cutting resulting to the formation of deep and narrow valleys. This landform category occupies a total area of 118 km<sup>2</sup> of the Khri Basin amounting to about 11% of the basin area. The narrow valleys interspersed through the steep hills occupies an area of about 14.75 km<sup>2</sup> amounting to about 1.4 % of the total basin area. The two mentioned categories of landforms occur at areas where two major sub-basin drainage lies i.e. the main drainage line known as Khri-Bah stretching from

# KHRI BASIN LANDFORM CLASSIFICATION

10 5 Km



## CLASSES

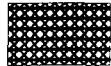
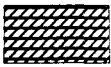

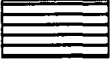


-  STEEP HILLS
-  MODERATELY SLOPING HILLS
-  GENTLY SLOPING HILLS
-  UNDULATING LANDS
-  NARROW VALLEYS
-  WIDE VALLEYS

Fig No. 12

Warmawsaw – Mawskei – Patharkmah – Nongliput – Nongthliew line and the other major sub-basin known as Khri-Synia stretching from Tyllang Nongriat – Kynrud – Mawdoh line. It is within these two categories that we encounter maximum slopes that are above 22° reaching to about 29° on an average at certain spots. These two categories are marked with the presence of a rugged and uneven terrain, ravines, cliffs, waterfalls, deep gorges and ridges.

**TABLE NO. 10 LANDFORM CLASSES**

<b>CLASSES</b>	<b>AREA (Km<sup>2</sup>)</b>	<b>PERCENTAGE (%)</b>
Steep Hills	118.00	11.0
Moderately Sloping Hills	66.25	6.2
Gently Sloping Hills	210.50	19.7
Undulating Lands	622.50	58.3
Narrow Valleys	14.75	1.4
Wide Valleys	35.75	3.3

The moderately sloping hills form another category of landform class which is found in the high uplands (above 1500 metres) spreading over an area of 210.5 km<sup>2</sup> amounting to 19.7 % of the Khri Basin area. This area shows moderate slopes ranging between 12° - 18° and in the south-western part below 12° and at certain parts slopes are as high as 20°. This area however, shows the slopes to be more stable mainly because it lies at the periphery of the basin where only small rivulets and streams are present and no major action of river water is experienced except through high intensity rainfall eroding the topsoil. The 1<sup>st</sup> and 2<sup>nd</sup> order streams are mainly present in this landform category.

The moderately sloping hills are found in the lowlands where the general elevation is below 500 metres with a general slope ranging between 13° - 19°. This is the point where the Khri river has reached its maturity and we could observe the river meandering before it joins with the River Kulsī that finally drains to the mighty Brahmaputra. This landform class spread over an area of 66.25 km<sup>2</sup> (approx) that amounts to about 6.2 % of the basin area.

The undulating lands are widely distributed all over the drainage basin occupying a total area of about 622.5 km<sup>2</sup> amounting to 58.3 % of the basin area having even slopes bringing of about a topography of rolling uplands. In this category low hills are found interspersed uniformly with moderate slopes of 18° - 20°. This highlights the true plateau nature of the Khri Basin as a whole with a smooth and gentle undulating skyline. In the lowlands (below 500 metres) and low uplands (500 – 1000 metres) of the basin wide valleys are found interspersed in this category spreading to about 35.75 which is 3.3 % of the Khri Basin area. This signify the gradual process of maturity of the Khri river where vast tracts of land reaching to 75 – 100 metres wide river deposits are observed particularly in the low-lying areas of the basin. These areas are the main wetland agricultural areas of the people living within the basin area.

## REFERENCES

1. **Monkhouse, F.J and Wilkinson, H.R** (1971): Maps and Diagrams, P.I Publication, New Delhi, 3<sup>rd</sup> Ed, 1971, pp 116
2. **Ibid**, pp 116.
3. **Strahler, T.N** (1952): "Determination of Stages of Landscape Evolution through relief Measures", Facets of geomorphology, Thinker's Library, Allahabad, 1985, pp. 200-07.
4. **Rai R.K.**(1978): Geomorphology of the Sonar-Bearma Basin, Concept Publishing Co., New Delhi, 1980 pp. 68.
5. **Morisawa, M** (1985): Geomorphology Texts: Rivers, Longmans Group, U.K., 1985, pp.140.

## **Chapter - IV**

### **SOIL CHARACTERISTICS**

#### **Introduction:**

As the sun is the source of energy for all life forms on Earth so is the soil being the essential medium for nurturing all terrestrial life forms and is one of the most complex features produced in nature. It is a mixture of weathered mineral particles, decaying organic matter, living organisms, gases and liquid solutions. In other words we can say soil is a zone of plant growth where plant nutrients are stored through the interaction of diverse factors such as water, air, sunlight, rocks, plants and animals. However, soil functions as a fundamental interface where atmosphere, lithosphere, hydrosphere and biosphere meet. Soils are mostly inorganic in nature and therefore are usually classed as part of the lithosphere though its relationship with the other three realms of the environment is both intimate and complex.

#### **Origin of Soil:**

The development of soil is initiated by the physical and chemical disintegration of rocks that is exposed to the earth's surface that is under the action of the atmospheric elements and the action of water percolating down the surface. The basic result of weathering is the weakening and breakdown of solid rock, the fragmentation of coherent rock masses forming regolith. Normally regolith has a crude gradation of particle sizes with the largest and least fragmented pieces at the bottom. Usually above the regolith lies the soil. Soil normally consists of an abundance of living plant roots, a variety of death and rotting plant parts in varying stages of decomposition, an unbelievable quantity of microscopic plants and animals both living and dead, and variable amount of air and water.

Thus soils are formed from hard (soil) rock masses, loose unconsolidated transported materials and organic residue. The weathering of rock masses forms the earth's loose materials such as stones, gravels, sands, silts, clay and soluble ions. The term soil is derived from the Latin word "solum". According to soil scientists, soil means that part of the earth's crust that have been changed as a result of soil forming processes.

As such, soils can be defined in a number of ways depending on the type of study it relates with. However, the two most common and simple definitions of soil are as follows:

(i) it is derived as the consolidated mineral material as the immediate surface of the earth that serves as a natural medium for the growth of plants.

(ii) it is a body subjected to a natural and historical development, which came into being on the surface of the earth as a result of a complex combination of the interaction of rocks, the organic macro and micro organisms, flora and fauna, climate, local relief and the production activities of man.

### **Soil Forming Factors:**

Soil formation can be said to take place when horizons develop with the soil profile. Soil horizons over a period of time acquire certain characteristics of colour, texture, pH, etc. Each environment has its own combination of soil-forming factors such as climate, parent material, topography (terrain), organisms and time. These soil-forming factors control the conditions under which the soil-forming processes operate and thus determine the state of any soil and soil response in any given location.

**(i) Geologic Factor:**

Almost all soils are largely composed of weathered fragments of rocks where the source is the parent material composed of solid bedrock or of loose sediments. Various agents resulting into disintegration and decomposition of the parent rock material provides the foundation for soil formation. However, the nature of the parent material often has a prominent influence on the characteristics of the soil that develop from it.

**(ii) Climatic Factor:**

Rainfall, temperature, radiation, humidity winds are among the climatic factors which affect soil formation. Climate is one of the dominant factors in soil formation where temperature and moisture has the greatest significance. Usually both chemical and biological processes in the soil are accelerated by high temperature and abundant moisture and are slowed down by low temperature and lack of moisture.

**(iii) Topographic Factor:**

Primarily the aspects of slope and drainage manifest topography as a factor in soil formation. It is found that where the land is flat, soil tends to develop at the bottom more rapidly. Thus, the deepest soils are usually on flat land. Areas where slopes are relatively steep, surface erosion progresses more rapidly than soil deepening resulting that such soils are normally thin and immaturely developed.

Usually most soils are well drained, so moisture relationships are relatively unremarkable in their development. However, most poor drained soils are in valley bottoms or in some other flat locale as soil and drainage are usually related to the slope of the land.

**(iv) Biological Factor:**

Vegetation of all kind grows in the soil and performs certain vital functions. Plants root provides passage for drainage and aeration, as it is a vital link between soil nutrients and growing plants. Detached plants parts such as leaves, twigs, flowers, stems etc and the entire dead plants are frequently added to the soil as they accumulate and decay.

Animals also largely contribute to soil development especially through the dropping of excreta. Some animals like the elephants, bisons and other large animals affect soil formation by compaction of their hooves, rolling on the ground and through grazing. Smaller animals such as ants, worms, etc spend their lives in the soil layer, tunnelling here and there, moving soil particles upward and downward thus creating passage for water and air to penetrate.

Microbes on the other hand help to release nutrients from dead organisms by decomposing organic matter into humus. Algae, fungi, protozoan and other minuscule organisms all play a role in soil development but bacteria probably make the greatest contribution as bacteria is responsible for the decomposition and decay of dead plants and animals along with the release of nutrients into the soil.

## **Soil Classification:**

The controversy over soil classification, which includes arguments about definitions and nomenclature, is almost as old as pedology itself. The search for order that is part of any science has been more difficult in this case because of the problem of correlation among soil units, identified by different national surveys in widely scattered parts of the world and labelled in different languages. The two Russian pedologists Dokuchev and Sibertzev had regarded the most common “free draining” soils of the main climatic zones as normal or zonal soils. Secondly, due to the dominance of some other soil-forming factors transitional or intra-zonal soils were formed. Lastly, soil that had not had an opportunity to develop and therefore could be found in any environment we called abnormal or azonal soils. Glinka K.D. (1924) recognised five major pedogenic processes i.e. lateritic, podsollic, chernozemic, solonetzic and swampy on which he based his soil classification. Marbut (1928) established a classification that is two-fold leached soils (pedalfers) and the non-leached soils (pedosols).

## **Classification of Tropical Soils:**

A relatively simple classification of tropical soils is shown in Table No.11 below. In the first level, classification into Zonal, Intrazonal and Azonal Orders is adopted as in the scheme proposed by Thorp and Smith's (1949). Separation of Zonal soils into Sub-Orders is according to Marbut (1928). Pedalfers are those soils that show a differentiation in the clay complex resulting in the accumulation of iron oxides and aluminium while podocals are characterised by a zone of calcium carbonate accumulation. It is unlikely that some of the Sub-Orders such as “dark-coloured soils of semi arid, sub humid and humid grasslands” are found in the tropics (Vine, in Webster and Wilson, 1966). Non-calcic Brown soils of “the forest-grasslands transition” in Thorp and Smith's classification have been reported from

**Table No.11: Classification of Tropical Soils (after, Vine in Webster and Wilson, 1966)**

Orders	Sub-Orders	Great Sub-Groups
Zonal	<p>Pedalfers</p> <p>Pedocals</p>	<p>Latosols, Reddish-Brown Latosolic, Yellowish-Brown Latosolic, Red-Yellow Lato - solic Podsols Fersiallitic soils: Red-Yellow Podsollic, Reddish-Brown Earth's, Noncalcic Brown soils. Reddish-Brown and Brown soils, Plain soils, Sierozems, Desert soils.</p>
Intrazonal	<p>Calcimorphic Halomorphic Hydromorphic</p> <p>Vertisols Allophane Soils</p>	<p>Rendzina. Solonchak, Solonetz, Solod Hummic Gley, Low Humic Gley, Ground Water Podsols, Ground Water Laterites, Peat/Muck, Acid Sulphate soils. Gnumusols, Margalite. Andosols.</p>
Azonal	<p>Lithosols Regosols Alluvial Soils</p>	

tropical countries (e.g. Moorman and Panabokke, 1961). The Intrazonal soils include not only the calcimorphic, holomorphic and hydromorphic soils of Thorp and Smith's classification of 1949 but also the vertisols and allophane soils were recognised subsequently.

In the 7<sup>th</sup> Approximation six categories of classification are defined i.e. I. Orders, II. Sub-Orders, III. Great Sub Group, IV. Sub-Group, V. Family, VI. Series with ten Orders.

1. **Entisols:** Soils with little or no profile development in deep regolith, except a ploughed surface or other evidence of man's activities. Soils on recent alluvium are commonly Entisols.

2. **Vertisols:** Heavy clay soils, with swelling clays of the montmorillonite group. Peds show slickensides, gilgais are common, and the soils crack widely when dry. It includes the Gnumusols and the Margalitic soils.

3. **Inceptisols:** Young soils with little profile development, the horizons present being those most readily formed, such as the A<sub>1</sub>. Structure has developed and iron oxide may form a coloured horizon, but there has been little clay illuviation to form a textural B horizon.

4. **Aridisols:** Soils of arid areas, usually dry, but may be moist because of seepage, when they are also saline.

5. **Mollisols:** Certain of these soils when a surface horizon which is dark in colour, has a low carbon-nitrogen ratio and base saturation above 50% with dominance of Calcium. These are the famous Prairie and Chernozem soils of the American and Russian grassland.

6. **Spodosols:** Soils with an illuvial accumulation of sesquioxides with organic matter, or organic matter, or iron oxide. These soils are usually formed on sandy material under humid conditions and coniferous forest in the Northern Hemisphere.

7. **Alfisols:** Soils with a clay B horizon derived at least in part from illuvial clay and saturation with metallic cations exceeding 35%.

8. **Ultisols:** Soils with clay B horizons derived at least in part from illuvial clay and saturation with metallic cations generally less than 35%. They are acidic, leached soils of humid areas, usually on ancient land surfaces.

9. **Oxisols:** Soils with sesquioxides of clay-size dimensions, mixed with silicate clays usually of 1:1 lattice structure. Free sesquioxides should exceed 12% of the total clay fraction.

10. **Histosols:** Soils rich in organic matter such as peats.

### **Soil Analysis:**

The only way to gain a thorough understanding of soils is to carry out investigations both in the field and in the laboratory. Therefore frequent visits should be made to the field to see the various types of soils, factors helpful in soil formation and its utilisation. For this specific study the samples are collected from below a particular chosen dominant species. However, it can be said, "the analysis can be no better than the sample".

Thus a varied range of soil samples have been collected and certain methods have been followed regarding the determination of the colour, the structure of the soils and the texture is analysed by the feeling method of the soil. The chemical

properties of the soils have been analysed at the Research Laboratory, Department of Agriculture, Govt of Meghalaya, Shillong.

**Methodology:**

(i) **Collection of soil samples:** The various requirements are a spade, polythene bags and a soil auger. The ground is first dug by a soil auger to about a depth of 15-20 cms and the soil which lies in this range is being collected in the polythene bags with the help of a spade. The amount of soil collected is about 700gms. The polythene bags are then sealed and then labelled according to their general location in the field (e.g. hilltop, hill slope, foothill and valley site). Thus in this way 118 samples have been collected from various sites within the Khri Basin and the soils are collected below the dominant tree species studied.

(ii) **Soil Colour:** For this purpose the “Munsell” Soil Colour Chart had been used in which three simple variables of colours are followed i.e. “Hue”- the dominant spectral colour, “Value” – the brilliance on total quality of light and “Chroma”- the relative purity on saturation of the dominant spectral colour.

The most important property of soil is its colour as it provides clues about its nature and capabilities though sometime can also be misleading. Soil scientists have recognised about 175 different grades of colour based on the Munsell Colour Chart mentioned earlier. The standard colours are generally the shades of black, brown, red yellow, grey and white.

Black or dark brown usually indicate a considerable humus content whereas reddish and yellowish colours usually indicate iron oxide stains on the outside of the soil particle. On the other hand light coloured soils – grey or white may imply much leaching in humid areas or accumulation of white alkali or other salts in dry climates.

(iii) **Soil Structure:** Sand, silt and clay which are the primary soil particles when grouped together into stable conditions, forming a definite pattern known as soil structure. The soil structure of the study area is studied in the field under the basis of three structural categories, i.e.

**(a) Structural Types.**

- (i) Angular Blocks
- (ii) Sub- Angular Blocks
- (iii) Crumb
- (iv) Granular
- (v) Columnar
- (vi) Prismatic
- (vii) Platelike

**(b) Structural Classes.**

- (i) Very fine or very thin; <1mm
- (ii) Fine or thin; 1-2 mm
- (iii) Medium; 2-5 mm
- (iv) Coarse or thick; 5-10 mm
- (v) Very coarse or very thick; >10 mm.

**(c) Structural Grades**

- (i) Strong
- (ii) Moderate
- (iii) Weak
- (iv) Structureless

The individual particle of most soils tends to aggregate into larger masses or clumps called "peds" which determine the structure of the soil. The size, shape, and

stability of such aggregate have a marked influence on the movement of water, air and organisms and also roots of plants into the soil. The various classes and types of soil structure are shown in Table No.12.

**(iv) Soil Texture:** The proportion and amount of sand, silt and clay in the soil determines the soil texture. No soil is made up of particles of uniform size. Thus the texture triangle shows the standard classification of soil texture based on the percentage of each separate by weight. The term “loam” in the triangle signifies that none of the separates dominate each other.

For determining the texture of the soil, “feel method” was introduced. This procedure consists merely of rubbing the soil between the thumb and forefinger and the following textural characteristics are felt.

(a) Sand: Sand is loose and single grained as individual grains can be readily seen or felt. Dry sand when squeezed in the hand will fall apart when the pressure is released. If squeezed when moist it forms a cast and crumbles when touched.

(b) Sandy Loam: A sandy loam is a soil containing much sand but enough silt and clay is present enabling the clods stick together a little. Individual sand grains can be readily seen and felt. If squeezed when dry it forms a cast that readily falls apart; if squeezed when moist, a cast can be handled quite freely without breaking.

(c) Loam: A loam is a soil that has a fairly even mixture of the different grades of sand, silt and clay. It feels somewhat gritty, yet fairly smooth and slightly plastic. If squeezed when dry, it will form cast that will bear with careful handling and if squeezed when moist, the cast formed can be handled quite freely without handling.

**TABLE NO:12 CLASSES AND TYPES OF SOIL STRUCTURE**

<b>CLASS</b>	<b>PLATELIKE</b>	<b>PRISMATIC</b>	<b>COLUMNAR</b>	<b>ANGULAR</b>	<b>SUB-ANGULAR BLOCK</b>	<b>GRANULAR BLOCK</b>	<b>CRUMB</b>
Very fine or very thin	Below 1 mm	Below 10 mm	Below 10 mm	Below 5 mm	Below 5mm	Below 1 mm	Below 1 mm
Fine or thin	1-2 mm	10-20 mm	10-20 mm	5-10 mm	5-10 mm	1-2 mm	1-2 mm
Medium	2-5 mm	20-50 mm	20-50 mm	10-20 mm	10-20 mm	2-5 mm	2-5 mm
Coarse or thick	5-10 mm	50-100 mm	50-100 mm	20-50 mm	20-50 mm	5-10mm	-----
Very coarse or very thick	above 10 mm	above 100 mm	above 100 mm	above 50 mm	above 50 mm	above 10 mm	-----

**Source: Soil Survey staff, Soil Taxonomy: A Basic System of Soil Classification for making and interpreting Soil Surveys, U.S.D.A. – Soil Conservation Service, Agriculture Handbook 436, Dec 1975 Pg. 475**

(d) Silt Loam: A silt loam is a soil with a moderate amount of fine grades of sand and only a small amount of clay with half of the particles are silt. When dry it feels soft, smooth and floury. Either when dry or moist, it will form casts that can be freely handled without breaking. However, if squeezed between the thumb and finger when moist it gives a broken appearance.

(e) Clay Loam: This is a fine-textured soil, with features midway between the characteristics of loam and clay. When moist it forms a ribbon when squeezed between the thumb and finger.

(f) Silty Clay Loam: A silty clay loam is a fine textured soil that breaks into clods and lumps. When dry it is hard to break with the squeeze of the hand. When moist if soil is squeezed between thumb and finger, it will form a cast that will bear much handling. When kneaded in the hand it does not crumble readily but tends to work into heavy, plastic compact mass.

(g) Clay: Clay is a fine-textured soil that usually forms very hard lumps or clods when dry, and is usually very sticky when wet. When moist soil is squeezed between the thumb and fingers, it forms a long, smooth, flexible ribbon.

With regard to the chemical characteristics of the soil such as determination of the pH value, Organic Carbon (OC), Phosphorous pentoxide ( $P_2O_5$ ) and Potassium oxide ( $K_2O$ ) content the soils have been analysed in the Research Laboratory, Department of agriculture, Govt of Meghalaya, Shillong.

### **Physical Characteristics of Soils:**

The physical properties of the soils include texture, structure, density, porosity, consistency, temperature, colour and moisture content of which only a few

major physical attributes have been studied and analysed in the present work. These attributes are colour, structure and the textural composition of the soil.

### **Soil Colour:**

The soil samples collected from the field show varied ranges of soil colour that was determined from the Munsell Soil Colour Chart. Three simple variables of colours are followed i.e. "Hue"- the dominant spectral colour, "Value" – the brilliance on total quality of light and "Chroma"- the relative purity on saturation of the dominant spectral colour. Table No.13 depicts that the various shades of colour ranges from dark red to red; dark reddish grey to reddish grey; dusky red to weak red; reddish black to dusky red; reddish brown to light reddish brown; dark brown to light brown and red to reddish yellow signifying that the soil have iron oxide contents. Since the various soil samples are mostly collected from below the different plant species surveyed, there are a number of variations in colour shades denoted as mentioned above. Shades of brown with a dark greyish colour and a light reddish stain denote that there is a certain percentage of humus present along with the iron oxides.

In general it can be said the most of the soil samples collected are red or reddish in colour that denotes the soils are related to unhydrated iron oxides. Since unhydrated iron oxides are relatively unstable under moist conditions red colour usually indicates good drainage and good aeration. Strongly red soils are usually the product related to the parent rock material and not due to soil-forming processes since the redness in some rocks persists for centuries together even under moist conditions. Red colour soils also signify that the soils are relatively old which are subjected to intense weathering for a considerable time. On the other hand yellowish shade soils are largely due to presence of iron oxides.

**TABLE NO.13**

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Patharkhmah	1	Hill Slope	Primary	Open	Dark Red	Red	Sub-Angular	Fine	Weak	Sandy Clay Loam
	2	Hill Slope	Primary	Open	Dark Red	Red	Sub-Angular	Medium	Weak	Clay Loam
	4	Hill Slope	Primary	Open	Weak Red	Weak Red	Granular	Fine	Moderate	Sandy Clay Loam
	5	Hill Slope	Primary	Open	Dark Reddish Gray	Reddish Gray	Granular	Fine	Moderate	Sandy Clay Loam
	6	Hill Slope	Primary	Open	Dusky Red	Weak Red	Granular	Medium	Moderate	Sandy Clay Loam
	7	Hill Slope	Primary	Open	Dusky Red	Red	Granular	Very Fine	Strong	Sandy Clay Loam
	8	Hill Slope	Primary	Open	Dusky Red	Weak Red	Granular	Very Fine	Strong	Sandy Clay Loam
	9	Hill Slope	Primary	Open	Dusky Red	Red	Granular	Fine	Moderate	Sandy Clay Loam
	10	Hill Top	Primary	Open	Dusky Red	Weak Red	Granular	Fine	Weak	Sandy Clay Loam
	11	Hill Top	Primary	Open	Dusky Red	Weak Red	Granular	Fine	Weak	Sandy Clay Loam
	12	Hill Slope	Primary	Open	Weak Red	Weak Red	Granular	Medium	Weak	Sandy Clay Loam
	13	Hill Slope	Primary	Open	Dark Reddish	Dark Red	Granular	Medium	Weak	Sandy Clay Loam
	14	Hill Slope	Primary	Open	Dark Reddish	Dark Red	Granular	Medium	Weak	Sandy Clay Loam
	15	Hill Slope	Primary	Open	Reddish Black	Dusky Red	Sub-Angular	Medium	Moderate	Sandy Clay Loam
	Mawskei	16	Valley	Primary	Degraded	Red	Reddish Yellow	Granular	Very Fine	Strong
17		Valley	Primary	Degraded	Dark Reddish Gray	Reddish Gray	Granular	Very Fine	Strong	Sandy Clay Loam

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type		Soil Colour		Soil Structure			Soil Texture
			Primary	Degraded	Wet	Dry	Type	Class	Grade	
Mawskei	18	Valley	Primary	Degraded	Dark Reddish Gray	Reddish Gray	Granular	Fine	Moderate	Clay Loam
	19	Valley	Primary	Degraded	Dusky Red	Weak Red	Granular	Very Fine	Strong	Sandy Clay Loam
	20	Valley	Primary	Degraded	Weak Red	Weak Red	Granular	Very Fine	Strong	Sandy Clay Loam
	22	Valley	Primary	Degraded	Reddish Black	Reddish Gray	Granular	Fine	Moderate	Sandy Clay Loam
	23	Valley	Primary	Degraded	Reddish Black	Reddish Gray	Granular	Fine	Moderate	Sandy Clay Loam
	24	Valley	Primary	Degraded	Dusky Red	Weak Red	Granular	Fine	Strong	Clay Loam
	25	Valley	Primary	Degraded	Dusky Red	Weak Red	Granular	Fine	Strong	Sandy Clay Loam
	26	Foot Hill	Primary	Degraded	Red	Weak Red	Granular	Medium	Moderate	Sandy Clay Loam
	27	Foot Hill	Primary	Degraded	Red	Weak Red	Granular	Medium	Moderate	Sandy Clay Loam
	28	Hill Slope	Primary	Degraded	Red	Red	Granular	Medium	Moderate	Clay Loam
	29	Hill Slope	Primary	Degraded	Red	Red	Granular	Fine	Strong	Sandy Clay Loam
	30	Hill Slope	Primary	Degraded	Red	Light Red	Granular	Medium	Moderate	Clay Loam
	31	Hill Slope	Primary	Degraded	Red	Red	Granular	Fine	Moderate	Clay Loam
	32	Hill Slope	Primary	Degraded	Red	Red	Granular	Fine	Strong	Clay Loam

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Mawskei	33	Hill Top	Primary	Degraded	Red	Weak Red	Sub-Angular	Medium	Moderate	Clay Loam
	34	Hill Top	Primary	Degraded	Reddish Brown	Light Reddish Brown	Sub-Angular	Very Fine	Strong	Clay Loam
	35	Hill Slope	Primary	Degraded	Dark Red	Red	Granular	Fine	Moderate	Clay Loam
	36	Hill Slope	Primary	Degraded	Dark Reddish Brown	Reddish Brown	Granular	Fine	Moderate	Sandy Clay Loam
Warmawsaw	37	Hill Slope	Primary	Degraded	Weak Red	Weak Red	Granular	Medium	Moderate	Sandy Clay Loam
	38	Hill Top	Primary	Degraded	Red	Light Red	Granular	Coarse	Weak	loamy
	39	Hill Top	Primary	Degraded	Light red	Light Red	Granular	Medium	Moderate	loamy
	40	Hill Slope	Primary	Degraded	Dark Red	Weak Red	Granular	Coarse	Weak	loamy
	41	Hill Slope	Primary	Degraded	Light red	Light Red	Granular	Medium	Moderate	loamy
	42	Hill Slope	Primary	Degraded	Red	Light Red	Granular	Fine	Moderate	Sandy Clay Loam
	43	Hill Slope	Primary	Degraded	Red	Light Red	Granular	Fine	Moderate	loamy
	44	Hill Slope	Primary	Degraded	Red	Light Red	Granular	Fine	Moderate	loamy
	45	Hill Slope	Primary	Degraded	Red	Light Red	Granular	Fine	Moderate	loamy
	46	Hill Slope	Primary	Degraded	Red	Light Red	Granular	Medium	Moderate	loamy
	47	Hill Slope	Primary	Degraded	Yellowish Red	Yellowish Red	Granular	Medium	Moderate	loamy
	48	Hill Slope	Primary	Degraded	Red	Light Red	Granular	Fine	Moderate	loamy
	49	Valley	Primary	Degraded	Red	Weak Red	Granular	Fine	Strong	loamy
	50	Valley	Primary	Degraded	Red	Weak Red	Granular	Fine	Strong	loamy
	51	Valley	Primary	Degraded	yellowish Red	Yellowish Red	Granular	Fine	Strong	loamy

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Mawiong	52	Hill Slope	Mixed Deciduous	Open	Weak Red	Weak Red	Granular	Medium	Moderate	Sandy loam
	53	Hill Slope	Mixed Deciduous	Open	Weak Red	Weak Red	Granular	Medium	Moderate	Sandy Clay Loam
	54	Hill Slope	Mixed Deciduous	Open	Weak Red	Weak Red	Granular	Coarse	Weak	Sandy Clay Loam
	55	Hill Slope	Mixed Deciduous	Open	Reddish Brown	Light Reddish Brown	Granular	Medium	Moderate	Sandy Clay Loam
	56	Hill Slope	Mixed Deciduous	Open	Weak Red	Weak Red	Granular	Medium	Moderate	Sandy Clay Loam
	57	Hill Slope	Mixed Deciduous	Open	Dusky Red	Weak Red	Granular	Medium	Moderate	Sandy Clay Loam
	58	Hill Slope	Mixed Deciduous	Open	Weak Red	Weak Red	Granular	Coarse	Weak	Sandy Clay Loam
	59	Hill Slope	Mixed Deciduous	Open	Weak Red	Weak Red	Granular	Medium	Moderate	Sandy Clay Loam
	60	Hill Slope	Mixed Deciduous	Open	Brown	Light Brown	Granular	Medium	Moderate	Sandy Clay Loam
	61	Hill Slope	Mixed Deciduous	Open	Dark Brown	Light Reddish Brown	Granular	Coarse	Weak	Sandy Clay Loam

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Mawiong	62	Hill Slope	Mixed Deciduous	Open	Dark Brown	Light Brown	Granular	Medium	Moderate	Sandy Clay Loam
	63	Hill Slope	Mixed Deciduous	Open	Dark Brown	Light Brown	Granular	Medium	Moderate	Sandy Clay Loam
	64	Hill Slope	Mixed Deciduous	Open	Reddish Yellow	Light Yellowish Brown	Granular	Medium	Moderate	Sandy Clay Loam
	65	Hill top	Mixed Deciduous	Open	Light Brown	Light Brown	Granular	Medium	Moderate	Sandy Clay Loam
	66	Hill Slope	Mixed Deciduous	Open	Reddish Yellow	Light Brown	Granular	Medium	Moderate	Sandy Clay Loam
	67	Hill Slope	Mixed Deciduous	Open	Dark Reddish Brown	Light Reddish Brown	Granular	Medium	Moderate	Sandy Clay Loam
	68	Hill top	Mixed Deciduous	Open	Dark Reddish Brown	Light Reddish Brown	Granular	Medium	Moderate	Sandy Clay Loam
	69	Hill top	Mixed Deciduous	Open	Yellowish Red	Yellowish Red	Granular	Fine	Strong	Sandy Clay Loam
	70	Hill top	Mixed Deciduous	Open	Reddish Brown	Light Brown	Granular	Medium	Moderate	Sandy Clay Loam
	Khawai	71	Hill Slope	Secondary Pine Forest	Open	Red	Light Red	Granular	Medium	Moderate
72		Hill Slope	Secondary Pine Forest	Open	Dark Reddish Brown	Light Reddish Brown	Granular	Medium	Moderate	Sandy loam
73		Hill Slope	Secondary Pine Forest	Open	Red	Light Red	Granular	Coarse	Weak	Sandy

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Khawai	74	Hill Top	Secondary Pine Forest	Open	Dark Red	Weak Red	Granular	Medium	Moderate	Sandy loam
	75	Hill Slope	Secondary Pine Forest	Open	Dark Red	Weak Red	Granular	Coarse	Weak	Sandy
	76	Hill Slope	Secondary Pine Forest	Open	Dusky Red	Weak Red	Granular	Medium	Moderate	Sandy loam
	77	Hill Slope	Secondary Pine Forest	Open	Dusky Red	Weak Red	Granular	Coarse	Weak	Sandy
	78	Hill Top	Secondary Pine Forest	Open	Dark Reddish Brown	Reddish Brown	Granular	Coarse	Weak	Sandy
	79	Hill Slope	Secondary Pine Forest	Open	Dark Red	Light Red	Granular	Coarse	Weak	Sandy
	80	Hill Slope	Secondary Pine Forest	Open	Dark Red	Light Red	Granular	Medium	Moderate	Sandy Loam
	81	Hill Top	Secondary Pine Forest	Open	Light red	Light Red	Granular	Coarse	Weak	Sandy
	82	Hill Top	Secondary Pine Forest	Open	Light red	Weak Red	Granular	Coarse	Weak	Sandy
	83	Hill Top	Secondary Pine Forest	Open	Light red	Weak Red	Granular	Coarse	Weak	Sandy
	84	Hill Top	Secondary Pine Forest	Open	Weak Red	Weak Red	Granular	Medium	Weak	Sandy
	85	Valley	Secondary Pine Forest	Open	Weak Red	Weak Red	Granular	Fine	Strong	Sandy

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Kynrud and Tyllang Nongriat	86	Hill Slope	Primary	Open	Dark Reddish Brown	Light Reddish Brown	Granular	Medium	Moderate	Sandy loam
	87	Hill slope	Pine Forest	Open	Weak Red	Weak Red	Granular	Fine	Moderate	Sandy loam
	88	Hill Slope	Pine Forest	Open	Dark Reddish Brown	Light Reddish Brown	Granular	Fine	Moderate	Sandy loam
	89	Hill Slope	Mixed Deciduous	Open	Dark Reddish Brown	Reddish Brown	Granular	Medium	Moderate	Sandy Clay Loam
	90	Hill Slope	Mixed Deciduous	Open	Dark Reddish Brown	Reddish Brown	Granular	Medium	Moderate	Sandy loam
	91	Hill Slope	Mixed Deciduous	Open	Dark Reddish Brown	Reddish Brown	Granular	Medium	Moderate	Sandy loam
	92	Hill Slope	Mixed Deciduous	Open	Dark Reddish Brown	Reddish Brown	Granular	Coarse	Weak	Sandy loam
	93	Hill Slope	Mixed Deciduous	Open	Weak Red	Weak Red	Granular	Coarse	Weak	Sandy loam
	94	Hill Slope	Mixed Deciduous	Open	Dark Red	light Red	Granular	Medium	Moderate	Sandy loam
	95	Hill Slope	Mixed Deciduous	Degraded	Dark Reddish Brown	Reddish Brown	Granular	Fine	Moderate	Sandy loam

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN ASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Kynrud and Tyllang Nongriat	96	Hill Slope	Mixed Deciduous	Degraded	Dark Reddish Brown	Reddish Brown	Granular	Coarse	Weak	Sandy loam
	97	Hill Slope	Mixed Deciduous	Degraded	Dark Reddish Brown	Reddish Brown	Granular	Coarse	Weak	Sandy loam
	98	Hill Slope	Mixed Deciduous	Degraded	Weak Red	Weak Red	Granular	Fine	Moderate	Sandy loam
	99	Hill Slope	Mixed Deciduous	Open	Dusky Red	Red	Granular	Fine	Moderate	Sandy loam
	100	Hill Slope	Mixed Deciduous	Open	Dark Reddish Brown	Reddish Brown	Granular	Fine	Moderate	Sandy loam
Mawdoh	101	Valley	Almost Barren	Degraded	Light Reddish Brown	Light Reddish Brown	Granular	Coarse	Weak	sandy
	102	Valley	Almost Barren	Degraded	Light Reddish Brown	Light Reddish Brown	Granular	Coarse	Weak	Sandy
	103	Valley	Almost Barren	Degraded	Light Reddish Brown	Light Reddish Brown	Granular	Medium	Moderate	Sandy loam
	104	Valley	Almost Barren	Degraded	Light Reddish Brown	Light Reddish Brown	Granular	Medium	Moderate	Sandy loam
	105	Hill Slope	Almost Barren	Degraded	Reddish Brown	Reddish Brown	Granular	Fine	Strong	loamy

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Mawdoh	106	Hill Slope	Almost Barren	Degraded	Reddish Brown	Light Reddish Brown	Granular	Fine	Moderate	Sandy
	107	Hill Slope	Almost Barren	Degraded	Reddish Yellow	Reddish Yellow	Granular	Medium	Moderate	Sandy loam
Nongthliew and Nongliput	108	Hill Top	Mixed Deciduous with Pine	Open	Dark Brown	Brown	Crumb	Medium	Moderate	Sandy Clay Loam
	109	Hill Slope	Mixed Deciduous with Pine	Open	Brown	Light Brown	Granular	Medium	Weak	Sandy Clay
	110	Hill Top	Mixed Deciduous with Pine	Open	Dark Reddish Brown	Light Reddish Brown	Crumb	Medium	Moderate	Sandy loam
	111	Hill Slope	Mixed Deciduous with Pine	Open	Brown	Light Brown	Crumb	Medium	Moderate	Sandy loam
	112	Hill Slope	Mixed Deciduous with Pine	Open	Brown	Light Brown	Granular	Medium	Weak	Sandy loam
	113	Hill Top	Mixed Deciduous with Pine	Open	Reddish Dark Brown	light red	Crumb	Medium	Moderate	Sandy Clay Loam
	114	Hill Top	Mixed Deciduous with Pine	Open	Dark Brown	Light Brown	Crumb	Medium	Moderate	Sandy Clay Loam

**PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

Area/Village	Sample No.	Sample Site	Forest Type	Nature of Forest	Soil Colour		Soil Structure			Soil Texture
					Wet	Dry	Type	Class	Grade	
Nongthliew and Nongliput	115	Hill Top	Mixed Deciduous with Pine	Open	Dark Brown	Light Brown	Crumb	Medium	Moderate	Sandy Clay Loam
	116	Hill Slope	Mixed Deciduous with Pine	Open	Reddish Brown	Light Reddish Brown	Crumb	Medium	Weak	Sandy Clay Loam
	117	Hill Slope	Mixed Deciduous with Pine	Open	Dark Brown	Brown	Granular	Medium	Moderate	Sandy Loam
	118	Hill Slope	Mixed Deciduous with Pine	Open	Reddish	Light Red	Crumb	Medium	Moderate	Sandy Clay Loam
	119	Hill Slope	Mixed Deciduous with Pine	Open	Reddish	Light Red	Crumb	Medium	Moderate	Sandy Clay Loam
	120	Hill Slope	Mixed Deciduous with Pine	Open	Dark Brown	Light Brown	Crumb	Medium	Weak	Sandy Clay Loam

## **Soil Structure:**

Soil structure is an aggregation of primary soil particles into compound particles. An individual natural soil aggregate is called a "ped". The importance of soil structure in soil classification and influencing productivity can scarcely be over emphasis on a) the shape (b) the size and (c) the durability of the peds. The shape of peds is designated as "type" of soil structure, the size of peds as "class" and degree of distinctness and durability as "grades".

There are seven types of structure i.e.

- (a) Angular blocks that are bounded by planes intersected as relatively sharp angles.
- (b) Sub-Angular blocks that are bounded by planes with vertices mostly rounded.
- (c) Crumbs are peds that are spheroidal and very porous in nature.
- (d) Granular are peds that are also spheroidal and which are relatively non-porous in nature.
- (e) Columnar are peds that are prism like but with rounded caps.
- (f) Prismatic are peds that are prism like but without rounded caps.
- (g) Plate-like are peds that are platy with particles arranged around a plane, generally horizontal.

Five structural classes are also recognised in each of the structural types depending on their size and fineness:

- (a) Very fine or very thin with grains having diameter below 1 mm.
- (b) Fine or thin with grains having diameter between 1 – 2 mm.
- (c) Medium grain size having diameter between 2 – 5 mm.
- (d) Coarse or thick grain size having diameter between 5 – 10 mm.
- (e) Very coarse or very thick grain size having diameter above 10 mm.

Four structural grades are also identified depending on the durability and strength of the peds:

- (a) Strong - Where the structural grade is characterised by durable peds that is mostly found in undisplaced soil.
- (b) Moderate - where the structural grade is characterised by well-formed distinct peds that are moderately durable.
- (c) Weak - where the degree of aggregation is characterised by poorly formed indistinct peds that are barely observable.
- (d) Structureless - where conditions of the peds have no definite orderly arrangement.

Soil structure was studied in the field showed varied forms depending on the location of the soil sample taken as shown in the Table No.12 and 13.

(i) Patharkmah – Mawskei – Warmawsaw stretch show that the soils in the hilltop are mostly weak, fine and granular. The peds are porous, fine and loosely packed with diameter 1 - 2 mm in size. However, certain differences are noticed in Mawskei village where the hilltop soils are moderate to strong, fine to very fine and sub-angular. The peds are rounded at the top with grain size 1 - 2 mm and are well packed to each other.

The soils in the hill slope show that they are mostly fine and granular. The peds are moderately packed with rounded tops and size ranging between 1 - 2 mm in diameter. However, certain differences were noticed in the Warmawsaw area where the soil structure ranges from strong to moderate, fine to medium and granular. This is because of the influence of vegetation on the soil signifying that the peds are loosely packed with grain size ranging between 2 - 5 mm.

The soils in the foothill and valley areas signify that valley soils in Mawskei area are varying from moderate to strong, fine to very fine and granular. The peds are closely packed to each other with moulded tops and not extremely porous with grain size varying between 1 – 2 mm in diameter. However, the soils in the foot hills of Mawskei and the valley area of Warmawsaw showed a lot of differences with peds being weak, moderate and granular depicting that the peds are loosely packed though not extremely porous and peds having grain size between 2 - 5 mm in diameter.

(ii) Mawiong – Khawai stretch showed that the soils structure in the hill top are mostly moderate, medium and granular in which the peds are not extremely porous with rounded tops and are moderately packed. The size ranges between 2 – 5 mm in diameter. However, certain differences is noticed in a few pockets at Khawai where the structure is weak coarse and granular mostly because the area is highly degraded and exposed to erosional activities.

The soils in the hill slope signify that the soil “peds” are ranging between strong to moderate, fine to medium and granular. These differences occur mainly because of the differences in vegetation cover and being exposed to erosional activities. Thus the peds here are moderately packed with rounded tops.

Soils in the valley area are mostly strong, fine and granular except in a few cases where the soils are moderate, medium and granular. Thus most of the soils in this belt have soil structure in which the peds are mostly strongly compact and their sizes ranging between 1 - 2 mm in diameter having slightly rounded tops and are porous.

(iii) Mawdoh – Kynrud – Tyllang Nongriat stretch showed that the soil structure in hill slope is variable in nature varying from strong to moderate and the

structural class ranging from fine to medium and the structural grade being granular. Thus the peds arrangement are ranging between strongly packed to moderately packed to being loosely packed with sizes varying from 1 – 2 mm to 2 – 5 mm in diameter.

Soils in the valley area varied from strong to moderate, fine to medium and granular. Thus the peds are either moderately or loosely packed with sizes ranging between 1 – 2 mm to 2 – 5 mm in diameter and the soils have rounded tops with porosity being moderate.

(iv) Nongthliew – Nongliput stretch showed that the soil structure in the hilltop is mostly moderate, medium and crumb in which the peds are extremely porous with rounded tops and are moderately packed. The grain size ranges between 2 – 5 mm in diameter.

The soils in the hill slopes signify that the soil “peds” are ranging between weak to moderate, medium and granular. Such differences occurred mainly because of the differences in the vegetation cover and being exposed to erosional activities. This result in the peds being moderately to loosely pack with rounded tops. The peds are however not extremely porous with sizes ranging between 1 - 2 mm to 2 – 5 mm in diameter.

Thus the study area shows that there is a great variation in the structural grades and class whereas the structural type is uniform being granular in nature. In general we can say that the soils at the hilltop are moderate, fine to medium and granular. Soils of the hill slope are mostly moderate, medium and granular whereas in the valley and foothills it is ranging from strong to moderate, fine to medium and are granular.

## **Soil Texture:**

Soil texture refers to the relative proportion of the various size groups of individual soil grains in a mass of soil particularly to the different proportion of clay, silt and sand in which clay being the finest particle and sand being the coarsest particle. Thus the relative proportion of soil separates in a particular soil determines its texture.

The soil separates i.e. sand, silt and clay here in this study has been determined in the field during survey by the feel method as discussed earlier. Soil texture that was determined in the field showed varied textural classes as shown in the Table No.12.

(i) Patharkhmah – Mawskei – Warmawsaw stretch showed that the soils in the hilltop belong to textural classes ranging from sandy to sandy loamy soils. On the other hand the hill slopes of this stretch belong to textural classes ranging from sandy to sandy loamy and loamy soils. In the foothills and the valley the soils ranged from loamy to silty loamy and clay loamy soils in the Patharkhmah and Mawskei area whereas it is mostly sandy in Warmawsaw area.

(ii) Kynrud – Mawiong – Khawai stretch showed that soils in the hilltop belonging to the textural classes ranging from sandy loamy to clay loamy soils are found in Kynrud and Mawiong whereas it is mostly sandy soils at Khawai area. On the other hand the hill slopes of this stretch belong to textural classes ranging from sandy to sandy loamy soils. In the valley area the soils also varied from sandy to sandy loamy soils.

(iii) Mawdoh – Tyllang Nongriat stretch showed that the soils in the hill slope have varied textural classes ranging from sandy to sandy loamy and loamy soils

whereas in the valley the soils had varied textural classes that ranged from sandy to sandy loamy soils.

(iv) Nongthliew – Nongliput stretch showed that the soils in the hill top belongs to the textural classes ranging from sandy loam to sandy clay loam though the most dominant being the sandy clay loams. On the other hand the soils at the hill slopes ranged from sandy to sandy clay loams.

Thus the soils of the Khri Basin in general are dominated by soils having textural classes ranging from sandy to sandy loamy soils.

### **Chemical Characteristics of Soils of the Khri Basin:**

Out of the 92 chemical elements that occur naturally, less than 20 elements are essential for plant growth and these are classified according to the needs of plants. The primary elements of Carbon (C), Hydrogen (H), Oxygen (O), and Nitrogen (N) occur in large quantities. On the other hand the secondary elements that include Calcium (Ca), Magnesium (Mg), Potassium (K) and Phosphorous (P) is found in smaller quantities.

The various chemical properties of soils covered in the present study are (a) determination of pH value (b) Presence of Organic Carbon in percentage (c) amount of Phosphorous Pentoxide content ( $P_2O_5$ ) content in kg / ha and (d) amount of Potassium Oxide ( $K_2O$ ) content in kg / ha. The soil samples collected are analysed in the Research Laboratory, Department of Agriculture, Government of Meghalaya, Shillong of which the various inferences are given in the Table No. 14.

**TABLE NO.14. CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN**

VILLAGE (S)	Sample No	Chemical Characteristics				Physical Characteristics		
		pH	OC	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	SAND	SILT	CLAY
NONGTHLIEW AND NONGLIPUT	1	5.44	1.35	4.84	109.27	44.17	22.61	33.22
	2	5.01	1.27	4.48	132.79	41.89	21.77	36.34
	3	5.49	1.63	0.89	121.01	54.11	29.68	16.21
	4	5.08	1.91	4.91	153.98	52.83	31.88	15.29
	5	5.04	2.18	1.89	101.01	54.11	29.88	16.01
	6	5.88	1.21	1.91	107.21	46.13	25.72	28.15
	7	6.43	1.21	1.86	100.06	46.13	24.22	29.65
	8	5.42	0.71	1.97	129.67	45.31	24.92	29.77
	9	4.11	2.57	2.24	201.61	40.59	23.51	29.99
	10	3.81	3.14	2.43	112.98	47.97	20.01	28.99
	11	4.02	2.01	2.22	291.96	54.19	22.52	22.48
	12	4.23	1.98	2.13	156.75	46.99	18.02	32.98
	13	4.07	1.99	2.34	218.81	54.84	18.51	24.29
	MEAN =	4.93	1.78	2.62	149.01	48.41	24.09	26.41
KYNRUD AND TYLLANG NONGRIAT	14	5.27	2.21	16.81	72.81	55.52	26.06	18.42
	15	5.04	2.69	16.81	61.61	54.17	28.11	17.72
	16	4.96	2.11	22.41	28.01	54.92	27.27	17.81
	17	5.01	2.28	19.61	28.01	50.56	27.98	21.46
	18	5.01	1.56	17.92	33.61	51.22	29.53	19.25
	19	4.91	1.01	17.92	16.81	52.57	31.82	15.61
	20	5.06	3.03	16.18	33.61	51.96	28.93	19.11
	21	4.87	2.41	19.61	16.81	54.11	29.68	16.21
	22	4.95	2.62	21.28	28.01	52.83	31.88	15.29
	23	4.99	1.81	17.92	16.81	54.11	29.88	16.01

## CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN

VILLAGE (S)	Sample No	Chemical Characteristics				Physical Characteristics		
		pH	OC	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	SAND	SILT	CLAY
	24	4.91	1.21	17.92	16.81	52.97	27.92	19.11
	25	4.93	0.31	17.92	33.61	52.67	28.81	18.52
	26	5.27	2.42	22.41	33.61	52.03	29.02	18.95
	27	5.37	3.03	21.28	16.81	54.53	25.56	19.91
	28	4.84	1.81	26.88	61.61	54.01	26.43	19.56
	<b>MEAN =</b>	5.03	2.03	19.53	33.24	53.21	28.59	18.19
<b>MAWDOH</b>	29	6.51	2.67	2.24	72.81	48.93	15.73	35.34
	30	5.91	2.01	2.24	78.4	44.17	22.61	33.22
	31	5.86	2.67	2.24	168.01	41.89	21.77	36.34
	32	5.75	2.01	4.48	123.01	46.67	16.07	37.26
	33	5.35	2.01	4.48	39.21	44.19	23.53	32.28
	34	5.43	2.67	2.24	44.81	48.83	14.16	37.01
	35	5.41	2.67	6.72	57.01	45.99	13.53	40.48
	<b>MEAN =</b>	5.75	2.39	3.52	83.32	45.82	18.19	35.99
<b>MAWIONG</b>	36	5.23	2.42	14.56	5.61	57.53	23.41	19.06
	37	4.94	1.86	26.88	28.01	55.01	25.08	19.91
	38	5.38	1.61	21.29	28.01	54.97	25.17	19.86
	39	5.48	1.71	22.96	16.81	56.01	24.13	19.86
	40	4.97	1.51	26.88	15.41	55.85	24.02	20.13
	41	4.99	1.38	22.41	5.61	57.01	23.35	19.64
	42	5.03	1.02	23.53	5.61	56.55	23.82	19.63
	43	5.34	1.81	23.52	5.61	55.89	24.15	19.96
	44	5.03	0.91	22.41	16.81	56.46	23.86	19.68

## CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN

VILLAGE (S)	Sample No	Chemical Characteristics				Physical Characteristics		
		pH	OC	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	SAND	SILT	CLAY
	45	4.06	0.91	22.41	28.01	53.93	25.71	20.36
	46	4.91	1.81	25.21	28.01	57.01	23.98	19.01
	47	5.15	0.91	17.92	16.81	57.13	23.71	19.16
	48	5.03	0.91	22.41	16.81	55.78	25.39	18.83
	49	5.61	1.32	14.56	5.61	55.87	25.52	18.61
	50	5.48	1.49	14.56	16.81	54.53	25.86	19.61
	51	5.29	1.87	15.12	5.61	56.07	22.92	21.01
	52	4.97	1.21	22.41	61.61	56.53	22.72	20.75
	53	4.93	2.04	22.41	16.81	55.67	24.84	19.49
	54	5.07	1.86	22.41	16.81	56.36	23.99	19.65
	<b>MEAN =</b>	5.11	1.51	21.26	17.92	56.01	24.29	19.69
<b>KHAWAI</b>	55	5.51	1.32	15.12	28.01	57.51	22.43	20.06
	56	5.38	1.74	22.41	196.01	55.21	26.18	18.61
	57	5.44	1.32	12.32	117.01	56.92	28.36	14.72
	58	4.31	2.14	16.81	33.61	54.37	30.46	15.17
	59	5.01	0.91	26.88	16.81	54.84	23.11	22.05
	60	5.56	1.11	21.28	28.01	57.18	25.06	17.76
	61	5.22	2.42	16.81	28.01	55.34	29.31	15.35
	62	4.93	1.51	25.21	16.81	54.72	25.09	20.19
	63	5.44	1.21	12.32	26.01	55.91	21.14	22.95
	64	4.94	1.21	13.44	16.81	56.54	29.07	14.39
	65	5.12	1.81	13.44	5.61	54.83	22.89	22.28
	66	5.01	1.81	17.92	28.01	53.76	24.51	21.73

## CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN

VILLAGE (S)	Sample No	Chemical Characteristics				Physical Characteristics		
		pH	OC	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	SAND	SILT	CLAY
	67	5.02	2.64	50.41	28.01	57.59	28.92	13.49
	68	5.56	0.82	14.56	16.81	56.46	29.11	14.43
	69	5.06	2.53	26.88	16.81	57.76	29.02	13.22
	<b>MEAN =</b>	5.17	1.63	20.39	40.16	55.93	26.31	17.76
<b>PATHARKHMAH</b>	70	5.31	1.51	22.41	33.61	47.12	24.81	28.07
	71	4.82	1.51	22.41	16.81	44.92	25.31	29.77
	72	5.16	0.31	17.92	16.81	42.03	25.02	32.95
	73	4.96	2.71	26.88	28.01	45.14	26.58	28.28
	74	5.14	1.44	17.92	16.81	44.15	25.93	29.92
	75	5.04	1.81	17.92	16.81	46.17	24.76	29.07
	76	5.85	1.61	26.88	16.81	45.98	24.98	29.04
	77	5.01	0.51	22.41	16.81	46.13	25.72	28.15
	78	5.01	2.25	22.41	28.01	46.13	24.22	29.65
	79	5.04	2.88	13.44	33.61	45.31	24.92	29.77
	80	4.95	0.61	17.92	33.61	46.03	24.02	29.95
	81	5.02	2.53	26.88	28.01	45.71	24.43	29.86
	82	4.86	2.41	17.92	28.01	45.63	24.49	29.88
	83	5.06	1.98	22.41	28.01	46.92	24.41	28.67
	<b>MEAN =</b>	5.09	1.71	21.12	24.41	45.53	24.97	29.49
<b>MAWSKEI</b>	84	5.33	1.21	17.92	72.81	46.62	26.77	26.61
	85	5.27	1.19	22.41	5.61	45.38	26.93	27.69
	86	5.49	1.52	22.41	5.61	44.76	27.31	27.93
	87	5.19	2.28	12.88	28.01	45.58	27.14	27.28

## CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN

VILLAGE (S)	Sample No	Chemical Characteristics				Physical Characteristics		
		pH	OC	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	SAND	SILT	CLAY
	88	5.39	2.03	16.24	33.61	46.13	26.22	27.65
	89	5.27	2.25	22.41	44.81	49.16	24.67	26.17
	90	5.45	2.76	16.24	28.01	46.84	28.01	25.15
	91	4.76	1.51	22.41	16.81	43.76	27.19	29.05
	92	5.51	2.03	6.72	16.81	46.11	26.91	26.98
	93	5.62	1.51	22.41	50.41	46.01	26.12	27.87
	94	5.31	1.71	16.81	33.61	46.11	27.18	26.71
	95	5.29	1.32	21.28	50.41	44.96	27.01	28.03
	96	5.66	2.36	10.64	5.61	45.31	26.41	28.28
	97	4.89	1.62	26.88	28.01	43.91	26.12	29.97
	98	5.16	1.32	19.61	28.01	44.99	26.27	28.74
	99	5.04	1.51	22.41	61.61	44.36	27.01	28.63
	100	4.85	1.81	26.88	33.61	41.13	27.93	30.94
	101	5.03	2.09	21.28	5.61	44.13	28.01	27.86
	102	5.01	1.61	26.88	28.01	43.41	27.67	28.92
	103	4.99	1.49	16.81	16.81	46.07	29.02	24.91
	104	4.91	1.68	26.88	28.01	42.99	30.16	26.85
	<b>MEAN =</b>	5.21	1.75	19.92	29.61	45.13	27.15	27.72
<b>WARMAWSAW</b>	105	4.91	2.11	17.92	16.81	48.06	27.82	24.12
	106	5.02	2.11	17.92	16.81	45.83	29.56	24.61
	107	5.05	2.36	19.61	5.61	45.62	28.94	25.44
	108	5.17	1.49	15.12	33.61	44.53	30.53	24.94
	109	4.92	1.81	22.41	5.61	44.56	28.06	27.38
	110	5.31	1.32	15.12	50.41	49.01	27.52	23.47

## CHEMICAL AND PHYSICAL CHARACTERISTICS OF THE SOILS OF KHRI BASIN

VILLAGE (S)	Sample No	Chemical Characteristics				Physical Characteristics		
		pH	OC	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	SAND	SILT	CLAY
	111	5.06	1.87	15.12	33.61	44.18	30.99	24.83
	112	4.93	1.21	22.41	16.81	45.03	29.52	25.45
	113	5.15	1.81	26.88	16.81	47.83	28.42	23.75
	114	5.25	0.98	16.81	16.81	45.92	31.01	23.07
	115	4.89	1.81	26.88	16.81	45.06	30.31	24.63
	116	5.21	1.51	22.41	33.61	45.13	29.83	25.04
	117	5.26	1.81	29.12	28.01	47.52	29.57	22.91
	118	5.32	1.81	13.44	61.6	48.12	28.97	22.91
	<b>MEAN =</b>	5.11	1.72	20.08	25.21	46.29	29.12	24.59

## **Soil Acidity:**

Acidity is the measure of the concentration of hydrogen ions in a solution in which the degree of acidity or alkalinity of a solution is measured on a pH scale. Rainfall is normally on the acid side with pH of 4.6 to 5.6. This is because rain absorbs atmospheric gases such as Carbon dioxide (CO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>) and Nitrogen dioxide (NO<sub>2</sub>) and form weak Carbonic (H<sub>2</sub>CO<sub>3</sub>), Sulphuric (H<sub>2</sub>SO<sub>4</sub>) and Nitric (HNO<sub>3</sub>) acids. Organic acids released from the plant add to the acidity level of the soil. This happens during the decaying process of the plant debris along with the rainwater as it percolates through the soil.

Table No.14 clearly shows that all the soils are acidic in nature because of the nature of the parent rock material, nature of vegetation and as such since the area is under heavy rainfall during the monsoon season all adds to such acidity. Nongthliew, Nongliput, Kynrud and Tyllang Nongriat stretch of West Khasi Hills accounts to have the highest level of acidity. Here average pH value is between 4.93 and 5.03 respectively largely because of the presence of pine vegetation surrounding the area and Mawdoh village. However, the lowest recorded pH of 3.81 is accounted in Nongliput village where the soil sample was collected from a low lying forested area which is damp and a lot of vegetal decay where the forest is primarily of mixed deciduous forest type accompanied with pine vegetation. The highest recorded pH value of 6.51 is recorded from Mawdoh village. Therefore we may conclude that the high acidic level in the study area showed rainfall and vegetation type (pine) to be prominent factors for high acidity of soil along with the interplay of the parent rock material.

## Soil Rating Status:

The soil rating chart shown on Table No.15 indicates the level of fertility of different soils depending on their chemical composition which includes, percentage of Organic Carbon, amount of phosphorous compound in kg / ha and the amount of potassium compound in kg / ha. Generally it expresses the suitability of the total soil environment essential for plant growth. Soil fertility is therefore one which has any or all the following features:

- (a) a sandy loam or loamy soil giving good drainage and aeration with an adequate water holding capacity.
- (b) a well developed crumb structure with adequate quantity of soil humus.
- (c) a good supply of nutrients from organic decay.
- (d) a neutral – to – slightly – acid pH.
- (e) a relatively deep soil for root development

**TABLE NO. 15 SOIL RATING CHART**

	LOW	MEDIUM	HIGH
ORGANIC CARBON (%)	< 0.5	0.50 - 0.75	> 0.75
P <sub>2</sub> O <sub>5</sub> Kg/Ha	< 28.03	28.03 - 56.05	> 56.05
K <sub>2</sub> O Kg/Ha	< 134.5	134.50 - 336.3	> 336.3
T.S.S.	Critical	Non-Critical	

Source: Research Laboratory, Department of Agriculture, Govt. of Meghalaya, Shillong.

The soil collected from Patharkmah – Mawskei – Warmawsaw range signifies that the soils are rich in Organic Carbon content which is the Nitrogen Equivalent having an average percentage ranging from 1.7 % to 1.75 %. The Phosphorous and Potassium content on the other hand is very low with an average of only around 20 kg / ha and 26 kg / ha respectively.

Soils of Mawiong – Khawai stretch also showed similar results with high percentage of Organic Carbon ranging from 1.5 % to 2 % and very low amount of phosphorous and potassium content showing an average of about 20 kg / ha and 30 kg / ha respectively.

Soils of Mawdoh – Kynrud – Tyllang Nongriat stretch also highlighted similar result with very high Organic Carbon content averaging to 2.39 % with critically low phosphorous content averaging to only 3.52 kg / ha and low potassium averaging to 83.32 kg / ha.

Soils of Nongthliew – Nongliput stretch signifies that the soils are rich in Organic Carbon i.e. the Nitrogen Equivalent having an average percentage of about 1.78 %. The phosphorous content is critically low with only 2.62 kg / ha. On the other hand the potassium content is relatively moderate with 149.01 kg / ha.

In general we can state that the soils of the study area have high Organic Carbon content with low to critically low phosphorous content and low to moderate composition of potassium content. Taking into consideration both the physical and chemical characteristics of the soil samples collected we can conclude that the soils in general are more or less fertile. This is because texturally they range from clayey to sandy loamy to loamy soils and have a well form crumb structure with high Organic Carbon content. On the other hand the chemical characteristics showing low to very low amount of phosphorous and potassium content confirms that the original has high content of iron oxides in which Cation Exchange takes place resulting to high acidity of the soils. Secondly as the area is hilly and under the influence of monsoon the soil cover is washed away which resulted to lowering both phosphate and potash content.

## REFERENCES

1. **Mc Knight T.L** (1993) *Physical Geography: A Landscape Appreciation* Prentice Hall, Englewood Cliffs, New Jersey 07632 Pg 336.
2. **Donahue R.L; Miller R.W** (1975); *A Introduction to Soils and Plant Growth* Shickluna J.C Prentice Hall of India, New Delhi 5<sup>th</sup> Edition 1985 Pg 569.
3. **Soil Science Society of America** October 1979 *Glossary of Soil Science Terms* Pg 15
4. **Dokuchaev V.V** (1886) *Data on Land Appraisal in Nizhnii-Novgonod Province in collected Works, Vol 4, acad sci Moscow, 1950.*
5. **O' Hare G.** (1988), *Soils, Vegetation and Ecosystems* Oliver and Boyd Longman House, Pg. 29.
6. **Cruickshank J.G** (1972) *Soil Geography* David and Charles, Newton Abbot pp. 155 & 158.
7. **Kalpage F.S.C.P** (1974) *Tropical Soils: Classification, Fertility and Management.* Macmillan pp 47 –48, 53-54.
8. **Munsel Colour Company** (1975) *Munsell Soil Colour Chart* Inc Battimore 2, Maryland
9. **US Dept.** (August 1951) *Agriculture Handbook No.18 Soil Survey Manual* Oxford & IBH Publishing Co pp. 189.
10. **O'HareG.**(1989), *Soils, Vegetation, Ecosystems Conceptual Frameworks* in *Geography* Oliver and Boyd pp. 17

**CHAPTER - V**  
**MORPHOLOGICAL CHARACTERISTICS OF**  
**THE DOMINANT TREE SPECIES**

**Introduction:**

Morphological studies of plants deal with the study of forms and features of different plant organs such as roots, stems, leaves, flowers, seeds and fruits. However, in the present study certain important morphological aspects are studied with regard to plant height, nature of the bark, leaves size, shape and pattern, nature of the flowers and other related aspects of which the trees are classified under specific family, genus and family.

**Units of Classification:**

“Species” is a group of individual (plants or animals) of one and of the same kind. Evidently they resemble one another in almost all the morphological characteristics – both vegetative and reproductive – so closely that they may be regarded as having been derived from the same parents. However occasionally owing to variations in climatic and edaphic conditions, individuals of a species may show a certain amount of variation in form, size, colour and other minor characteristics forming varieties.<sup>1</sup>

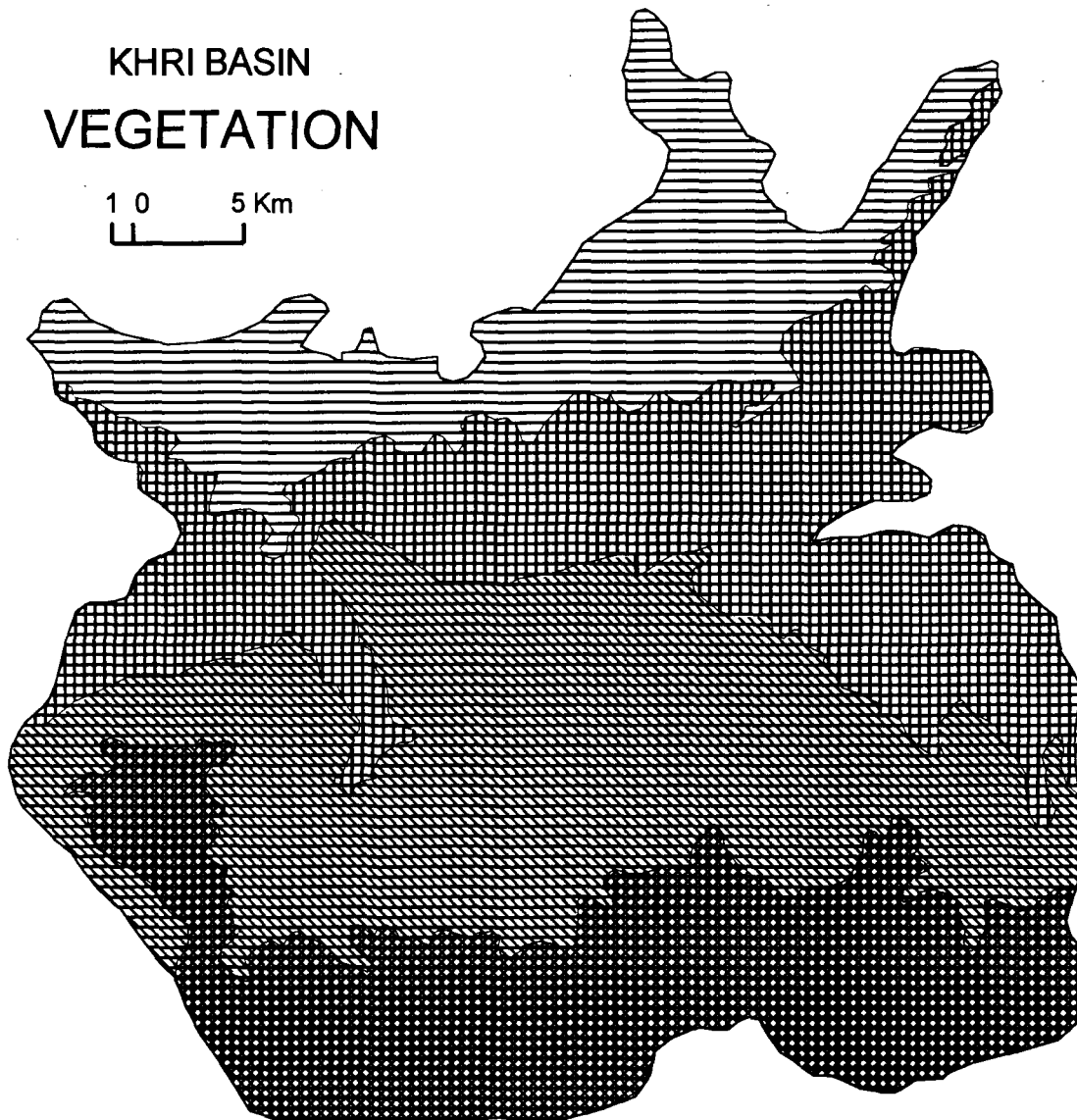
“Genus” is a collection of species that bear a close resemblance to one another in the morphological characters of the floral or reproductive parts. On the other hand a “Family” is a group of genera that show general structural resemblance with one another, mainly in their floral organs.

Nomenclature of the identified tree species is followed in accordance to Binomial Nomenclature that was first introduced by Linnaeus (1735) that is the scientific method of naming species of plants or animals of which the first refers to the genus and the second to the species. The various plant species studied represents the different areal units as mentioned in the earlier chapters. In the study a vegetation map (Fig.No.13) as shown has been prepared in accordance to the relief map where 4 (four) areal units have been identified with different vegetal coverage.

- (i) The High Uplands: Nongthliaw – Nongliput stretch where mixed deciduous forests are present along with the pines;
- (ii) The Mid-central Uplands: Kynrud – Tyllang Nongriat – Mawdoh stretch which is purely dominated by pine forests along with a few deciduous tree species;
- (iii) The Low Uplands: Mawiong – Khawai stretch where sub-tropical forests are found dominating and pine forests plantations are also present and;
- (iv) The Lowlands: Patharkmah – Mawskei – Warmawsaw stretch where tropical to sub-tropical forest species are found prevalent.

# KHRI BASIN VEGETATION

1 0 5 Km



## TYPES OF VEGETATION

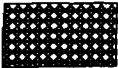



-  Mostly mixed deciduous / Pine Vegetation
-  Mostly Pine Vegetation / Mixed Deciduous
-  Sub -Tropical Vegetation / Pine Vegetation
-  Sub - tropical Vegetation / Tropical Vegetation

Fig No. 13

**High Uplands: Nongthliew – Nongliput Stretch**

1. Family: Fagaceae  
Genus: Quercus  
Species: *Quercus griffithii*  
Vern: Dieng-wah

**Morphological Characteristics:**

Trees upto 15 metres high, crown lax

Bark ashy grey, fissured, warty and rough

Leaves (crowded at branch tips) 10 - 22 x 3.5 - 12 cms, oblanceolate-elliptic, obovate-elliptic, acuminate, base narrowed, cuneate or rounded, sharply distantly serrate.

2. Family: Symplocaceae  
Genus: Symplocos  
Species: *Symplocos glomerata*  
Vern: Kynja-dieng-pic, Tiew-dieng-peiiiong.

**Morphological Characteristics:**

Shrubs or small trees, 5 - 15 metres high, crown lax, spreading

Bark gray or blackish-gray

Leaves 6 - 18 x 2 - 5 cms, oblong-lanceolate, oblong-elliptic or oblanceolate, acuminate, base narrowed, cuneate, crenate serrate, glabrous, coriaceous.

3. Family: Magnoliaceae  
Genus: Manglietia  
Species: ***Manglietia insignis***  
Vern: Dieng-rhi-basaw, Dieng-rhi-balib.

**Morphological Characteristics:**

Tall trees, 10 - 20 metres high, crown dense, oval or spreading

Bark dark brown, fissured or winged

Leaves size 12 - 25 x 3 - 6 cms, oblanceolate, oblong-oblanceolate, acuminate, base narrowed, cuneate, entire, glabrous and shining above.

4. Family: Ericaceae  
Genus: Lyonia  
Species: ***Lyonia ovalifolia***  
Vern: Diengla-samiang, Jirhap

**Morphological Characteristics:**

Middle sized, crooked trees or shrubs, 1 - 10 metres high, crown lax, stems twisted

Bark reddish-brown, reticulately fissured, thin

Leaves 2.5 - 15 x 1.2 - 10 cms, ovate to oblong-elliptic, abruptly acuminate, base rounded, cordate or acute, brown punctate beneath.

5. Family: Aceraceae

Genus: Acer

Species: ***Acer laevigatum***

Vern: Dieng-tyrthiaiong, Dieng-than, Dieng-sohtyrkum.

**Morphological Characteristics:**

Large trees up to 30 metres high, crown spreading, irregularly oval

Bark grayish-brown or dark brown, warty

Leaves 6 - 12 x 2 - 4 cm, ovate, oblong or elliptic-lanceolate, caudate acuminate, base rounded, truncate or subcordate, nerves prominent on both surfaces.

6. Family: Mimosaceae

Genus: Acacia

Species: ***Acacia delbata***

Vern: Tiew-babur

**Morphological Characteristics:**

Middle sized trees, upto 15 metres high; crown elongated, oval, dense

Bark dark-brown or grayish-brown, nearly smooth

Leaves are 10 - 20 cms long.

7. Family: Fabaceae  
Genus: Erythrina  
Species: *Erythrina arborescens*  
Vern: Dieng-song.

**Morphological Characteristics:**

Small or middle sized trees with a spreading, umbrella-shaped crown.

Bark grayish-brown, greenish-brown, and spiny in branchlets, vertically fissured or furrowed

Leaves up to 45 cm long, leaflets 16 - 22 x 12 - 22 cms, often broader, broadly triangular, ovoid or rhomboid, acuminate, base broadly cuneate, glabrous, glaucous beneath, 3-nerved from base, nerves often purplish-red.

8. Family: Fabaceae  
Genus: Erythrina  
Species: *Erythrina Stricta*  
Vern: Dieng-song, Dieng-songdkhar.

**Morphological Characteristics:**

Large trees, reaching to 30 metres high, crown oval, lax, branches horizontally spreading Bark yellowish gray, vertically fissured with conical thorns.

Leaves reaching to 50 cm in length, leaflets 7 - 20 x 4.5 - 18 cms, often broader than long, rhomboid-orbicular or ovate, lateral ones oblique, acuminate, base broadly cuneate, truncate, glaucous beneath.

9. Family: Myricaceae  
Genus: Myrica  
Species: ***Myrica esculenta***  
Vern: Sohphi.

Morphological Characteristics:

Trees 5 - 15 metres high, crown dense

Bark dark or blackish-brown, minutely pustuled, horizontally wrinkled

Leaves 6 - 15 x 1.5 - 5 cms, oblong-oblongeolate, oblongeolate-elliptic, acute, base narrowed, cuneate, glabrous, entire or remotely serrate. Family :  
Dipterocarpaceae

10. Family: Ericaceae  
Genus: Gaultheria  
Species: ***Gaultheria fragrantissima***  
Vern: Jirhap, Jirhapiong, Soh-lingthrait, Dieng-lashyrhap.

Morphological Characteristics:

Bushy shrubs, reaching to 4 metres high, branchlets angled, reddish

Bark brown

Leaves 3 - 9 x 1.3 - 4 cms, broadly elliptic, oblong or oblong-lanceolate or oblongeolate-elliptic, sometimes orbicular, obtuse or subacute, base.

**Mid-Central Uplands: Kynrud – Tyllang Nongriat - Mawdoh Stretch**

11. Family: Piniaceae

Genus: Pinus

Species: *Pinus khasyana*

Vern: Diengkseh

**Morphological Characteristics:**

The leaves are needle-like, 3 in each follicle, circular, trifoliate. The pine needles are on the average 16 cms long and with spirally arranged spurs.

The bark is dry, corky having a shedding outer bark. The average thickness of the bark is 3 - 5 cms.

The average height of the trees is 23 metres.

12. Family: Symplocaceae

Genus: Symplocos

Species: *Symplocos paniculata*

Vern: Dieng-iong, Jam-iang

**Morphological Characteristics:**

Bushy shrubs or small trees, 2 - 10 metres high

Bark light gray, rough, lenticellate

Leaves 3 - 10 x 1.5 - 5 cms, obovate-lanceolate or ovate-lanceolate, broadly elliptic, base rounded or cordate, sharply crenate or serrate.

13. Family: Theaceae

Genus: Schima

Species: *Schima khasiana*

Vern: Dieng-ngan

**Morphological Characteristics:**

Middle sized trees, upto 20 m high, crown oblong-ovate

Bark reddish-brown to dark-brown, nearly smooth

Leaves 9 - 20 x 4 - 8 cms, broadly lanceolate, elliptic-oblong, oblong-lanceolate, acuminate, base cuneate, acute, glabrous, coriaceous, sharply serrate.

14. Family: Fabaceae

Genus: Erythrina

Species: *Erythrina stricta*

Vern: Dieng-song, Dieng-songdkhar

**Morphological Characteristics:**

Large trees, upto 30 metres high, crown oval, lax, branches horizontally spreading Bark yellowish-gray, vertically fissured with conical thorns

Leaves upto 50 cm long, leaflets 7 - 20 x 4.5 - 18 cms, often broader than long, rhomboid-orbicular or ovate, lateral ones oblique, acuminate, base broadly cuneate, truncate, glaucous beneath.

15. Family: Anacardiaceae

Genus: Rhus

Species: *Rhus javanica*

Vern: Dieng-sohma, Dieng-sohmia

**Morphological Characteristics:**

Small to middle sized trees, upto 12 m high, crown lax, spreading

Bark gray, warty; leaflets 4 - 15 x 2 - 7 cms, variable in shape, ovate, ovate-lanceolate, shortly acute or acuminate, base subcordate, truncate or rounded, crenate, dentate.

16. Family: Rosaceae

Genus: Photinia

Species: *Photinia arguta*

Vern: Dieng-snam, Dieng-um, Dieng-sohkhikhiew

**Morphological Characteristics:**

Small or middle sized trees reaching to 15 m high, crown lax, oval, branches spreading

Bark dark brown or blackish-brown, nearly smooth

Leaves 5 - 15 x 1.5 - 5 cms, oblong-lanceolate, ovate-elliptic, abruptly acuminate, often caudate, base acute to rounded.

17. Family: Theaceae

Genus: Eurya

Species: *Eurya acuminata*

Vern: Dieng-shit, Dieng-pyrshitheh

**Morphological Characteristics:**

Trees or large shrubs, branches usually horizontal or drooping

Bark dark-brown

Leaves (lower ones sometimes shorter) 4 – 9 x 1 - 2 cms, oblong-lanceolate or linear-elliptic-lanceolate, acuminate, base cuneate, rounded or obtuse, crenate, glabrous.

18. Family: Saurauiceae

Genus: *Saurauia*

Species: *Saurauia punduana*

Vern: Dieng-jalangap, Dieng-sohlapot, Dieng-sohkhijut

Morphological Characteristics:

Small trees 8 - 10 m high, branchlets scaly

Bark brown or brownish-gray, lenticellate

Leaves 15 - 30 x 7 - 15 cms, elliptic, obovate, oblanceolate, acuminate, base rounded, truncate, serrate, glabrous above, nearly tomentose beneath.

19. Family: Aquifoliaceae

Genus: *Ilex*

Species: *Ilex odorata*

Morphological Characteristics:

Small trees, 5-7 m high, crown lax, branches slender

Bark brownish-gray, lenticellate, smooth

Leaves 3 – 8 x 1.5 - 3 cms, oblong-lanceolate or ovate lanceolate, acute or shortly acuminate, base rounded or obtuse, glabrous, dark green above and pale beneath.

20. Family: Lauraceae

Genus: Litsea

Species: *Litsea elongata*

Vern: Dieng-jalong-ngap

**Morphological Characteristics:**

Middle sized trees, 10 - 15 metres high with a compact crown

Bark dark brown in colour, smooth or slightly fissured

Leaves 5.5 - 20 x 1.5 - 5.5 cms, oblong-lanceolate, oblong-oblanceolate, acute or subacute, base narrowed or obtuse, brown pubescent beneath.

21. Family: Betulaceae

Genus: Betula

Species: *Betula alnoides*

Vern: Dieng-lieng

**Morphological Characteristics:**

Lofty trees 20 - 30 metres high

Bark pale brown, peeling off in horizontal rolls, horizontally linear lenticellate

Leaves 5 - 12 x 2.5 - 6 cms, ovate, ovate-lanceolate, acuminate, base rounded or truncate, sometimes oblique, cuspidate serrate.

22. Family: Araliaceae  
Genus: Schefflera  
Species: *Schefflera hypoleuca*  
Vern: Dieng-latymphu

**Morphological Characteristics:**

Middle sized trees 10 - 15 metres high, crown compact, branches erect or suberect

Bark smooth, brown, greenish brown, often angular thickened, leaflets polymorphic, terminal one largest, 12 - 20 x 4 - 10 cms, oblong or ovate-oblong, acute, base rounded.

23. Family: Juglandaceae  
Genus: Engelhardtia  
Species: *Engelhardtia spicata*  
Vern: Dieng-lamba, Dieng-lyba.

**Morphological Characteristics:**

Lofty trees up to 25 - 35 metres high, crown ovoid, umbrella-shaped

Bark grey or greyish-brown, vertically split and scaly

Leaves 13 - 30 cms long, leaflets 4 - 15 x 1.5 - 5 cms, oblong-elliptic, oblong oblanceolate, acute or shortly acuminate, base rounded.

**Low Uplands: Mawiong – Khawai Stretch**

24. Family: Rutaceae

Genus: *Micromelum*

Species: ***Micromelum integerrimum***

Vern: Dieng-syrngam, Dieng-jaiaw, Dieg-sohsat

**Morphological Characteristics:**

Small trees, often shrubby, crown spreading

Bark whitish-gray, smooth

Leaves 15 - 40 cms long, leaflets 5 - 15 x 2 - 5 cms, ovate-lanceolate, oblong-lanceolate, long acuminate, cuneate, oblique at base.

25. Family: Anacardiaceae

Genus: *Rhus*

Species: ***Rhus acuminata***

Vern: Dieng-khlaw

**Morphological Characteristics:**

Middle sized trees upto 20 metres high

Bark dark gray or greyish-brown, reticulately fissured, peeling off in regular flakes Petioles 7 - 25 cms long, leaflets 4.5 - 9 x 1.5 - 3 cms, ovate, ovate-lanceolate, oblong-lanceolate or oblong elliptic, acuminate, rounded or cuneate, slightly recurved at margin.

26. Family: Theaceae

Genus: Schima

Species: ***Schima wallichii***

Vern: Dieng-nganbuit

**Morphological Characteristics:**

Large trees, 15 - 50 metres high, crown ovoid, dense

Bark reddish-brown, warty or blotched,

Leaves 8 - 16 x 2.5 - 6 cms, elliptic-lanceolate, oblong-elliptic, oblanceolate, acute, base cuneate, margin entire, deciduously bulbous hairy beneath, glabrous above.

27. Family: Tetramelaceae

Genus: Tetrameles

Species: ***Tetrameles nudiflora***

Vern: Dieng-sarat

**Morphological Characteristics:**

Tall deciduous trees upto 50 metres high, crown spreading, bole straight, base buttressed Bark brown, shining in young trees, smooth, horizontally wrinkled

Leaves 8 - 14 x 6.5 - 15 cms, orbicular or suborbicular, ovate, acuminate, base cordate or truncate.

28. Family: Rubiaceae

Genus: Wendlandia

Species: ***Wendlandia grandis***

**Morphological Characteristics:**

Small or middle sized trees 8 - 15 metres high

Bark greyish-brown, peeling off in thin flakes

Leaves 11 - 22 x 5 - 10 cms, broadly elliptic, obovate-elliptic or ovate elliptic, acuminate; base narrowed, cuneate, glabrescent.

29. Family: Pinaceae

Genus: Pinus

Species: *Pinus insularis*

Vern: Diengkseh

Morphological Characteristics:

The leaves are needle-like, 3 in each follicle, circular, trifoliate. The pine needles are on the average 16 cms long and with spirally arranged spurs.

The bark is dry, corky having a shedding outer bark. The average thickness of the bark is 3 - 5 cms. The average height of the trees is 23 metres.

**Lowlands: Patharkmah – Mawskei - Warmawsaw Stretch**

30. Family: Dipterocarpaceae

Genus: Shorea

Species: *Shorea robusta*

Vern: Dieng-blei, dieng sal.

Morphological Characteristics:

Tall deciduous trees reaching upto 30 metres, crown oval

Bark brown with prominent longitudinal fissures

Leaves ovate-oblong, acuminate or acute, base cordate or truncate, pinkish when young, orange yellow at senescence, glabrous above, puberulous with nerves beneath, lateral nerves 11 - 16.

31. Family: Verbenaceae

Genus: Tectona

Species: *Tectona grandis*

Vern: Segun

**Morphological Characteristics:**

Large trees, up to 30 metres high with a straight bole and narrow crown.

Leaves 15 – 75 cms x 10 - 50 cms, broadly ovate, ovate-elliptic or obovate, acuminate or obtuse, base cuneate, attenuate rough above, stellate tomentose beneath; panicles 75 cms across.

32. Family: Combretaceae

Genus: Terminalia

Species: *Terminalia myriocarpa*

Vern: Dieng-maraoditar, Dieng-tal

**Morphological Characteristics:**

Tall trees upto 35 metres high with an ovoid crown and pendulous branches

Bark gray to grayish-brown in colour, scaly with vertical flakes

Leaves 10 – 25 cms x 4 - 7 cms, oblong-lanceolate or oblong-elliptic, sometimes falcate, acute to acuminate, base truncate or subcordate, glabrous when mature, panicles terminal and upper axillary, large, upto 30 cm long and broad spreading.

33. Family: Cannabaceae

Genus: Artocarpus

Species: *Artocarpus chaplasha*

Vern: Dieng-laram, Dieng-sohram, Dieng-soh-phankhlaw

**Morphological Characteristics:**

Lofty trees 30 - 50 metres high, crown large and spreading

Bark brown with white patches, peels off in broad scales, exposing orange yellow dotted surfaces

Leaves 12 – 30 cms x 7 - 18 cms, broadly obovate or ovate-elliptic, obtuse or cuspidate, base rounded or sub-cordate.

34. Family: Verbenaceae

Genus: Gmelina

Species: *Gmelina arborea*

Vern: Dieng-lophiang

**Morphological Characteristics:**

Large deciduous trees up to 30 metres high, crown lax, spreading

Bark grey with dark patches, nearly smooth

Leaves 6 - 18 x 4 - 15 cms, ovate, acute or acuminate, panicles up to 25 cm long.

35. Family: Moraceae

Genus: Ficus

Species: *Ficus maclelandi*

**Morphological Characteristics:**

Trees 15 - 20 metres high, stems often fluted

Bark gray or whitish

Leaves 7-15 X 3-6 cm, elliptic, elliptic-lanceolate, acuminate, base rounded or cuneate, entire, glabrous and shining above

36. Family: Moraceae

Genus: Ficus

Species: *Ficus elastica*

Vern: Diengjri

Morphological Characteristics:

Large trees, much spreading

Leaves 12 - 30 x 5 - 12 cms, broadly elliptic, elliptic oblong, acute or abruptly caudate acuminate, base narrowed or rounded, glabrous

37. Family: Elaeocarpaceae

Genus: Elaeocarpus

Species: *Elaeocarpus tectorius*

Vern: Dieng-sohkhyllam

Morphological Characteristics:

Large trees upto 35 metres high, crown oval, lax

Bark gray, often warty and fluted

Leaves 12 - 20 x 4.5 - 8 cms, ovate-oblong, oblong-elliptic, acuminate, base obtuse or rounded, remote repand, silky tomentose when young.

38. Family: Bignoniaceae

Genus: *Oroxylum*

Species: *Oroxylum indicum*

Vern: Ja-ranghon, Diengititkongling

**Morphological Characteristics:**

Small or middle sized trees, 5-15 m high, laxly branched or unbranched, branches erect or suberect

Bark greyish, corky

Leaves 1 - 2 metres long, leaflets 5.5 - 15 cms long, ovate, broadly ovate-orbicular, obtuse to acuminate, base usually oblique, often cordate or subcordate, pale beneath.

39. Family: Dilleniaceae

Genus: *Dillenia*

Species: *Dillenia scrubrella*

Vern: Dieng-soh-bar

**Morphological Characteristics:**

Deciduous trees, 20-35 m tall

Bark grey, smooth

Leaves 20 - 40 x 6 - 15 cms, obovate-oblong or oblanceolate, obtuse or sub-acute, base acute, cuneate, dentate or serrate, hispid above, pubescent beneath; petiole winged.

40. Family: Verbenaceae  
Genus: Callicarpa  
Species: *Callicarpa arborea*  
Vern: Dieng-lakhoit

**Morphological Characteristics:**

Middle sized trees upto 15 cm high, much branched, usually from base

Bark dark gray or brown, usually smooth

Leaves 15 - 30 x 5 - 15 cms, elliptic-lanceolate, oblong-lanceolate, acuminate, base cuneate, entire or subentire, tomentose beneath.

41. Family: Lauraceae  
Genus: Litsea  
Species: *Litsea khasyana*  
Vern: Dieng – mosu

**Morphological Characteristics:**

Small or middle sized trees upto 15 metres high, often shrubby

Bark brown, horizontally wrinkled

Leaves 6 - 25 x 3 - 10 cms, oblong-lanceolate, oblong-elliptic, acute or acuminate, base narrowed, cuneate.

**Bamboo Species:**

- |                             |                                |
|-----------------------------|--------------------------------|
| 1. Dendrocalamus hamiltonii | Large bamboos                  |
| 2. Dendrocalamus giganteus  | Very tall bamboos              |
| 3. Bambusa bambos           | Tall bamboos with yellow culms |

4. *Chimonobambusa Khasiana*

Bushy shrubs

5. *Melocanna bambusoides*

Dwarf, slender bamboos

## REFERENCES

1. Haridasan K. and Rao R.R (1985) Forest Flora of Meghalaya, Volume I and II, Shiva Printers Dehradun

## **CHAPTER VI**

### **LANDFORMS - SOIL- PLANT RELATIONSHIP**

#### **Introduction:**

The early chapters that dwelt with studies on geology, geomorphic landforms, physical and chemical characteristics of the soils, plant morphology and the micro-climatic conditions of the study area exhibit a close relationship between them. Geomorphology and geology determines the physical and chemical characteristics of the soils and variations in the morphological characteristics of the plant species. The soil conditions along with climatic conditions determine the nature of natural vegetation that may influence geomorphic processes in humid areas.

Referring to the micro areal units a detailed study particularly of soil and dominant tree species has been made. The whole study area has been classified into 4 zones i.e.

1. The High Uplands: Nongthliew – Nongliput stretch where mixed deciduous forests are present along with the pines;
2. The Mid-central Uplands: Kynrud – Tyllang Nongriat – Mawdoh stretch which is purely dominated by pine forests along with a few deciduous tree species;
3. The Low Uplands: Mawiong – Khawai stretch where sub-tropical forests are found dominating and pine forest plantations are also present and;
4. The Lowlands: Patharkmah – Mawskei – Warmawsaw stretch where tropical to sub-tropical forest species are found prevalent.

It may be accounted that geomorphology provides the framework on which climate is acting through vegetation, forms the soil. All the sites studied are subject to pedogenesis - the complex of physical, chemical and biological processes that form the soil profiles where the depth of soils tends to increase downslope. However, differences in soil humus (organic carbon) structure and fertility results from the base status of the parent rock materials. In the study area the soils are derived from acidic rocks and the colour ranges from brown to dark brown showing that the soils contain iron oxides.

On the other hand vegetation is often a good indicator of the soil and climatic conditions but there are instances where the reliability varies from place to place, depending on other local factors particularly the geomorphic attributes. In some cases the presence or absence of certain plant species indicates the texture of the soil. For example a narrow seepage zone changes the vegetal density and height of the dominant tree species.

In general all soils are greatly influenced by geomorphology and climate has a dominating influence too on the distribution of plant species. In general the finer the soil texture better is the inherent fertility but poor drainage leads to a longer time for the salts to be removed or be dissolved through leaching. Therefore because of the control of geomorphic boundaries on moisture conditions that coincide with soil boundaries, geomorphology determines the major plant communities.

The analysis of geomorphic characteristics of landforms indicate that there is a close relationship among the three i.e. geomorphology, dominant tree species and soil characteristics along with the interplay of climate and geology.

### **Nongthliew – Nongliput Stretch:**

In this areal unit where the general relief is above 1500 metres mean sea level, the average slope is mostly ranging between 12° - 18°. In certain portions it reaches up to 20° with drainage density mostly ranging from 4 - 6 km / km<sup>2</sup> though in certain pockets goes up to as high as 7 km/ km<sup>2</sup>. Drainage frequency of the area lies within the range 4 - 8 streams / km<sup>2</sup> though at certain parts goes up to as high as 10 streams / km<sup>2</sup>. The area is weakly dissected reaching levels ranging between 0.1 - 0.3. This area is highly marked with small streams and rivulets and though widely interspersed their level of dissection is comparatively low. As such mostly 1<sup>st</sup> Order and 2<sup>nd</sup> Order Streams are identified here. Much undercutting of water is not observed in this areal unit resulting to low – moderate slopes and drainage density with low level of dissection.

With regard to the geological set up, this areal unit is dominated by the presence of gneiss. Only in the south-western portion that we observe the presence of schist and in the northern fringe of this areal unit granites are found.

The physical characteristics of the soil show that the soils of this areal unit have colour ranging between reddish brown to brown signifying the presence of iron oxides. The soil structure ranges between crumb to granular with peds being fine to moderate and texture ranges between sandy clay – sandy loam – sandy clay loamy soils.

The chemical characteristics signify that the soils here are highly acidic with pH value ranging from 3.81 to 5.44. On the other hand the soils are rich in Organic Carbon i.e. the Nitrogen Equivalent, whereas the amount of phosphorous content is critically low and that of potassium is relatively moderate.

This areal unit is dominated by indigenous plant species of mixed deciduous type and temperate forest nature. However, the length of trees on an average ranges between 15 - 20 metres with average leaf size being (16 x 5) cms. The dominant tree species in this area are *Quercus griffithii*, *Symplocos glomerata*, *Monglietia insignis*, *Michelia champaca*, *Acer laerigatum*, *Pinus khasyana*, *Lyonia ovalifolia*, *Gaultheria fragrantissima*, *Litsea elongata*, *Betula alnoides* and *Schefflera hypolenca*.

The area of Nongthliew – Nongliput stretch is under the influence of the monsoon with average maximum range of temperature being 13.7°C - 24.2°C and minimum range of temperature being 4.8°C - 17.5°C. Total average annual rainfall reaches to about 211.4 cm with relative humidity ranging from 72 % - 87 %.

#### **Kynrud – Tyllang Nongriat – Mawdoh Stretch:**

In this areal unit where the general relief is between 1000-1500 metres, the average slope is mostly ranging between 18° - 24°. At certain pockets the slopes are above 24° some reaching up to 29° with drainage density ranging between 6 - 8 km / km<sup>2</sup> and at some pockets reaching up to 9km / km<sup>2</sup>. Drainage frequency of the area lies within the range 8 - 12 streams / km<sup>2</sup> though at certain pockets goes up as high as 14 streams / km<sup>2</sup>. The area is moderately dissected with dissection level ranging between 0.1 - 0.3 and 0.3 - 0.6 and at some pockets reaching up to 0.7. This area is highly marked with fast flowing streams, deep ravines, gorges and waterfalls.

With regard to the geological set up this areal unit is largely dominated by the presence of granites to about 65 % and the remaining is dominated by gneiss. Maximum under-cutting is observed in this areal unit with high and steep slopes, moderate to high drainage density and moderate to high levels of dissection. It is

very interesting to note here that maximum granites are found located only in this areal unit and this happens to be a pine belt area where 90 % of the vegetation is dominated by pines other than other mixed deciduous species.

The physical characteristics of the soils of this areal unit have colour ranging between light reddish brown to dark reddish brown signifying the presence of iron oxides. The soil structure is mostly granular with 'peds' ranging between fine to moderate and structural grades ranging between strong to moderate. The soil texture ranges between sandy – sandy loamy.

The chemical characteristics signify that the soils are highly acidic with pH value ranging from 4.93 - 5.91. On the other hand the soils are rich in Organic Carbon which is the Nitrogen Equivalent with critically low levels of phosphorous and potassium contents.

This areal unit is dominated by pine forest with the presence of a few mixed deciduous species. The length of trees on an average ranges between 15 - 25 metres with average leaf size being (17 x 6) cms. The dominant tree species in this area are *Pinus khasyana*, *Symplocos paniculata*, *Schima khasyana*, *Erythrina stricta*, *Photina arguta*, *Eurya accuminata*, *Saurania panduana*, *Ilex odorata*, *Engelhardtia spicata*, *Rhus javanica*, *Erythrina arborescens*, *Myrica esculanta*, *Litsea elongata*, *Betula alnoides* and *Schefflera hypoleuca*.

The area of Kynrud - Tyllang Nongriat – Mawdoh stretch is also under the influence of the monsoon. The average maximum temperature ranges between 14.5°C to 24.3°C and minimum temperature ranges between 5.8°C – 17.8°C. Total average annual rainfall is about 193.1 cms with relative humidity ranging from 55 % - 88 %.

### **Mawiong – Khawai Stretch:**

In this areal unit the general relief is between 500 –1000 metres, the average slope is mostly ranging between 18° - 24°. At certain pockets the slopes are above 24° reaching up to 26° with drainage density ranging between 6 - 8 km / km<sup>2</sup> and at some pockets reaching up to 9.5 km / km<sup>2</sup>. Drainage frequency of the area lies within the range 8 - 12 streams / km<sup>2</sup> though at certain pockets goes as high as 13 streams / km<sup>2</sup>. The area is moderately to highly dissected with dissection level ranging between 0.3 - 0.6 and in some pockets reaching up to 0.7 dissection level. This area is marked by widening of streams where down cutting of the river course is proceeding towards maturity though at certain pockets deep wide valleys, gorges are also present.

With regard to the geological set up of this areal unit it is largely dominated by gneiss other than granites found in the southern fringes of this areal unit. In pockets where steep slopes we observe the presence of granites and it is at this level that pine plantations (*Pinus insularis*) are found to be thriving well.

The physical characteristics of the soil show that the soils of this areal unit have colour ranging between dark red to weak red again signifying the presence of iron oxides in the soils. The soils structure is mostly granular with 'peds' ranging between fine to moderate and structural grades ranging between strong to moderate. The soil texture ranges between sandy – sandy loam – sandy clay loam.

The chemical characteristics signify that the soils are again highly acidic with pH value ranging from 4.06 – 5.56. On the other hand the soils are rich in Organic Carbon that is the Nitrogen Equivalent with critically low phosphorous and potassium contents.

Sub-tropical forests dominate this areal unit with the presence of a few spot having pine plantations as secondary growth. The length of trees on an average ranges between 20 - 35 metres with average leaf size being (17 x 8) cms . The dominant tree species of this area are *Micromellum integerrinum*, *Tetrameles nudiflora*, *Wenlandia grandis*, *Schima wallichii*, *Rhus accuminata*.

The area of Mawiong – Khawai stretch is also under the influence of monsoon where average maximum temperature ranges between 18.5°C – 27.8°C and minimum temperature ranges between 6.1°C – 20.6°C. Total average annual rainfall is about 272.6 cms with relative humidity ranging from 55 % - 89 %.

#### **Patharkmah – Mawskei – Warmawsaw Stretch:**

In this areal unit where the general relief is below 500 metres, the average slope is mostly varies from <12° - >24° i.e. <12°; 12° - 18°; 18° - 24°; 24° with drainage density ranging between 6 - 8 km / km<sup>2</sup> and at some pockets reaching to 10 km / km<sup>2</sup>. Drainage frequency of the area lies within the range 8 - 12 streams / km<sup>2</sup> though at certain pockets goes up as high as 13 streams / km<sup>2</sup>. The area is moderately dissected with dissection levels ranging between 0.3 – 0.6 and in some pockets reaching up to 0.8 dissection level. Wide valleys, undulating lands and meandering of the main drainage line signifying the maturity of the river courses marks this area.

This areal unit is largely dominated by gneiss where the land is mostly undulating and the soil depth is moderately high. This is due to the deposition of debris by the Khri River.

The physical characteristics of the soil show that the soils of this areal unit have colour ranging between dark red to weak red also signifying the presence of

iron oxides in the soil. The soil structure ranges between sub angular to granular with 'peds' ranging between fine to moderate with sizes 1 mm and 2 - 5 mm respectively and structural grades ranging between weak to moderate. The soil texture ranges between loamy – sandy clay loamy soils.

The chemical characteristics of the soil signify that the soils are acidic with pH levels ranging from 4.82 to 5.66. On the other hand the soils are rich in Organic Carbon that is the Nitrogen Equivalent with critically low phosphorous and potassium contents.

This areal unit is dominated by tropical to sub-tropical forests. The height of trees in average ranges between 20 - 35 metres and the average leaf size is (25 x 12) cms. The dominant tree species in the area are *Shorea robusta*, *Tectona grandis*, *Terminalia myriocarpa*, *Artocarpus chaplasha*, *Gemlina arborea*, *Ficus machelandi*, *Ficus elastica*, *Elaecarpus tectorius*, *Oroxylum indicum*, *Dillenia scrabella*, *Callicarpa arborea*, *Litsea khasyana*.

The area of Patharkmah – Mawskei – Warmawsaw stretch is also under the influence of monsoon where average maximum temperature ranges between 14.8°C – 28.2°C and average minimum temperature ranges between 12.2°C – 25.2°C. Total average annual rainfall is about 147.8 cms with relative humidity ranging from 70 % - 90 %.

On superimposing the vegetation map based on absolute relief and the geological map of the Khri Basin we find that the granites mainly dominate in the area, the absolute relief is between 1000 – 1500 metres. This areal unit is under the pine belt area where 90 % of the vegetation is mostly pines and its allied plants species such as *Schima wallichii*, *Rhus accuminata*, *Rhus javanica*, *Erthrina*

*aborescens, Myrica esculante, Litsea elonggata, Betula alnoides, Schefflera hypolenca, Lyonia ovalifolia and Gaultheria fragrantissima.*

Based on the above findings a map depicting phyto-geomorphological relationships of the study area is prepared (Fig. No.14). The relationships are based on 5 (five) categories, that is, strong, moderately strong, moderate, moderately weak and weak.

Three dominant tree species have been found to be prevalent in all the four areal units of the Khri Basin where 28 observations are made 7 (seven) at each areal unit. These dominant species are

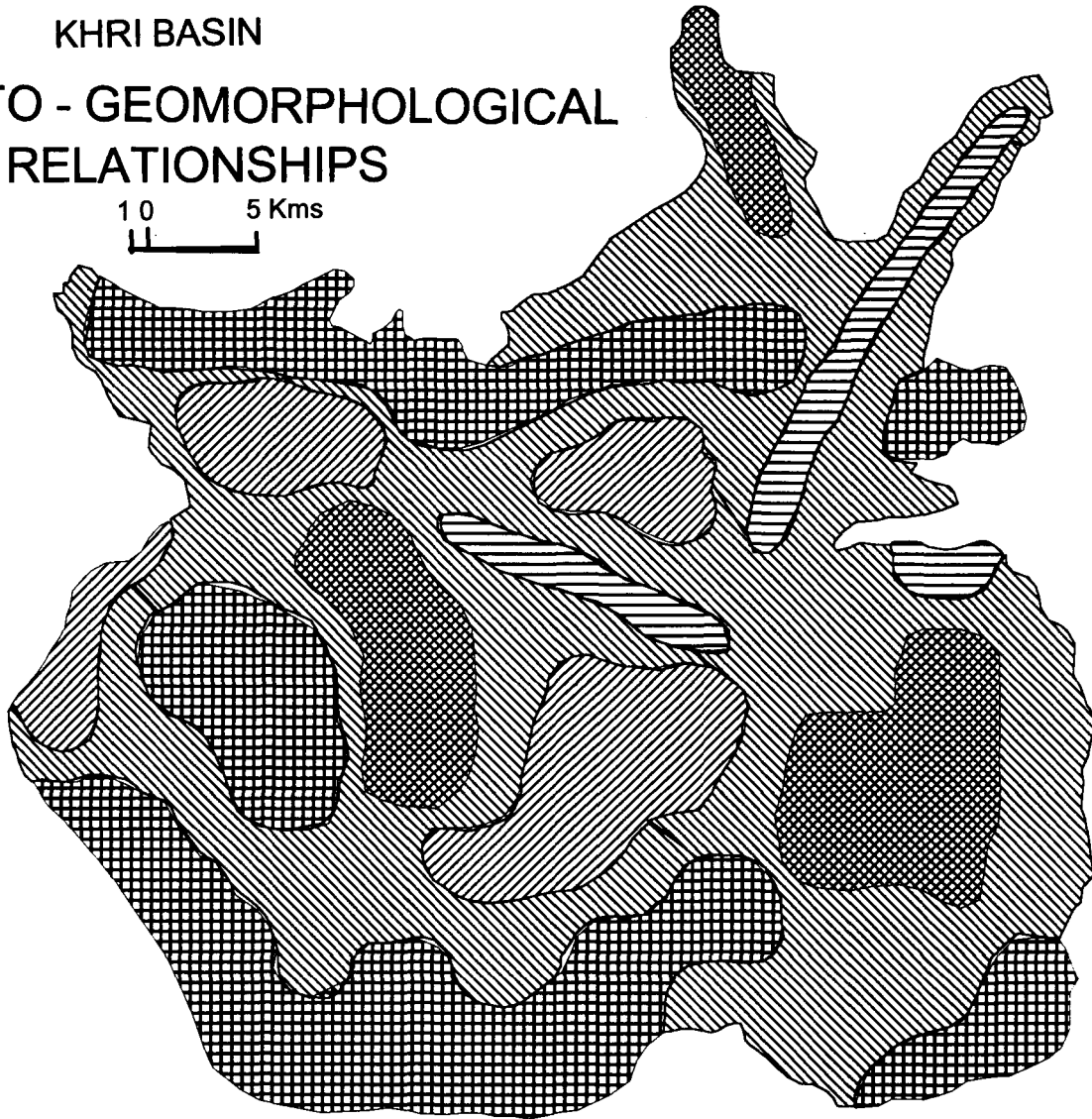
- (i) *Pinus khasyana* (above 1000 metres) and *Pinus insularis* (below 1000 metres).
- (ii) *Litsea elongata* (above 1000 metres) and *Litsea khasyana* (below 1000 metres )
- (iii) *Schima khasyana* (above 1000 metres) and *Schima wallichii* (below 1000 metres)

It is important to note here that the pine forests that are present at 700 – 1000 metres are mainly the plantations under social forestry programme. *Pinus insularis* is found to thrive well at these altitudes. The same species is also found at 400 metres but is still at experimental level. Here the trees do not thrive well due to certain constraints in the climate and soil conditions. However for the benefit of the research work a number of samples are collected from the experimental plots found within the study area.

The various parameters studied at each areal unit are shown in Table No.16

KHRI BASIN  
PHYTO - GEOMORPHOLOGICAL  
RELATIONSHIPS

10 5 Kms  
-----



RELATIONSHIPS

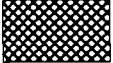


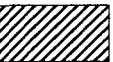
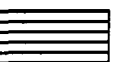
-  Strong
-  Moderately Strong
-  Moderate
-  Moderately weak
-  Weak

Fig No. 14

**TABLE NO.16 LANDFORMS – SOIL – PLANT RELATIONSHIPS OF THE MOST DOMINANT TREE SPECIES**

	No of Obs	Height (mts)	Leaf / Follicle (cms)		pH	OC	P2O5	K2O	SAND	SILT	CLAY	Height (asl)	Slope
Pinus insularis	1	12	19	0.2	4.76	1.51	22.41	16.81	43.76	27.19	29.05	below 500	12
	2	13	20	0.2	4.89	1.62	26.88	28.01	43.91	26.12	29.97	below 500	11
	3	13	20	0.2	4.91	2.11	17.92	16.81	48.06	27.82	24.12	below 500	11
	4	14	19	0.2	4.89	1.81	26.88	16.81	45.06	30.31	24.63	below 500	11
	5	12	19	0.2	4.85	1.81	26.88	33.61	41.13	27.93	30.94	below 500	10
	6	13	22	0.2	4.89	1.62	26.88	28.01	43.91	26.12	29.97	below 500	12
	7	12	21	0.2	4.76	1.51	22.41	16.81	43.76	27.19	29.05	below 500	12
	8	22	20	0.2	4.93	2.04	22.41	16.81	55.67	24.84	19.49	500 - 1000	15
	9	21	18	0.2	4.97	1.21	22.41	61.61	56.53	22.72	20.75	500 - 1000	16
	10	20	19	0.2	4.94	1.21	13.44	16.81	56.54	29.07	14.39	500 - 1000	14
	11	18	19	0.2	4.93	1.51	25.21	16.81	54.72	25.09	20.19	500 - 1000	14
	12	19	18	0.2	4.31	2.14	16.81	33.61	54.37	30.46	15.17	500 - 1000	15
	13	21	19	0.2	4.91	1.81	25.21	28.01	57.01	23.98	19.01	500 - 1000	13
	14	20	20	0.2	4.06	0.91	22.41	28.01	53.93	25.71	20.36	500 - 1000	13
Pinus khasyana	15	29	20	0.2	4.96	2.11	22.41	28.01	54.92	27.27	17.81	1000 - 1500	13
	16	28	18	0.2	4.84	1.81	26.88	61.61	54.01	26.43	19.56	1000 - 1500	13
	17	28	17	0.2	4.93	0.31	17.92	33.61	52.67	28.81	18.52	1000 - 1500	16
	18	30	17	0.2	4.91	1.21	17.92	16.81	52.97	27.92	19.11	1000 - 1500	22
	19	30	18	0.2	4.99	1.81	17.92	16.81	54.11	29.88	16.01	1000 - 1500	22
	20	29	19	0.2	4.95	2.62	21.28	28.01	52.83	31.88	15.29	1000 - 1500	17
	21	32	19	0.2	4.87	2.41	19.61	16.81	54.11	29.68	16.21	1000 - 1500	23
	22	25	17	0.2	4.93	1.78	2.62	149.01	48.41	24.09	26.41	above 1500	17
	23	24	16	0.2	4.07	1.99	2.34	218.81	54.84	18.51	24.29	above 1500	19
	24	26	15	0.2	4.23	1.98	2.13	156.75	46.99	18.02	32.98	above 1500	12
	25	24	17	0.2	4.02	2.01	2.22	291.96	54.19	22.52	22.48	above 1500	19
	26	23	16	0.2	3.81	3.14	2.43	112.98	47.97	20.01	28.99	above 1500	21
	27	25	16	0.2	4.11	2.57	2.24	201.61	40.59	23.51	29.99	above 1500	14
	28	25	15	0.2	5.42	0.71	1.97	129.67	45.31	24.92	29.77	above 1500	15

## LANDFORMS – SOIL – PLANT RELATIONSHIPS OF THE MOST DOMINANT TREE SPECIES

	No of Obs	Height (mts)	Leaf size (cms)	pH	OC	P2O5	K2O	SAND	SILT	CLAY	Height (asl)	Slope	
<i>Schima wallichii</i>	1	32	14	4	5.32	1.81	13.44	61.6	48.12	28.97	22.91	below 500	12
	2	31	15	4	5.26	1.81	29.12	28.01	47.52	29.57	22.91	below 500	11
	3	31	15	4	5.45	2.76	16.24	28.01	46.84	28.01	25.15	below 500	11
	4	33	15	6	5.27	2.25	22.41	44.81	49.16	24.67	26.17	below 500	11
	5	34	16	6	5.39	2.03	16.24	33.61	46.13	26.22	27.65	below 500	10
	6	32	15	6	5.85	1.61	26.88	16.81	45.98	24.98	29.04	below 500	12
	7	34	16	6	5.31	1.51	22.41	33.61	47.12	24.81	28.07	below 500	12
	8	28	13	4	5.56	1.11	21.28	28.01	57.18	25.06	17.76	500 - 1000	15
	9	28	13	4	5.29	1.87	15.12	5.61	56.07	22.92	21.01	500 - 1000	16
	10	29	14	4	5.48	1.49	14.56	16.81	54.53	25.86	19.61	500 - 1000	14
	11	29	14	4	5.61	1.32	14.56	5.61	55.87	25.52	18.61	500 - 1000	14
	12	30	14	5	5.48	1.71	22.96	16.81	56.01	24.13	19.86	500 - 1000	15
	13	32	15	5	5.38	1.61	21.29	28.01	54.97	25.17	19.86	500 - 1000	13
	14	28	13	4	5.23	2.42	14.56	5.61	57.53	23.41	19.06	500 - 1000	13
<i>Schima khasiana</i>	15	17	16	7	4.84	1.81	26.88	61.61	54.01	26.43	19.56	1000 - 1500	13
	16	17	16	7	5.37	3.03	21.28	16.81	54.53	25.56	19.91	1000 - 1500	13
	17	16	15	5	5.27	2.42	22.41	33.61	52.03	29.02	18.95	1000 - 1500	16
	18	16	16	5	5.75	2.01	4.48	123.01	46.67	16.07	37.26	1000 - 1500	22
	19	19	18	8	5.86	2.67	2.24	168.01	41.89	21.77	36.34	1000 - 1500	22
	20	16	15	5	5.91	2.01	2.24	78.4	44.17	22.61	33.22	1000 - 1500	17
	21	18	17	7	6.51	2.67	2.24	72.81	48.93	15.73	35.34	1000 - 1500	23
	22	17	16	6	5.04	2.18	1.89	101.01	54.11	29.88	16.01	above 1500	17
	23	18	16	6	5.08	1.91	4.91	153.98	52.83	31.88	15.29	above 1500	19
	24	17	18	8	5.42	0.71	1.97	129.67	45.31	24.92	29.77	above 1500	12
	25	20	17	7	6.43	1.21	1.86	100.06	46.13	24.22	29.65	above 1500	19
	26	19	17	7	5.88	1.21	1.91	107.21	46.13	25.72	28.15	above 1500	21
	27	19	15	5	5.49	1.63	0.89	121.01	54.11	29.68	16.21	above 1500	14
	28	17	18	8	5.44	1.35	4.84	109.27	44.17	22.61	33.22	above 1500	15

## LANDFORMS – SOIL – PLANT RELATIONSHIPS OF THE MOST DOMINANT TREE SPECIES

	No of Obs	Height (mts)	Leaf size (cms)	pH	OC	P2O5	K2O	SAND	SILT	CLAY	Height (asl)	Slope	
Litsea khasyana	1	14	24	8	4.99	1.49	16.81	16.81	46.07	29.02	24.91	below 500	12
	2	13	22	8	5.01	1.61	26.88	28.01	43.41	27.67	28.92	below 500	11
	3	13	25	9	5.03	2.09	21.28	5.61	44.13	28.01	27.86	below 500	11
	4	15	25	9	4.85	1.81	26.88	33.61	41.13	27.93	30.94	below 500	11
	5	15	24	8	5.04	1.51	22.41	61.61	44.36	27.01	28.63	below 500	10
	6	15	22	7	5.16	1.32	19.61	28.01	44.99	26.27	28.74	below 500	12
	7	12	22	7	4.89	1.62	26.88	28.01	43.91	26.12	29.97	below 500	12
	8	14	25	10	5.02	2.64	50.41	28.01	57.59	28.92	13.49	500 - 1000	15
	9	12	24	10	5.01	1.81	17.92	28.01	53.76	24.51	21.73	500 - 1000	16
	10	12	24	10	5.12	1.81	13.44	5.61	54.83	22.89	22.28	500 - 1000	14
	11	14	22	8	4.94	1.21	13.44	16.81	56.54	29.07	14.39	500 - 1000	14
	12	14	22	8	5.44	1.21	12.32	26.01	55.91	21.14	22.95	500 - 1000	15
	13	14	22	8	4.93	1.51	25.21	16.81	54.72	25.09	20.19	500 - 1000	13
	14	15	23	8	5.22	2.42	16.81	28.01	55.34	29.31	15.35	500 - 1000	13
Litsea elongata	15	13	14	4	4.87	2.41	19.61	16.81	54.11	29.68	16.21	1000 - 1500	13
	16	10	13	3	5.06	3.03	16.18	33.61	51.96	28.93	19.11	1000 - 1500	13
	17	10	13	3	4.91	1.01	17.92	16.81	52.57	31.82	15.61	1000 - 1500	16
	18	10	13	3	5.01	1.56	17.92	33.61	51.22	29.53	19.25	1000 - 1500	22
	19	12	13	4	5.01	2.28	19.61	28.01	50.56	27.98	21.46	1000 - 1500	22
	20	13	14	4	4.96	2.11	22.41	28.01	54.92	27.27	17.81	1000 - 1500	17
	21	13	14	4	5.04	2.69	16.81	61.61	54.17	28.11	17.72	1000 - 1500	23
	22	15	16	5	5.04	2.18	1.89	101.01	54.11	29.88	16.01	above 1500	17
	23	14	15	5	5.08	1.91	4.91	153.98	52.83	31.88	15.29	above 1500	19
	24	14	15	5	5.42	0.71	1.97	129.67	45.31	24.92	29.77	above 1500	12
	25	14	16	4	6.43	1.21	1.86	100.06	46.13	24.22	29.65	above 1500	19
	26	13	14	4	5.88	1.21	1.91	107.21	46.13	25.72	28.15	above 1500	21
	27	13	14	4	5.04	2.18	1.89	101.01	54.11	29.88	16.01	above 1500	14
	28	15	16	5	5.08	1.91	4.91	153.98	52.83	31.88	15.29	above 1500	15

- |                            |                              |                        |
|----------------------------|------------------------------|------------------------|
| (a) height of trees        | (b) Size of leaf / follicles | (c) pH (acidity level) |
| (d) Organic Carbon content | (e) Phosphorous content      | (f) Potassium content  |
| (g) Sand %                 | (h) Silt %                   | (i) Clay % and         |
| (j) Slope.                 |                              |                        |

The above parameters have been analysed statistically using both Multiple Regression and Correlation methods. In the analysis height of tree and size of leaves / follicles has been identified as dependent variables and the other 8 (eight) parameters as independent variables.

During the first analysis, height of pine species has been taken as a dependant variable. After calculating the coefficient of multiple regression ( $\beta$ ) and partial correlation, the results are shown in Table No.17 and Table No.18.

(i) The coefficient of regression of the level of acidity of the soil (pH) to height of pines is 2.57275 with a standard error of 1.42591. The t-test value is positive at (+) 1.80428 and the p-level, which is the level of significance, is found to be 0.087947 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the level of acidity of the soil does not play a significant role in determining the height of pine trees.

(ii) The coefficient of regression of the amount of organic carbon content of the soil (OC) to height of pines is (-) 0.04883 with a standard error of 0.77029. The t-test value is negative at (-) 0.06339 and the p-level, which is the level of significance, is found to be 0.950155 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that organic carbon which is the nitrogen equivalent of the soil does not play a significant role in determining the height of pine trees.

**TABLE NO.17: Multiple Regression**

Dependant Variable: Height of Pine species

N = 28	$\beta$	St. Err of $\beta$	t- value	p- level
Intercept	14.77303	51.60922	0.28625	0.777957
PH	2.57275	1.42591	1.80428	0.087947
Organic Carbon	-0.04883	0.77029	-0.06339	0.950155
Phosphorus Comp. ( $P_2O_5$ )	0.20077	0.08855	2.26735	0.035920
Potassium Comp ( $K_2O$ )	-0.01323	0.01077	-1.22847	0.235092
Sand	-0.25459	0.52403	-0.48583	0.632950
Silt	-0.13873	0.55849	-0.24840	0.806637
Clay	-0.45334	0.56653	-0.80020	0.434029
Elevation	6.48168	0.76037	8.52434	0.000000
Slope	0.21483	0.15258	1.40798	0.176174

**TABLE NO.18: Correlation**

Dependant Variable: Height of Pine species

	Partial Correlation	R - Square	t- Value	p- level
PH	0.391354	0.570837	1.80428	0.087064
Organic Carbon (OC)	-0.014939	0.349817	-0.06339	0.950119
Phosphorus Comp. ( $P_2O_5$ )	0.471334	0.803171	2.26735	0.035227
Potassium Comp. ( $K_2O$ )	-0.278128	0.791175	-1.22847	0.234271
Sand	-0.113767	0.982155	-0.48583	0.632645
Silt	-0.058448	0.964685	-0.24840	0.806490
Clay	0.185341	0.987309	-0.80020	0.433486
Elevation	0.895246	0.809142	8.52434	0.000000
Slope	0.314973	0.575239	1.40798	0.175289

(iii) The coefficient of regression of the amount of phosphorus compound ( $P_2O_5$ ) to height of pines is 0.20077 with a standard error of 0.08855. The t-test value is positive at (+) 2.26735 and the p-level, which is the level of significance is found to be 0.035920 showing that it is significant at 3 % level. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of phosphorus content in the soil plays a significant role in determining the height of pine trees.

(iv) The coefficient of regression of the amount of potassium compound ( $K_2O$ ) to height of pines is (-) 0.01323 with a standard error of 0.01077. The t-test value is negative at (-) 1.22847 and the p-level, which is the level of significance, was found to be 0.235092 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of potassium content in the soil does not play a significant role in determining the height of pine trees.

(v) The coefficient of regression of the percentage of sand to height of pines is (-) 0.25459 with a standard error of 0.52403. The t-test value is negative at (-) 0.48583 and the p-level, which is the level of significance is found to be 0.632950 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that percentage of sand in the soil does not play a significant role in determining the height of pine trees.

(vi) The coefficient of regression of the percentage of silt to height of pines is (-) 0.13873 with a standard error of 0.55849. The t-test value is negative at (-) 0.13873 and the p-level, which is the level of significance is found to be 0.806637 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of silt in the soil does not play a significant role in determining the height of pine trees.

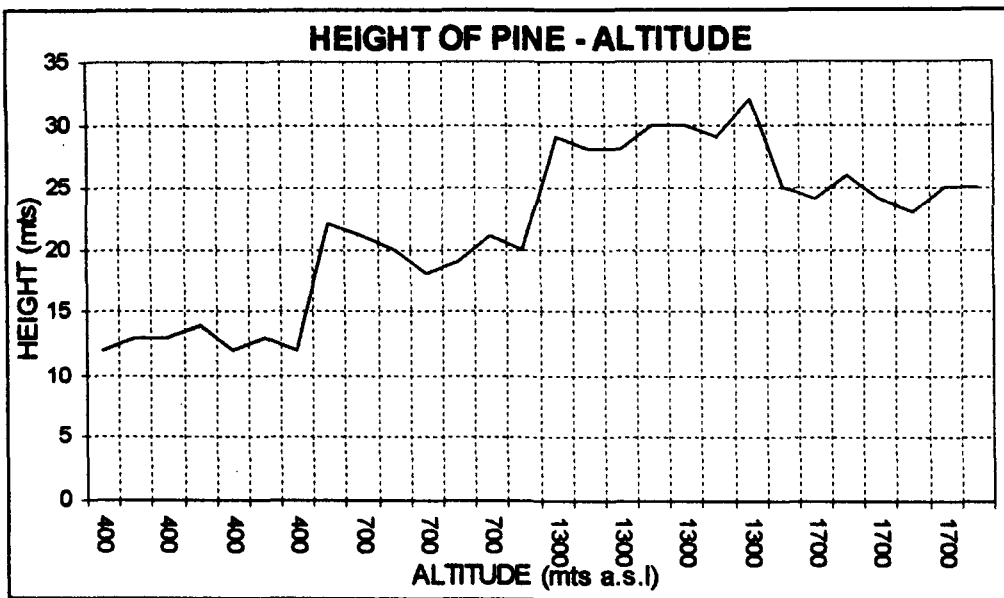
(vii) The coefficient of regression of the percentage of clay to height of pines is (-) 0.45334 with a standard error of 0.56653. The t-test value is negative at (-) 0.80020 and the p-level, which is the level of significance is found to be 0.434029 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of clay in the soil does not play a significant role in determining the height of pine trees.

(viii) The coefficient of regression of the elevation of the study area at different micro-areal units to height of pines is 6.48168 with a standard error of 0.76037. The t-test value is highly positive at (+) 8.52434 and the p-level, which is the level of significance is found to be 0.00000 showing that it is highly significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that elevation plays a very significant role in determining the height of pine trees.

(ix) The coefficient of regression of average slope of an area to height of pines is 0.21483 with a standard error of 0.176174. The t-test value is positive at (+) 1.40798 and the p-level, which is the level of significance is found to be 0.176174 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the average slope of an area does not play a significant role in determining the height of pine trees.

Thus from the above analysis we can conclude that the height of pines which is a dependant variable differs greatly with difference in altitude and also with the amount of phosphorus ( $P_2O_5$ ) content present in the soil. Due to its variation in height we can also infer that climate also plays an important role in the determination of pine height. The graphical representation showing height in metres to altitude as shown in Graph No. 5 depicts that the average height of pines at 1700

**GRAPH NO.5**



metres is ranging between 23 - 26 metres. On the other hand the average height of pines at 1300 metres is ranging between 28 - 32 metres. This is mainly because of two reasons; one is the change in climatic parameters due to change in altitude and secondly is due to soil depth. The hilltops and its adjoining slopes are under the impact of soil erosion especially during the monsoon season when the intensity of rainfall is at the highest level. However, at 700 metres altitude there has been a decrease in height ranging between 18 - 22 metres mainly because of change in climatic conditions. Further decrease is observed at altitudes of 400 metres with average height of about 12 -14 metres.

During the second analysis, length of pine follice has been taken as a dependant variable. After calculating the coefficient of multiple regression ( $\beta$ ) and partial correlation, the results are shown in Table No.19 and Table No.20.

- (i) The coefficient of regression of the level of acidity of the soil (pH) to length of pine follice is (-) 0.127428 with a standard error of 0.175148. The t-test value is negative at (-) 0.16957 and the p-level, which is the level of significance, is found to be 0.867239 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the level of acidity of the soil does not play a significant role in determining the length of pine follices.
- (ii) The coefficient of regression of the amount of organic carbon content of the soil (OC) to length of pine follice is 0.548104 with a standard error of 0.40596. The t-test value is positive at (+) 1.35015 and the p-level, which is the level of significance, is found to be 0.19701 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that organic carbon which is the nitrogen equivalent of the soil does not play a significant role in determining the length of pine follice.

**TABLE NO.19: Multiple Regression**

Dependant Variable: Pine follicles

N = 28	$\beta$	St. Err of $\beta$	t- value	p- level
Intercept	8.384811	27.19886	0.30828	0.761410
PH	-0.127428	0.75148	-0.16957	0.867239
Organic Carbon	0.548104	0.40596	1.35015	0.193701
Phosphorus Comp. ( $P_2O_5$ )	0.066222	0.04667	1.41902	0.172978
Potassium Comp ( $K_2O$ )	0.002082	0.00568	0.36690	0.717970
Sand	0.120465	0.27617	0.43620	0.667881
Silt	0.113286	0.29433	0.38489	0.704829
Clay	0.077310	0.29857	0.25893	0.798624
Elevation	-0.989408	0.40073	-2.46903	0.023789
Slope	-0.003719	0.08041	-0.04625	0.963621

**TABLE NO.20 Correlation**

Dependant Variable: Pine follicles

	Partial Correlation	R - Square	t- Value	p- level
PH	-0.039936	0.570837	-0.16957	0.867140
Organic Carbon	0.303249	0.349817	1.35015	0.192832
Phosphorus Comp. ( $P_2O_5$ )	0.317194	0.803171	1.41902	0.172091
Potassium Comp. ( $K_2O$ )	0.086158	0.791175	0.36690	0.717747
Sand	0.102273	0.982155	0.43620	0.667611
Silt	0.090348	0.964685	0.38489	0.704594
Clay	0.060918	0.987309	0.25893	0.798471
Elevation	-0.502982	0.809142	-2.46903	0.023204
Slope	-0.010900	0.575239	-0.04625	0.963594

(iii) The coefficient of regression of the amount of phosphorus compound ( $P_2O_5$ ) to length of pine follicle 0.066222 with a standard error of 0.04667. The t-test value is positive at (+) 1.41902 and the p-level, which is the level of significance is found to be 0.172978 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of phosphorus content in the soil does not play a significant role in determining length of pine follicle.

(iv) The coefficient of regression of the amount of potassium compound ( $K_2O$ ) to length of pine follicle is 0.002082 with a standard error of 0.00568. The t-test value is positive at (+) 0.36690 and the p-level, which is the level of significance, is found to be 0.717970 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of potassium content in the soil does not play a significant role in determining the length of pine follicle.

(v) The coefficient of regression of the percentage of sand to length of pine follicle is 0.120465 with a standard error of 0.27617. The t-test value is positive at (+) 0.43620 and the p-level, which is the level of significance is found to be 0.667881 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that percentage of sand in the soil does not play a significant role in determining the length of pine follicle.

(vi) The coefficient of regression of the percentage of silt to length of pine follicle is 0.113286 with a standard error of 0.29433. The t-test value is positive at (+) 0.38489 and the p-level, which is the level of significance is found to be 0.704829 showing that it is highly insignificant. Similar results were obtained after calculating

the coefficient of partial correlation. Thus we can infer that the percentage of silt in the soil does not play a significant role in determining the length of pine follice.

(vii) The coefficient of regression of the percentage of clay to length of pine follice is 0.077310 with a standard error of 0.29857. The t-test value is positive at (+) 0.25893 and the p-level, which is the level of significance is found to be 0.798624 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of clay in the soil does not play a significant role in determining the length of pine follice.

(viii) The coefficient of regression of the elevation of the study area at different micro-areal units to length of pine follice is (-) 0.989408 with a standard error of 0.40073. The t-test value is highly negative at (-) 2.46903 and the p-level, which is the level of significance is found to be 0.023789 showing that it is highly significant at 2 % level of significance. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that elevation plays a very significant role in determining the length of pine follice.

(ix) The coefficient of regression of average slope of an area to length of pine follice is (-) 0.003719 with a standard error of 0.08041. The t-test value is negative at (-) 0.04625 and the p-level, which is the level of significance is found to be 0.963621 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the average slope of an area does not play a significant role in determining the length of pine follice.

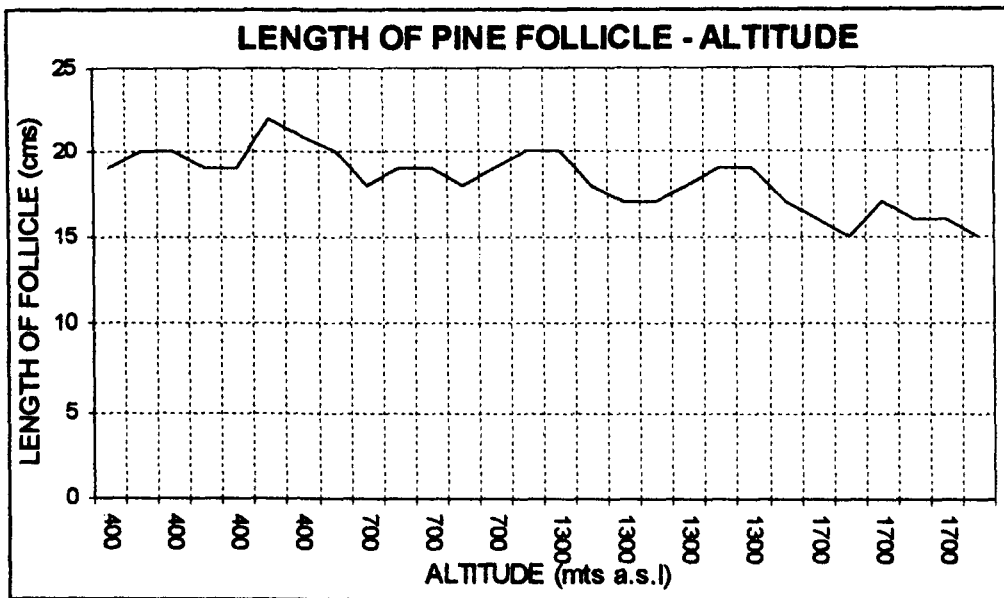
From the above results we can conclude that the length of pine follice differs with change in altitude. The t-test value shows that the length of pine follice

increases with decrease in altitude. The graphical representation showing length of pine follice in centimetres to altitude as shown in Graph No.6 depicts that the average length of pine follice at 1700 metres is ranging between 15 - 17 cms. On the other hand the average length of pine follice at 1300 metres is ranging between 16 - 18 cms. At 700 metres altitude there has been a further increase in follice length ranging between 18 - 20 cms and at 400 metres above sea level follice ranges between 18 -22 cms. However through the graph we observe that there is an increase in length of the follice with decrease in altitude that may be due high *rate of transpiration at lower altitudes with increase in temperatures.*

During the third analysis, height of schima species has been taken as a dependant variable. After calculating the coefficient of multiple regression ( $\beta$ ) and partial correlation, the analysis shown in Table No.21 and Table No.22 show that:

- (i) The coefficient of regression of the level of acidity of the soil (pH) to height of schima species is 0.98198 with a standard error of 2.66489. The t-test value is positive at (+) 0.68681 and the p-level, which is the level of significance, is found to be 0.501076 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the level of acidity of the soil does not play a significant role in determining the height of schima species.
  
- (ii) The coefficient of regression of the amount of organic carbon content of the soil (OC) to height of schima species is (-) 0.188465 with a standard error of 1.26722. The t-test value is negative at (-) 1.87576 and the p-level, which is the level of significance, is found to be 0.077003 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that organic carbon which is the nitrogen equivalent of the soil does not play a significant role in determining the height of schima species.

**GRAPH NO.6**



**TABLE NO.21: Multiple Regression**

Dependant Variable: Height of Schima species

N = 28	$\beta$	St. Err of $\beta$	t- value	p- level
Intercept	30.25767	30.35000	0.99696	0.331999
PH	0.98198	2.66489	0.68661	0.501076
Organic Carbon	-0.188465	1.26722	-1.87576	0.077003
Phosphorus Comp. (P <sub>2</sub> O <sub>5</sub> )	-0.075136	0.11599	-0.47379	0.641346
Potassium Comp (K <sub>2</sub> O)	-0.056763	0.02596	-0.31174	0.758821
Sand	0.056224	0.28748	0.28861	0.776176
Silt	0.056911	0.32141	0.33928	0.738323
Clay	-0.071201	0.25337	-0.29512	0.771281
Elevation	-0.802201	0.94444	-5.18478	0.000062
Slope	-0.117861	0.29963	-0.74064	0.468464

**TABLE NO.22: Correlation**

Dependant Variable: Height Schima species

	Partial Correlation	R - Square	t- Value	p- level
PH	0.159758	0.519747	0.68661	0.500621
Organic Carbon	-0.404362	0.026939	-1.87576	0.076140
Phosphorus Comp. (P <sub>2</sub> O <sub>5</sub> )	-0.110984	0.609412	-0.47379	0.641048
Potassium Comp. (K <sub>2</sub> O)	-0.073280	0.703721	-0.31174	0.758634
Sand	0.067870	0.741157	0.28861	0.776004
Silt	0.079715	0.650882	0.33928	0.738118
Clay	-0.069392	0.831242	-0.29512	0.771104
Elevation	-0.773917	0.589661	-5.18478	0.000053
Slope	-0.171970	0.612101	-0.74064	0.467967

(iii) The coefficient of regression of the amount of phosphorus compound ( $P_2O_5$ ) to height of schima species is (-) 0.075136 with a standard error of 1.26722. The t-test value is negative at (-) 0.47379 and the p-level, which is the level of significance is found to be 0.641346 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of phosphorus content in the soil does not play a significant role in determining the height of schima species.

(iv) The coefficient of regression of the amount of potassium compound ( $K_2O$ ) to height of schima species is (-) 0.056763 with a standard error of 0.02596. The t-test value is negative at (-) 0.31174 and the p-level, which is the level of significance, is found to be 0.758821 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of potassium content in the soil does not play a significant role in determining the height of schima species.

(v) The coefficient of regression of the percentage of sand to height of schima species is 0.056224 with a standard error of 0.28748. The t-test value is positive at (+) 0.28861 and the p-level, which is the level of significance is found to be 0.776176 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that percentage of sand in the soil does not play a significant role in determining the height of schima species.

(vi) The coefficient of regression of the percentage of silt to height of schima species is 0.056911 with a standard error of 0.32141. The t-test value is positive at (+) 0.33928 and the p-level, which is the level of significance is found to be 0.738323 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of silt in the soil does not play a significant role in determining the height of schima species.

(vii) The coefficient of regression of the percentage of clay to height of schima species is (-) 0.071201 with a standard error of 0.25337. The t-test value is negative at (-) 0.29512 and the p-level, which is the level of significance is found to be 0.771281 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of clay in the soil does not play a significant role in determining the height of schima species.

(viii) The coefficient of regression of the elevation of the study area at different micro-areal units to height of schima species is (-) 0.802201 with a standard error of 0.94444. The t-test value is highly negative at (-) 5.18478 and the p-level, which is the level of significance is found to be 0.000062 showing that it is highly significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that elevation plays a very significant role in determining the height of schima species.

(ix) The coefficient of regression of average slope of an area to height of schima species is (-) 0.116871 with a standard error of 0.29963. The t-test value is negative at (-) 0.74064 and the p-level, which is the level of significance is found to be 0.468464 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the average slope of an area does not play a significant role in determining the height of schima species.

Thus from the above analysis we can conclude that the height of schima species which is a dependant variable differs greatly with difference in altitude. Due to its variation in height we can also infer that climate also plays an important role in the determination of the species height. However, the conditions here are reversed unlike pine where the schima tree species are found to increase in height with

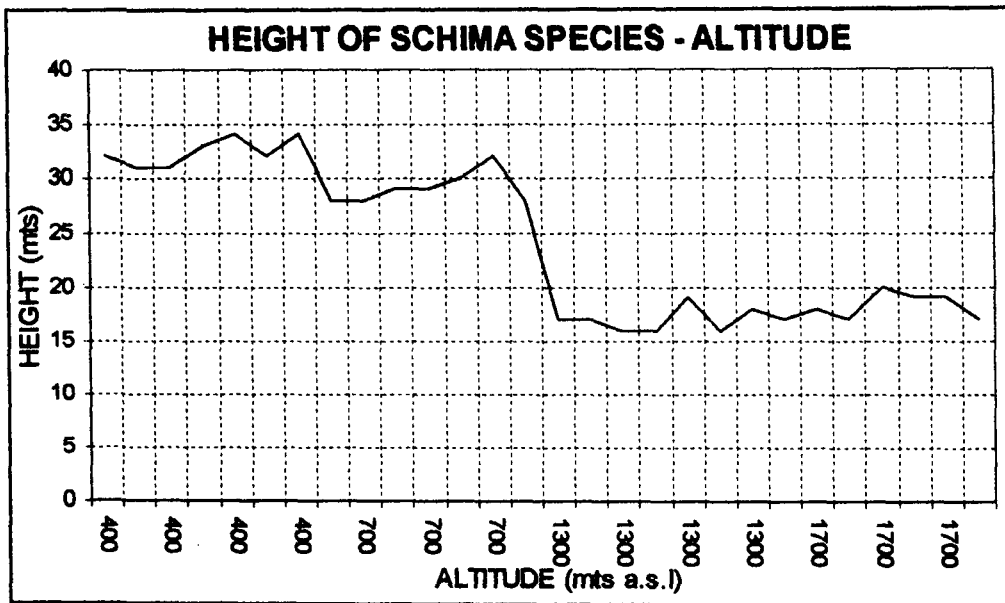
decrease in altitude. The graphical representation showing height in metres to altitude as shown in Graph No.7 depicts that the average schima species at 1700 metres above sea level is ranging between 16 - 20 metres and at 1300 metres is ranging between 16 - 19 metres. However, at 700 metres altitude there had been a sharp increase in height ranging between 27 - 32 metres mainly because of change in climatic conditions. Further increase is observed at altitudes of 400 metres with average heights of about 31 - 34 metres. This signifies that the species are more adaptable to warmer climates than to cooler areas.

During the fourth analysis, size of schima leaf has been taken as a dependant variable. After calculating the coefficient of multiple regression ( $\beta$ ) and partial correlation, the analysis shown in Table No.23 and Table No.24 show that:

(i) The coefficient of regression of the level of acidity of the soil (pH) to size of schima leaf is (-) 0.0021 with a standard error of 15.6797. The t-test value is negative at (-) 0.000132 and the p-level, which is the level of significance, is found to be 0.999896 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the level of acidity of the soil does not play any role in determining the size of schima leaf.

(ii) The coefficient of regression of the amount of organic carbon content of the soil (OC) to size of schima leaf is 3.0431 with a standard error of 7.4561. The t-test value is positive at (+) 0.047874 and the p-level, which is the level of significance, is found to be 0.688176 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that organic carbon which is the nitrogen equivalent of the soil does not play a significant role in determining the size of schima leaf.

**GRAPH NO.7**



**TABLE NO.23: Multiple Regression**

Dependant Variable: Schima leaf Size

N = 28	$\beta$	St. Err of $\beta$	t- value	p- level
Intercept	123.4664	178.5743	0.691401	0.498135
PH	-0.0021	15.6797	-0.000132	0.999896
Organic Carbon	3.0411	7.4561	0.407874	0.688176
Phosphorus Comp. ( $P_2O_5$ )	0.8571	0.6825	1.255918	0.225204
Potassium Comp ( $K_2O$ )	0.1733	0.1527	1.134803	0.271344
Sand	-1.6664	1.6915	-0.985169	0.337599
Silt	-0.8511	1.8911	-0.450037	0.658057
Clay	1.0995	1.4908	0.737564	0.470286
Elevation	15.7140	5.5569	2.827821	0.011151
Slope	-1.5883	1.7630	-0.900933	0.379520

**TABLE NO.24: Correlation**

Dependant Variable: Schima leaf size

	Partial Correlation	R - Square	t- Value	p- level
PH	-0.000031	0.519747	-0.000132	0.999896
Organic Carbon	0.095696	0.026939	0.407874	0.687925
Phosphorus Comp. ( $P_2O_5$ )	0.283847	0.609412	1.255918	0.224371
Potassium Comp. ( $K_2O$ )	0.258392	0.703721	1.134803	0.270572
Sand	-0.226188	0.741157	-0.985169	0.336921
Silt	-0.105483	0.650882	-0.450037	0.657776
Clay	0.171277	0.831242	0.737564	0.469791
Elevation	0.554618	0.589661	2.827821	0.010751
Slope	-0.207720	0.612101	-0.900933	0.378902

(iii) The coefficient of regression of the amount of phosphorus compound ( $P_2O_5$ ) to size of schima leaf is 0.8571 with a standard error of 0.6825. The t-test value is positive at (+) 1.255918 and the p-level, which is the level of significance is found to be 0.225204 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of phosphorus content in the soil does not play a significant role in determining size of schima leaf.

(iv) The coefficient of regression of the amount of potassium compound ( $K_2O$ ) to size of schima leaf is 0.1733 with a standard error of 0.1527. The t-test value is positive at (+) 1.134803 and the p-level, which is the level of significance, is found to be 0.271344 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of potassium content in the soil does not play a significant role in determining the size of schima leaf.

(v) The coefficient of regression of the percentage of sand to size of schima leaf is (-) 1.6664 with a standard error of 1.6915. The t-test value is negative at (-) 0.43620 and the p-level, which is the level of significance is found to be 0.337559 showing that it is not significant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that percentage of sand in the soil does not play a significant role in determining the size of schima leaf.

(vi) The coefficient of regression of the percentage of silt to size of schima leaf is (-) 0.8511 with a standard error of 1.8911. The t-test value is negative at (-) 0.450037 and the p-level, which is the level of significance is found to be 0.658057 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of silt in the soil does not play a significant role in determining the size of schima leaf.

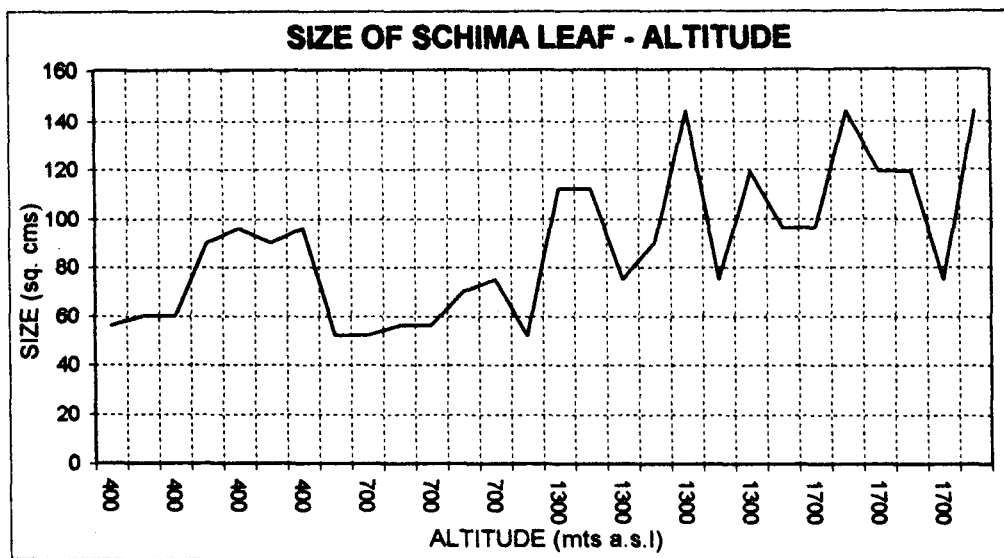
(vii) The coefficient of regression of the percentage of clay to size of schima leaf is 1.0995 with a standard error of 1.4908. The t-test value is positive at (+) 0.737564 and the p-level, which is the level of significance is found to be 0.470286 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of clay in the soil does not play a significant role in determining the size of schima leaf.

(viii) The coefficient of regression of the elevation of the study area at different micro-areal units to size of schima leaf is 15.7140 with a standard error of 5.5569. The t-test value is highly positive at (+) 2.827821 and the p-level, which is the level of significance is found to be 0.011151 showing that it is highly significant at 1 % level of significance. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that elevation plays a very significant role in determining the size of schima leaf.

(ix) The coefficient of regression of average slope of an area to size of schima leaf is (-) 1.5883 with a standard error of 1.7630. The t-test value is negative at (-) 0.900933 and the p-level, which is the level of significance is found to be 0.379520 showing that it is highly insignificant. Similar results were obtained after calculating the coefficient of partial correlation. Thus we can infer that the average slope of an area does not play a significant role in determining the size of schima leaf.

From the above analysis we can conclude that the size of schima leaf differs with change in altitude. The t-test value shows that the length of pine follicle increases with increase in altitude. The graphical representation showing size of schima leaf in square centimetres to altitude as shown in Graph No.8 depicts that the average size of schima leaf at 1700 metres is ranging between 80 - 144 cms<sup>2</sup>.

**GRAPH NO.8**



On the other hand the average size of schima leaf at 1300 metres is ranging between 78 - 144 cms<sup>2</sup>. At 700 metres altitude there has been a decrease in leaf size ranging between 52 - 75 cms<sup>2</sup> and at 400 metres leaf size ranges between 76 - 96 cms<sup>2</sup>. However through the graph we observe that there is an increase in size of schima leaf with increase in altitude. However this has been a peculiarity that has been observed in the present study. One of the reasons may be because of the presence of two different sub-species at the different altitudes. In the higher altitudes *schima khasiana* has been identified whereas in the lower altitudes *schima wallichii* is mostly found. The second reason may be due to the influence of pedology being the outcome of the interplay of the parent rock materials, climate and vegetation itself.

During the fifth analysis, height of litsea species has been taken as a dependant variable. After calculating the coefficient of multiple regression ( $\beta$ ) and partial correlation, the analysis shown in Table No.25 and Table No.26 show that:

- (i) The coefficient of regression of the level of acidity of the soil (pH) to height of litsea species is 1.093146 with a standard error of 1.15365. The t-test value is positive at (+) 0.94755 and the p-level, which is the level of significance, is found to be 0.355907 showing that it is not significant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the level of acidity of the soil does not play a significant role in determining the height of litsea species.
  
- (ii) The coefficient of regression of the amount of organic carbon content of the soil (OC) to height of litsea species is 0.031154 with a standard error of 0.56885. The t-test value is positive at (+) 0.05476 and the p-level, which is the level of significance, is found to be 0.956930 showing that it is highly insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we

can infer that organic carbon which is the nitrogen equivalent of the soil does not play a significant role in determining the height of litsea species.

**TABLE NO.25: Multiple Regression**

Dependant Variable: Height Litsea species

N = 28	$\beta$	St. Err of $\beta$	t- value	p- level
Intercept	0.823058	12.94582	0.68154	0.504207
PH	1.093146	1.15365	0.94755	0.355907
Organic Carbon	0.031154	0.56885	0.05476	0.956930
Phosphorus Comp. ( $P_2O_5$ )	0.003583	0.03638	0.09848	0.922636
Potassium Comp ( $K_2O$ )	0.023314	0.00916	2.54511	0.020306
Sand	0.049013	0.11613	0.42203	0.677998
Silt	-0.023377	0.15735	-0.14856	0.883551
Clay	-0.029054	0.11179	-0.25989	0.797897
Elevation	-0.742959	0.45080	-1.64811	0.116675
Slope	-0.120477	0.09003	-1.33821	0.197487

**TABLE NO.26: Correlation**

Dependant Variable: Height of Litsea species

	Partial Correlation	R - Square	t- Value	p- level
PH	0.217970	0.473343	0.94755	0.355255
Organic Carbon	0.012907	0.234432	0.05476	0.956899
Phosphorus Comp. ( $P_2O_5$ )	0.023207	0.489127	0.09848	0.922580
Potassium Comp. ( $K_2O$ )	0.514425	0.544545	2.54511	0.019763
Sand	0.098986	0.765312	0.42203	0.677737
Silt	-0.034995	0.562930	-0.14856	0.883464
Clay	-0.061142	0.825525	-0.25989	0.797743
Elevation	-0.362101	0.710316	-1.64811	0.115768
Slope	-0.300811	0.308945	-1.33821	0.196623

(iii) The coefficient of regression of the amount of phosphorus compound ( $P_2O_5$ ) to height of litsea species is 0.003583 with a standard error of 0.03638. The t-test value is positive at (+) 0.09848 and the p-level, which is the level of significance is found to be 0.922636 showing that it is highly insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of phosphorus content in the soil does not play a significant role in determining the height of litsea species.

(iv) The coefficient of regression of the amount of potassium compound ( $K_2O$ ) to height of litsea species is 0.023314 with a standard error of 0.00916. The t-test value is highly positive at (+) 2.54511 and the p-level, which is the level of significance, is found to be 0.020306 showing that it is highly significant at 2 % level of significance. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of potassium content in the soil does not play a significant role in determining the height of litsea species.

(v) The coefficient of regression of the percentage of sand to height of litsea species is 0.049013 with a standard error of 0.11613. The t-test value is positive at (+) 0.422203 and the p-level, which is the level of significance is found to be 0.677998 showing that it is highly insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that percentage of sand in the soil does not play a significant role in determining the height of litsea species.

(vi) The coefficient of regression of the percentage of silt to height of litsea species is (-) 0.023377 with a standard error of 0.15735. The t-test value is negative at (-) 0.14856 and the p-level, which is the level of significance is found to be 0.883551 showing that it is highly insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage

of silt in the soil does not play a significant role in determining the height of litsea species.

(vii) The coefficient of regression of the percentage of clay to height of litsea species is (-) 0.029054 with a standard error of 0.11179. The t-test value is negative at (-) 0.25989 and the p-level, which is the level of significance is found to be 0.797897 showing that it is highly insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of clay in the soil does not play a significant role in determining the height of litsea species.

(viii) The coefficient of regression of the elevation of the study area at different micro-areal units to height of litsea species is (-) 0.742959 with a standard error of 0.45080. The t-test value is highly negative at (-) 1.64811 and the p-level, which is the level of significance is found to be 0.116675 showing that it is not significant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that elevation does not play a very significant role in determining the height of litsea species.

(ix) The coefficient of regression of average slope of an area to height of litsea species is (-) 0.120477 with a standard error of 0.09003. The t-test value is negative at (-) 1.33821 and the p-level, which is the level of significance is found to be 0.197847 showing that it is not significant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the average slope of an area does not play a significant role in determining the height of litsea species.

Thus from the above analysis we can conclude that the height of litsea species which is a dependant variable does not differ greatly with difference in

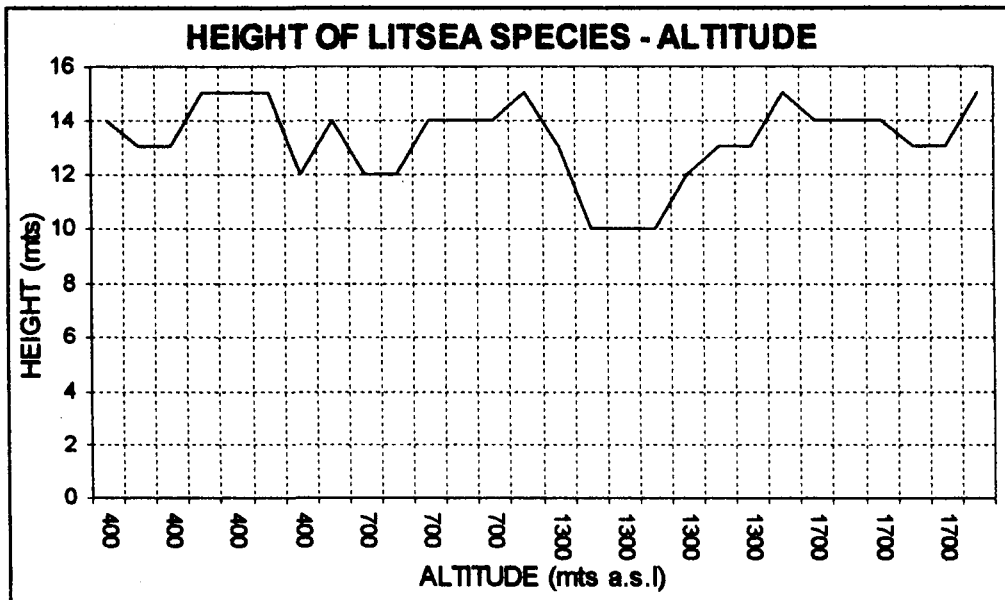
altitude. This is because in the study two different sub-species are analysed where *litsea elongata* is found at the higher altitudes, whereas *litsea khasiana* is present at the lower altitudes. Thus the two different sub-species may be assuming different heights which resulted to the variability in heights with change in altitude. The graphical representation showing height in metres to altitude as shown in Graph No.9 depicts that the average litsea species at 1700 metres is ranging between 13 - 15 metres and at 1300 metres is ranging between 10 - 13 metres. However, at 700 metres altitude height ranges between 12 - 15 metres whereas at altitudes of 400 metres above sea level the height ranges between 13 -15 metres. However, there has been a positive relationship between the height of litsea trees to that of the amount of potassium content present in the soil. The analysis infers that there is an increase of potassium with increase in altitude.

During the sixth analysis, size of litsea leaf has been taken as a dependant variable. After calculating the coefficient of multiple regression ( $\beta$ ) and partial correlation, the analysis shown in Table No.27 and Table No.28 show that:

(i) The coefficient of regression of the level of acidity of the soil (pH) to size of litsea leaf is 16.6089 with a standard error of 40.7422. The t-test value is positive at (+) 0.40766 and the p-level, which is the level of significance, is found to be 0.688332 showing that it is highly insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the level of acidity of the soil does not play a significant role in determining the size of litsea leaf.

(ii) The coefficient of regression of the amount of organic carbon content of the soil (OC) to size of litsea leaf is (-) 1.2823 with a standard error of 20.0904. The t-test value is positive at (-) 0.06383 and the p-level, which is the level of significance, is found to be 0.949810 showing that it is highly insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we

**GRAPH NO.9**



can infer that organic carbon which is the nitrogen equivalent of the soil does not play a significant role in determining the size of litsea leaf.

**TABLE NO.27: Multiple Regression**

Dependant Variable: Litsea Leaf

N = 28	$\beta$	St. Err of $\beta$	t- value	p- level
Intercept	234.3296	457.1920	0.51254	0.614505
PH	16.6089	40.7422	0.40766	0.688332
Organic Carbon	-1.2823	20.0904	-0.06383	0.949810
Phosphorus Comp. ( $P_2O_5$ )	1.1421	1.2848	0.88887	0.385796
Potassium Comp ( $K_2O$ )	0.3708	0.3235	1.14613	0.266748
Sand	3.1513	4.1014	0.76836	0.452238
Silt	-6.6054	5.0571	-1.18864	0.250027
Clay	-0.8400	3.9481	-0.21276	0.833905
Elevation	-45.6553	15.9202	-2.86776	0.010233
Slope	-4.7190	3.1794	-1.48422	0.155051

**TABLE NO.28: Correlation**

Dependant Variable: Litsea Leaf

	Partial Correlation	R - Square	t- Value	p- level
PH	0.095645	0.473343	0.40766	0.688081
Organic Carbon	-0.015043	0.234432	-0.06383	0.949773
Phosphorus Comp. ( $P_2O_5$ )	0.205058	0.489127	0.88887	0.385186
Potassium Comp. ( $K_2O$ )	0.260798	0.544545	1.14613	0.265970
Sand	0.178205	0.765312	0.76836	0.451720
Silt	-0.269778	0.562930	-1.18864	0.249226
Clay	-0.050085	0.825525	-0.21276	0.833780
Elevation	-0.560006	0.710316	-2.86776	0.009852
Slope	-0.330211	0.308945	-1.48422	0.154151

(iii) The coefficient of regression of the amount of phosphorus compound ( $P_2O_5$ ) to size of litsea leaf 1.1421 with a standard error of 1.2848. The t-test value is positive at (+) 0.88887 and the p-level, which is the level of significance is found to be 0.385796 showing that it is not significant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of phosphorus content in the soil does not play a significant role in determining size of litsea leaf.

(iv) The coefficient of regression of the amount of potassium compound ( $K_2O$ ) to size of litsea leaf is 0.3708 with a standard error of 0.3235. The t-test value is positive at (+) 1.14613 and the p-level, which is the level of significance, is found to be 0.266748 showing that it is insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the amount of potassium content in the soil does not play a significant role in determining the size of litsea leaf.

(v) The coefficient of regression of the percentage of sand to size of litsea leaf is 3.1513 with a standard error of 4.1014. The t-test value is positive at (+) 0.76836 and the p-level, which is the level of significance is found to be 0.452238 showing that it is insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that percentage of sand in the soil does not play a significant role in determining the size of litsea leaf.

(vi) The coefficient of regression of the percentage of silt size of litsea leaf is (-) 6.6054 with a standard error of 5.0571. The t-test value is negative at (-) 1.18864 and the p-level, which is the level of significance is found to be 0.250027 showing that it is insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of silt in the soil does not play a significant role in determining the size of litsea leaf.

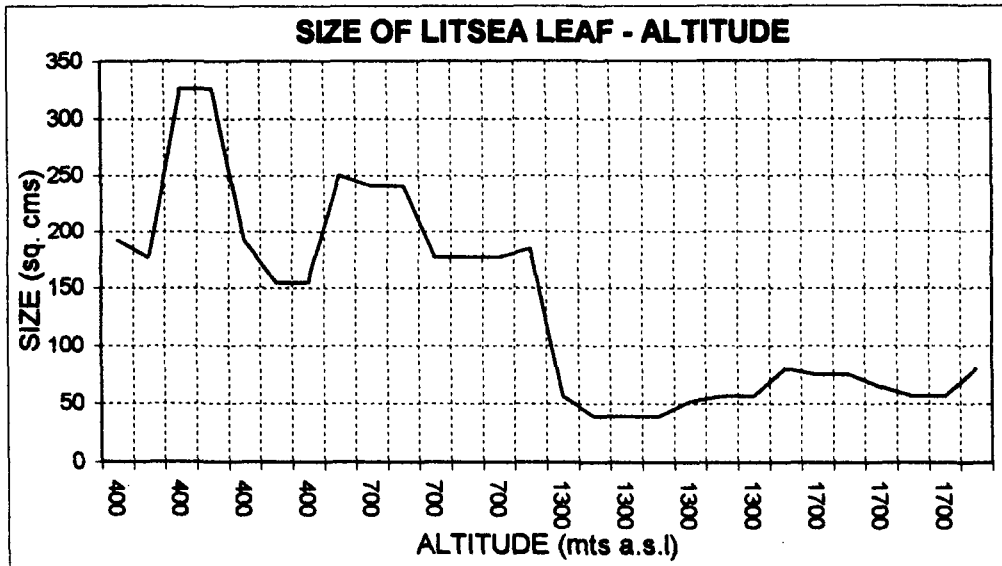
(vii) The coefficient of regression of the percentage of clay to size of litsea leaf is (-) 0.8400 with a standard error of 3.9481. The t-test value is negative at (-) 0.21276 and the p-level, which is the level of significance is found to be 0.833905 showing that it is highly insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the percentage of clay in the soil does not play a significant role in determining the size of litsea leaf.

(viii) The coefficient of regression of the elevation of the study area at different micro-areal units size of litsea leaf is (-) 45.6553 with a standard error of 15.9202. The t-test value is highly negative at (-) 2.86776 and the p-level, which is the level of significance is found to be 0.010233 showing that it is highly significant at 1 % level of significance. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that elevation plays a very significant role in determining the size of litsea leaf.

(ix) The coefficient of regression of average slope of an area to size of litsea leaf is (-) 4.7190 with a standard error of 3.1794. The t-test value is negative at (-) 1.48422 and the p-level, which is the level of significance is found to be 0.155051 showing that it is insignificant. Similar results are obtained after calculating the coefficient of partial correlation. Thus we can infer that the average slope of an area does not play a significant role in determining the size of litsea leaf.

From the above analysis we can conclude that the size of litsea leaf differs with change in altitude. The t-test value shows that the size of litsea leaf increases with decrease in altitude. The graphical representation showing size of litsea leaf in square centimetres to altitude as shown in Graph No.10 depicts that the average size of litsea leaf at 1700 metres is ranging between 52 cms<sup>2</sup> - 96 cms<sup>2</sup>. On the other hand the average size of litsea leaf at 1300 metres is ranging between 48 cms<sup>2</sup> - 100 cms<sup>2</sup>. At 700 metres altitude there has been a further increase in leaf

**GRAPH NO.10**



size ranging between 102 cms<sup>2</sup> - 250 cms<sup>2</sup> and at 400 metres above sea level leaf size ranges between 150 cms<sup>2</sup> - 325 cms<sup>2</sup>. However through the graph we observe that there is an increase in size of litsea leaf with decrease in altitude that may be due high rate of transpiration at lower altitudes with increase in temperatures.

Thus from the six analysis we can conclude that all the three most dominant species which are found at all the 4 (four) micro areal units with changes in their types we can conclude that:

(a) The height of the tree species varies with change in altitude primarily because of a number of physical factors of which the most outstanding being climate, soil depth and the influence of the parent rock material.

(b) The size, length and width of the leaves or folicles of the three species is reduced with increase in altitude. This is again mainly because of climatic variations especially with regard to relative humidity having an effect on the rate of transpiration. However, it is interesting to find that this is not true with regard to the schima species where at the lower altitudes the leaves are narrower and shorter than those found at the higher altitudes.

## CHAPTER VII

### CONCLUSION AND SUGGESTIONS

The study area Khri Basin, extends to an area of about 1067.75kms<sup>2</sup> occupies a very important position in understanding the interrelationship between geomorphic features, plant distribution and soil characteristics. Soil is the most important component on which man relies directly or indirectly other than water and is influenced by the parent rock material, landscape and vegetal cover in association with the climatic parameters which reign in a particular location.

However this study draws attention to the importance of the major environmental factors that is the geomorphic attributes, the dominant tree species and the soil characteristics though the interplay of both climate and geology has also been given importance. Also, as accounted earlier it can ascertain that each of these factors expresses identifiable characteristics of the environment where sometimes vegetal or landform or soil differences or their respective combinations have a great significance to the study of phytogeomorphology.

The following findings are mainly highlighted through the landform-plant-soil relationships with the interplay of both climate and geology.

#### **1. Climate:**

The area experiences a tropical monsoon type of climate where maximum rainfall is received during the months of June to October accounting to about 85% of the total annual rainfall. However a lot of temperature variations are accounted where the high altitudinal areas differ greatly from the low altitudinal areas. These differences do also occur in short distances depending with the difference in height and due to the nature of terrain and other local conditions. However it is accounted in the study that two major types of weather conditions prevail. The High Uplands

in the study that two major types of weather conditions prevail. The High Uplands enjoy temperate humid climatic conditions with harsh cold winters accompanied with winter winds, whereas as we move to low lying areas the weather conditions change and gets warmer. The Lowlands experience warm tropical to sub-tropical climatic conditions. The uniformity of the climatic phenomena is that the basin under study generally experiences a monsoonal type of climate throughout the year.

## **2. Geology:**

Three major rocks have been identified in the study area, that is, gneiss, granite and schist. All these three major rock structures are overlying the Gneissic Complex. Gneiss is found to be the most common signifying that the rocks are very hard and resistant. These rocks are found to be present mostly in the High Uplands, Low Uplands and the Lowlands bringing about gentle to moderate slopes signifying the true nature of a plateau. Granites are predominantly found in the Mid-Central Uplands and in the other zones where the main drainage basin passes through. Schist has been accounted in a small pocket in the High Upland areal unit.

## **3. Physical Setting:**

The study area has diverse and varied topography that is highly marked, dissected and irregular terrain. The area is also notable for its rolling uplands intersected by streams and rivers and dotted by rounded hills, scarps, gorges, deep valleys etc. The area is formed by contours ranging from 200 -1800 metres. The 4 (four) zones mentioned earlier could be termed "Uplands" and are broadly classified into 4 (four) divisions where each micro areal unit is under study.

- (i) High Uplands (above 1500 metres)
- (ii) Mid-Central Uplands (1000 - 1500 metres)
- (iii) Low Uplands (500 - 1000 metres)
- (iv) Lowlands (below 500 metres)

The High Uplands are hilly and rugged associated with steep slopes. Small streams are seen to start arising from this areal unit. The streams cut through the rugged topography carving through the exposed rock surfaces. This areal unit is also marked with peaks 1800 metres in height i.e. Nongthliew Peak and is also dotted by rounded hills.

The Mid-Central Uplands have altitude ranging between 1000 – 1500 metres. Here the streams are wider and fast flowing cutting through the dissected topography. The drainage pattern within this areal unit is mainly dendritic in nature and a rolling type of topography showing the true nature of being a plateau. Scarps, cliffs and waterfalls are notable features and hills with rounded tops are prominent in this areal unit.

The Low Uplands has altitude ranging between 500 – 1000 metres mean. The slopes are gentle and the streams are almost parallel. Rounded hilltops, scarps with valleys and ridges are notable.

The Lowlands has altitude ranging below 500 metres. Here the slopes are very gentle and undulating. In this area we encounter the meandering of streams that are slow flowing signifying the maturity of the river course.

Thus in general we can say that the main physical features of the study area are the presence of rounded hill tops, escarpments, cliffs, waterfalls, ridges, valleys

and low-lying areas with gentle and undulating slopes and a smooth skyline showing the true nature of a plateau with a rolling topography.

#### **4. Dissection Index:**

Level of dissection within the Khri Basin varies from 0.1 to 0.8 which signifies that the basin is highly contrasting, where the level of dissection at some areas within the basin is at a low level comprising of about 55%. On the other hand dissection at a high degree is found mostly at the low-elevated areas (below 500 metres) comprising approximately about 10% of the basin area. This is largely because of the altitudinal differentiation, which ranges from about 200 metres to 1800 metres. However, it is noted that the level of dissection in general is seen to increase with lowering of altitude where maximum dissection is noted at the lowlands particularly in the areas where the main river is flowing.

Secondly it is noted that drainage network is also responsible for determining the level of dissection in the Khri Basin. The level of dissection is directly proportional to the degree of density and frequency of streams. The analysis reveals that dissection is high at those areas where the higher stream orders are present and diminishes in the areas where the 1<sup>st</sup> and 2<sup>nd</sup> stream orders are present. However 55% of land is highly dissected in the areal unit where relief is below 500 metres. This signifies the intensity of work of the Khri River at the lowland areas, thus showing high density and frequency of the said drainage system. On the other hand, lowest dissection that is below 0.1 occurs in the high uplands (i.e. above 1500 metres). This signifies the low intensity of work of the Khri Basin at the high upland zone as this is the periphery of the drainage basin or otherwise the origin of smaller rivulets and streams. The only form of dissection is mainly the erosion of the topsoil at high slopes that is negligible in the overall activity of the 1<sup>st</sup> and 2<sup>nd</sup> order streams.

From this we can conclude that in the study basin most of the areas are not highly dissected. However, we can infer from the results that there is a trend of progressive dissection through the intensity of rainfall especially during the monsoon season. This is the period when the streams are at spate eroding the soils and carrying along with them a massive load and transporting the debris in the form of sediments down stream. Secondly we can also conclude that the belt of dissection with indices above 0.3 shows a continuous belt suggesting some kind of transition from one plane to another.

## **5. Slope:**

The study area has lowest slope at 4.5° and the highest being at 29° approximately. Steepest slopes are found at areas where narrow valleys marked with ravines, deep gorges, waterfalls, etc are present. On an overall picture the average slope is between 18°-24° which occupies more than 60% of the basin area. However the moderately steep to moderate slopes spread to an area of about 840 km<sup>2</sup> which amounts to about 79 % of the basin area. This signifies that the basin in general is within the plateau region with the dominance of rolling uplands having moderately steep to moderate slopes. Highest slopes i.e. above 24° are present where the main drainage line passes or cuts through forming deep valleys, gorges, and ravines with highly rugged terrain. It may be noted here that the main Khri Basin bifurcates into two major sub-basins at Mawdem village forming the interfluve. The main drainage line known as Khri-Synia that passes through Tyllang Nongriat – Kynrud – Mawdoh stretch and the other major sub-basin known as Khri-Bah which passes through Warmawsaw – Mawskei – Patharkmah – Nongliput – Nongthliew stretch. It is in these areas where deep cutting of water takes place. However, the steep slopes occupy an area of about 180 km<sup>2</sup> of the Khri Basin that is about 16.8% of the basin area.

## **6. Drainage Density:**

Maximum drainage density is recorded where the slopes are at the steepest and where the main drainage line passes through. In accordance to Morisawa's Classification this part of the Khri Basin has a medium texture and the lithological conditions of the underlying rocks signify that they are permeable. Since the study area is having high rainfall and is well vegetated it enables high level of water holding capacity of the soil in association with the roots. Secondly we may infer that about 50% of the Khri Basin is under a coarse texture where the underlying rocks are permeable and resistant experiencing heavy rainfall with high humidity signifying again that the area is well vegetated.

## **7. Land Classification:**

Undulating lands coupled with gentle to moderately sloping hills interspersed by wide valleys and the dominance of rolling uplands signifies the true nature of a plateau represented in the basin. The hill ranges are found dipping from almost SSW direction to NNW direction. The south-western portion, central western portion and the central eastern portion are marked by steep hills interspersed (dissected) by narrow valleys, deep gorges, ravines etc.

## **8. Soil Colour:**

In general it can be said the most of the soil samples collected are red or reddish in colour generally denotes that the soils are related to unhydrated iron oxides. Since unhydrated iron oxides are relatively unstable under moist conditions red colour usually indicates good drainage and good aeration. Strongly red soils are usually the product related to the parent rock material and not due to soil-forming processes since the redness in some rocks persists for centuries together even

under moist conditions. Red colour soils signify that the soils are relatively old which are subjected to intense weathering for a considerable time. On the other hand yellowish shade soils are largely due to presence of iron oxides.

#### **9. Soil Structure:**

The study area shows that there is a great variation in the structural grades and class whereas the structural type is uniform being granular in nature. In general we can say that the soils in the hill top ranges between strong to moderate, fine to medium and granular. Soils of the hill slopes are mostly moderate, medium and granular whereas in the valley and foothills it is highly variable ranging from strong to moderate to weak, fine to medium.

#### **10. Texture:**

The soils of the Khri Basin in general are dominated by soils having textural classes ranging from sandy to sandy loamy soils.

#### **11. Acidity:**

Soils of the study area are acidic in nature because of the nature of the parent rock material, nature of vegetation and as such since the area is under heavy rainfall during the monsoon season all adds to high acidity. This is compounded largely because of the presence of pine forests, as the pine needles are strongly acidic. Lowest recorded pH of 3.81 is accounted in Nongliput village where the soil sample was collected from a low lying forested area which is damp and a lot of vegetal decay where the forest is primarily of mixed deciduous forest type accompanied with pine vegetation. Therefore we may conclude that the high acidic

level in the study area shows that rainfall and pine vegetation to be prominent factors for high acidity of soil along with the interplay of the parent rock material.

## **12. Soil Rating:**

In general we can state that the soils of the study area have high Organic Carbon content with low to critically low phosphorous content and low to moderate composition of potassium content. Taking into consideration both the physical and chemical characteristics of the soil samples collected we can conclude that the soils in general are more or less fertile. This is because texturally they range from clayey to sandy loamy to loamy soils and have a well form crumb structure with high Organic Carbon content. On the other hand high content of iron oxides in which cation exchange takes place results to high acidity of the soils. Secondly as the area is hilly and under the influence of monsoon the soil cover is washed away which results in lowering both phosphate and potash content.

The dominant types of soil in the study area are that of red loamy Soils and laterite soils which are a result of the weathering of the exposed parent rock material such as granites, gnessis's, quartzite's, schist, conglomerates and dolerites which are rich in clay forming minerals, iron and aluminium. They vary from clayey to sandy loamy to loamy soils that are yellowish to brown to dark brown in colour. The soils of the low lying areas and valleys particularly those having loamy soils are the newly formed alluvial soils known as "Khaddar" where new layers are deposited year after year during the monsoon season. As the basin experiences humid climatic conditions, the formation and development of soils are similar to other humid areas where cation exchange is high resulting to the acidity of soils. The type and structure of rocks also play an important role in the evolution of soils. Granites and gneiss's dominate the basin and they are transformed mainly into kaolinite but the ferruginous concretions give such soils a reddish colour.

### **13. Vegetation:**

Natural vegetation varies from mixed tropical evergreen forests to that of temperate forests mainly based on altitude and rainfall distribution. The main tree species found in the study area are that of pines (*Pinus khasyana* and *Pinus insularis*), *shorea*, *schima*, *litsea* and *tectona* species. From the various areal units where vegetation is studied it is observed that as we move higher in altitude the shape of the leaves gradually becomes acute signifying that the leaves in trees in the lower elevations are broader thus having more canopy coverage rather than that at higher elevations. The tropical forests can further be classified into numerous subtypes such as evergreen, semi-evergreen, moist and dry deciduous forests, etc. These forests usually occur in high rainfall areas as well as near catchment areas. They harbour very rich species diversity forming a closed evergreen canopy. The temperate forests on the other hand occupy the higher elevations mostly along the southern slope of the study area. Such forests are having high rainfall with severe winters during the months of November to March. Ground frost is also common during the months of December – January.

### **14. Statistical Findings:**

(i) Height of pine differs greatly with change in altitude and also with the amount of phosphorus ( $P_2O_5$ ) content present in the soil. Due to its variation in height we can also infer that climate also plays an important role in the determination of pine height. This is mainly because of two reasons; one is the change in climatic parameters due to change in altitude and secondly is due to soil depth.

(ii) Length of pine follicle differs with change in altitude. Analysis shows that there is an increase in length of the follicle with decrease in altitude that may be due to high rate of transpiration at lower altitudes with increase in temperatures.

(iii) Height of schima species differs greatly with change in altitude. Due to its variation in height it can be inferred that climate plays an important role in the determination of the species height. However, the conditions here are reversed unlike pine where the schima tree species are found to increase in height with decrease in altitude. This signifies that the species are more adaptable to warmer climates than to cooler areas.

(iv) Size of schima leaf differs with change in altitude. There is an increase in size of schima leaf with increase in altitude. However this have been a peculiarity that has been observed in the present study. One of the reasons may be because of the presence of two different sub-species at the different altitudes. In the higher altitudes *schima khasiana* have been identified whereas in the lower altitudes *schima wallichii* are mostly found. The second reason may be due to the influence of pedology being the outcome of the interplay of the parent rock materials, climate and vegetation itself.

(v) The height of litsea species does not differ greatly with difference in altitude. This is because in the study area two different sub-species are analysed where *litsea elongata* is found at the higher altitudes, whereas *litsea khasiana* is present at the lower altitudes. There has been a positive relationship between the heights of litsea trees to that of the amount of potassium content present in the soil.

(vi) The size of litsea leaf differs with change in altitude. There is an increase in size of litsea leaf with decrease in altitude may be due to high rate of transpiration at lower altitudes with increase in temperatures.

Thus from the analysis we can conclude that all the three most dominant species which are found at all the 4 (four) micro areal units with changes in their types we can conclude that:

(a) The height of the tree species varies with change in altitude primarily because of a number of physical factors of which the most outstanding being climate, soil depth and the influence of the parent rock material.

(b) The size, length and width of the leaves or folicles of the three species are reduced with increase in altitude. This is again mainly because of climatic variations especially with regard to relative humidity having an effect on the rate of transpiration. However, it is interesting to find that this is not true with regard to the schima species where at the lower altitudes the leaves are narrower and shorter than those found at the higher altitudes.

Thus, it can be said that geomorphology provides the framework on which climate is acting through vegetation resulting in the formation of soils. All the sites studied are subject to pedogenesis - the complex of physical, chemical and biological processes that forms the soil profiles where the depth of soils tend to increase downslope. In the other hand vegetation is often a good indicator of soil and climatic conditions but there are instances where the reliability varies from place to place. This depends on other local factors particularly the geomorphic attributes.

Soil characteristics are greatly influenced by geomorphology and have a dominating influence too on the distribution of plant species. In general the finer the soil texture better is the inherent fertility but poor drainage leads to a longer time for the salts to be removed or be dissolved through leaching. Therefore the control of geomorphic boundaries on moisture conditions coincides with soil boundaries and determines the major plant communities.

In the light of the above discussions it can be said that phytogeomorphology provides the base to solve the problems of land management and landuse planning through detailed surveys. Also, mismanagement of an area especially in the field of land- use results to the loss of soil fertility, soil erosion, crop failures and associated economic problems which can be avoided by accessing in advance the land potentiality basing on geomorphic characteristics, natural and induced vegetation and soil characteristics.

Thus depending on the findings given in the above paragraphs a number of suggestions can be made for proper landuse planning with a view of proper managing the natural ecosystem of the area.

(1) Phytogeomorphic studies can provide the base for geological exploration and survey not only for the normal mapping of stratigraphic units but also for that of mineral and water resources. However topography and vegetation can be used to indicate geological features such as dip, foliation, folds, faults and beds through the absence or presence and / or the changes in the type of vegetation.

(2) Mineral resources tend to be related to landscape through a number of predictions. They occasionally are visible on the surface but are more usually interpreted from the understanding of the location of plant groups under particular soil conditions reflecting geological formation.

(3) Geomorphic attributes can assist in landuse and land evaluation studies where the effects of geomorphology through the parent rock material, the topography and drainage system with the interplay of climatic factors would reveal a lot of information on the potential landuse.

(4) Topography along with the influence of soils and the natural and induced vegetation becomes a prime determinant of landuse planning.

(5) Slope has a strong influence on the mechanization of activities. At the point where the slope is too steep land is devoted to forestry though the soil may be well suited for farming.

(6) As natural vegetation is an excellent expression of the total effect of environmental factors, the population of the plant community, its species composition (including the dominant species) and vegetal succession contributes a lot to maintain the ecological balance and bio-diversity.

(7) Landforms and vegetation in association with soil can effectively be used to the classification of landscape for various engineering purposes.

(8) Studies in phytogeomorphology can be used for the management of forest either for the classification of existing forest or for land under afforestation particularly in relation to site quality.

(9) Soil erosion in high to medium relief and also in low relief areas is vigorous in humid areas particularly through rainfall and fluvial activity. Soil degradation assessment can highly be ascertained through a phytogeomorphic approach.

(10) Since soils are natural bodies that are closely related to geology, climate, geomorphology and vegetation, phytogeomorphic interpretation can be used as a fundamental tool for explaining soil formation in different environments.

Thus Phytogeomorphology provides a sound base to an integrated approach of dividing landscapes into meaningful units, which have a uniformity of geology, geomorphology, vegetation, climate and soil.

## BIBLIOGRAPHY

**Bandopadhyay, D.N. (1978)** : Report on Systematic Geological Mapping & Preliminary Investigation in parts of Khasi Hills District (Meghalaya, Nowgong & Kamrup Districts, Assam), GSI, Unpublished Reports, Shillong.

**Cruickshank J.G (1972)** Soil Geography David and Charles, Newton Abbot.

**Das, M.K; Goswami, A.C; Talukdar, S.C; Mazumdar, S.K; and Murphy, M.V.N. (1967)**: The Jadukata Formation the Eldest Formation within Cretaceous Shelf Sediments of the Assam Plateau.

**Dokuchaev V.V (1886)** Data on Land Appraisal in Nizhnii-Novgonod Province in collected Works, Vol 4, acad sci Moscow,1950.

**Donahue R.L; Miller R.W (1975)**; A Introduction to Soils and Plant Growth Shickluna J.C Prentice Hall of India, New Delhi 5<sup>th</sup> Edition 1985.

**Fox C.S. (1936 - 38)**: *General Report, G.S.I., Rec.G.S.I., Vol.69, pt.1, pg.82- 84, Vol. 71, pt.1, pg. 81 - 86, Vol.72, pt.1, pg.85 - 90, Vol.73, pt.1, pg.75-80. Vol.74, pt.1.*

**Geological Survey of India, Misc. Publication No. 30** *Geology and Mineral Resources of the States of India- Part IV*: Glasgow Printing Company 1974.

**Geology of Khasi Hills Based on "Know Your District"**, Published by Geological Survey of India, 1976.

**Ghosh, A.M.N. (1936-39)**: *General Report G.S.I, Rec. G.S.I., Vol.71, pt.1, Vol.72, pt.1, Vol.73, pt.1, Vol.74, pt.1.*

**Godwin Austin, H.H. (1869)**; *Notes to accompany a Geological Map of a portion of the Khasi Hills*, Journal,A.S.B. Vol.38.

**Good R. (1974)** *The Geography of Flowering Plants*, Longman Group Ltd.  
**Haridasan K. and Rao R.R (1985)** *Forest Flora of Meghalaya, Volume I and II*, Shiva Printers Dehradun.

**Howard J.A. and Mitchell C.W.** *Phytogeomorphology*. A Wiley- Interscience Publications; John Wiley & Sons 1985.  
in Geography Oliver and Boyd.

**Kalpage F.S.C.P** (1974) *Tropical Soils: Classification, Fertility and Management*. Macmillan.

**Khedkar, V.R. and Mukherji, P.N.** (1938-39): *Unpublished Progress Report of G.S.I. Assam*.

**La Touche T.H.D.** (1883): *Cretaceous Coal resources in the Khasi Hills*, Rec. G.S.I. Vol.16, pg.164 - 165. (1839): *On Cherrapunji coalfields*, Rec. G.S.I. Vol.8.

**Lasker, B.** (1949) : Preliminary Report on the Dam Site on Umtru River in Khasi Hills, GSI Unpubl. Reports, Shillong.Longman House.

**Mallet, F.R.** (1875): *Notes on Coal Recently found near Mawphlang, Khasi Hills*, Rec. G.S.I. Vol.8.

**Mc Knight T.L** (1993) *Physical Geography: A Landscape Appreciation* Prentice Hall, Englewood Cliffs, New Jersey 07632.

**Medlicott,H.B.** (1869); *Geological Sketch of the Shillong Plateau* Mem; G.S.I. Vol.7.

**Meyen F.J.F.** (1846) *Geography of Plants*, London; Avishkar Publishers Reprinted 1986.

**Monkhouse, F.J and Wilkinson, H.R** (1971): *Maps and Diagrams*, P.I Publication, New Delhi, 3<sup>rd</sup> Ed, 1971.

**Moore, B. & Moore, C.B.** (1982) : *Principles of Geochemistry*, Wiley Eastern Ltd. 4 th Ed, n.Delhi.

**Morisawa, M** (1985): *Geomorphology Texts: Rivers*, Longmans Group, U.K., 1985.

**Munsel Colour Company** (1975) *Munsell Soil Colour Chart* Inc Battimore 2, Maryland.

**Murphy, M.V.N**, (1970): Tectonic and Mafic Igneous Activity in North-East India in Relation to the Upper Mantle, of Second Symposium on Proc. II Symp Upper Mantle Project, Dec 1970, Hyderabad.

**Murphy, M.V.N; Chakravarty, G; and Talukdar, S.C.** (1971): Stratigraphic Revision of the Cretaceous – Tertiary Sediments of North Eastern India. Unpublished Paper Read in Seminar on Geology of North Eastern India, Held at Shillong in 1967.

**O' Hare G.** (1988), Soils, Vegetation and Ecosystems Oliver and Boyd

**O'Hare G.**(1989), Soils, Vegetation, Ecosystems Conceptual Frameworks

**Oldham, T.** (1959) *On geological structure of a part of "Khasi Hills"* Mem;G.S.I. Vol.I.

**Palmer R.V.** (1923): *Geology as part of the Khasi and Jaintia Hills*, Rec. G.S.I, Vol.55, pt.2.

**Rai R.K.**(1978): Geomorphology of the Sonar-Bearma Basin, Concept Publishing Co., New Delhi, 1980.

**Ram M and Singh B.D** (1993): "*Soil Fertility Management in Farming Systems*", Lecture Notes: Off-Camping Training on Farming Systems, Aizawl, Department of Agriculture Mizoram and ICAR Research Complex for NEH Region, Barapani, 1993.

**Soil Science Society of America** October 1979 Glossary of Soil Science Terms.

**Spate O.H.K.** (1967) *India & Pakistan*.(3rd ed.) Methuen & Co. Ltd.

**Strahler, T.N** (1952): "Determination of Stages of Landscape Evolution through relief Measures", Facets of geomorphology, Thinker's Library, Allahabad, 1985.

**Stratigraphical position of the Cherra sandstone, Assam.** The Records of the Geographical survey of India, Vol.IXXV presonal paper No.4(1940).

***Unpublished Progress Reports on the Assam Circle***, G.S.I. for the field seasons from 1961-62 to 1972-73.

**US Dept.** (August 1951) Agriculture Handbook No.18 Soil Survey Manual  
Oxford & IBH Publishing Co.

**Varma, P.P. & Rajendran, N.** (1985) : A Report on the Photo Geological mapping in the area around Nongkhlaw and South of Nongpoh, East and West Khasi Hills District, Meghalaya, GSI Unpbl. Reports, Shillong.



**Plate No.1 - VIEW OF THE KHRI RIVER AT THE INTERFLUVE**



**Plate No.2 - KHRI RIVER AT WARMAWSAW**



**Plate No. 3 - ROADSIDE CUTTING AT KYNRUD**



**Plate No. 4 - ROADSIDE CUTTING AT KHAWAI**



**Plate No.5 - EXPOSED QUARTZITE ROCK AT KYNRUD**



**Plate No.6 - ROADSIDE CUTTING AT KYNRUD  
EXPOSING QUARTZITE**



**Plate No.7 - GRANITE MASS AT KYNRUD**



**Plate No.8 - WEATHERED GRANITE ROCK AT KYNRUD**



**Plate No.9 - VIEW OF THE KHRI RIVER AT PATHARKHMAH**



**Plate No.10 - VIEW OF THE KHRI RIVER DURING THE DRY  
SEASON AT PATHARKHMAH**



**Plate No.11 - TRIBUTARY OF THE KHRI RIVER AT KHAWAI**



**Plate No.12 - TRIBUTARY OF THE KHRI RIVER AT KHAWAI**



**Plate No.13 - TRIBUTARY OF THE KHRI RIVER AT MAWIONG**



**Plate No.14 - GROUND FLORA AT WARMAWSAW**



**Plate No.15 - SUB - TROPICAL FOREST COVER AT PATHARKHMAH**



**Plate No.16 - DEGRADED PINE FOREST AT KHAWAI**



**Plate No.17 - MIXED DECIDUOUS FOREST AT KYNRUD**



**Plate No.18 - MIXED DECIDUOUS FOREST AT KYNRUD**